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(54) **HETEROCYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME**

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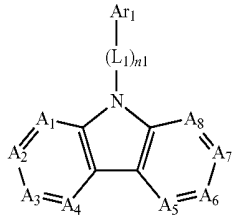
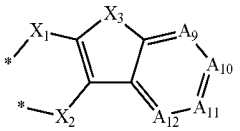
(57) **ABSTRACT**

A heterocyclic compound is represented by Formula 1. In Formulae 1, 1a, and 1b, two adjacent groups among A_1 to A_8 are each independently connected with a respective * of Formulae 1a or 1b to form a ring, where each * is a carbon atom of Formula 1. An organic light-emitting device includes the heterocyclic compound.

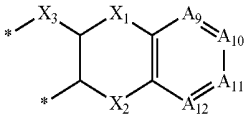
Formula 1

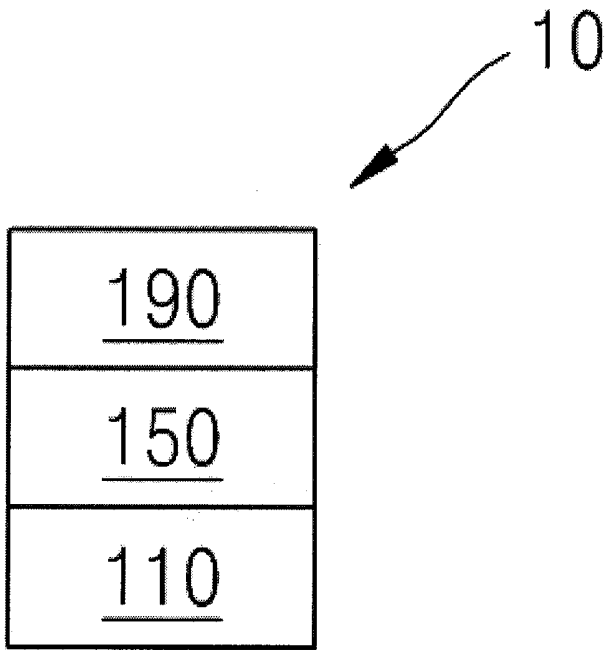


Formula 1a



Formula 1b

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190
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HETEROCYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2014-0079115, filed on Jun. 26, 2014, and Korean Patent Application No. 10-2015-0035154, filed on Mar. 13, 2015, in the Korean Intellectual Property Office, the entire contents of both of which are incorporated herein by reference.

BACKGROUND

[0002] 1. Field

[0003] One or more example embodiments relate to a heterocyclic compound and an organic light-emitting device including the same.

[0004] 2. Description of the Related Art

[0005] Organic light-emitting devices are self-emitting devices that have wide viewing angles, high contrast ratios, short response times, and excellent luminance, driving voltage, and response speed characteristics, and produce full-color images.

[0006] The organic light-emitting device may include a first electrode disposed on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode sequentially formed on the first electrode. Holes injected from the first electrode are transported to the emission layer through the hole transport region, and electrons injected from the second electrode are transported to the emission layer through the electron transport region. Carriers, such as the holes and electrons, recombine in the emission layer to generate excitons. When the excitons drop (relax) from an excited state to a ground state, light is emitted.

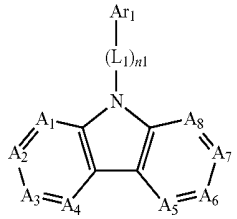
SUMMARY

[0007] One or more example embodiments include a heterocyclic compound and an organic light-emitting device including the same.

[0008] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

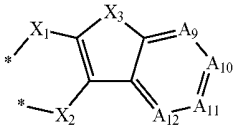
[0009] According to one or more example embodiments, there is provided a heterocyclic compound represented by Formula 1 (e.g., represented by Formula 1 with Formula 1a and/or Formula 1b):

Formula 1

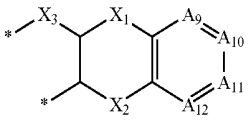


-continued

Formula 1a



Formula 1b



[0010] In Formulae 1, 1a, and 1b,

[0011] A_1 is selected from CR_1 and nitrogen, A_2 is selected from CR_2 and N, A_3 is selected from CR_3 and N, A_4 is selected from CR_4 and N, A_5 is selected from CR_5 and N, A_6 is selected from CR_6 and N, A_7 is selected from CR_7 and N, A_8 is selected from CR_8 and N, A_9 is selected from CR_9 and N, A_{10} is selected from CR_{10} and N, A_{11} is selected from CR_{11} and N, and A_{12} is selected from CR_{12} and N;

[0012] two adjacent groups among A_1 to A_8 are each independently connected with a respective * in Formulae 1a or 1b, to form a ring, wherein each * is a carbon atom of Formula 1;

[0013] L_1 is selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene, a substituted or unsubstituted C_3-C_{10} cycloalkenylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene, a substituted or unsubstituted C_6-C_{60} arylene, a substituted or unsubstituted C_1-C_{60} heteroarylene, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0014] n1 is selected from 0, 1, 2, 3, and 4;

[0015] X_1 is selected from a single bond, $C(R_{13})(R_{14})$, $N(R_{13})$, O, S, Se, Te, Po, $Si(R_{13})(R_{14})$, $Ge(R_{13})(R_{14})$, $P(R_{13})$, $P(R_{13})(=O)$, C=O, and $B(R_{13})$;

[0016] X_2 is selected from a single bond, $C(R_{15})(R_{16})$, $N(R_{15})$, O, S, Se, Te, Po, $Si(R_{15})(R_{16})$, $Ge(R_{15})(R_{16})$, $P(R_{15})$, $P(R_{15})(=O)$, C=O, and $B(R_{15})$;

[0017] X_3 is selected from $C(R_{17})(R_{18})$, $N(R_{17})$, O, S, Se, Te, Po, $Si(R_{17})(R_{18})$, $Ge(R_{17})(R_{18})$, $P(R_{17})$, $P(R_{17})(=O)$, C=O, and $B(R_{17})$;

[0018] Ar_1 and R_1 to R_{18} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group;

[0019] two adjacent groups among R_1 to R_{18} are optionally connected with each other (e.g., fused together) to form a ring; and

[0020] at least one substituent of the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

[0021] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

[0022] a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{11})(Q_{12})$, $—Si(Q_{13})(Q_{14})(Q_{15})$, and $—B(Q_{16})(Q_{17})$;

[0023] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0024] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{21})(Q_{22})$, $—Si(Q_{23})(Q_{24})(Q_{25})$, and $—B(Q_{26})(Q_{27})$; and

[0025] $—N(Q_{31})(Q_{32})$, $—Si(Q_{33})(Q_{34})(Q_{35})$, and $—B(Q_{36})(Q_{37})$,

[0026] wherein Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{37} are each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_1-C_{60} alkoxy group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0027] According to one or more example embodiments, an organic light-emitting device includes: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode and including an emission layer, wherein the organic layer includes at least one of the heterocyclic compound.

BRIEF DESCRIPTION OF THE DRAWING

[0028] These and/or other aspects will become apparent and more readily appreciated from the following description of the example embodiments, taken in conjunction with the accompanying drawing which is a schematic view of a structure of an organic light-emitting device according to an example embodiment of the present disclosure.

DETAILED DESCRIPTION

[0029] Reference will now be made in detail to example embodiments, an example of which is illustrated in the accompanying drawing. In this regard, the present example embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the example embodiments are merely described below, by referring to the accompanying drawing, to explain aspects of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0030] As used herein, the singular forms "a", "an", and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0031] It will be further understood that the terms "comprises" and/or "comprising" used herein specify the presence of stated features or components, but do not preclude the presence or addition of one or more other features or components.

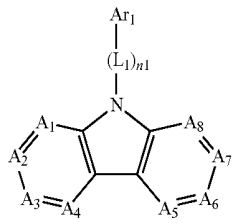
[0032] It will be understood that when a layer, region, or component is referred to as being "formed on" another layer, region, or component, it can be directly or indirectly on or formed on the other layer, region, or component. That is, for example, intervening layers, regions, or components may be present.

[0033] Sizes of components in the accompanying drawing may be exaggerated for convenience of explanation. In other words, since sizes and thicknesses of components in the accompanying drawing may be arbitrarily illustrated for convenience of explanation, the following embodiments are not limited thereto.

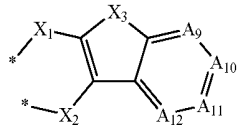
[0034] As used herein, the term "substantially," "about," and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art. Also, any numerical range recited herein is intended to include all subranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein. All such ranges are intended to be inherently described in this specification such that amending to expressly recite any such subranges would comply with the requirements of 35 U.S.C. §112(a), and 35 U.S.C. §132(a).

[0035] According to an example embodiment, a heterocyclic compound may be represented by Formula 1 (e.g., represented by a combination of Formula 1 and Formula 1a and/or Formula 1b):

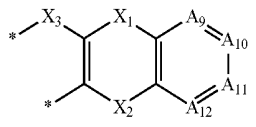
Formula 1



Formula 1a



Formula 1b



[0036] In Formulae 1, 1a, and 1b, A_1 may be selected from CR_1 and nitrogen (N), A_2 may be selected from CR_2 and N, A_3 may be selected from CR_3 and N, A_4 may be selected from CR_4 and N, A_5 may be selected from CR_5 and N, A_6 may be selected from CR_6 and N, A_7 may be selected from CR_7 and N, A_8 may be selected from CR_8 and N, A_9 may be selected from CR_9 and N, A_{10} may be selected from CR_{10} and N, A_{11} may be selected from CR_{11} and N, and A_{12} may be selected from CR_{12} and N;

[0037] two adjacent groups among A_1 to A_8 may be each independently connected with a respective * of Formulae 1a or 1b to form a ring, wherein each * is a carbon atom of Formula 1 (e.g., a carbon atom of one of A_1 to A_8); and

[0038] R_1 to R_{12} may be as defined in the following description.

[0039] For example, in Formulae 1, 1a, and 1b, A_1 may be CR_1, A_2 may be CR_2, A_3 may be CR_3, A_4 may be CR_4, A_5 may be CR_5, A_6 may be CR_6, A_7 may be CR_7, A_8 may be CR_8, A_9 may be CR_9, A_{10} may be CR_{10}, A_{11} may be CR_{11}, and A_{12} may be CR_{12}, but embodiments are not limited thereto.

[0040] In Formula 1, L_1 may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene, a substituted or unsubstituted C_3-C_{10} cycloalkenylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene, a substituted or unsubstituted C_6-C_{60} arylene, a substituted or unsubstituted C_1-C_{89} heteroarylene, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

[0041] For example, in Formula 1, L_1 may be selected from a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, a benzofuranylene group, a benzothiophenylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, and a dibenzocarbazolylene group; and

[0042] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene

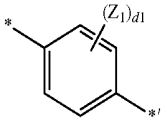
group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, a benzofuranylene group, a benzothiophenylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, and a dibenzocarbazolylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, and an imidazopyridinyl group, but embodiments are not limited thereto.

[0043] For example, in Formula 1, L_1 may be selected from a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group, and a triazinylene group;

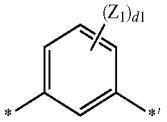
[0044] a naphthylene group, a pyridinylene group, a pyrimidinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group, and a triazinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, but embodiments are not limited thereto.

[0045] For example, in Formula 1, L_1 may be selected from groups represented by (e.g., each represented by) Formulae 3-1 to 3-22, but embodiments are not limited thereto:

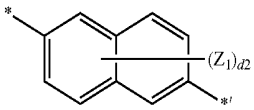
3-1



3-2



3-3



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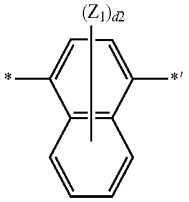
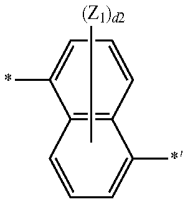


3-5



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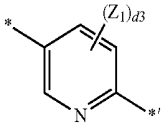

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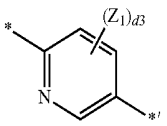

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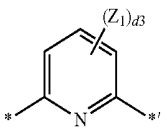

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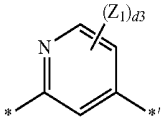

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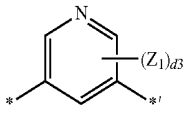

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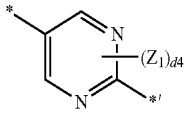

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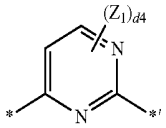

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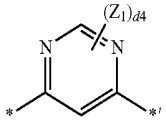

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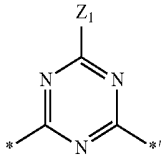

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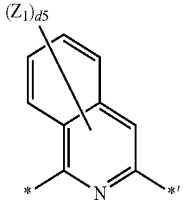

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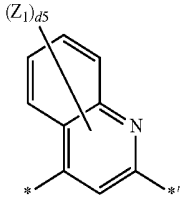
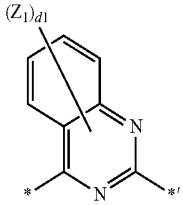


3-17



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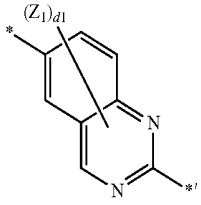

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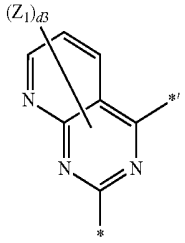
3-19



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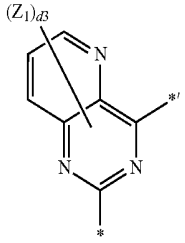

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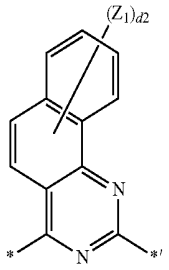
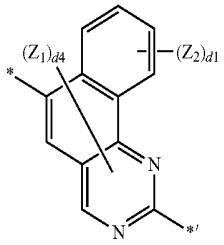


3-22



[0046] In Formulae 3-1 to 3-22,

[0047] Z_1 and Z_2 may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group,

[0048] d1 may be selected from 1, 2, 3, and 4;

[0049] d2 may be selected from 1, 2, 3, 4, 5, and 6;

[0050] d3 may be selected from 1, 2, and 3;

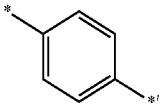
[0051] d4 may be selected from 1 and 2;

[0052] d5 may be selected from 1, 2, 3, 4, and 5; and

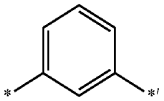
[0053] * and *' may be each independently a binding site to a neighboring atom.

[0054] For example, in Formula 1, L_1 may be selected from groups represented by (e.g., each represented by) Formulae 4-1 to 4-22, but embodiments are not limited thereto:

4-1



4-2



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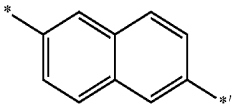
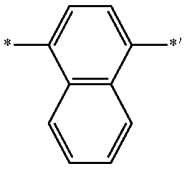
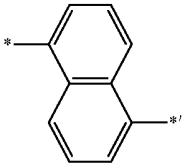


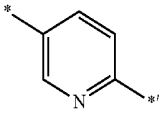
4-4



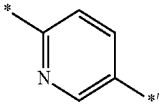
4-5



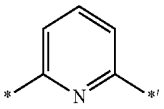
4-6



4-7



4-8



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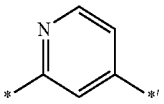

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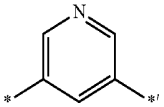

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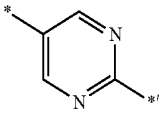

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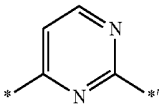

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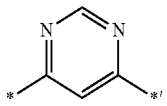
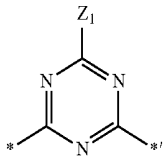
4-13



4-14



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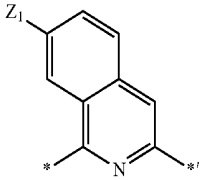

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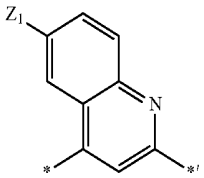

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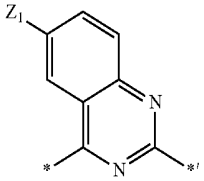
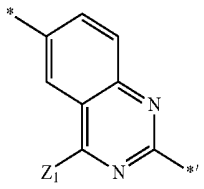


4-18



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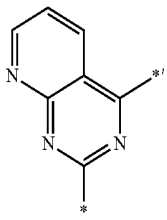
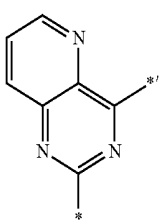


4-20



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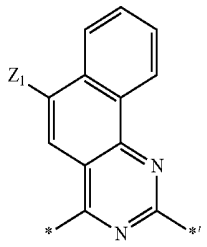
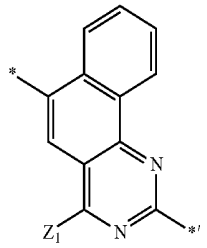


4-22



[0055] In Formulae 4-1 to 4-22,

[0056] Z_1 may be selected from a hydrogen, a deuterium, —F, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

[0057] * and *' may be each independently a binding site to a neighboring atom.

[0058] In Formula 1, n1 denotes the number of L_1 and may be selected from 0, 1, 2, 3, and 4. When n1 is 0, $(L_1)_{n1}$ is a single bond. When n1 is 2 or greater, a plurality of L_1s may be identical to or different from each other. For example, in Formula 1, n1 may be selected from 0, 1, and 2, but embodiments are not limited thereto. For example, in Formula 1, n1 may be selected from 0 and 1, but embodiments are not limited thereto. For example, in Formula 1, n1 may be 0, but embodiments are not limited thereto.

[0059] In Formula 1a, X_1 may be selected from a single bond, $C(R_{13})(R_{14})$, $N(R_{13})$, O, S, Se, Te, Po, $Si(R_{13})(R_{14})$, $Ge(R_{13})(R_{14})$, $P(R_{13})$, $P(R_{13})(=O)$, C=O, and $B(R_{13})$;

[0060] R_{13} and R_{14} may be connected with each other (e.g., fused together) to form a ring; and

[0061] R_{13} and R_{14} may be as defined in the following description.

[0062] For example, in Formula 1a, X_1 may be selected from a single bond, O, and S, but embodiments are not limited thereto.

[0063] In Formula 1a, X_2 may be selected from a single bond, $C(R_{15})(R_{16})$, $N(R_{15})$, O, S, Se, Te, Po, $Si(R_{15})(R_{16})$, $Ge(R_{15})(R_{16})$, $P(R_{15})$, $P(R_{15})(=O)$, C=O, and $B(R_{15})$;

[0064] R_{15} and R_{16} may be connected with each other (e.g., fused together) to form a ring; and

[0065] R_{15} and R_{16} may be as defined in the following description.

[0066] For example, in Formula 1a, X_2 may be selected from a single bond, O, and S, but embodiments are not limited thereto.

[0067] In Formula 1b, X_3 may be selected from $C(R_{17})(R_{18})$, $N(R_{17})$, O, S, Se, Te, Po, $Si(R_{17})(R_{18})$, $Ge(R_{17})(R_{18})$, $P(R_{17})$, $P(R_{17})(=O)$, C=O, and $B(R_{17})$;

[0068] R_{17} and R_{18} may be connected with each other (e.g., fused together) to form a ring; and

[0069] R_{17} and R_{18} may be as defined in the following description.

[0070] For example, in Formula 1b, X_3 may be selected from $C(R_{17})(R_{18})$ and

[0071] $N(R_{17})$, but embodiments are not limited thereto.

[0072] In Formulae 1, 1a, and 1b, Ar_1 and R_1 to R_{18} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group; and

[0073] two adjacent groups among R_1 to R_{18} may be optionally connected with each other (e.g., fused together) to form a ring.

[0074] For example, in Formula 1, Ar_1 may be selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovaleny group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

[0075] a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a

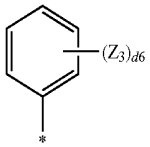
dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, but embodiments are not limited thereto.

[0076] For example, in Formula 1, Ar_1 may be selected from a methyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group; and

[0077] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group, but embodiments are not limited thereto.

[0078] For example, in Formula 1, Ar_1 may be selected from groups represented by (e.g., each represented by) Formulae 5-1 to 5-48, but embodiments are not limited thereto:

5-1



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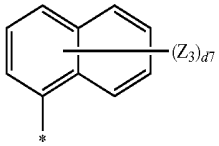

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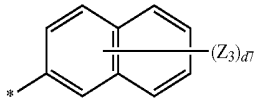

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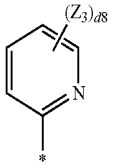

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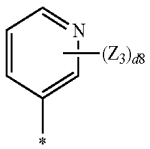

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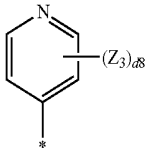

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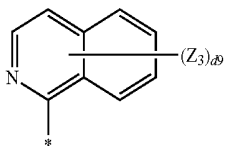

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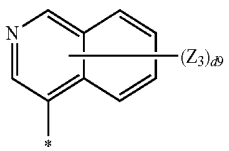

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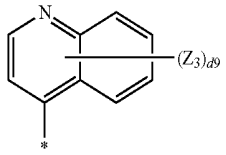

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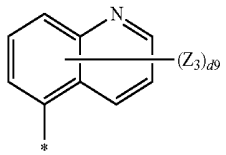

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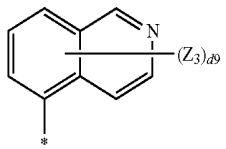

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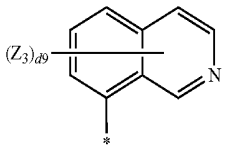

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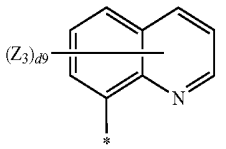

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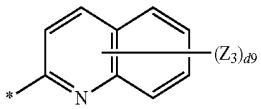

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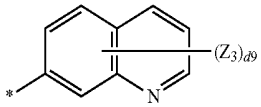

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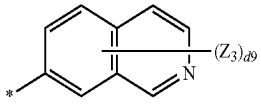

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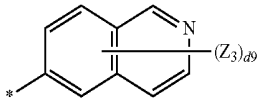

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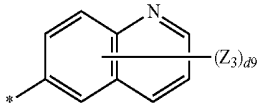

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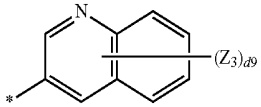

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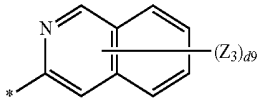

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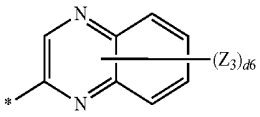

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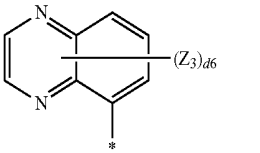

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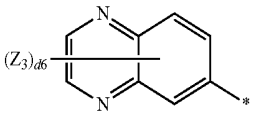

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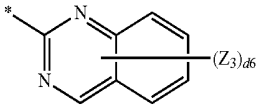

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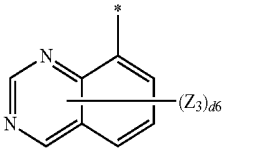

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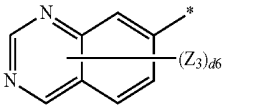

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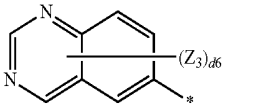

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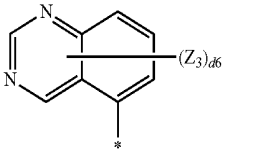

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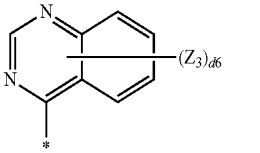

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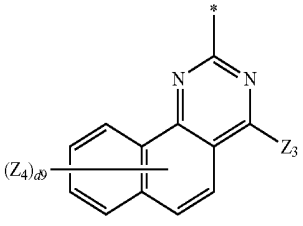

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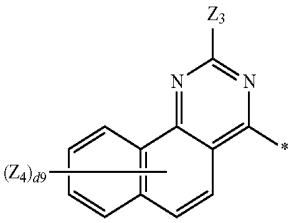

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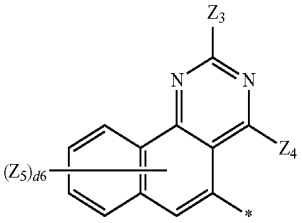

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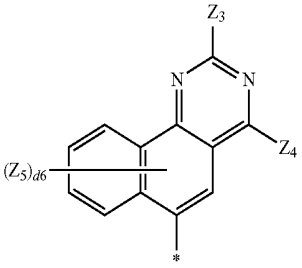
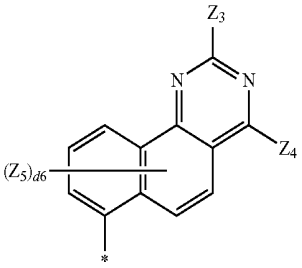
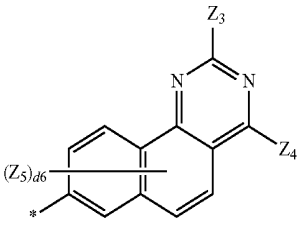


5-34



5-35



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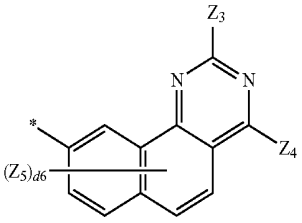

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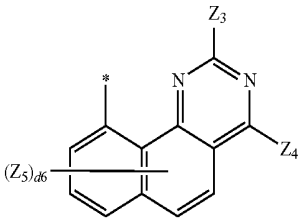
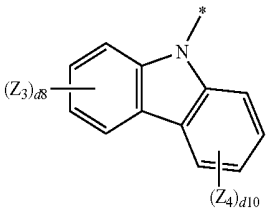
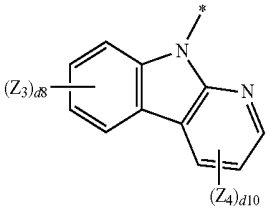


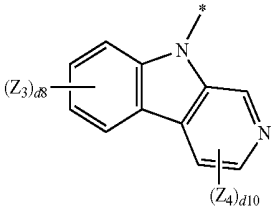
5-38



5-39



5-40



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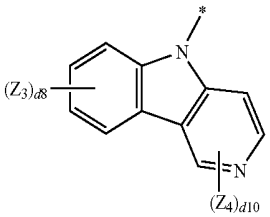
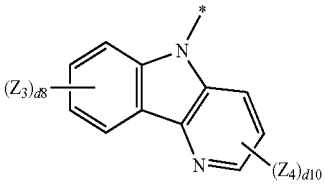
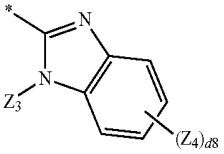


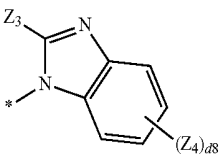
5-42



5-43



5-44



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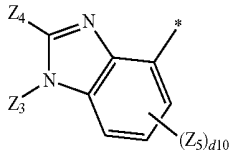
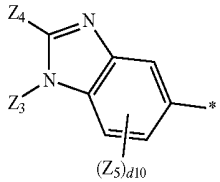
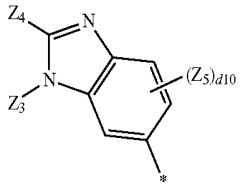
5-45



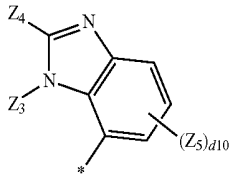
5-46



5-47



5-48



[0079] In Formulae 5-1 to 5-48,

[0080] Z_3 to Z_5 may be each independently selected from a hydrogen, a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

[0081] d6 may be selected from 1, 2, 3, 4, and 5;

[0082] d7 may be selected from 1, 2, 3, 4, 5, 6, and 7;

[0083] d8 may be selected from 1, 2, 3, and 4;

[0084] d9 may be selected from 1, 2, 3, 4, 5, and 6;

[0085] d10 may be selected from 1, 2, and 3; and

[0086] * may be a binding site to a neighboring atom.

[0087] For example, in Formulae 1, 1a, and 1b, R_1 to R_{18} may be each independently selected from a hydrogen, a deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

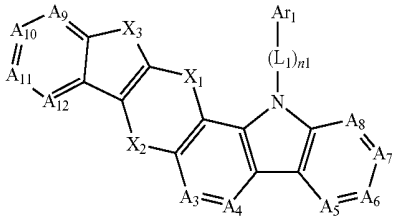
[0088] a phenyl group, a naphthyl group, and a pyridinyl group, each substituted with at least one of a phenyl group, a naphthyl group, and a pyridinyl group, but embodiments are not limited thereto.

[0089] For example, in Formulae 1, 1a, and 1b, R_1 to R_{18} may be each independently selected from a hydrogen, a methyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

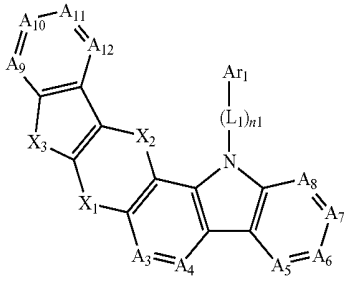
[0090] a phenyl group substituted with a phenyl group, but embodiments are not limited thereto.

[0091] For example, the heterocyclic compound may be represented by any one of Formulae 1-1 to 1-12, but embodiments are not limited thereto:

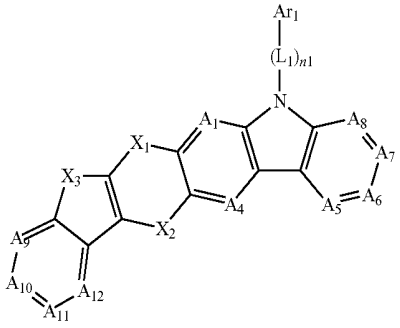
1-1



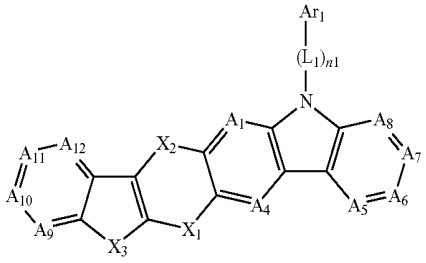
1-2



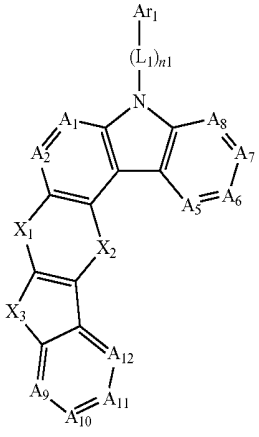
1-3



1-4



1-5



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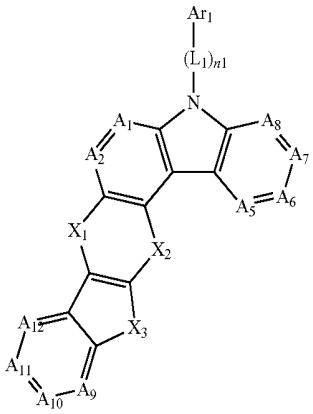
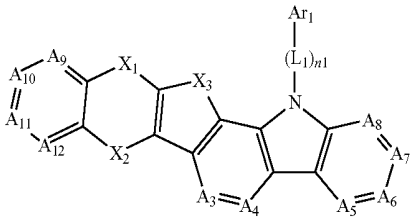
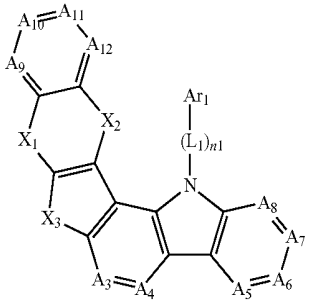
1-6



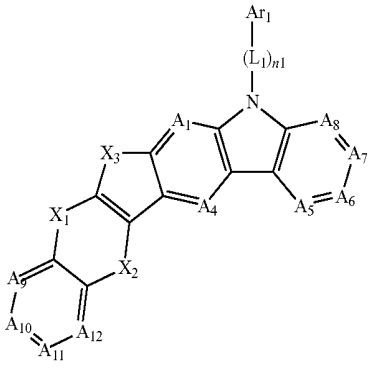
1-7



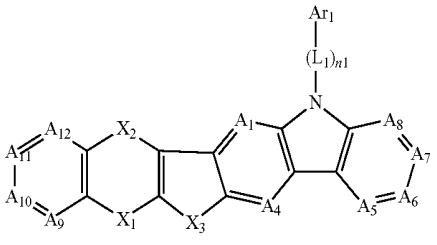
1-8



1-9



1-10



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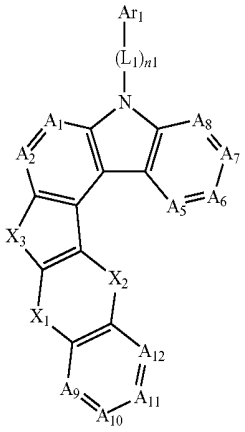
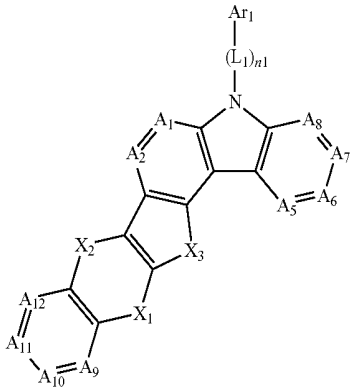
1-11



1-12



[0092] In Formulae 1-1 to 1-12,

[0093] A_1 to A_{12}, L_1, n1, X_1, X_2, X_3, Ar_1, and R_1 to R_{12} may be defined the same by referring to the description of Formula 1 (e.g., A_1 to A_{12}, L_1, n1, X_1, X_2, X_3, Ar_1, and R_1 to R_{12} may be the same or substantially the same as described with respect to Formula 1).

[0094] For example, when the heterocyclic compound is represented by any one of Formulae 1-1 to 1-12 above,

[0095] A_1 may be selected from CR_1 and N, A_2 may be selected from CR_2 and N, A_3 may be selected from CR_3 and N, A_4 may be selected from CR_4 and N, A_5 may be selected from CR_5 and N, A_6 may be selected from CR_6 and N, A_7 may be selected from CR_7 and N, A_8 may be selected from CR_8 and N, A_9 may be selected from CR_9 and N, A_{10} may be selected from CR_{10} and N, A_{11} may be selected from CR_{11} and N, and A_{12} may be selected from CR_{12} and N;

[0096] L_1 may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene, a substituted or unsubstituted C_3-C_{10} cycloalkenylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene, a substituted or unsubstituted C_6-C_{60} arylene, a substituted or unsubstituted C_1-C_{60} heteroarylene, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0097] n1 may be selected from 0, 1, and 2;

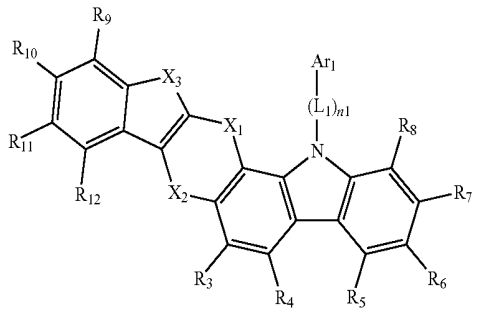
[0098] X_1 and X_2 may be each independently selected from O and S;

[0099] X_3 may be selected from $C(R_{17})(R_{18})$ and $N(R_{17})$; and

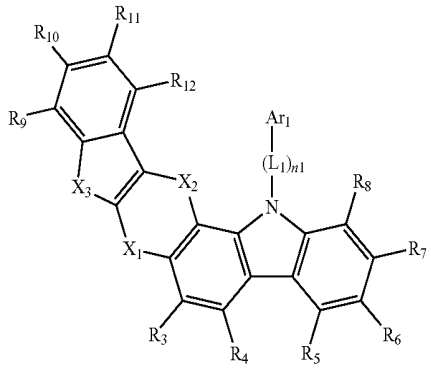
[0100] Ar_1 and R_1 to R_{18} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, but embodiments are not limited thereto.

[0101] For example, the heterocyclic compound may be represented by any one of Formulae 1-21 to 1-32, but embodiments are not limited thereto:

1-21



1-22



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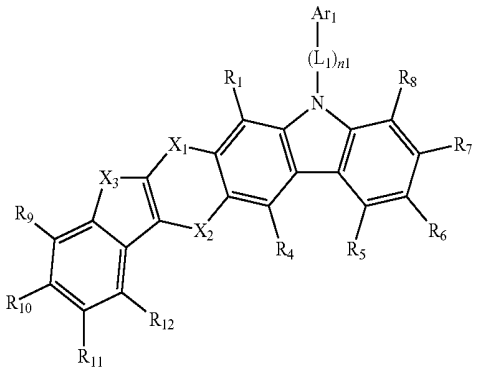
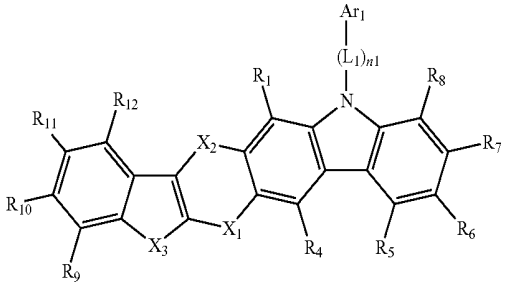
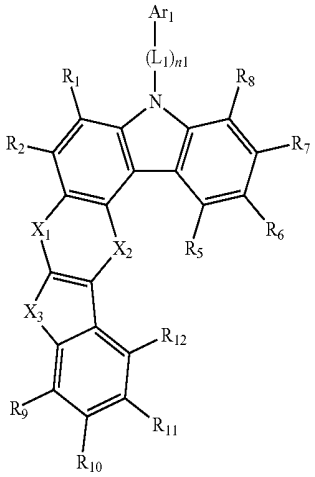
1-23



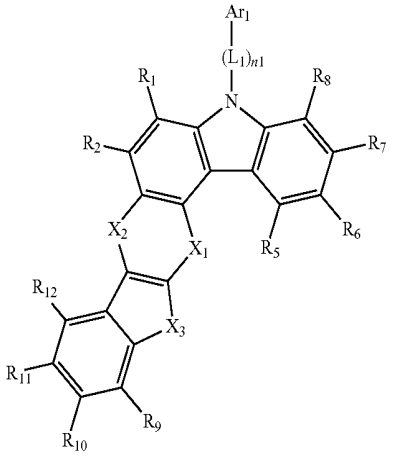
1-24



1-25



1-26



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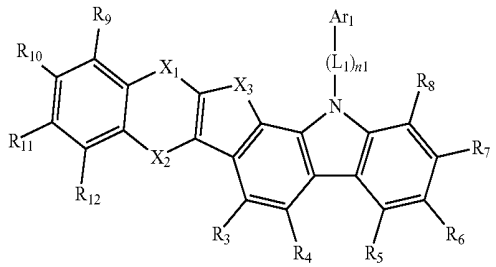
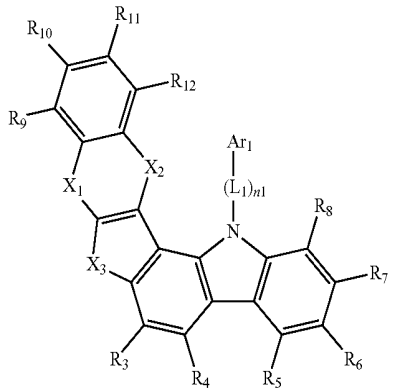
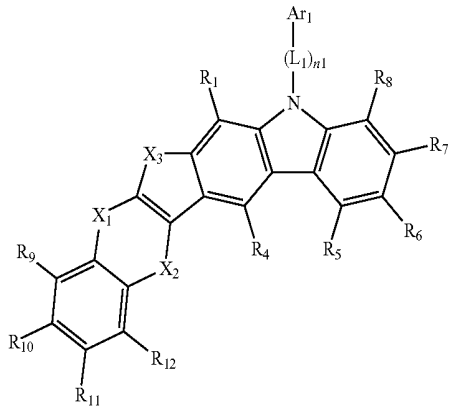
1-27



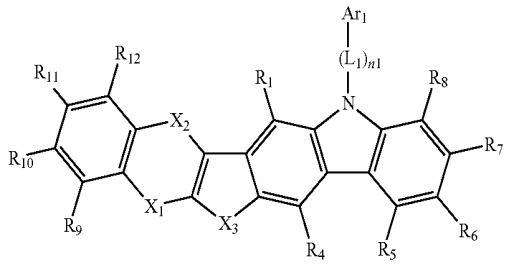
1-28



1-29



1-30



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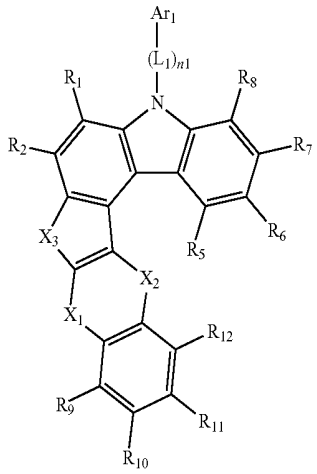
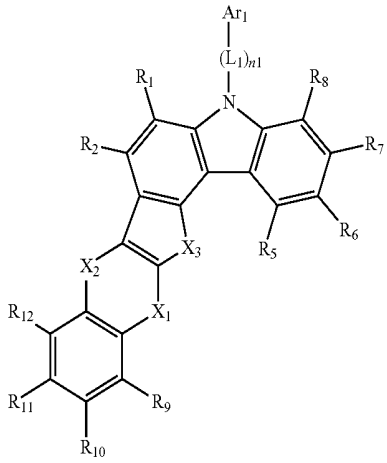
1-31



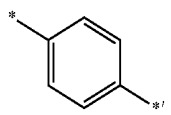
1-32



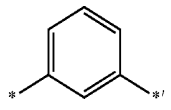
[0102] In Formulae 1-21 to 1-32,

[0103] L_1 may be selected from groups represented by (e.g., each represented by) Formulae 4-1 to 4-22;

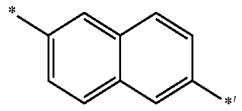
4-1



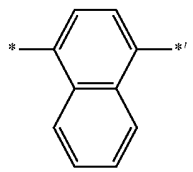
4-2



4-3



4-4



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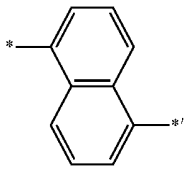
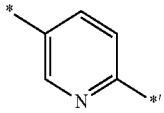
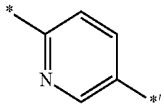
4-5



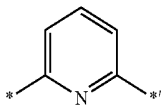
4-6



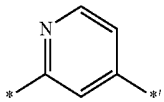
4-7



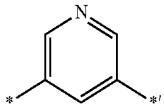
4-8



4-9



4-10



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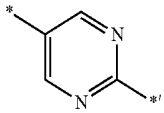

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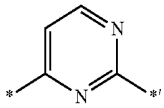

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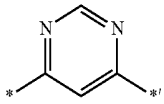

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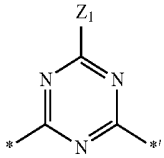

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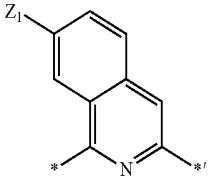

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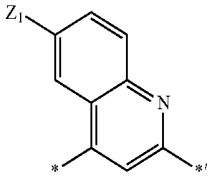

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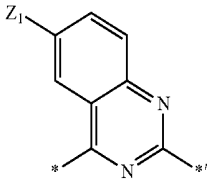
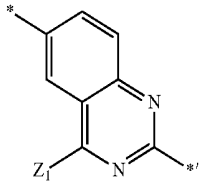


4-18



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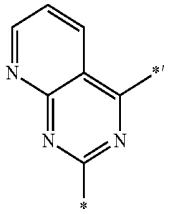

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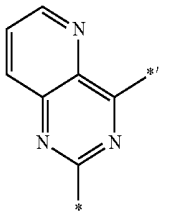
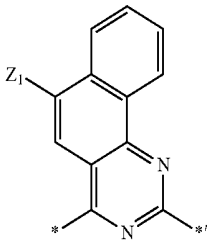
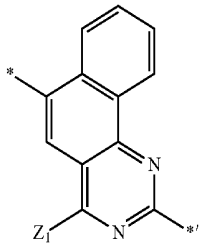


4-21



4-22



[0104] In Formulae 4-1 to 4-22,

[0105] Z_1 may be selected from a hydrogen, a deuterium, —F, a methyl group, an ethyl group, a tert-butyl group, a

methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

[0106] * and *' may be each independently a binding site to a neighboring atom;

[0107] n1 may be selected from 0, 1, and 2;

[0108] X_1 and X_2 may be each independently selected from O and S;

[0109] X_3 may be selected from $C(R_{17})(R_{18})$ and $N(R_{17})$;

[0110] Ar_1 may be selected from a methyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group; and

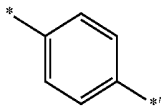
[0111] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group; and

[0112] R_1 to R_{18} may be each independently selected from a hydrogen, a deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

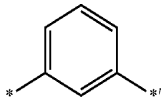
[0113] a phenyl group, a naphthyl group, and a pyridinyl group, each substituted with at least one of a phenyl group, a naphthyl group, and a pyridinyl group.

[0114] For example, when the heterocyclic compound is represented by any one of Formulae 1-21 to 1-32 above, L_1 may be selected from groups represented by (e.g., each represented by) Formulae 4-1 to 4-22;

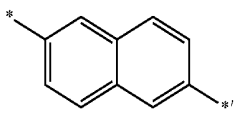
4-1



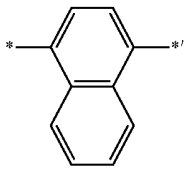
4-2



4-3



4-4



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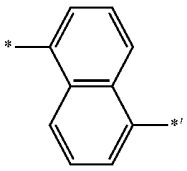
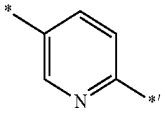
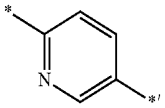
4-5



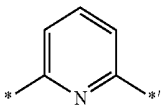
4-6



4-7



4-8



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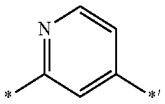

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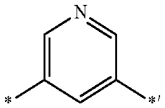
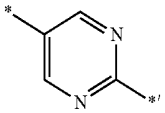


4-11



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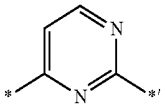

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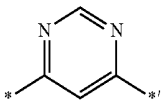
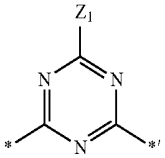
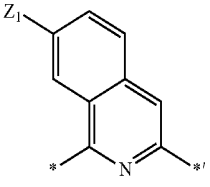


4-14



4-15



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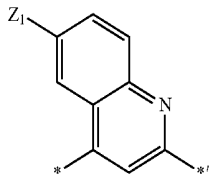
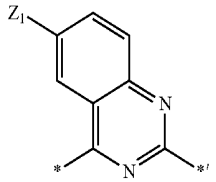
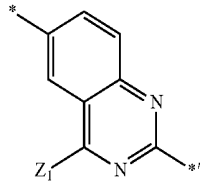


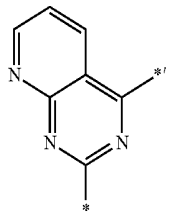
4-17



4-18



4-19



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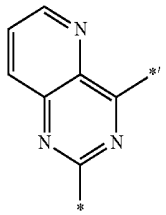

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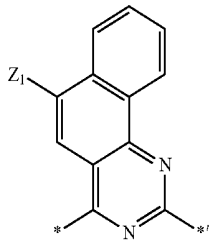
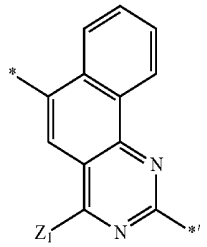


4-22



[0115] In Formulae 4-1 to 4-22,

[0116] Z_1 may be selected from a hydrogen, a deuterium, —F, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

[0117] * and *' may be each independently a binding site to a neighboring atom;

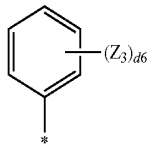
[0118] n1 may be selected from 0, 1, and 2;

[0119] X_1 and X_2 may be each independently O and S;

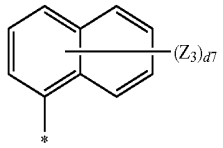
[0120] X_3 may be selected from $C(R_{17})(R_{18})$ and $N(R_{17})$; and

[0121] Ar_1 may be selected from groups represented by Formulae 5-1 to 5-48:

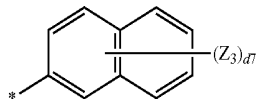
5-1



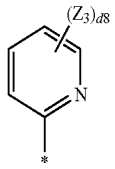
5-2



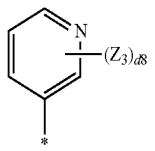
5-3



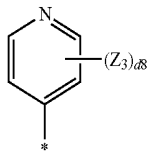
5-4



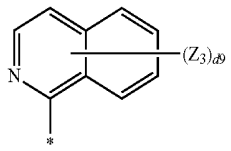
5-5



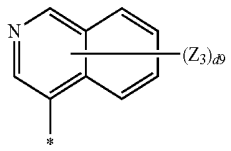
5-6



5-7



5-8



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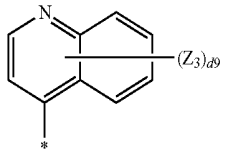
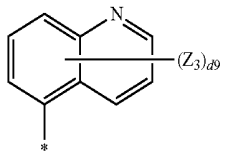
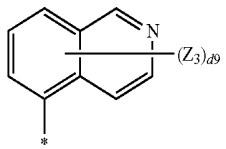
5-9



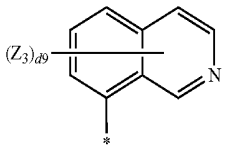
5-10



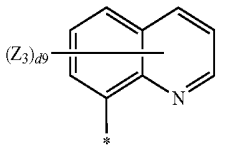
5-11



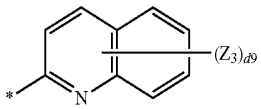
5-12



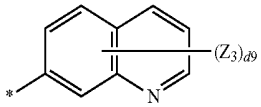
5-13



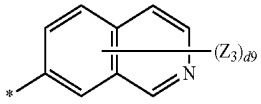
5-14



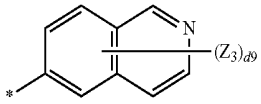
5-15



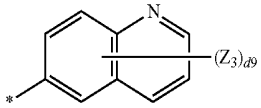
5-16



5-17



5-18



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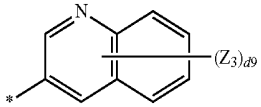

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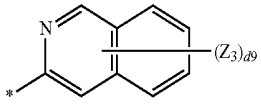

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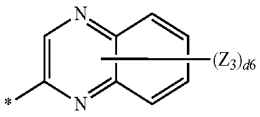

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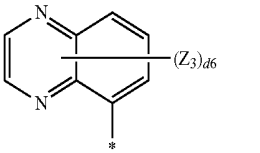

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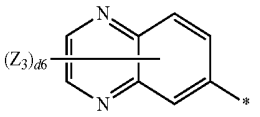

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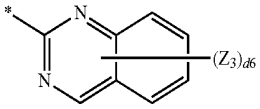

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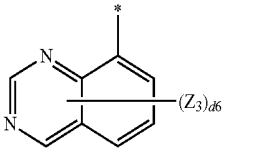

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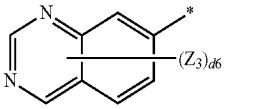

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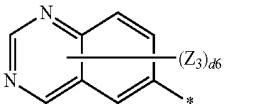

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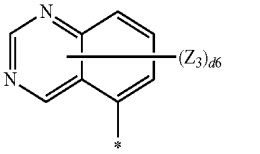

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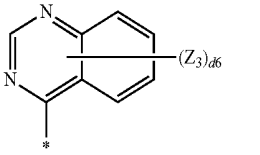

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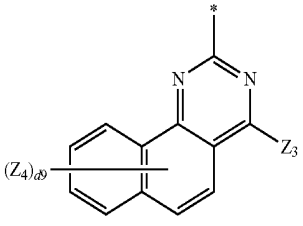

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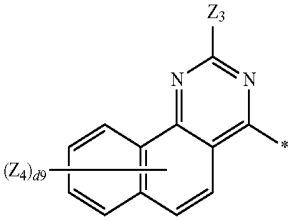

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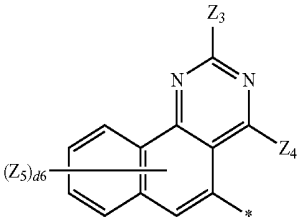

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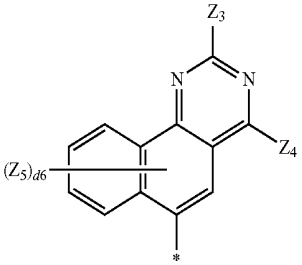

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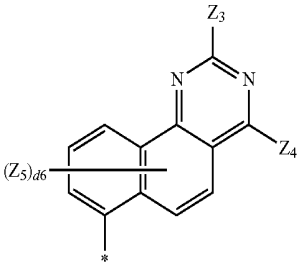

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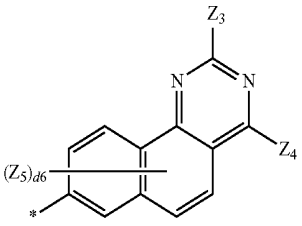

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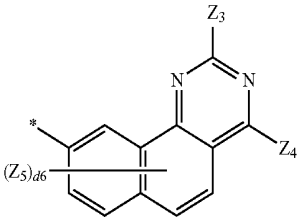

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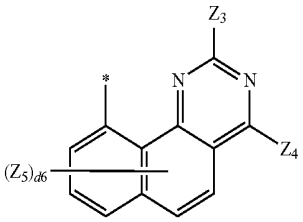

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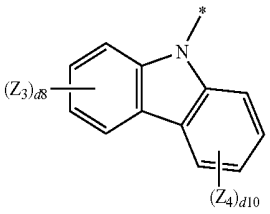

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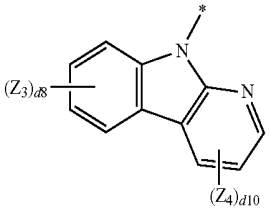

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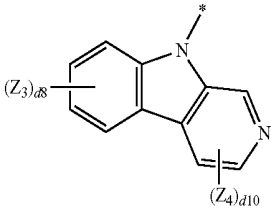

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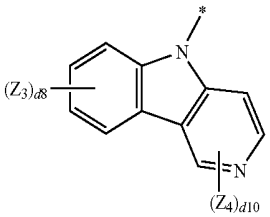

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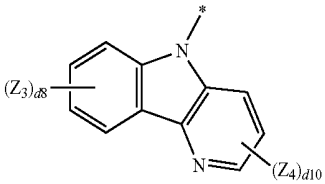

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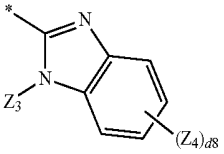

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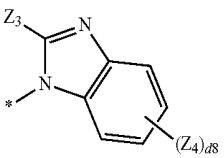

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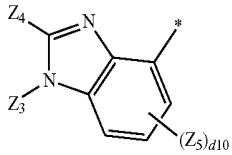

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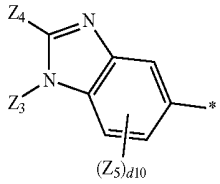

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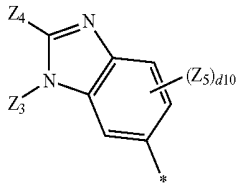

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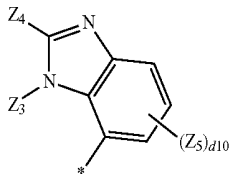


[0122] In Formulae 5-1 to 5-48,

[0123] Z_3 to Z_5 may be each independently selected from a hydrogen, a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

[0124] d6 may be selected from 1, 2, 3, 4, and 5;

[0125] d7 may be selected from 1, 2, 3, 4, 5, 6, and 7;

[0126] d8 may be selected from 1, 2, 3, and 4;

[0127] d9 may be selected from 1, 2, 3, 4, 5, and 6;

[0128] d10 may be selected from 1, 2, and 3;

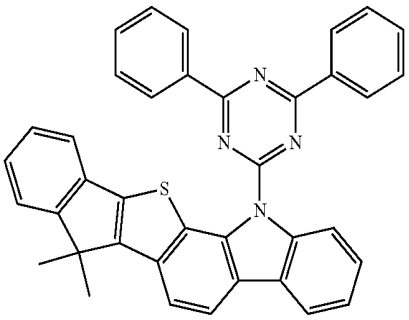
[0129] * may be a binding site to a neighboring atom; and

[0130] R_1 to R_{18} may be each independently selected from a hydrogen, a deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

[0131] a phenyl group, a naphthyl group, and a pyridinyl group, each substituted with at least one of a phenyl group, a naphthyl group, and a pyridinyl group, but embodiments are not limited thereto.

[0132] For example, the heterocyclic compound may be any one of Compounds 2 to 580, but embodiments are not limited thereto:

2



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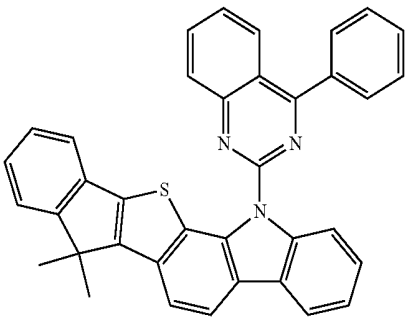

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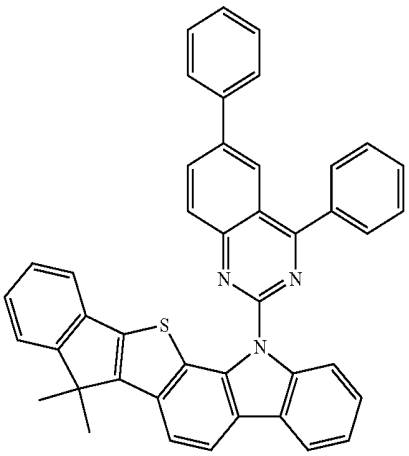

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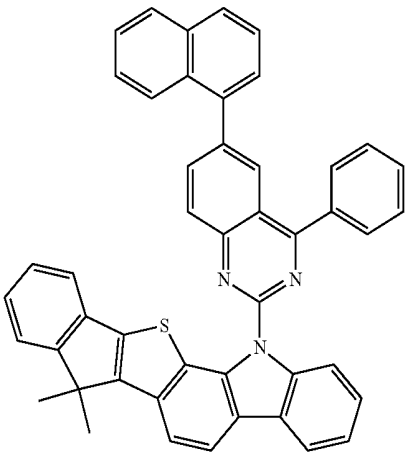

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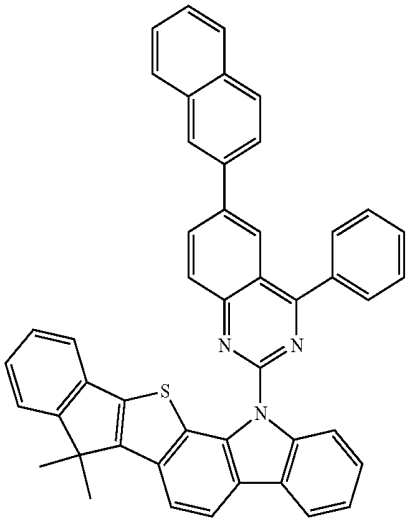

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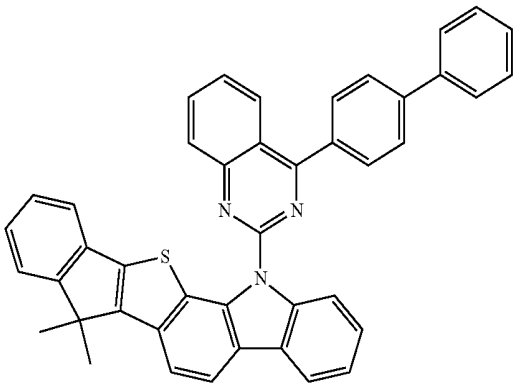

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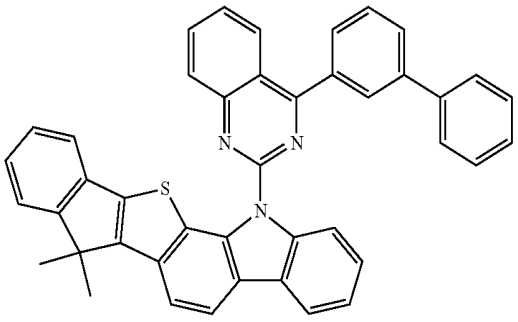

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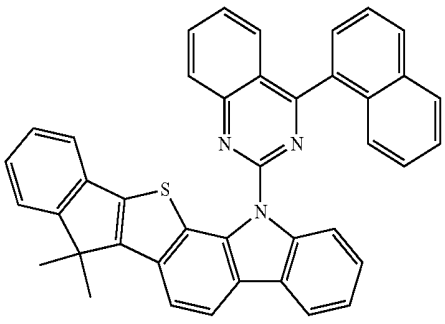

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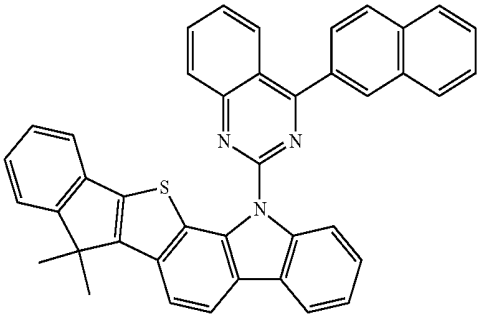

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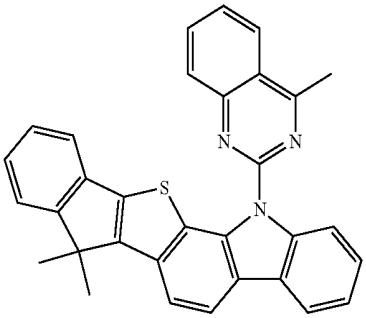

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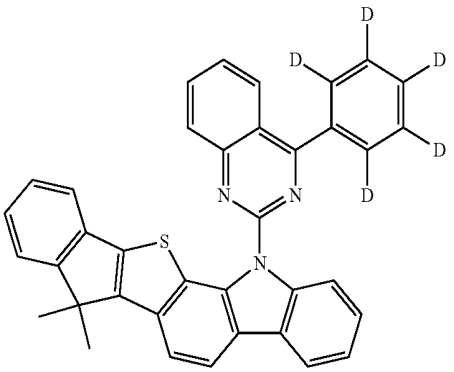

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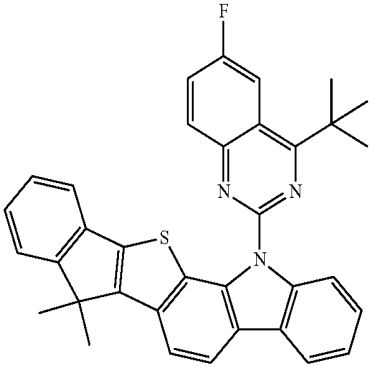

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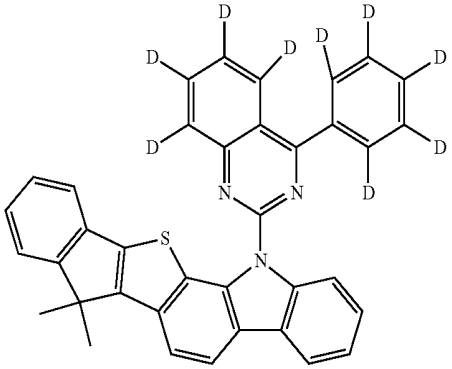

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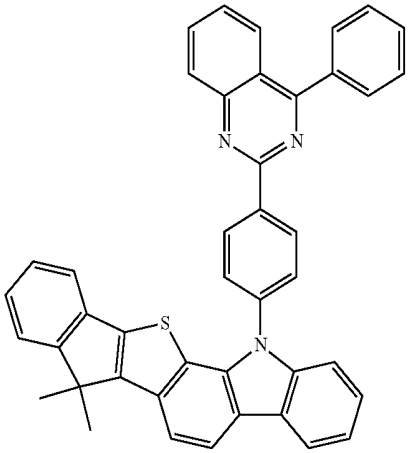

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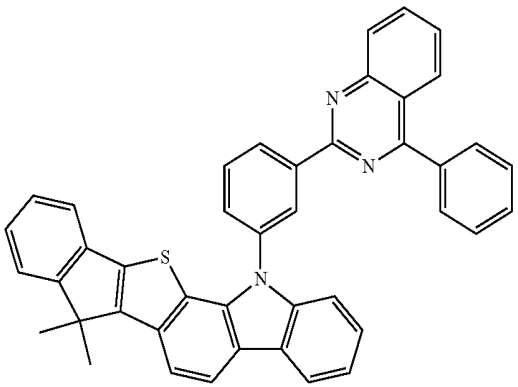

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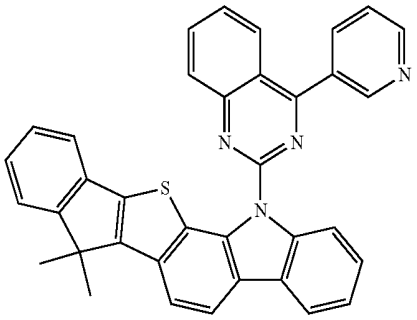

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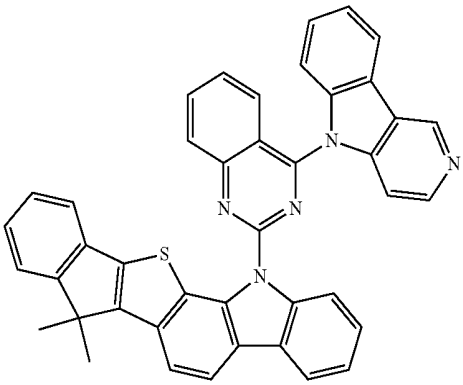

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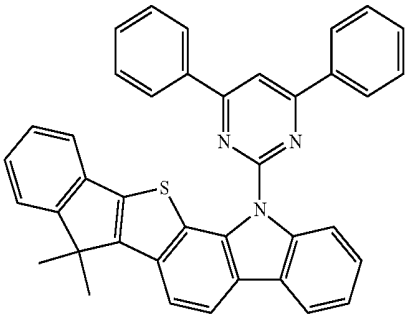

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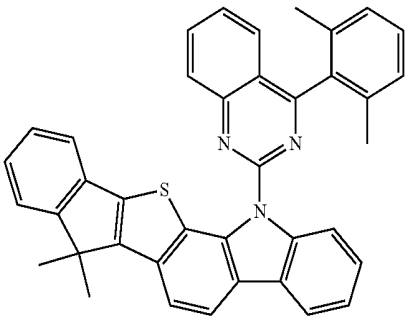

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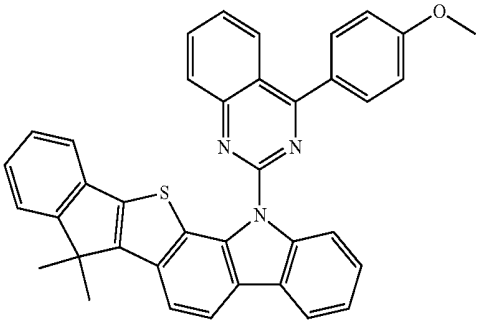

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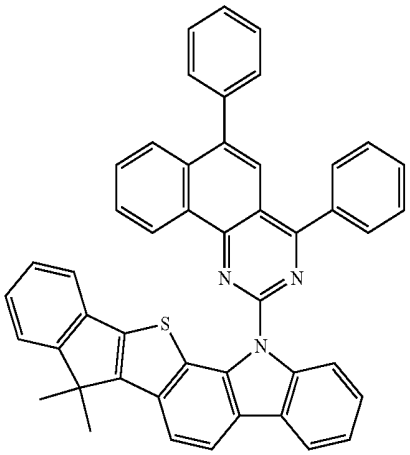

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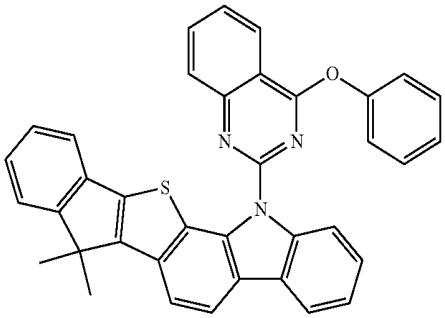

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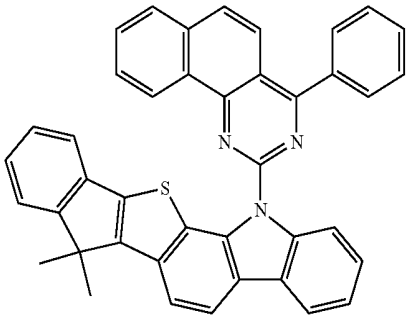

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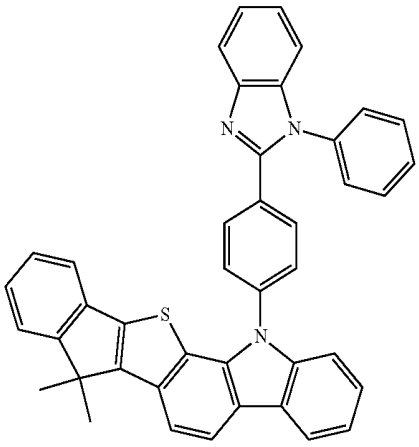

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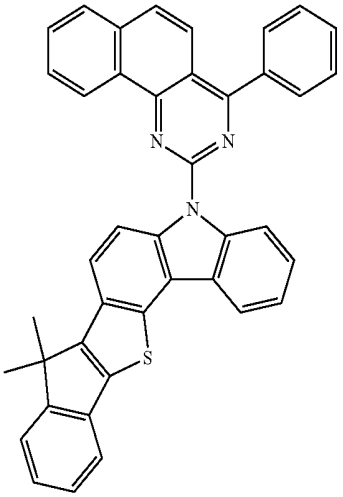

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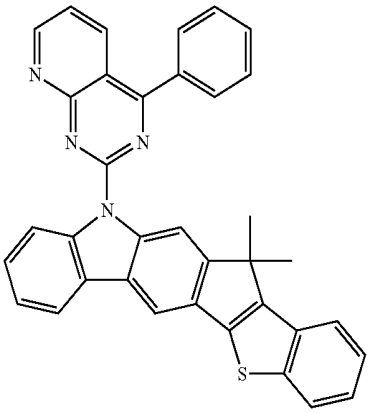

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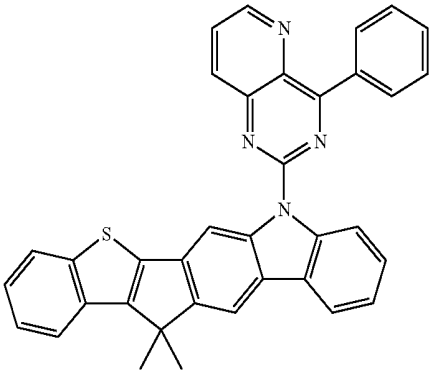

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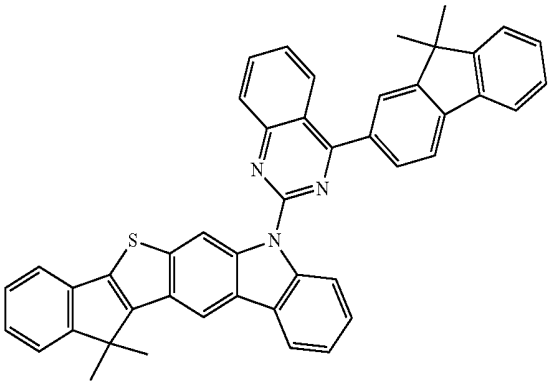

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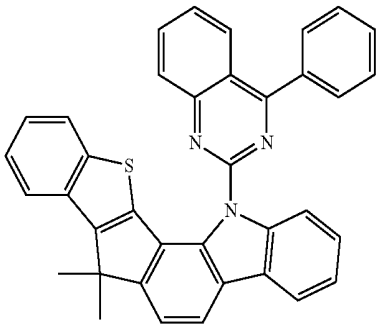

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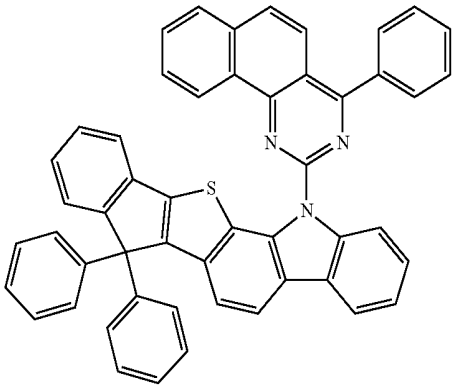

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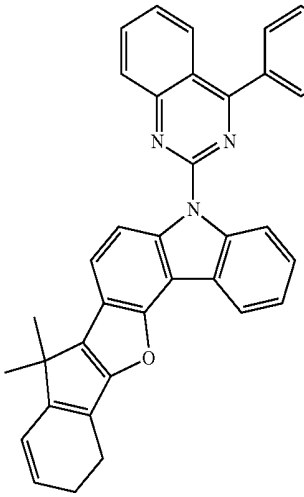

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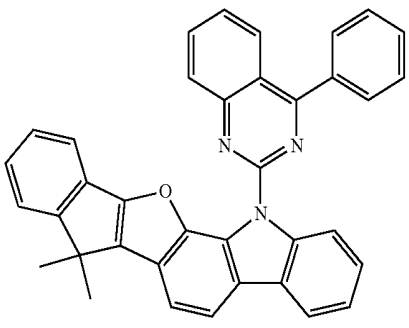

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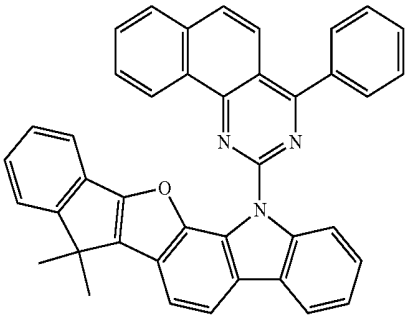

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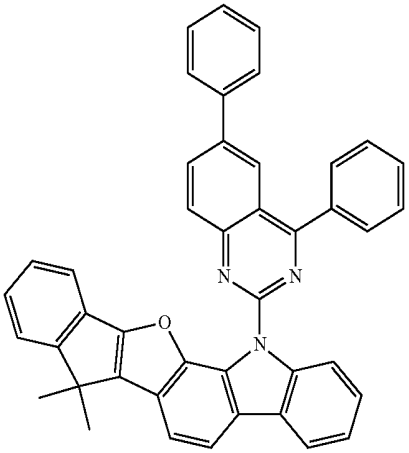

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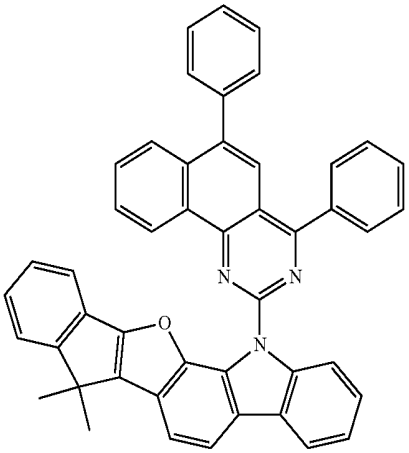

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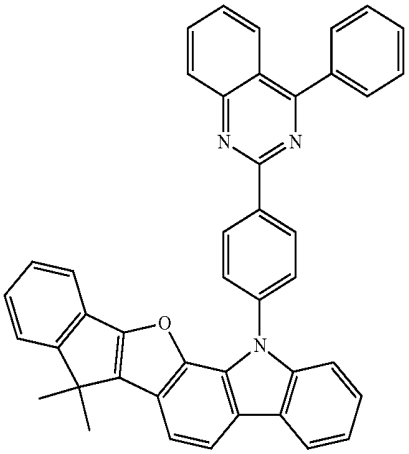

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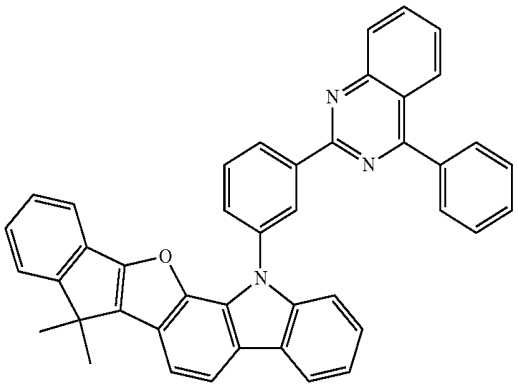

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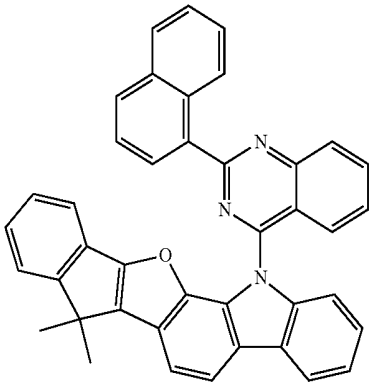

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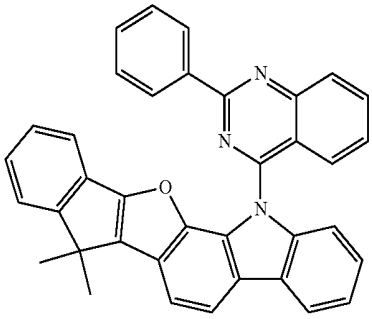

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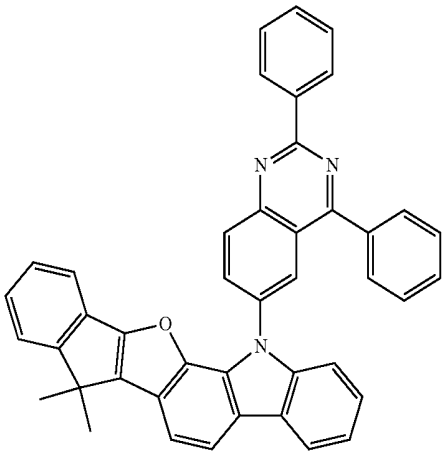

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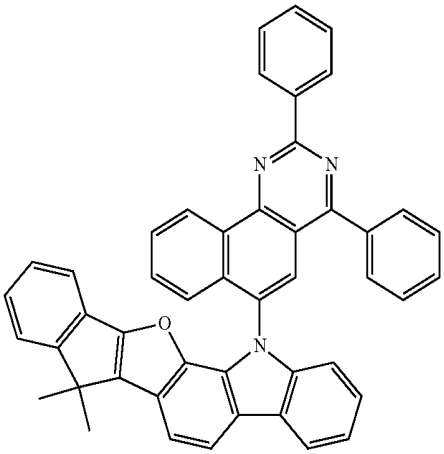

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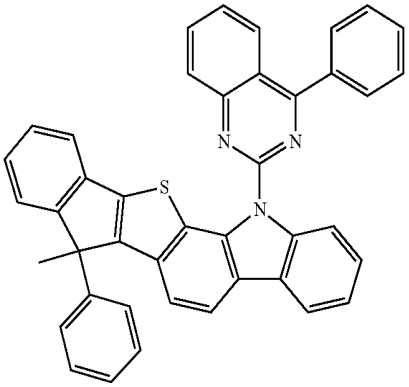

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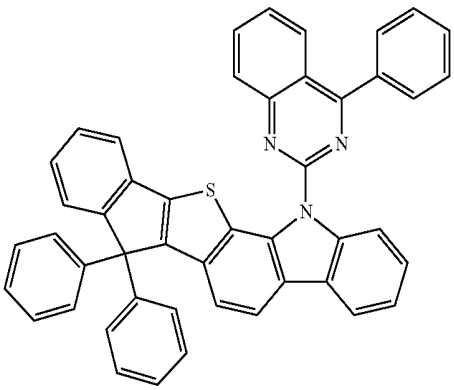

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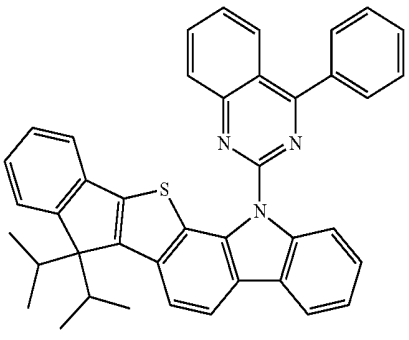

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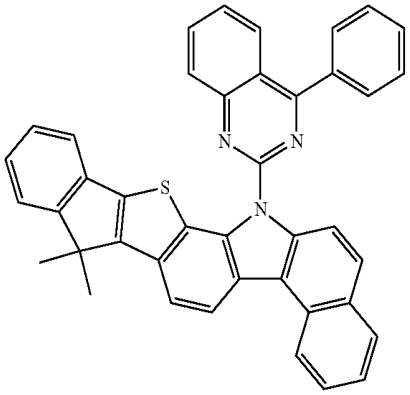

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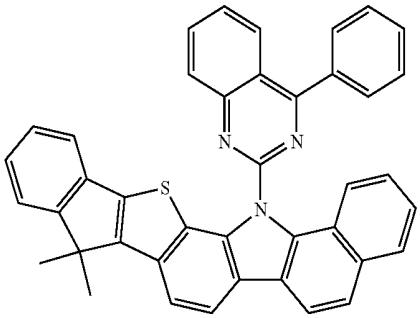

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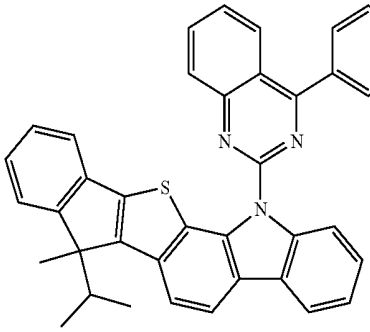

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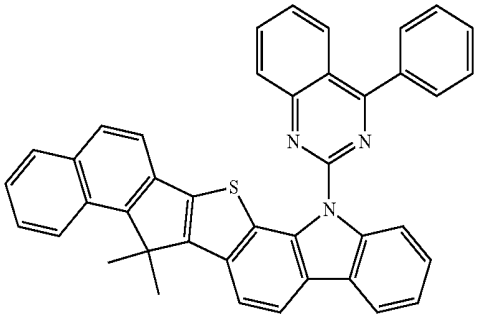

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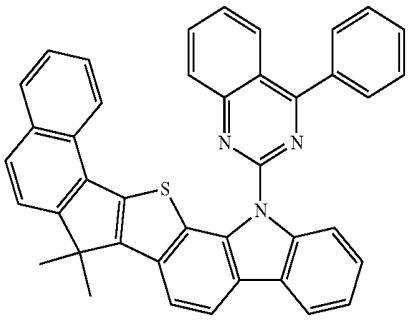

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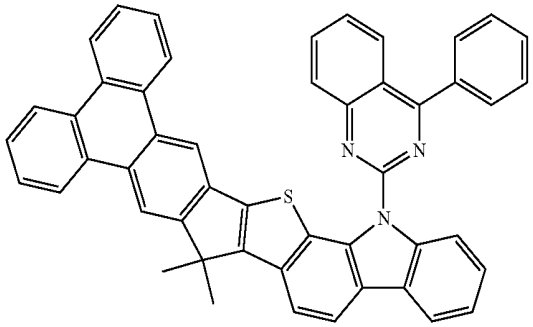

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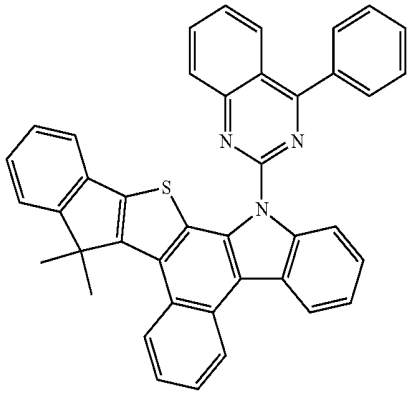

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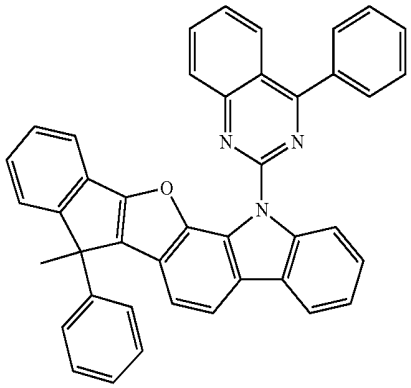

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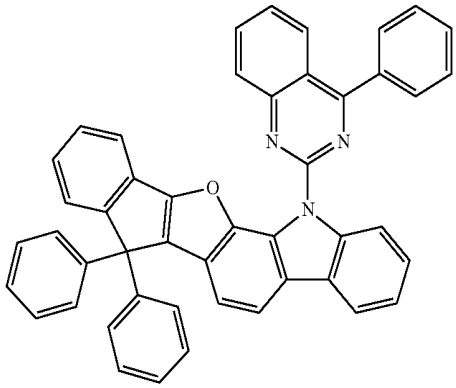

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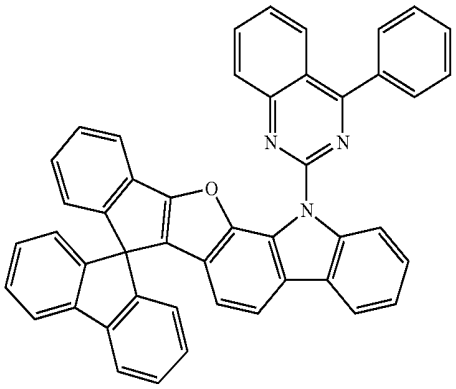

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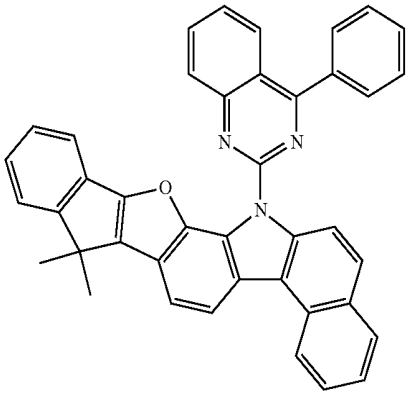

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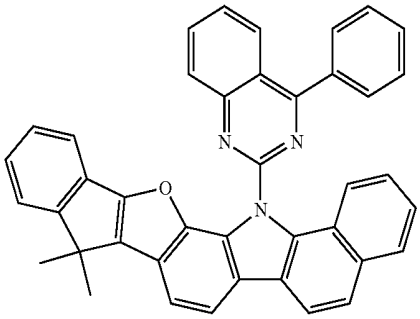

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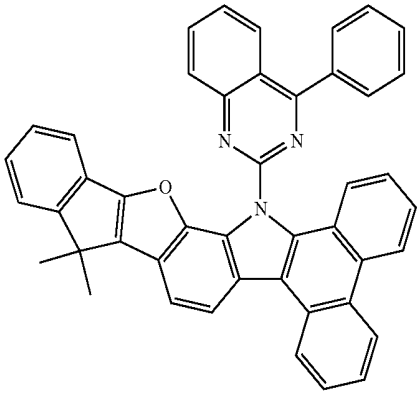

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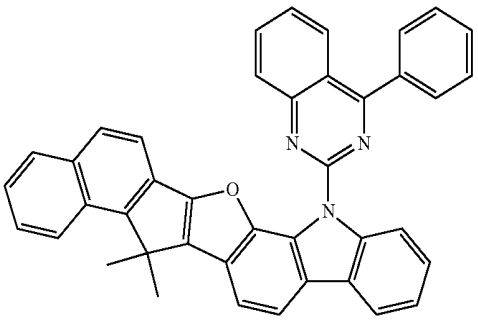

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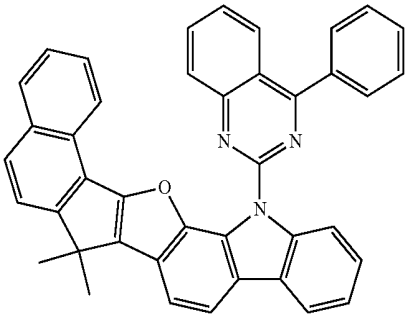

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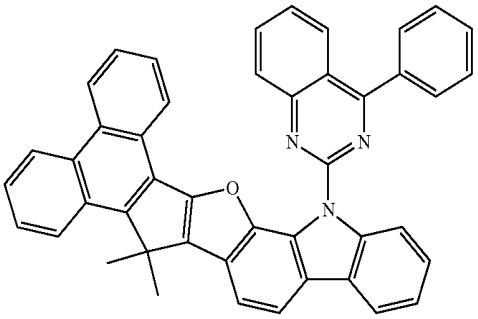

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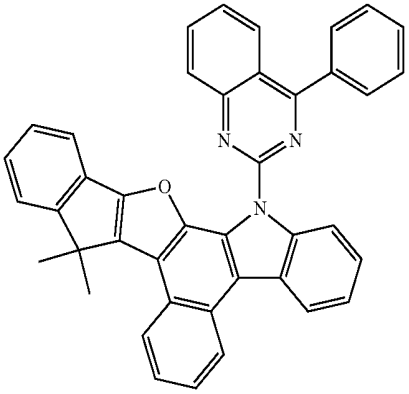

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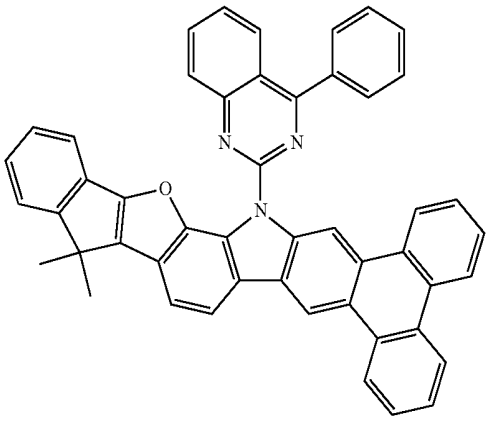

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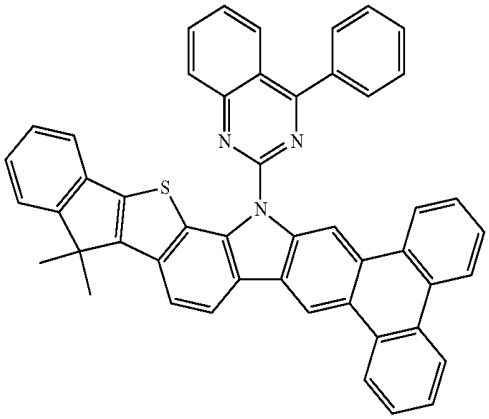

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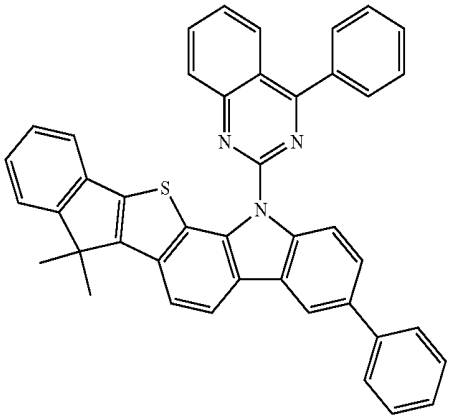

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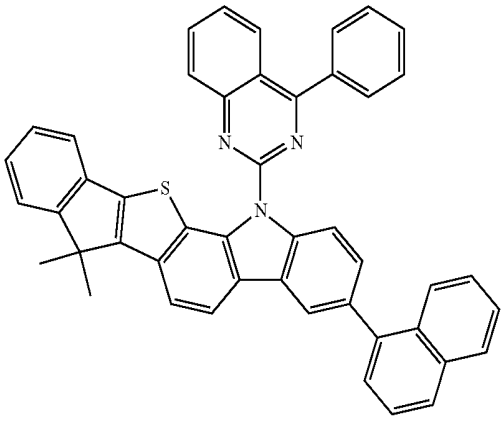

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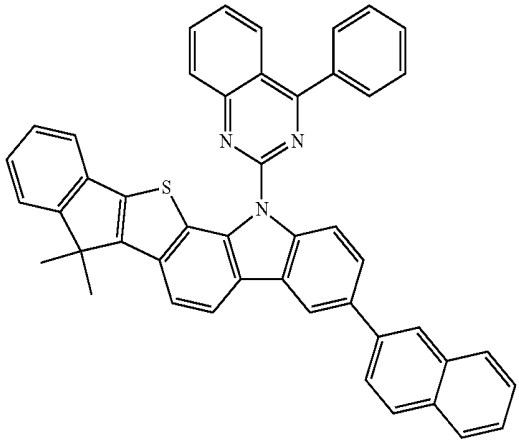

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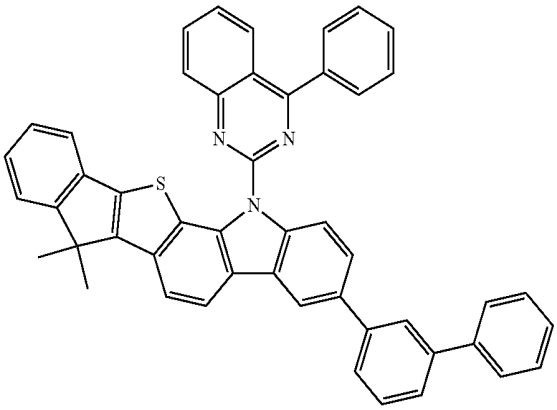

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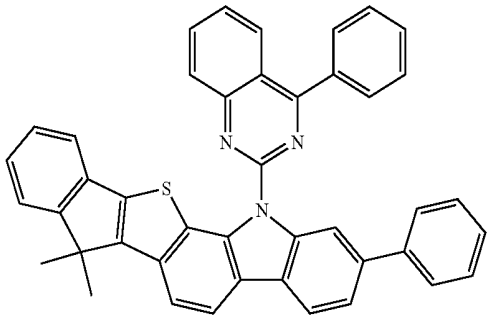

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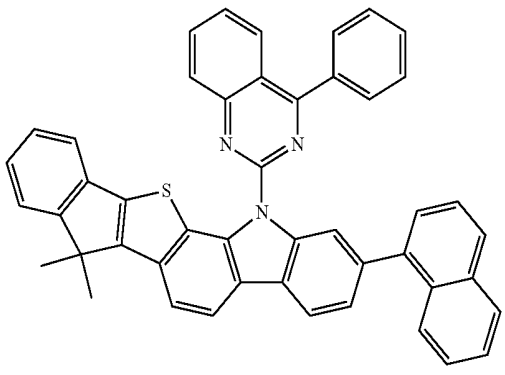

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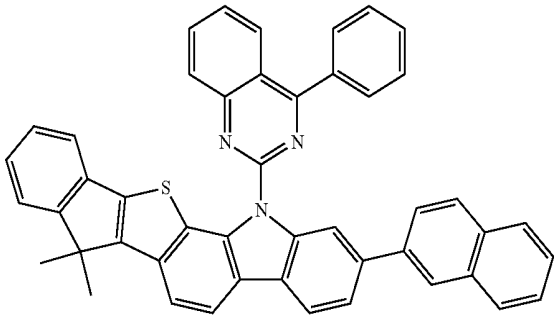

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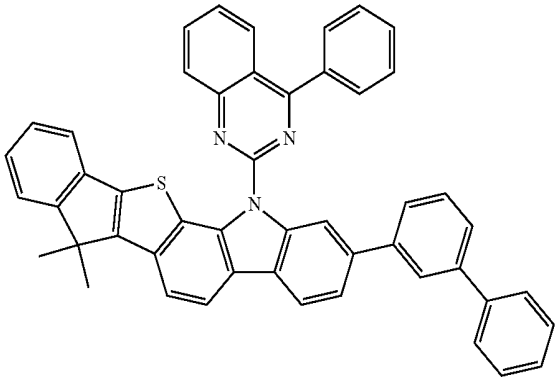

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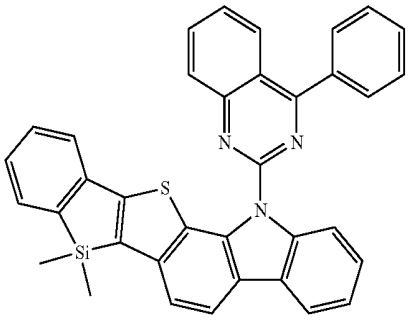

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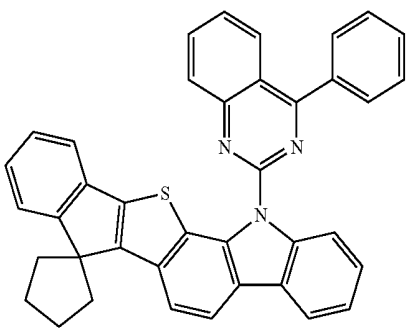

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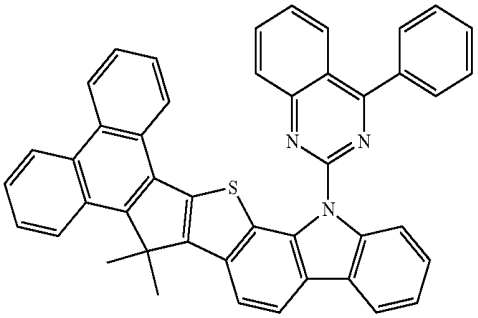

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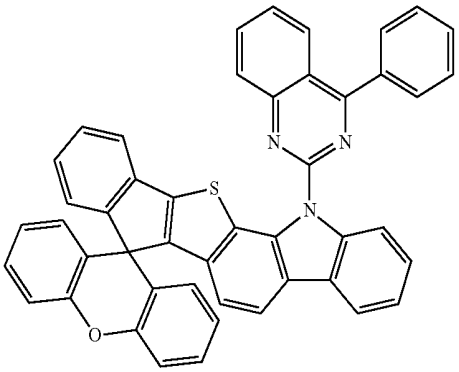

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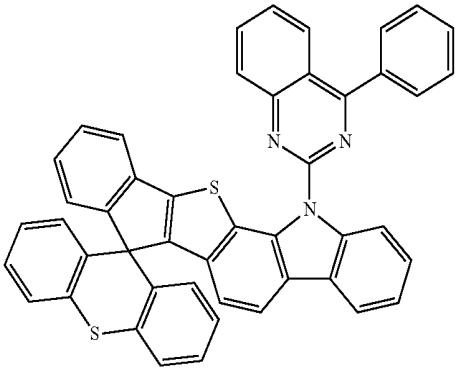

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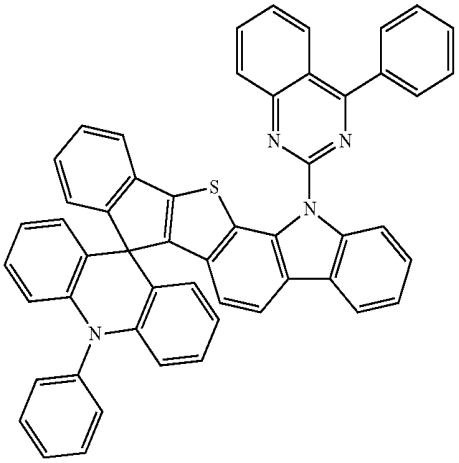

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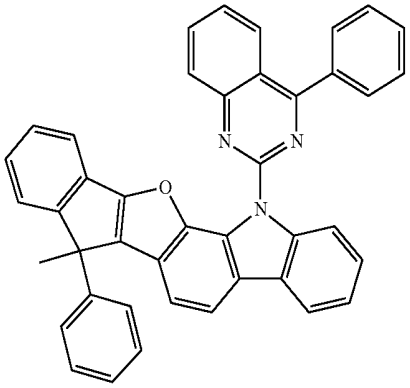

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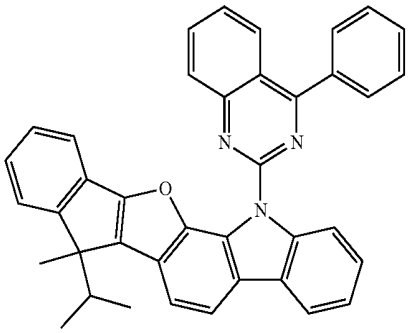

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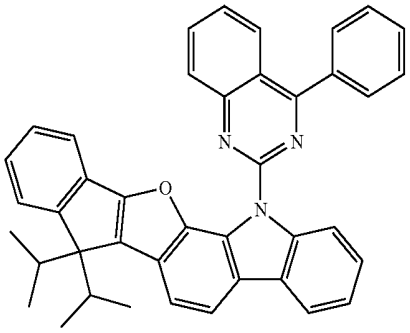

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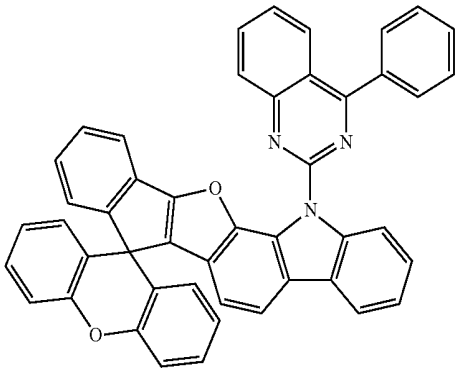

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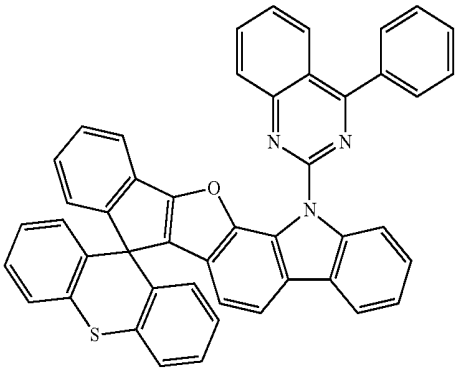

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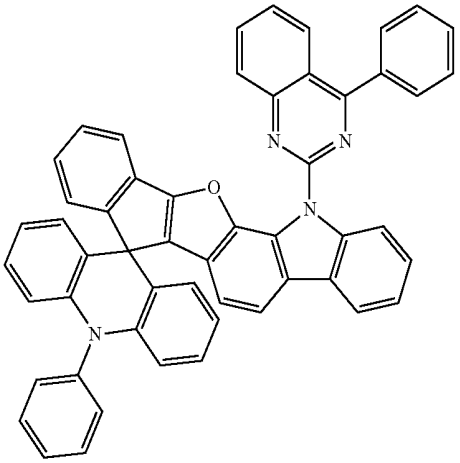

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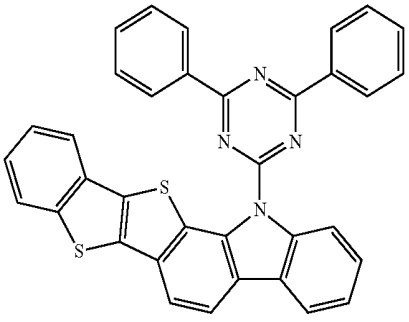

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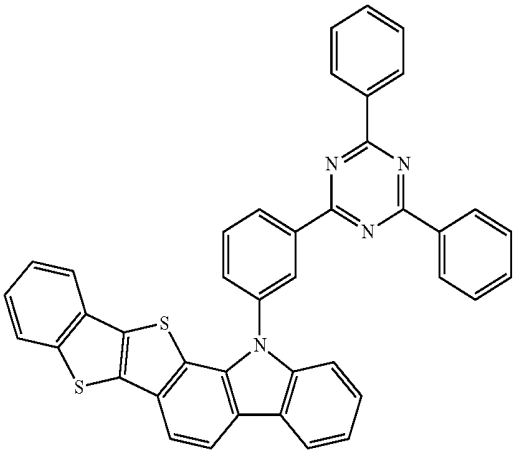

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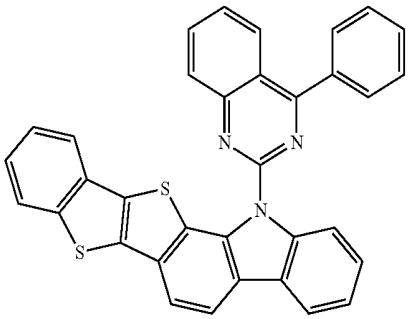

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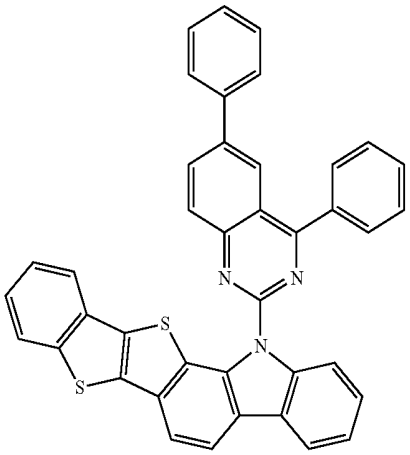

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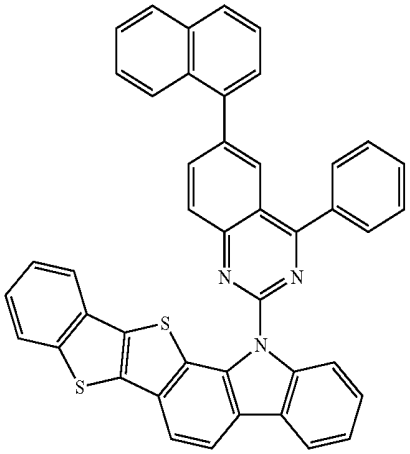

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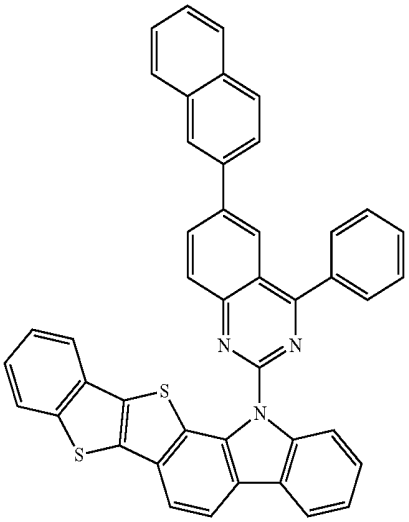

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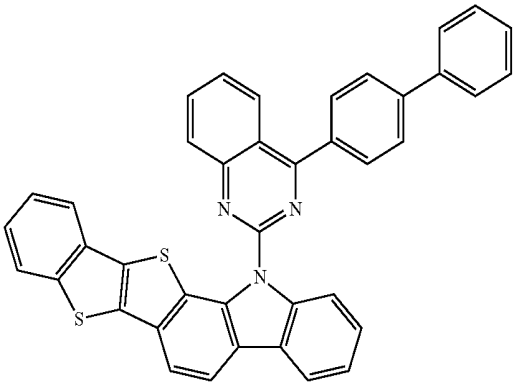

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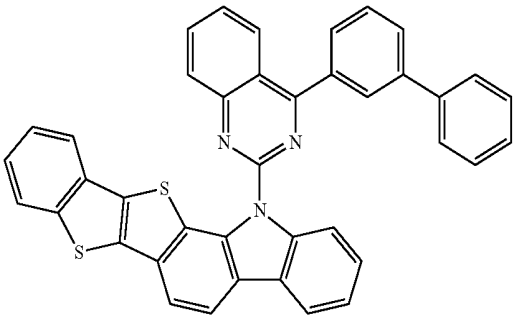

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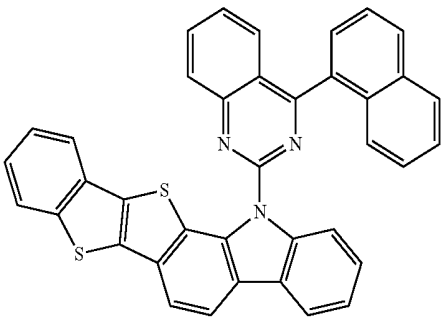

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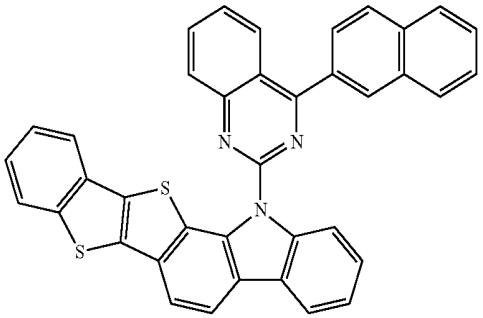

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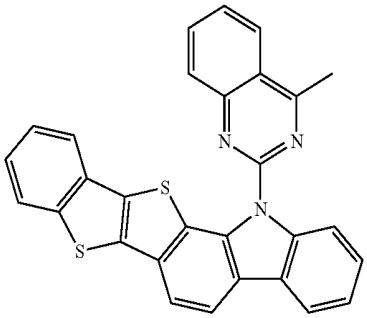

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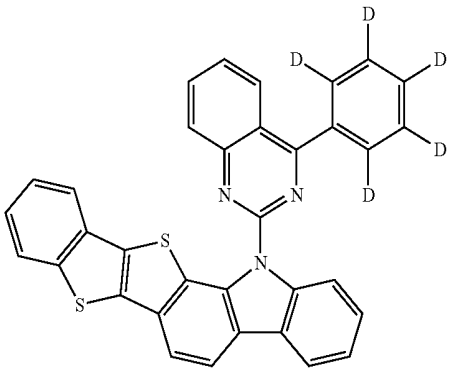

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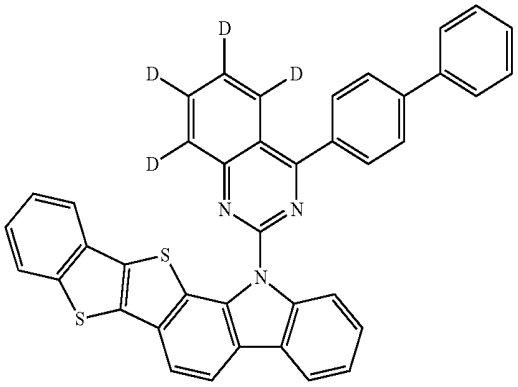

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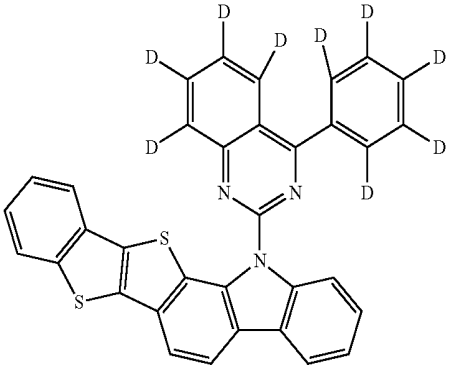

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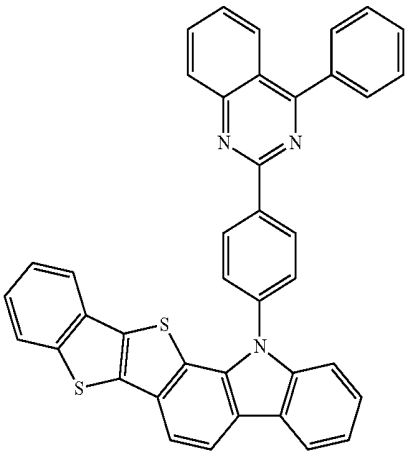

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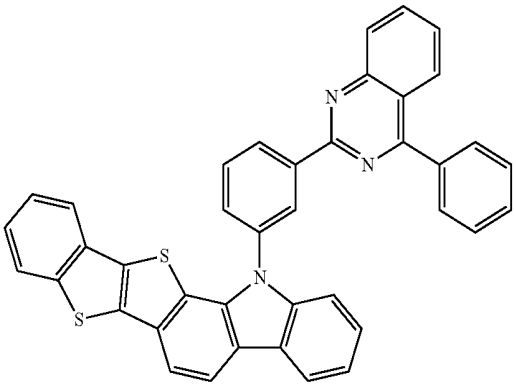

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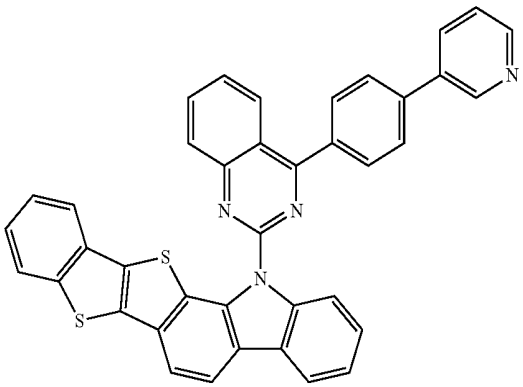

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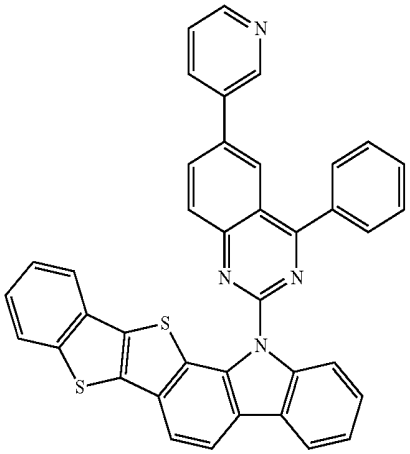

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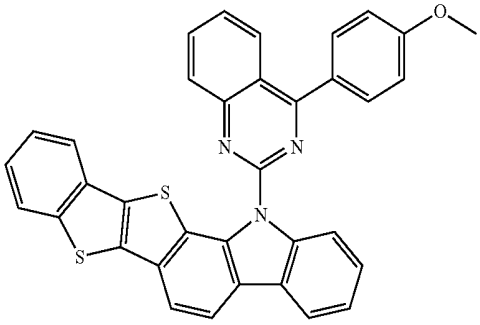

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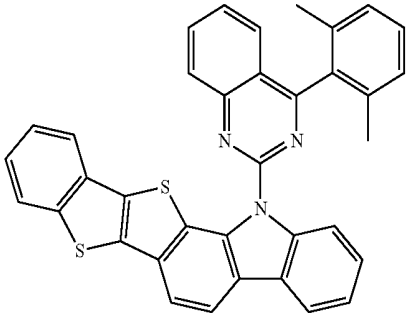

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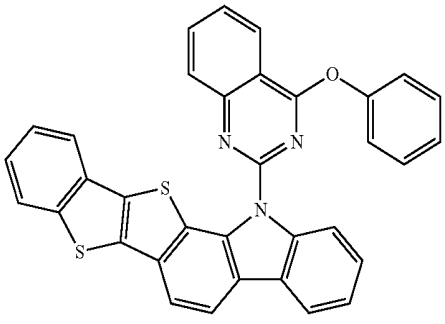

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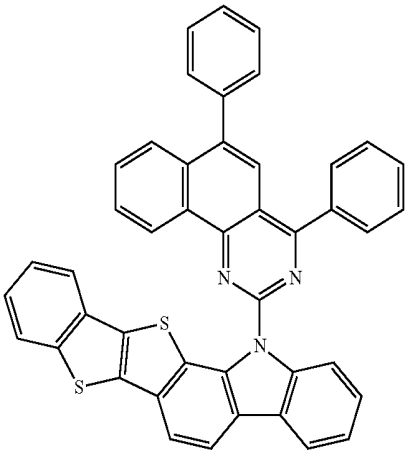

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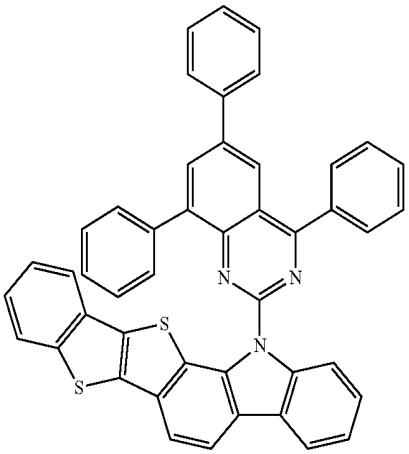

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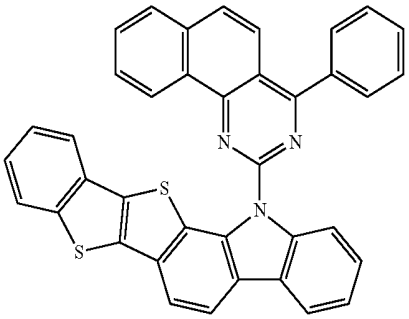

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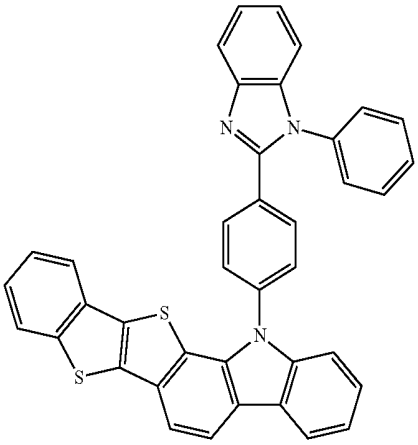

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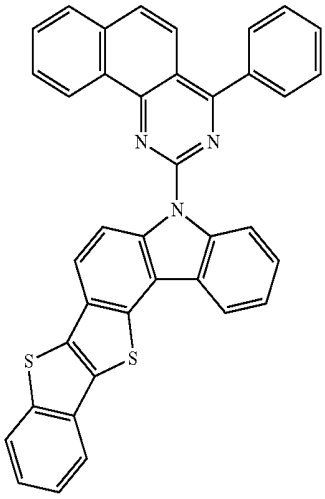

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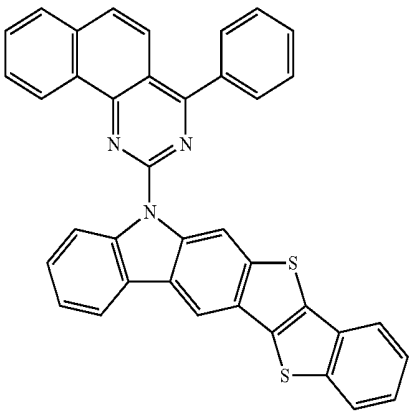

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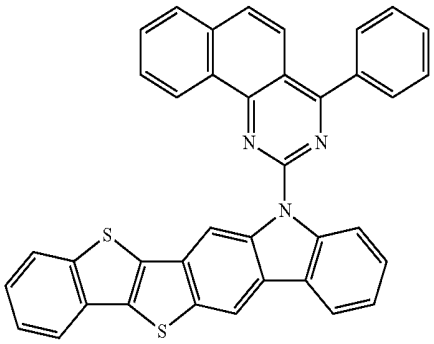

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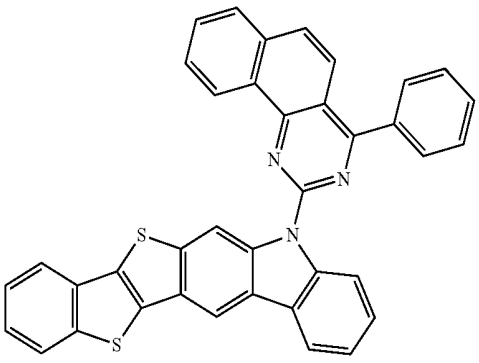

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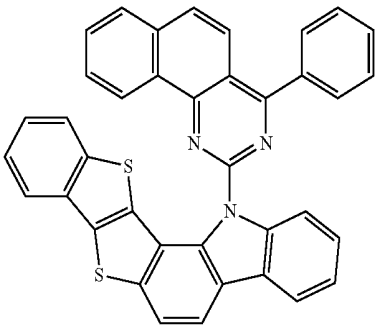

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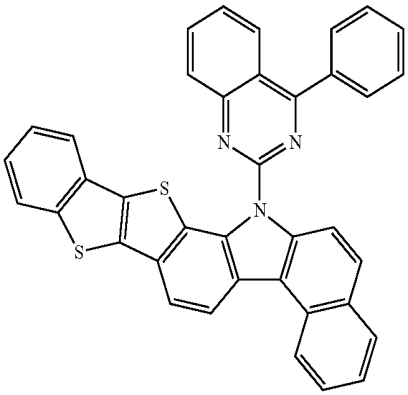

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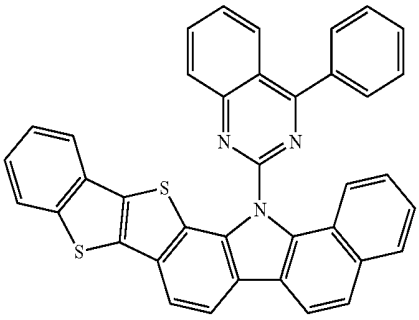

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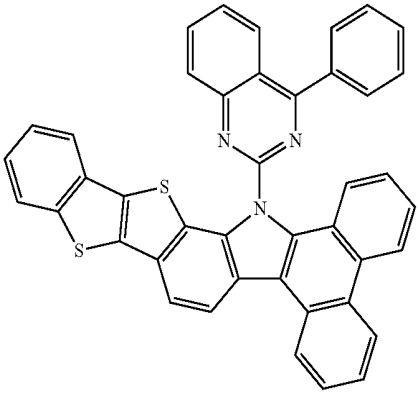

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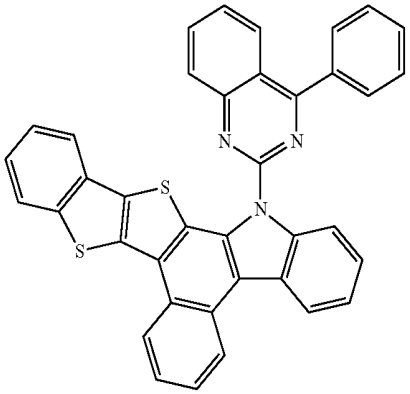

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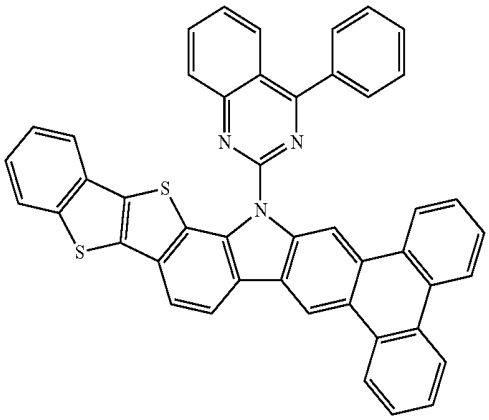

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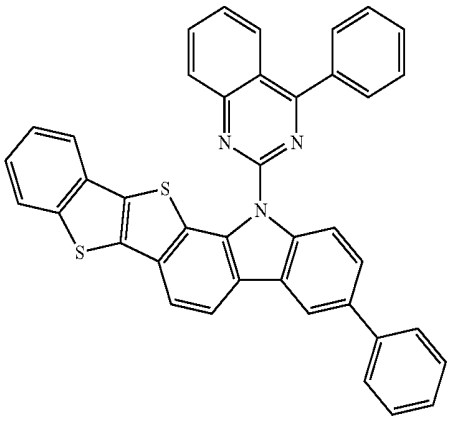

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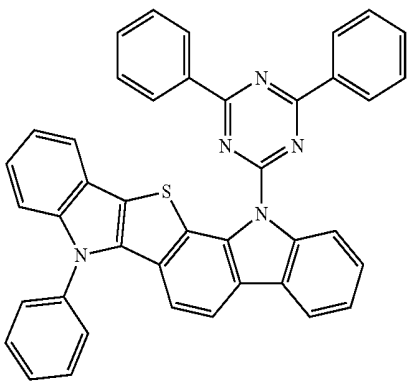

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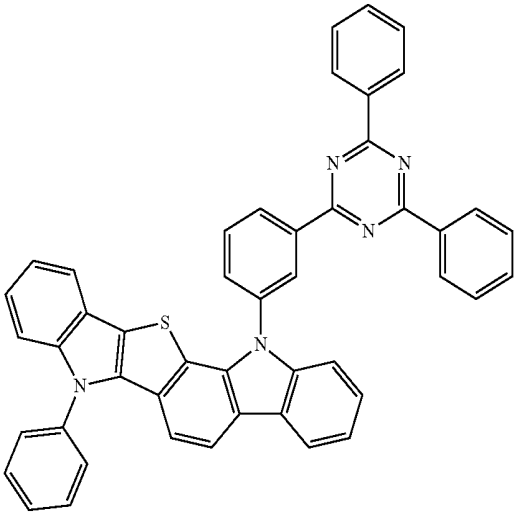

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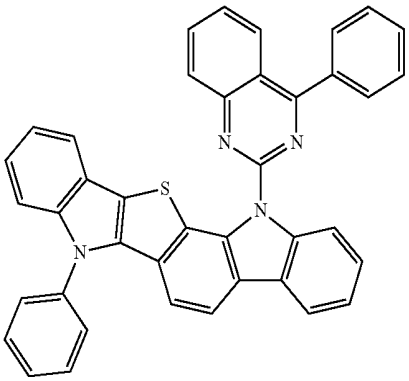

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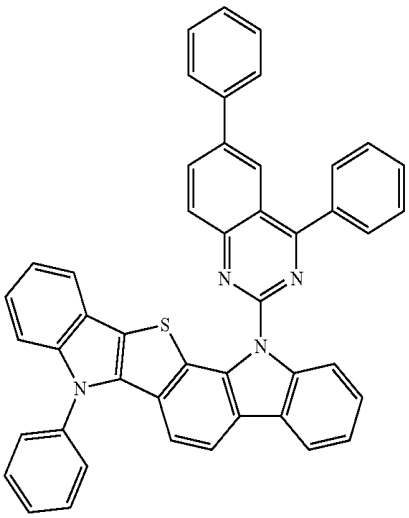

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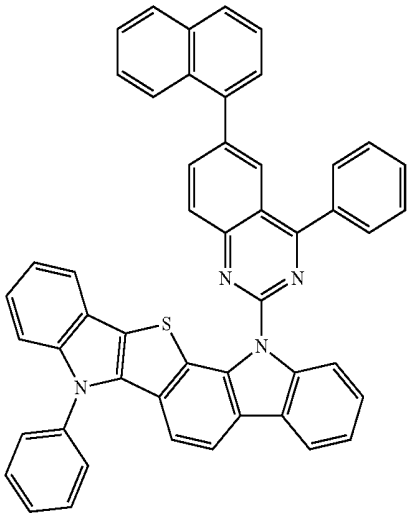

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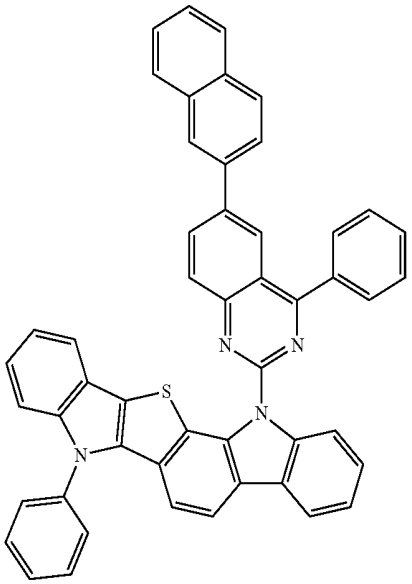

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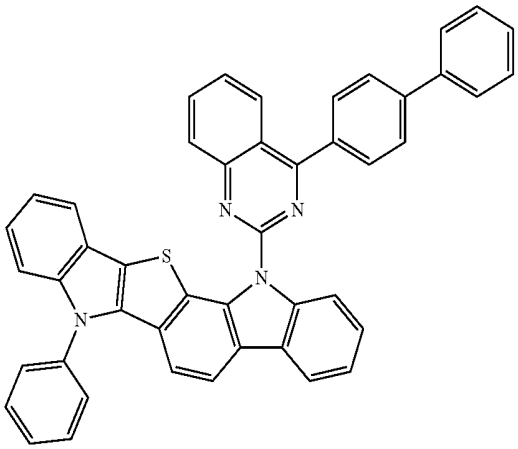

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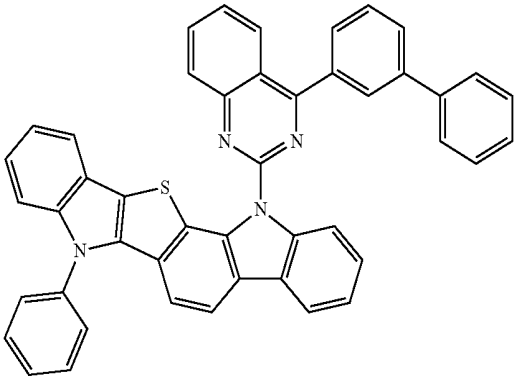

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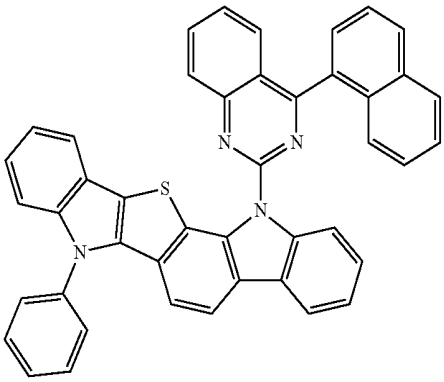

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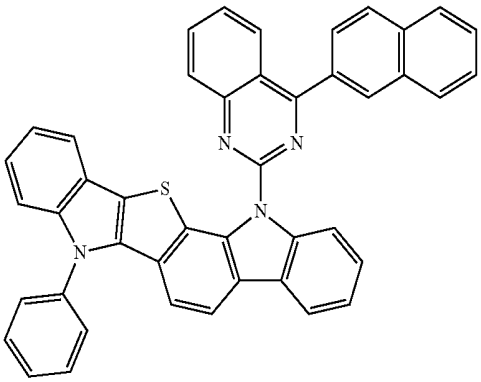

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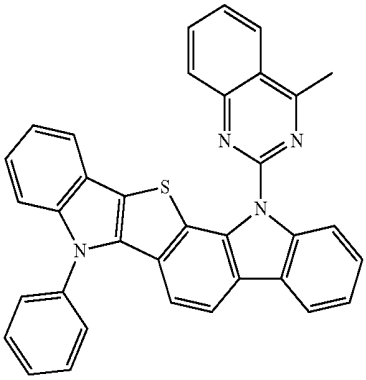

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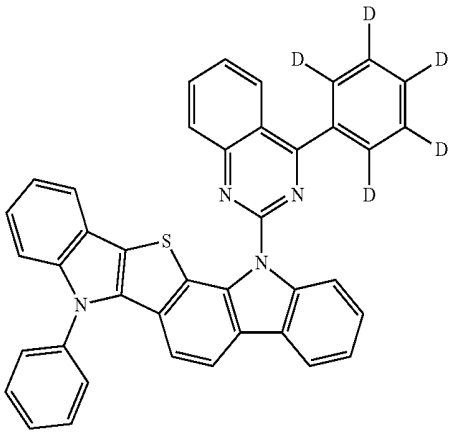

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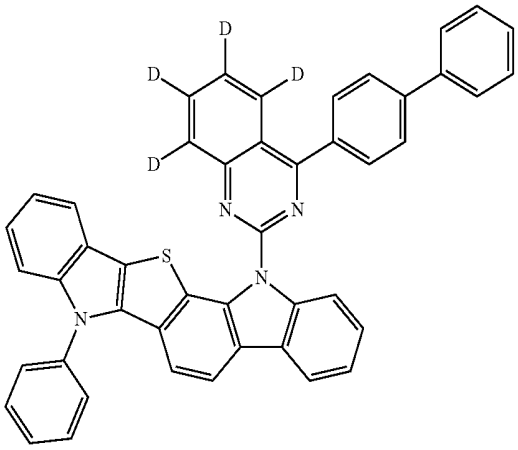

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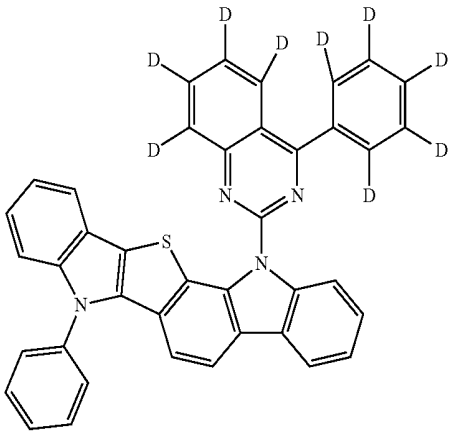

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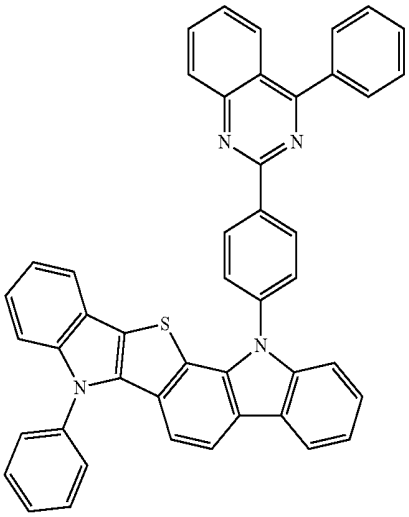

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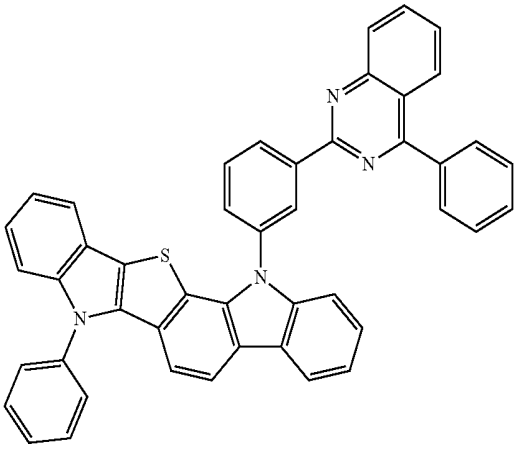

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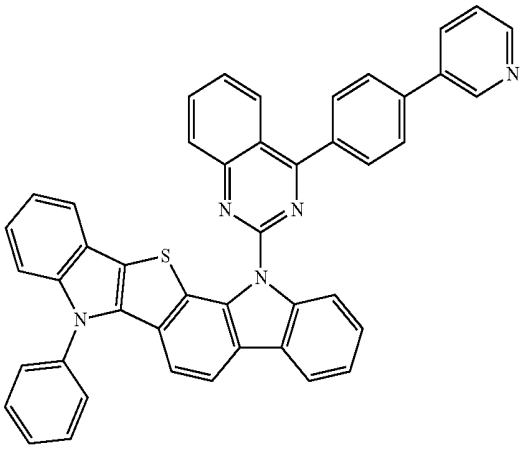

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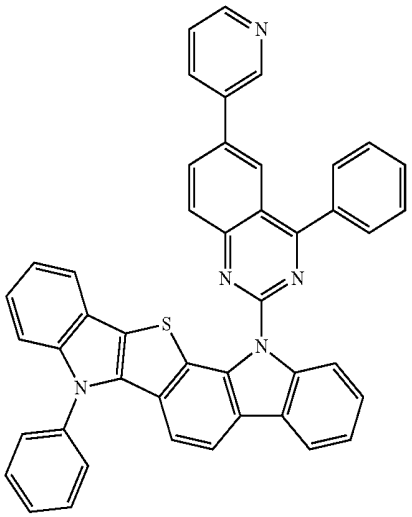

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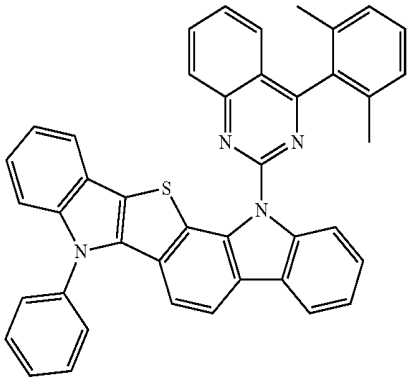

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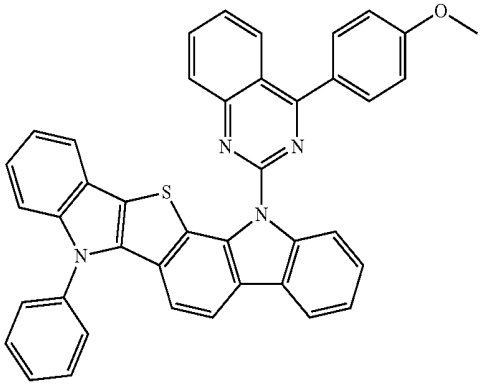

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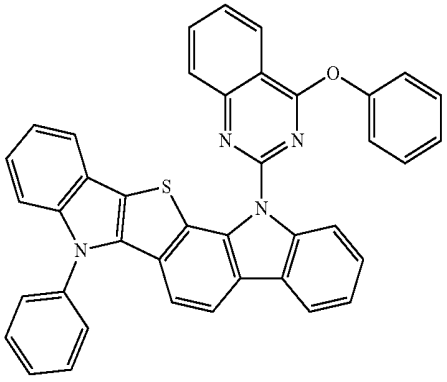

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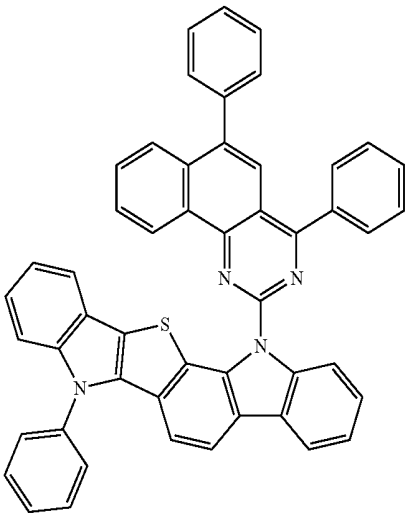

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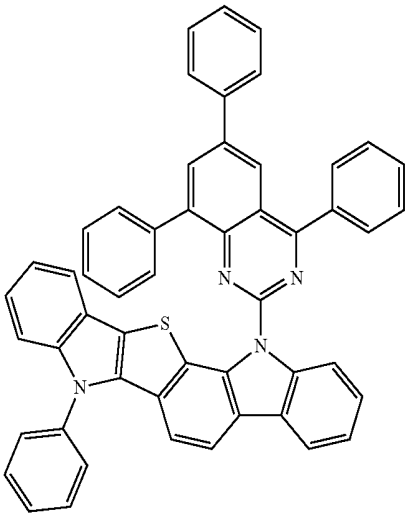

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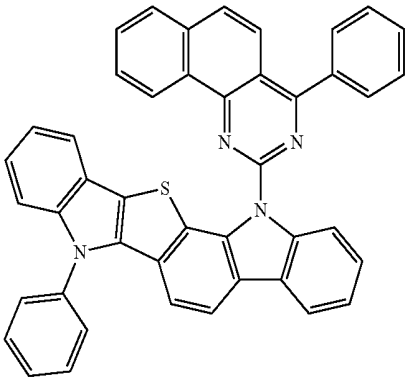

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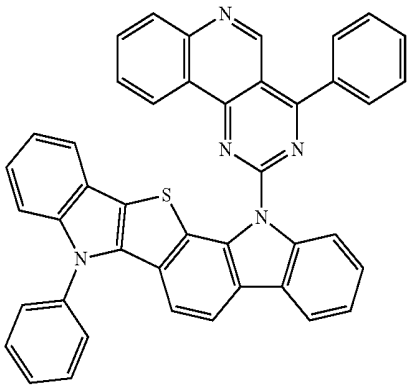

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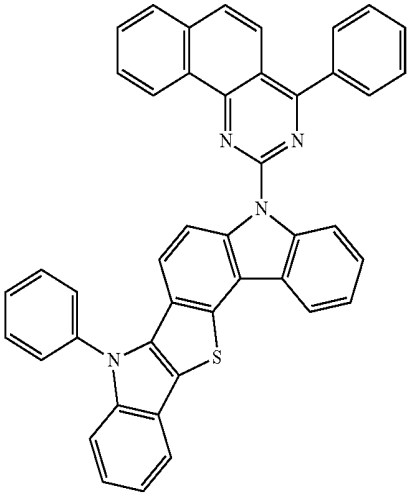

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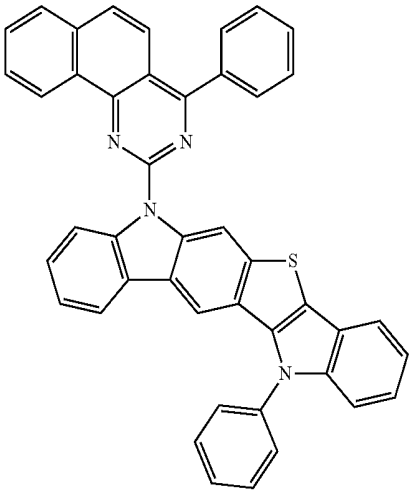

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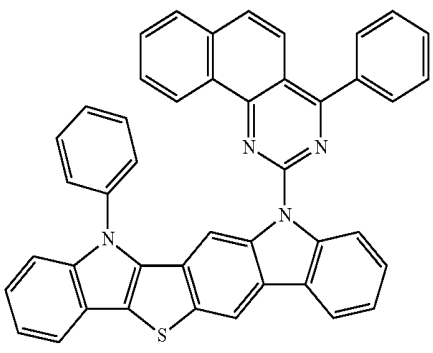

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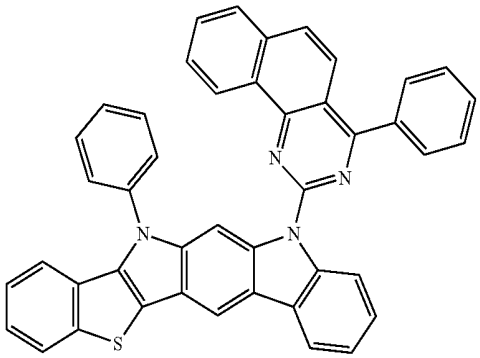

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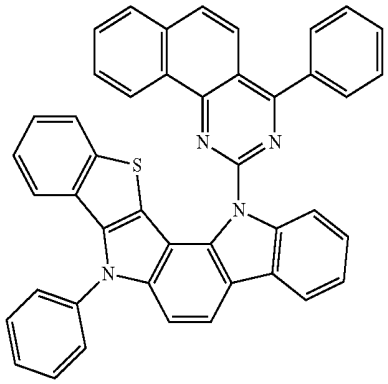

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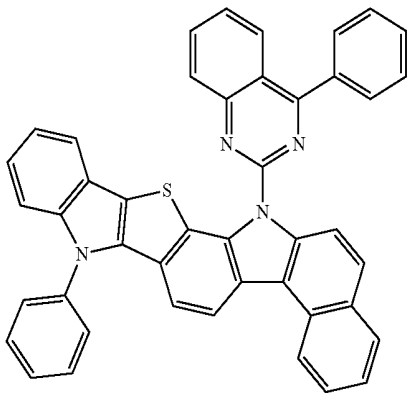

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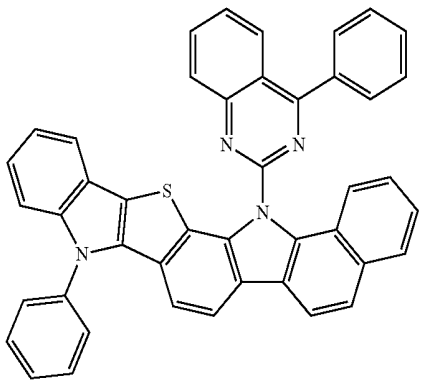

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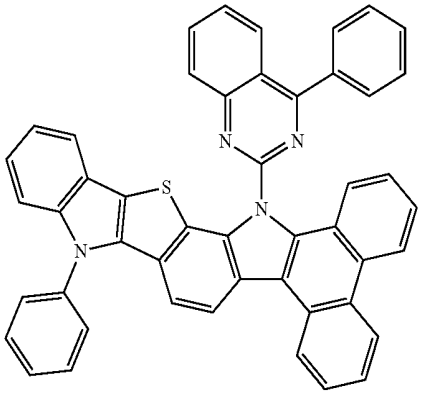

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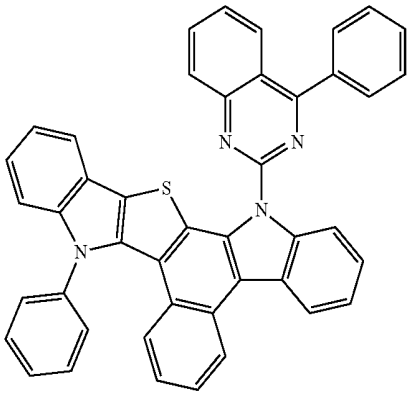

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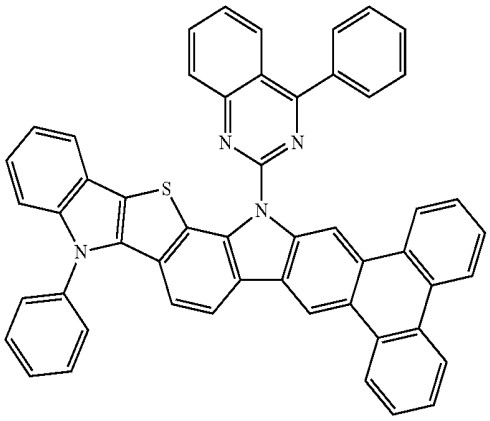

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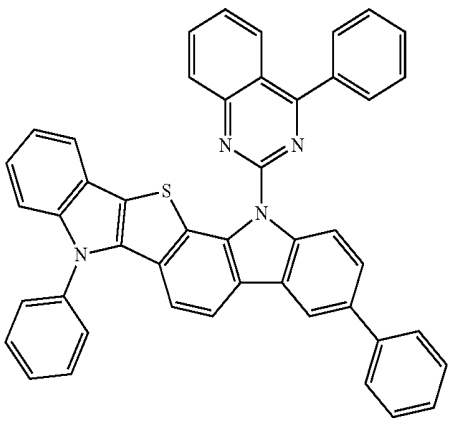

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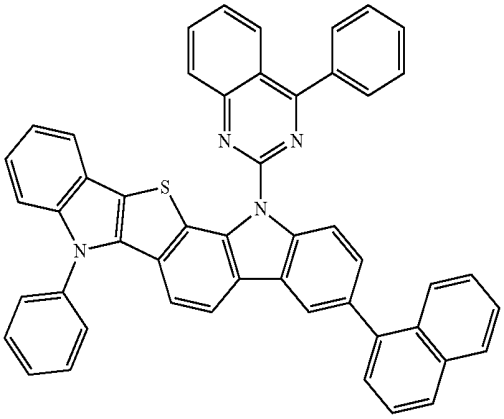

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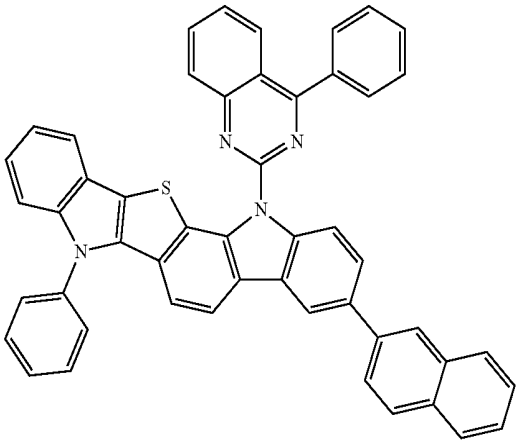

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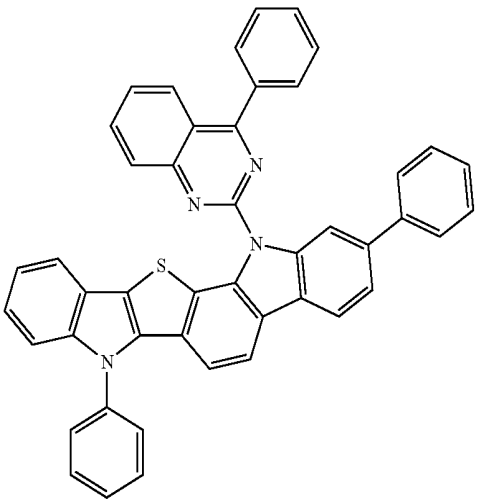

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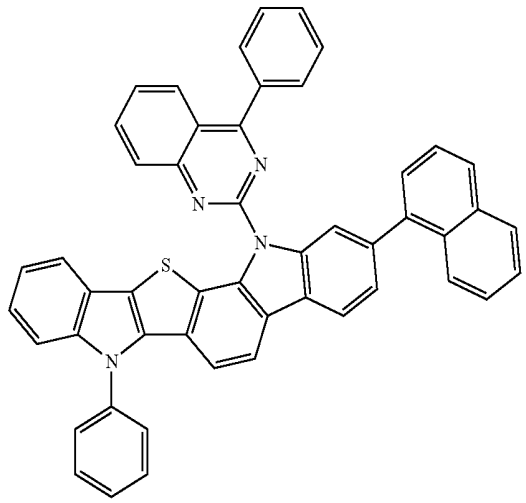

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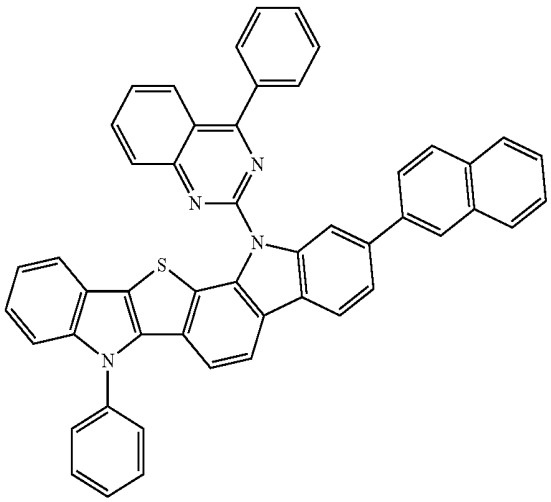

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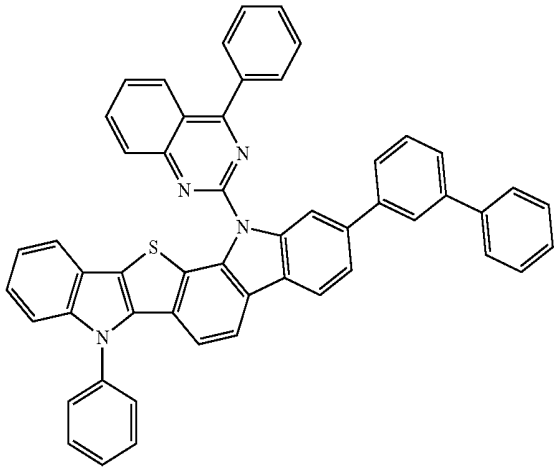

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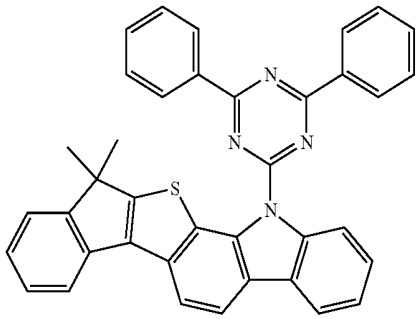

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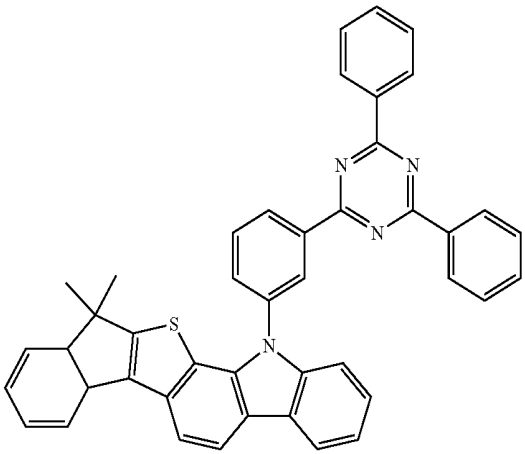

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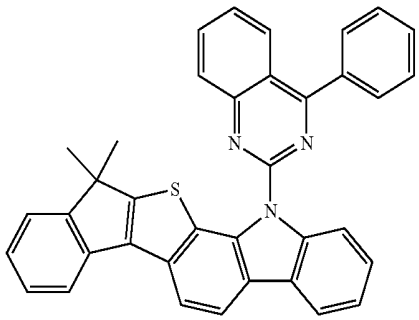

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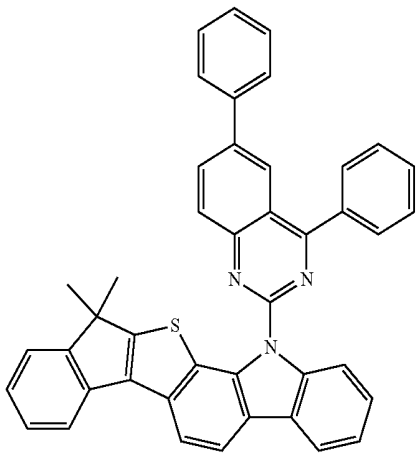

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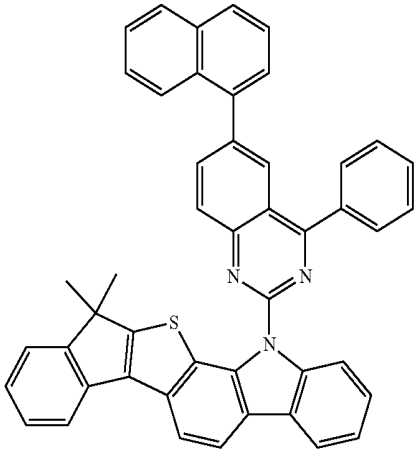

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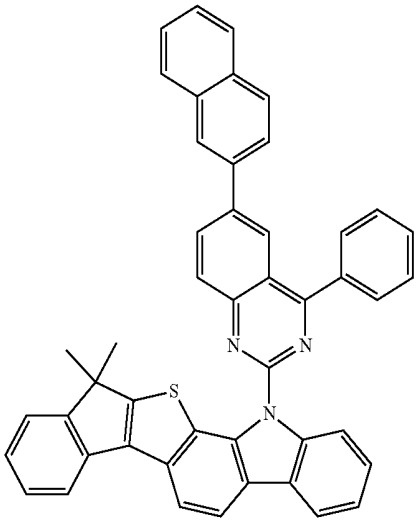

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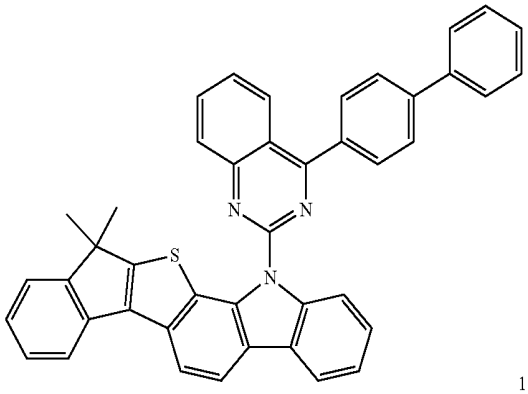

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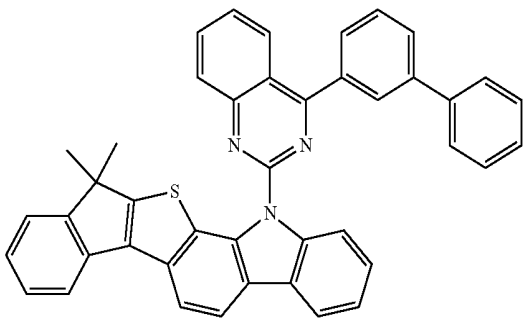

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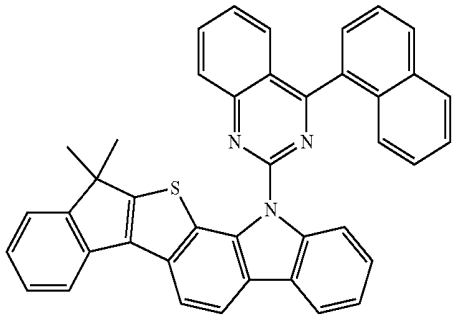

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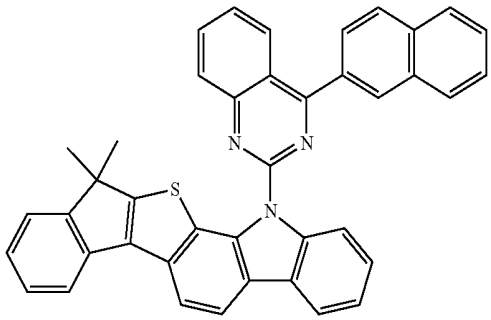

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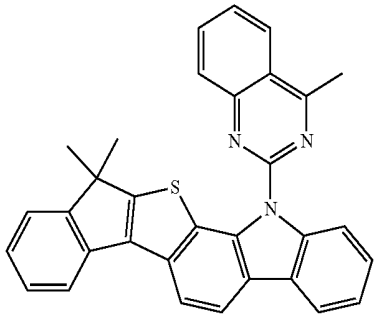

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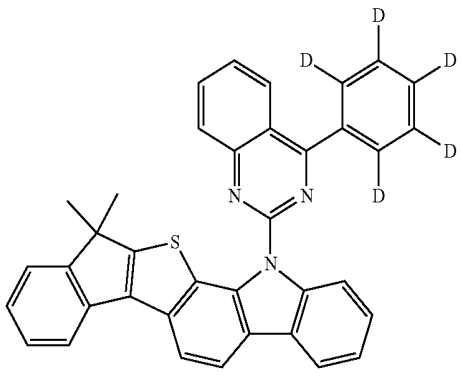

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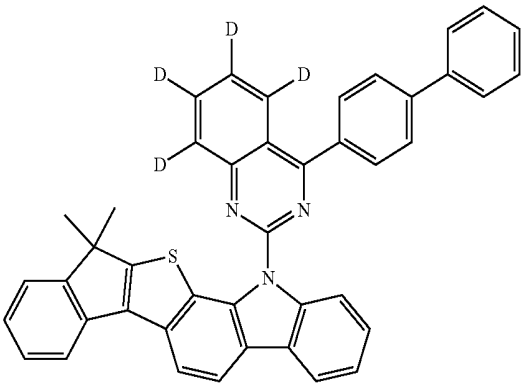

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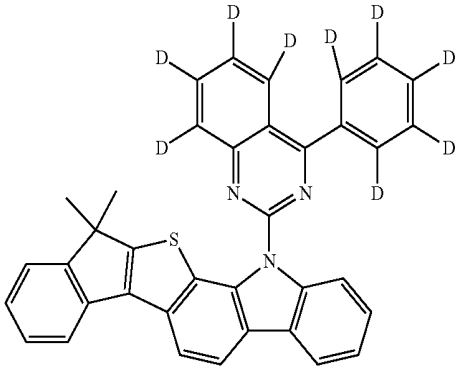

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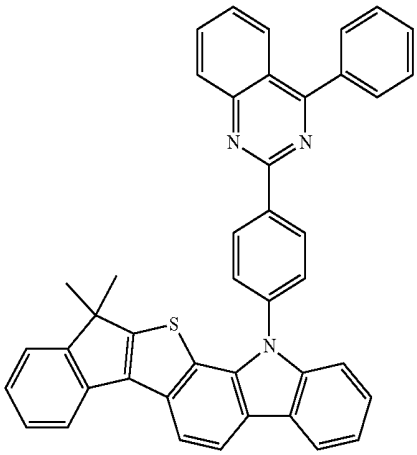

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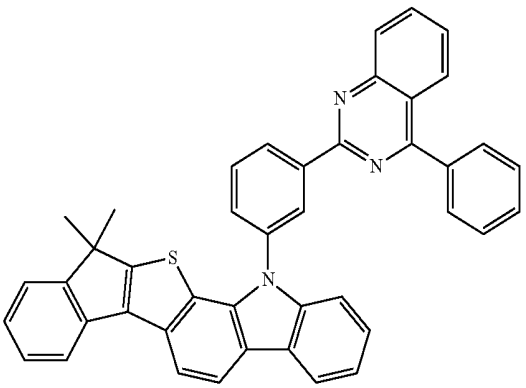

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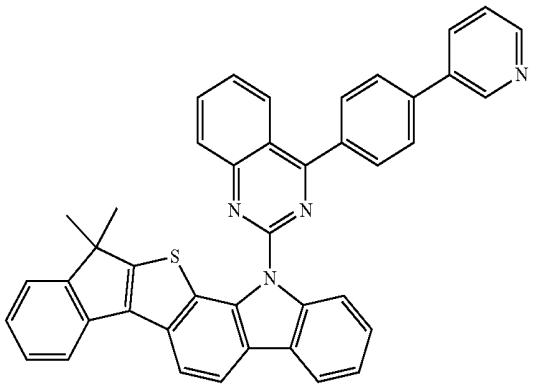

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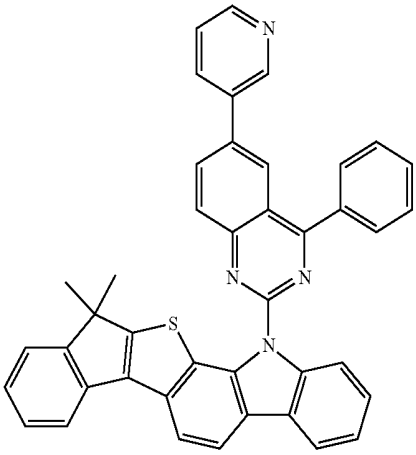

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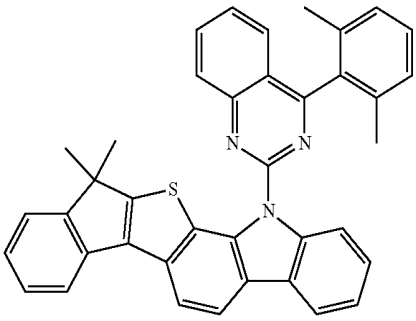

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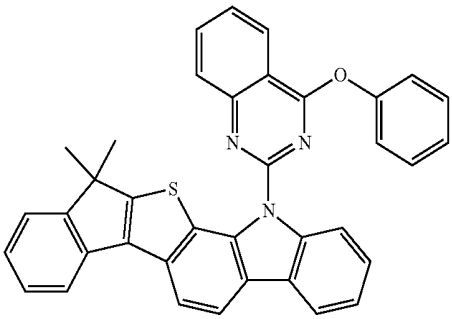

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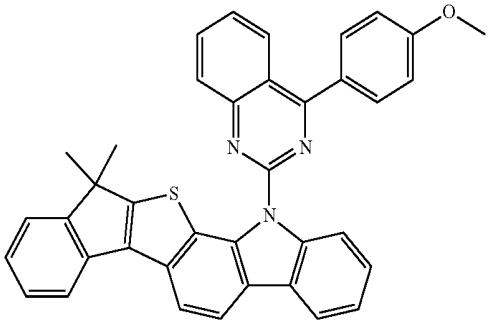

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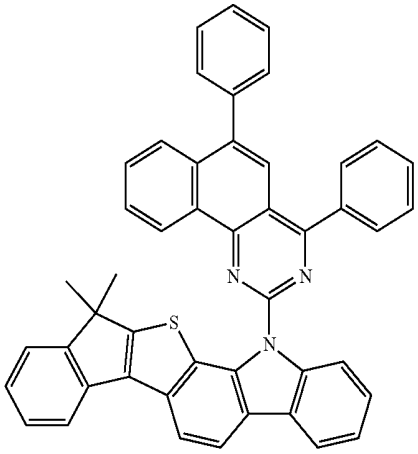

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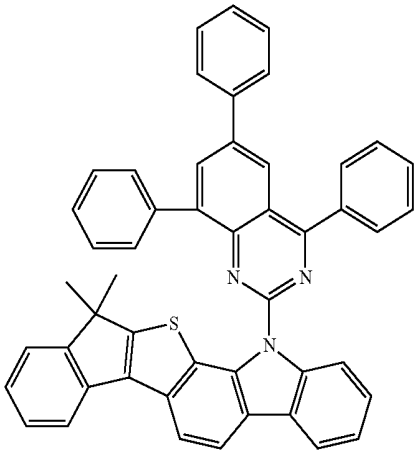

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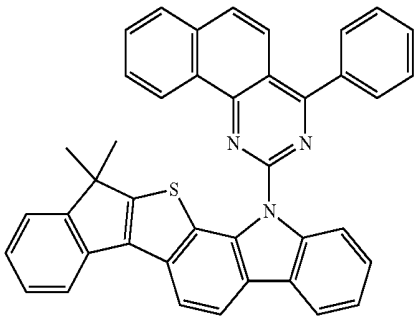

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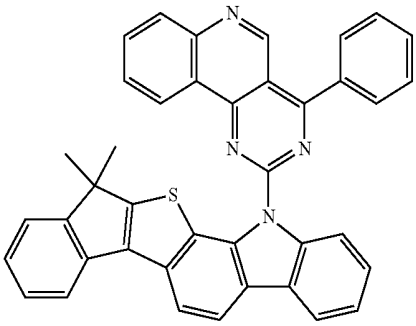

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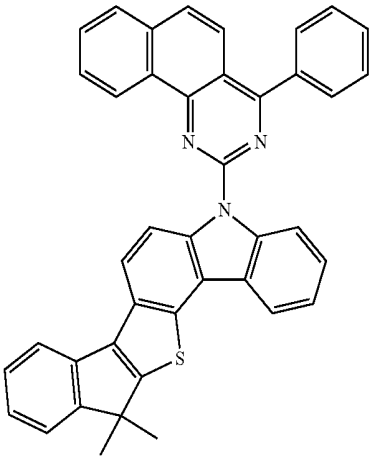

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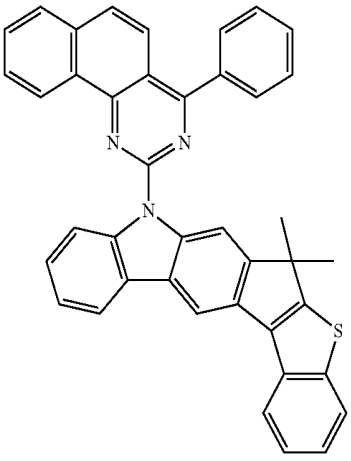

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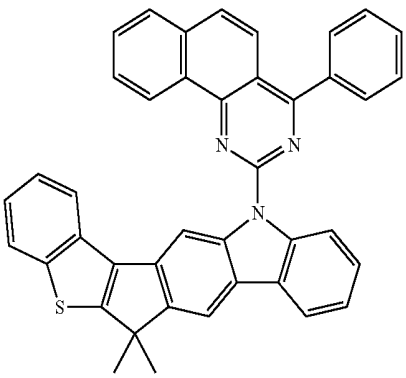

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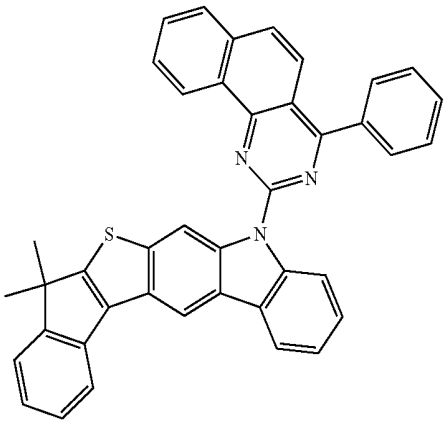

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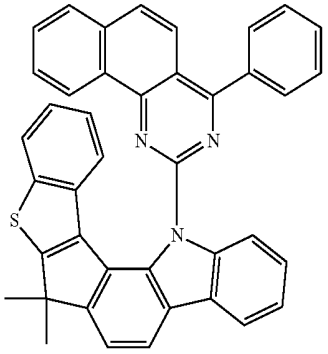

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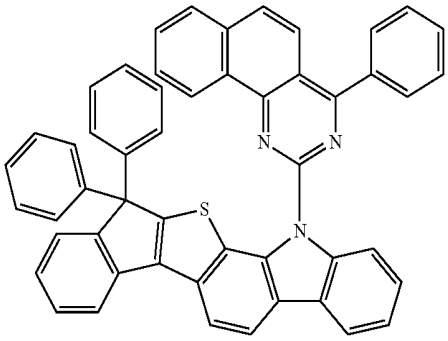

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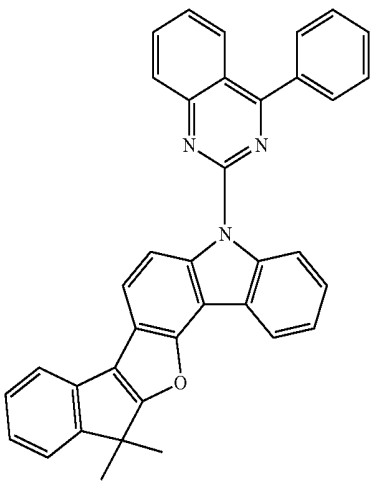

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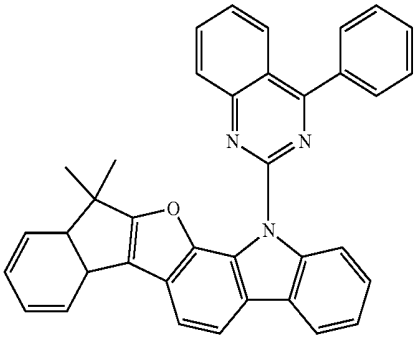

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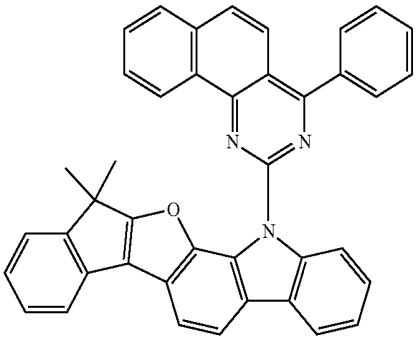

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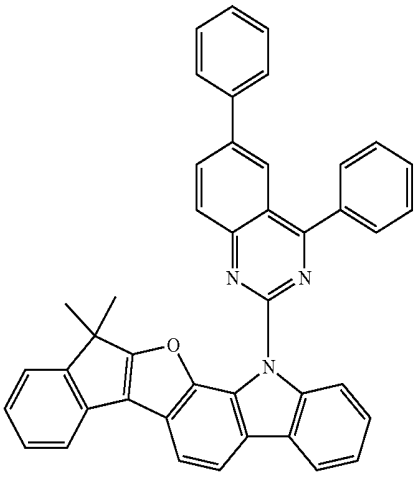

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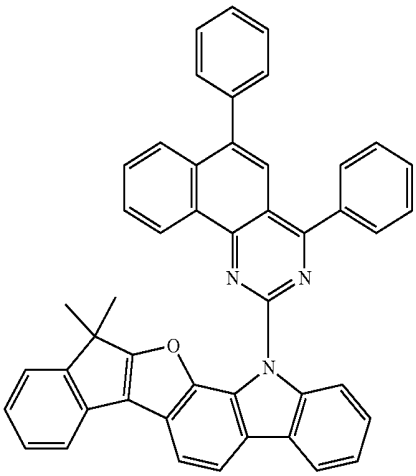

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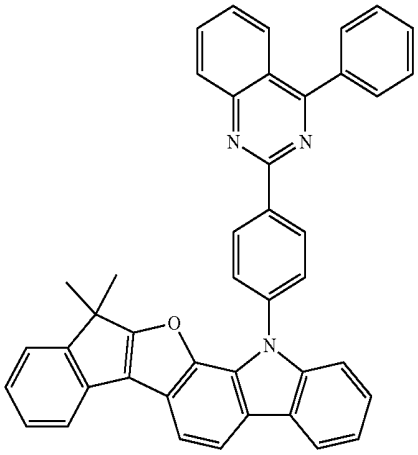

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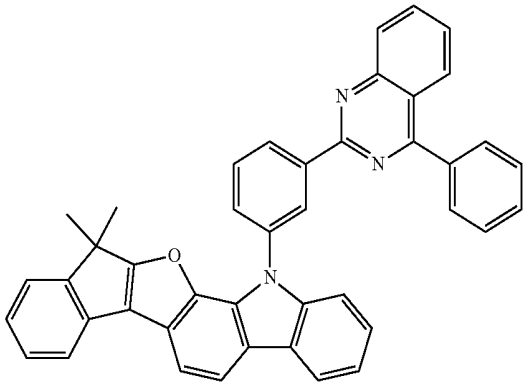

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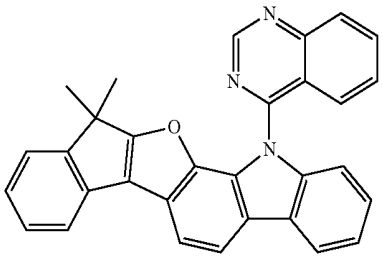

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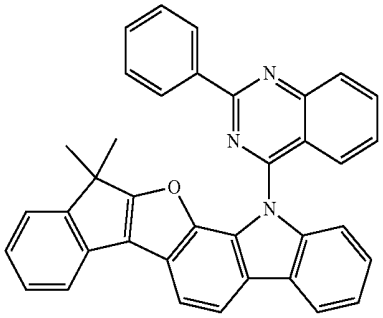

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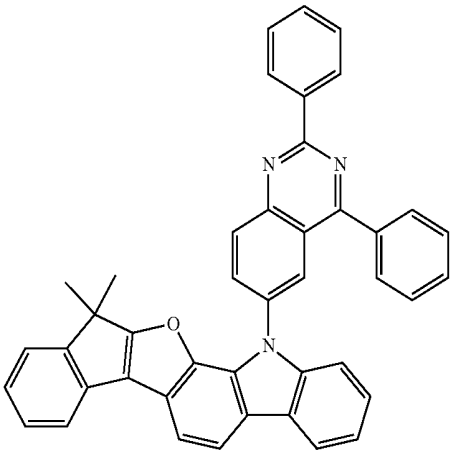

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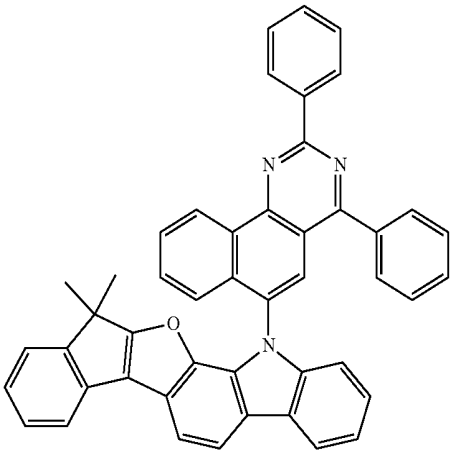

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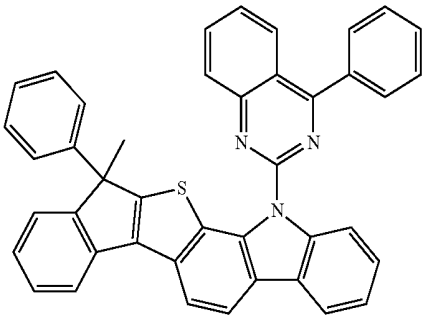

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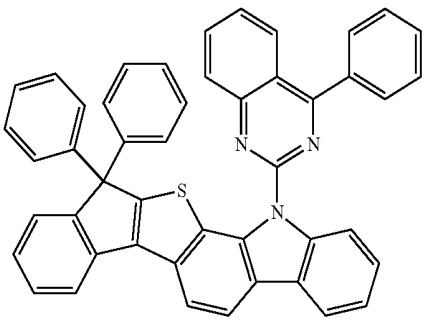

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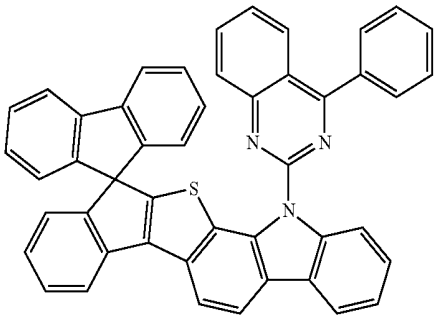

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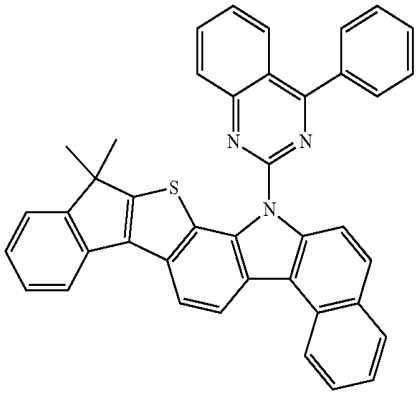

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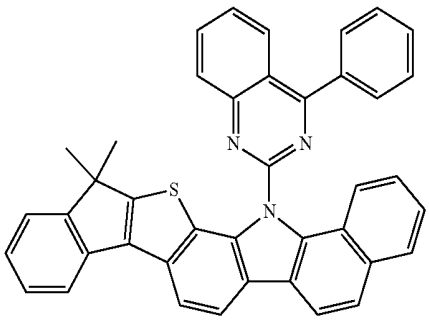

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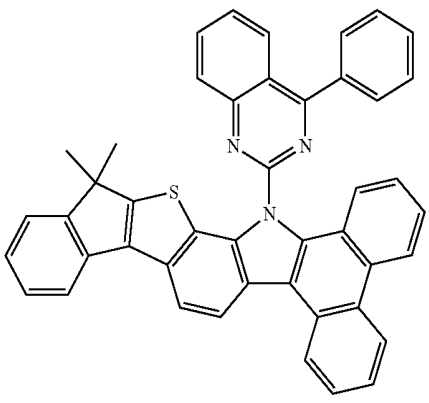

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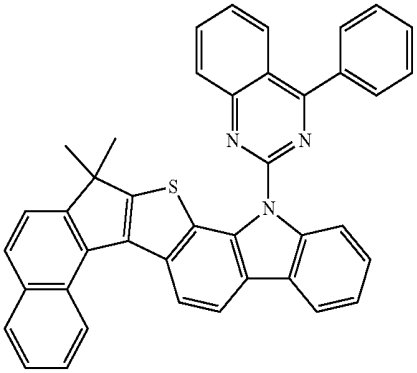

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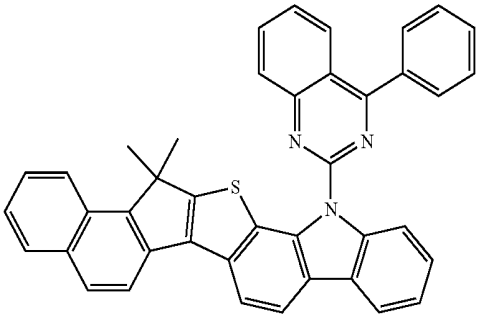

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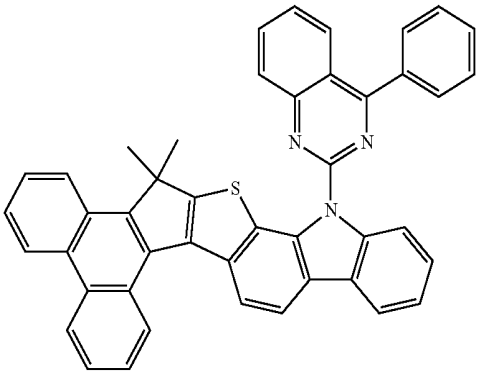

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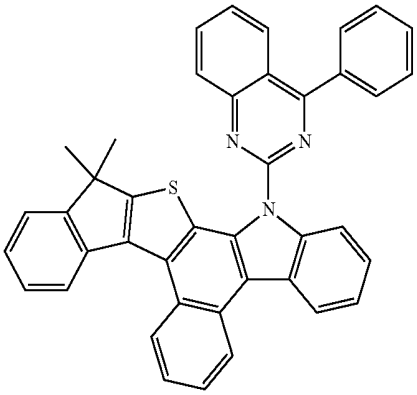

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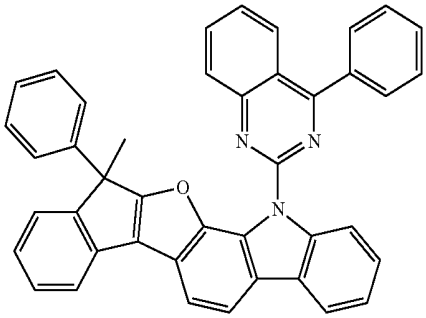

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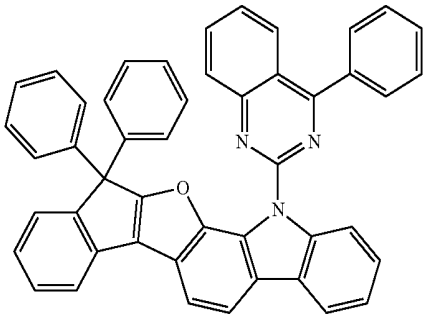

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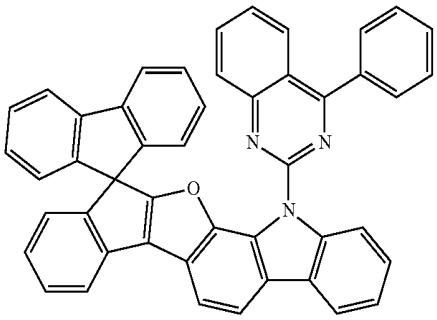

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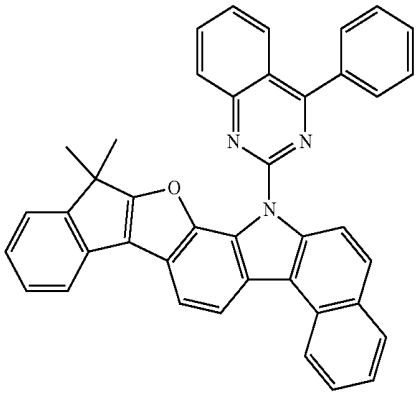

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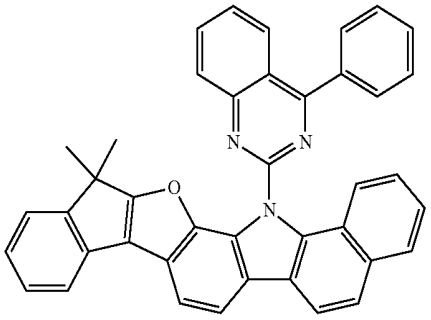

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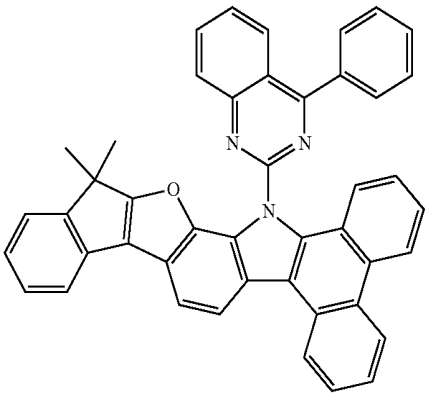

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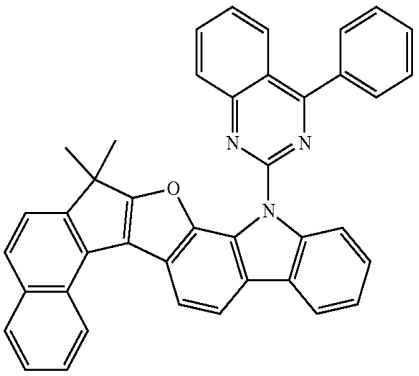

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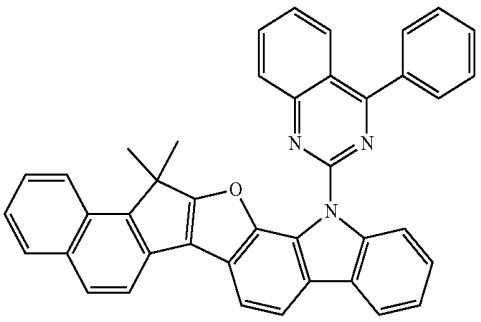

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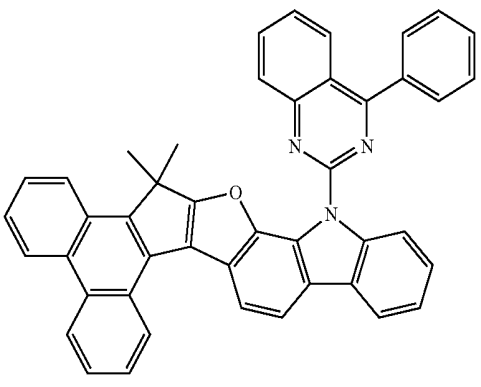

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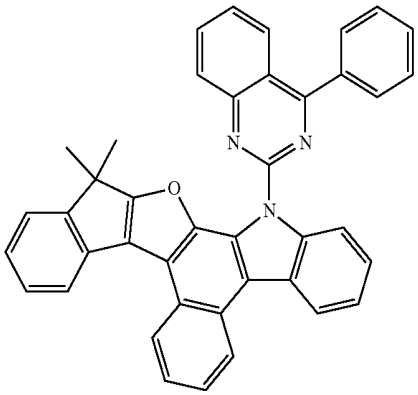

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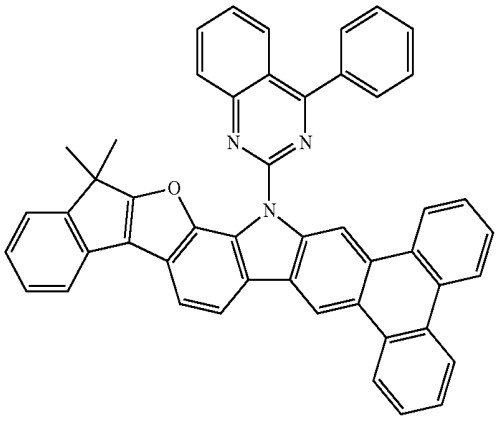

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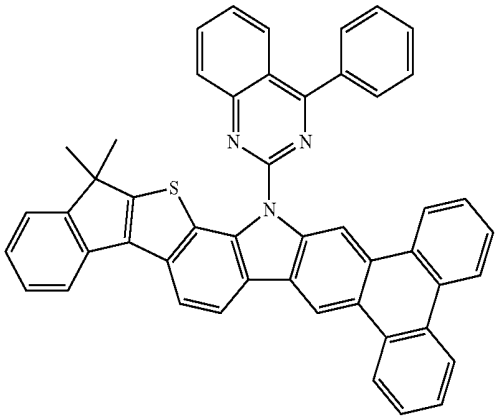

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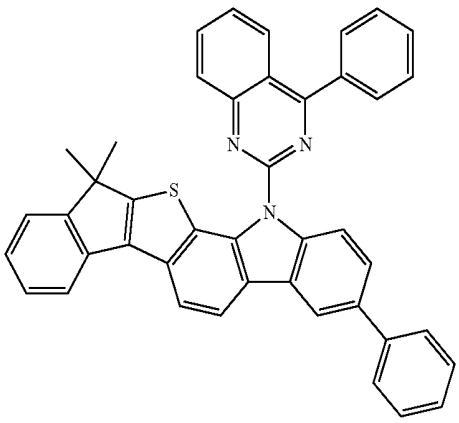

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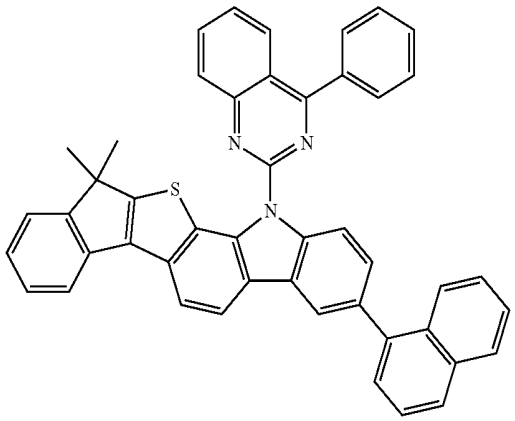

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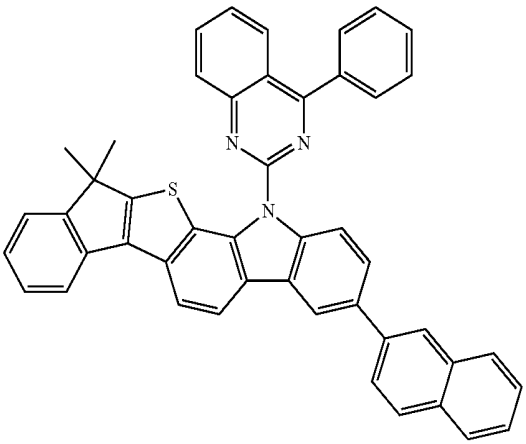

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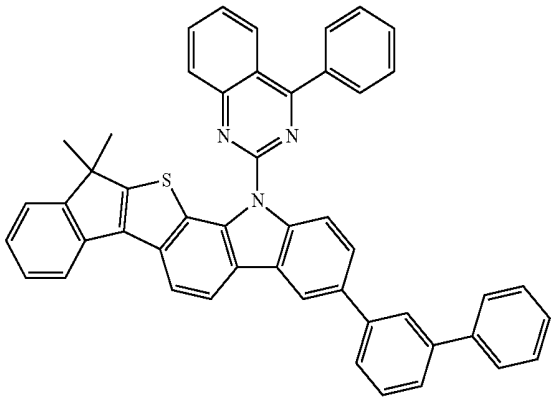

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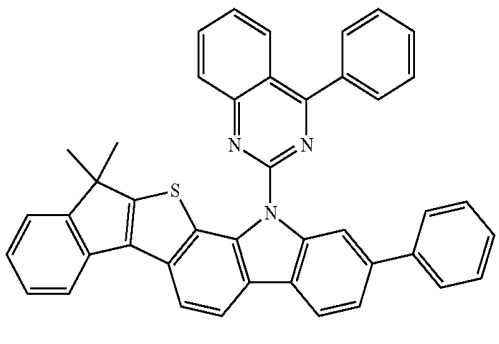

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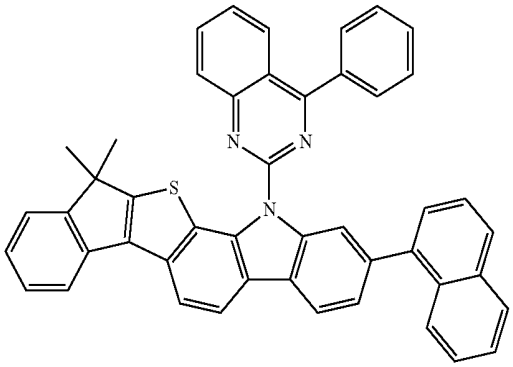

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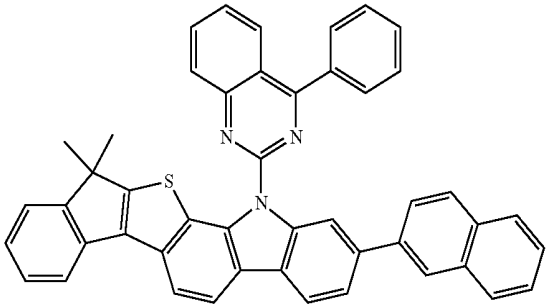

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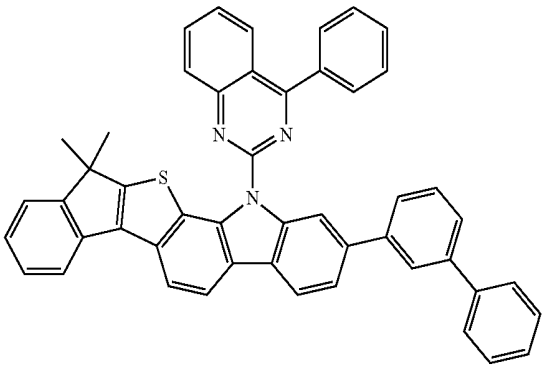

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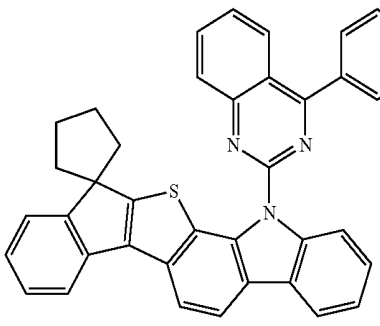

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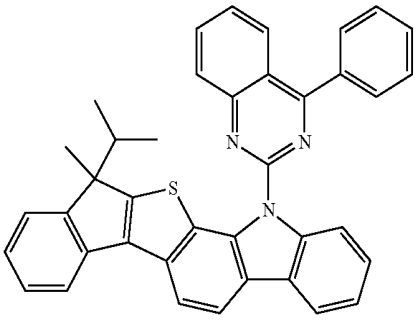

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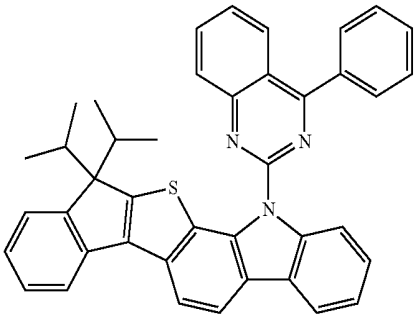

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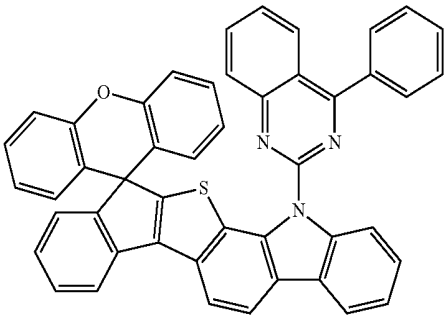

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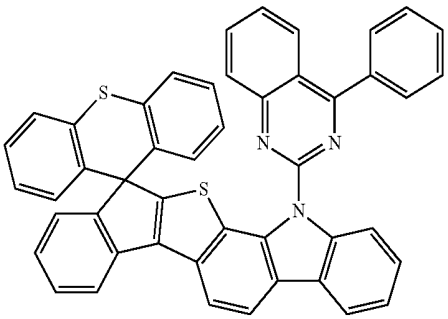

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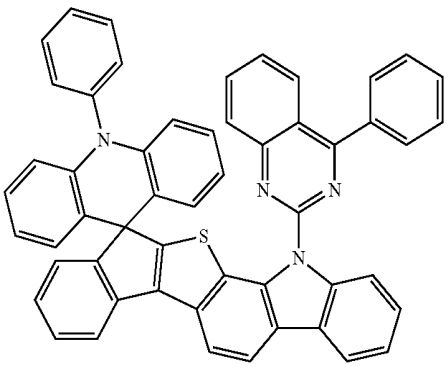

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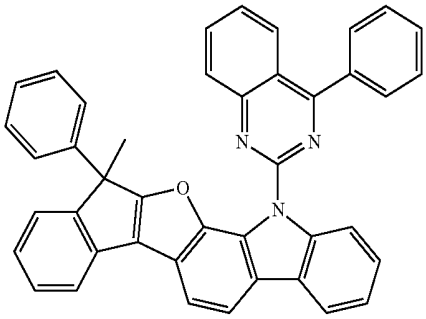

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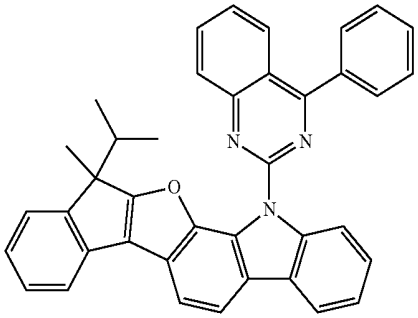

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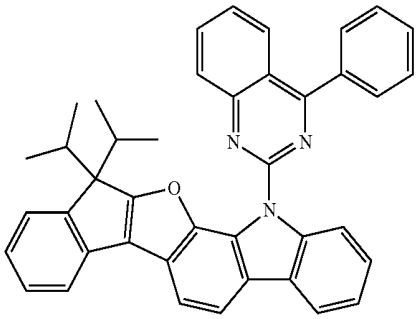

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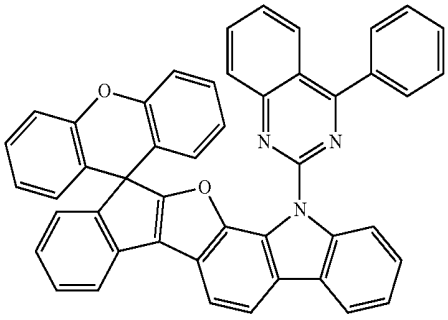

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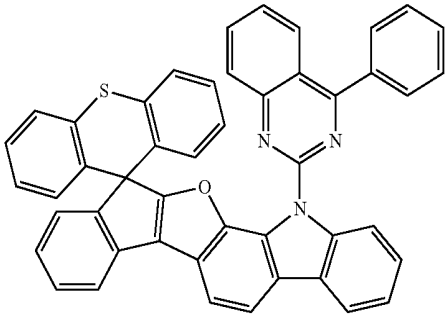

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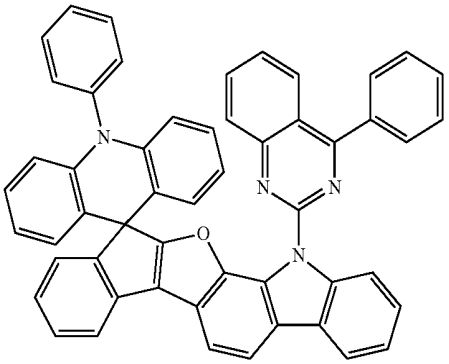

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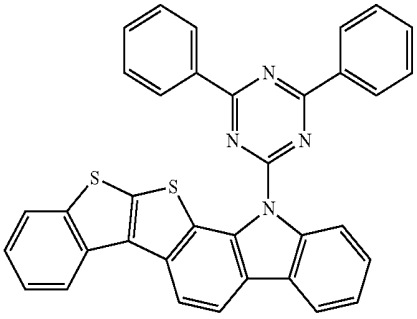

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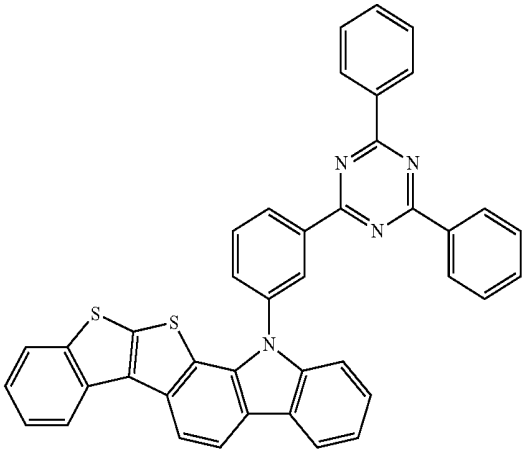

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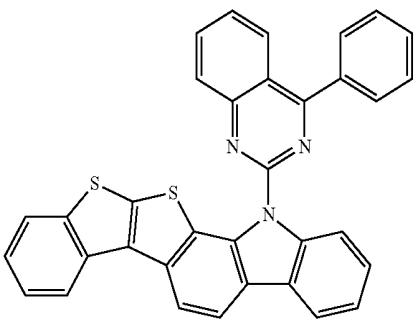

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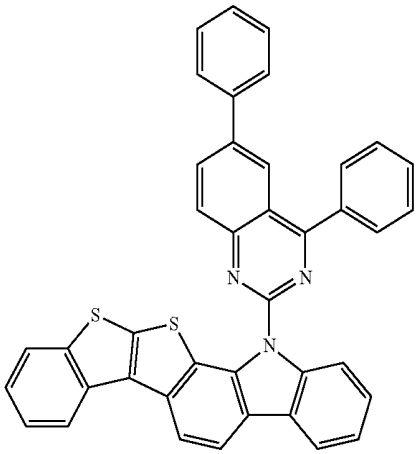

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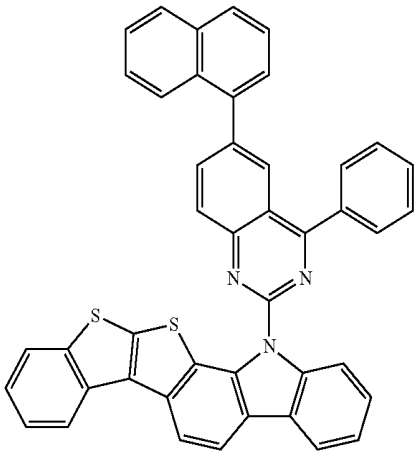

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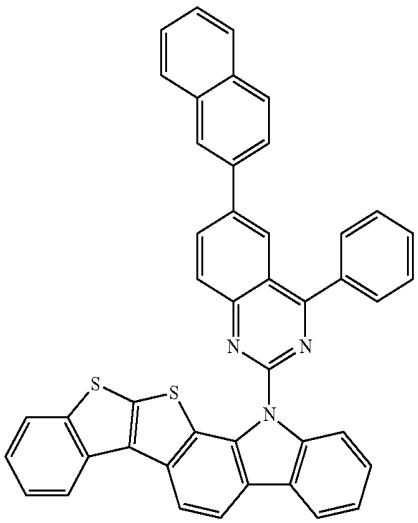

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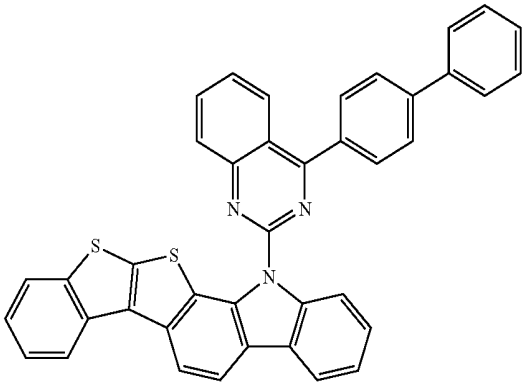

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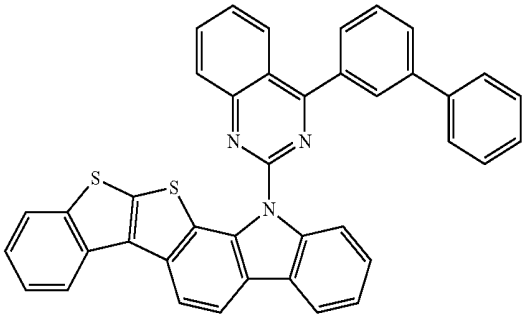

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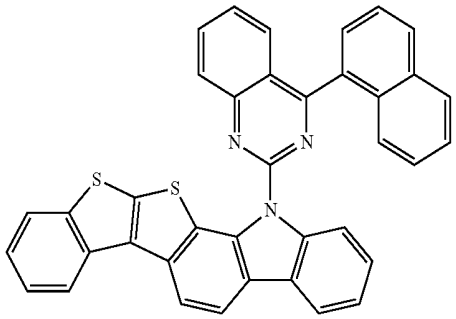

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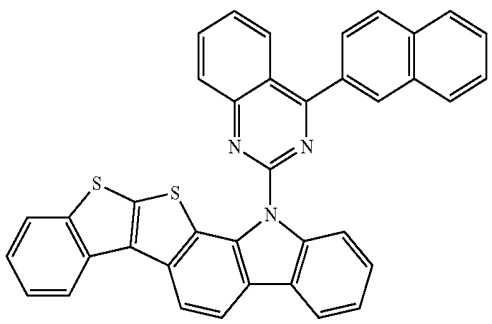

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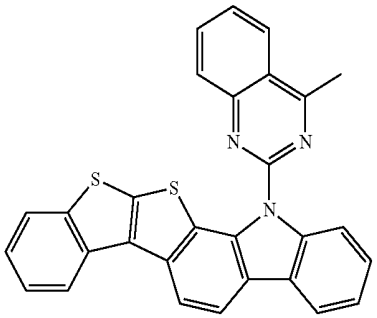

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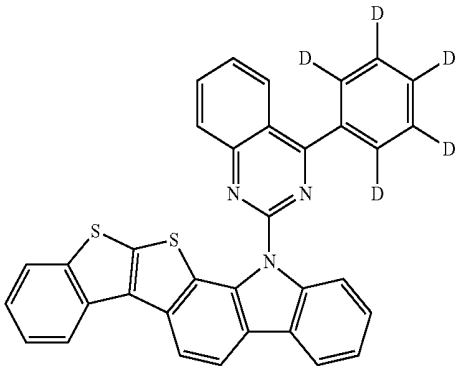

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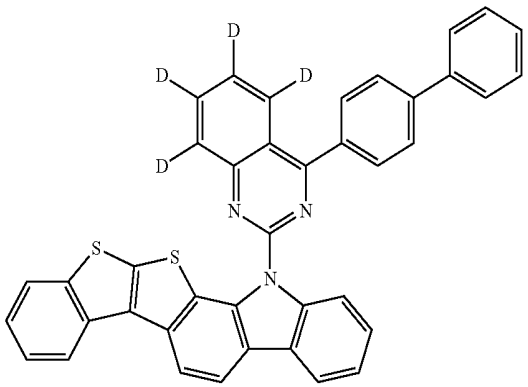

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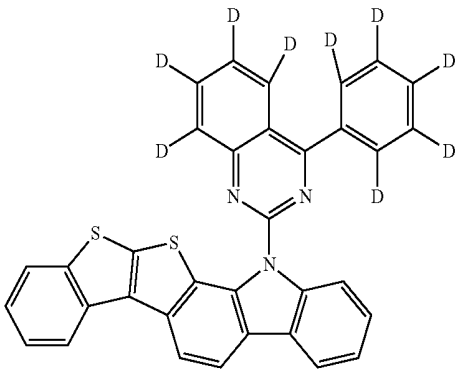

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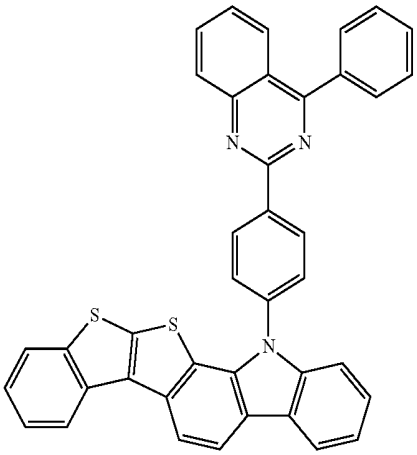

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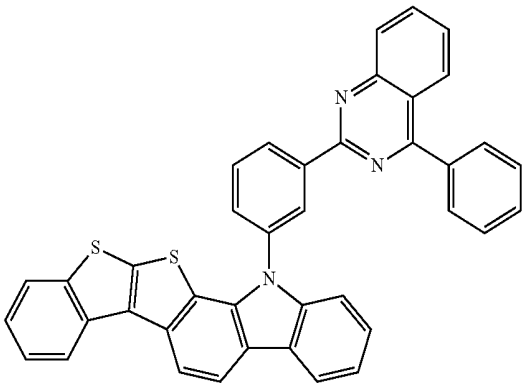

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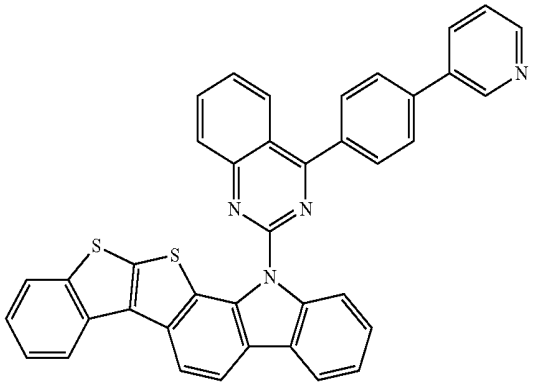

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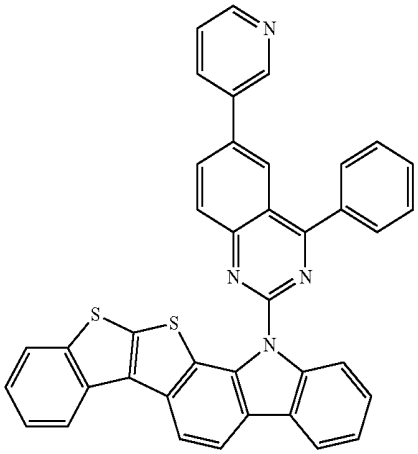

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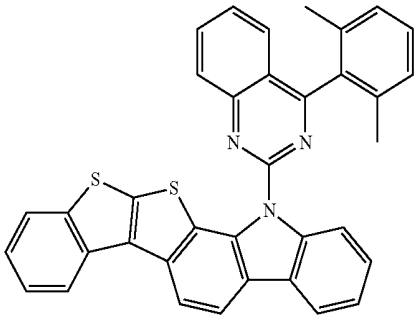

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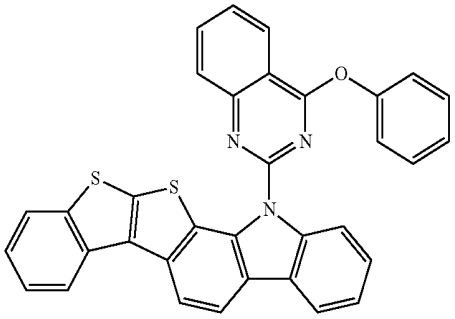

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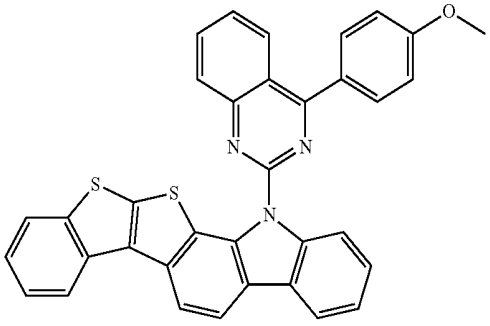

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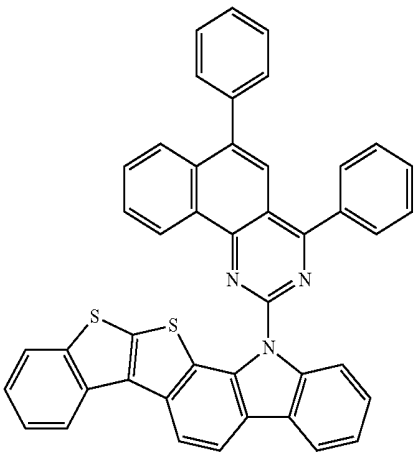

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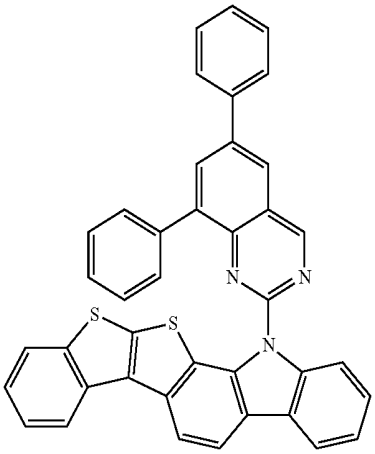

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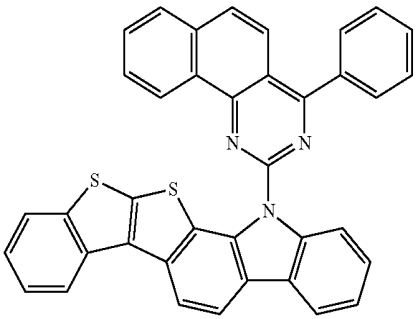

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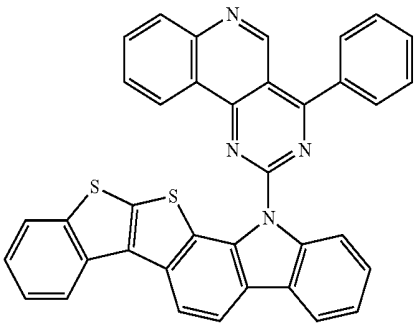

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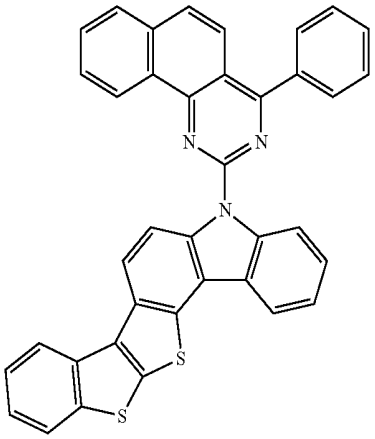

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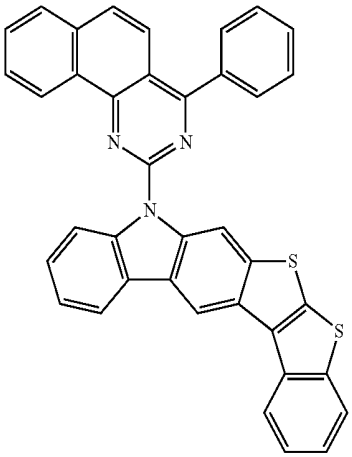

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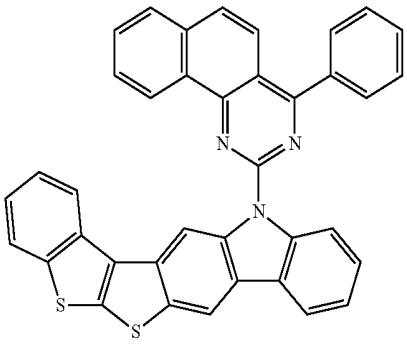

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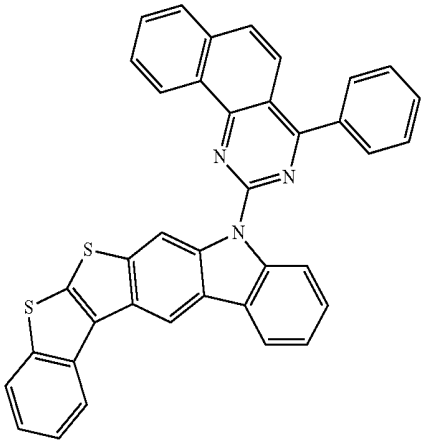

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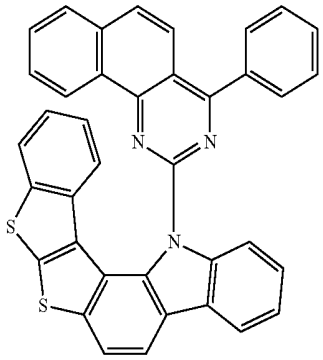

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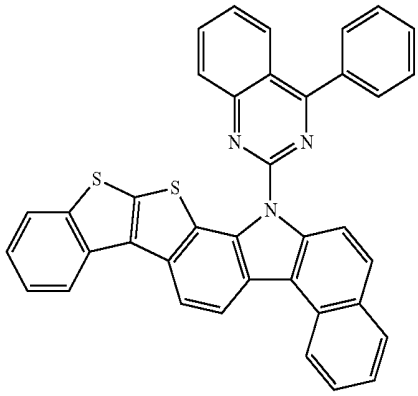

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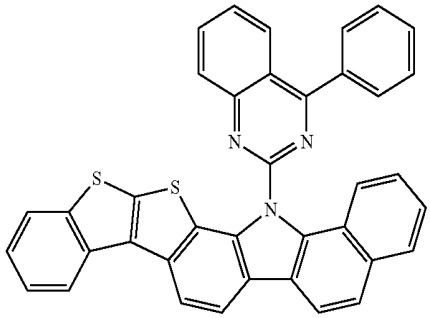

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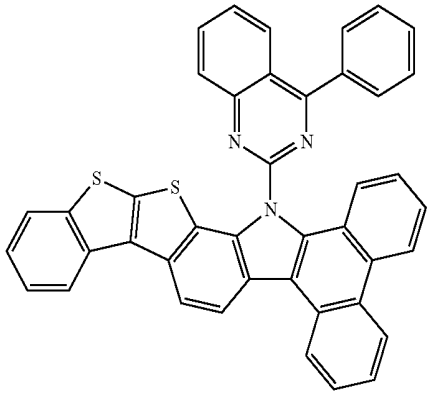

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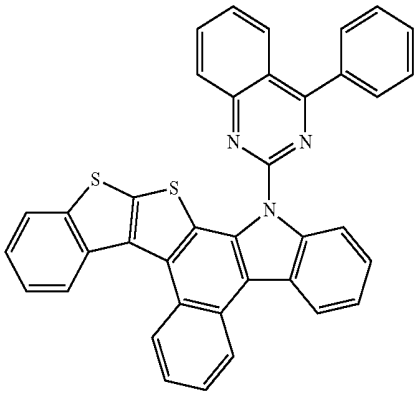

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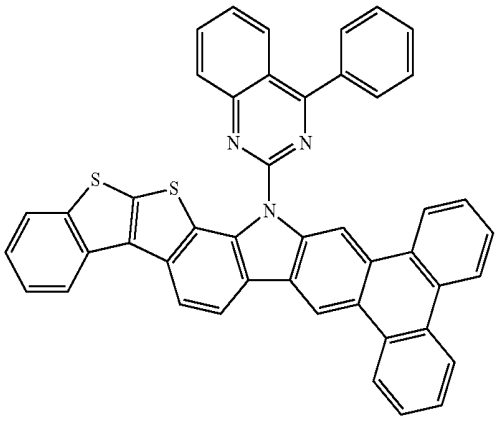

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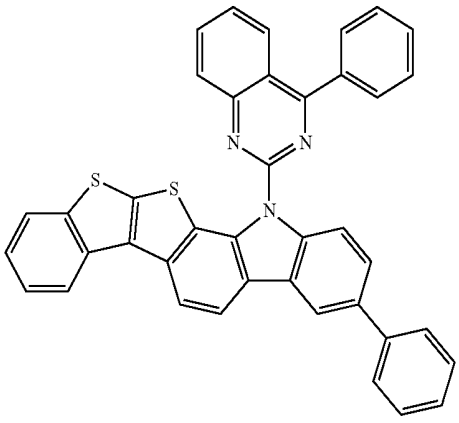

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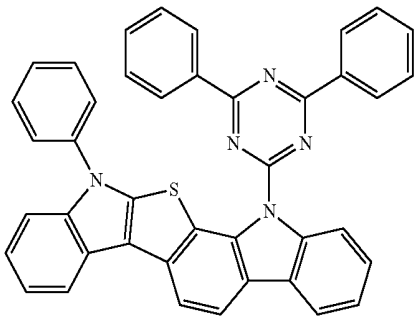

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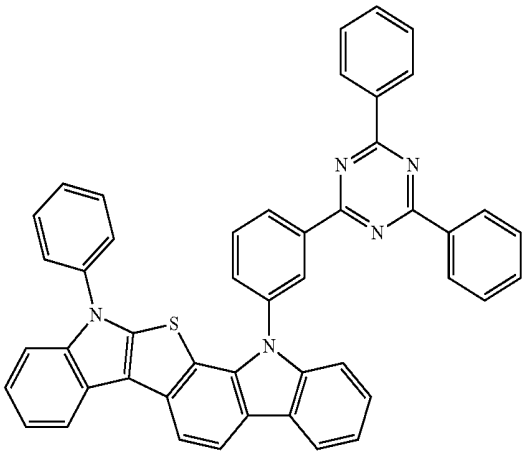

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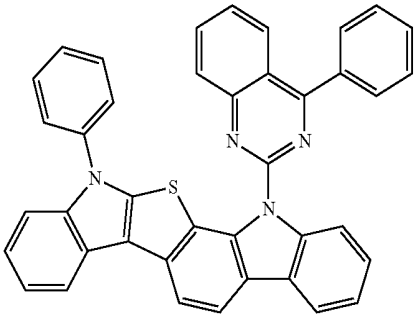

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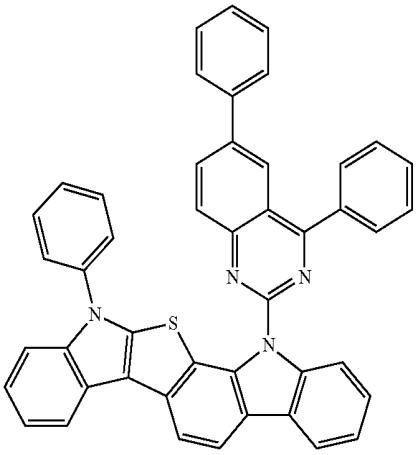

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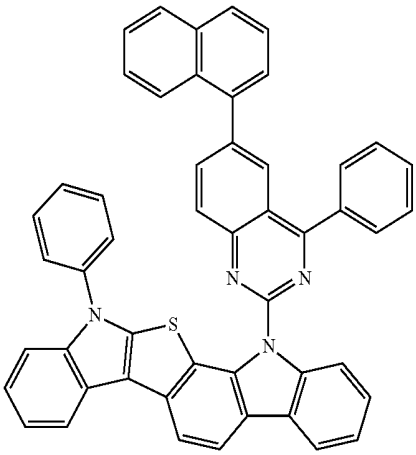

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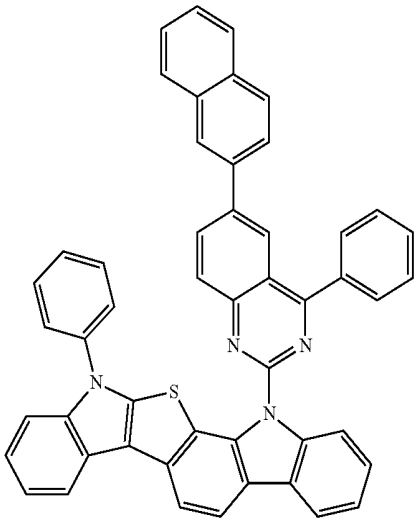

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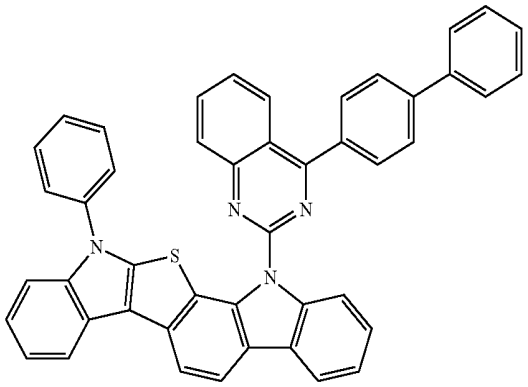

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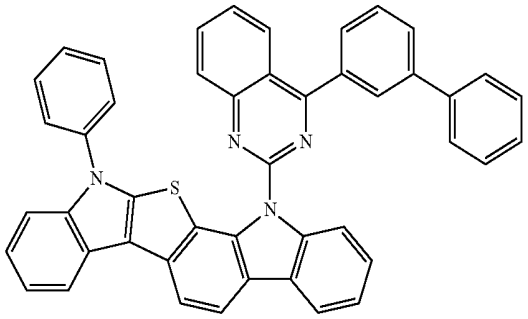

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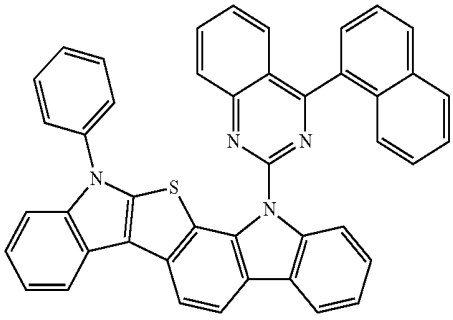

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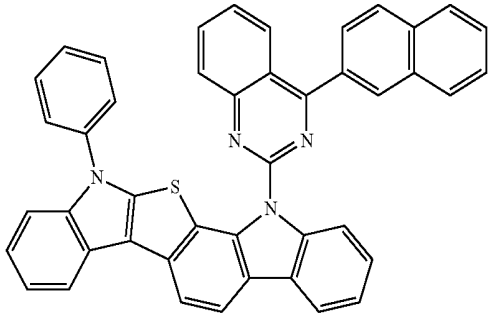

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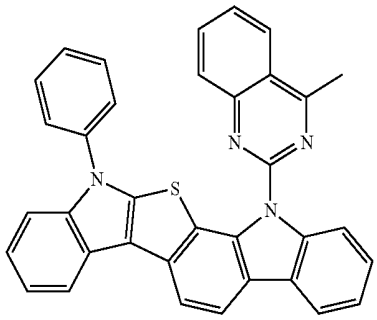

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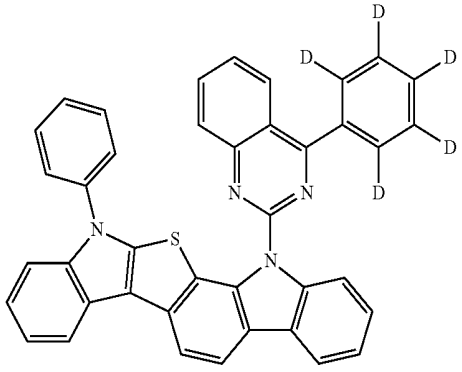

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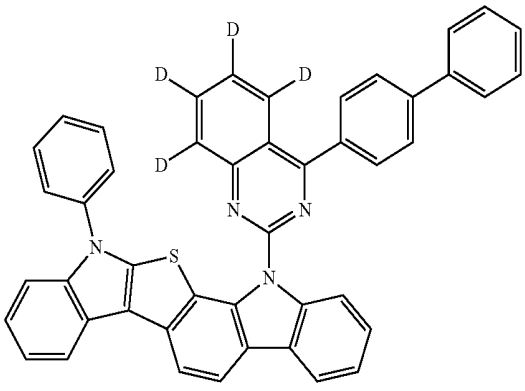

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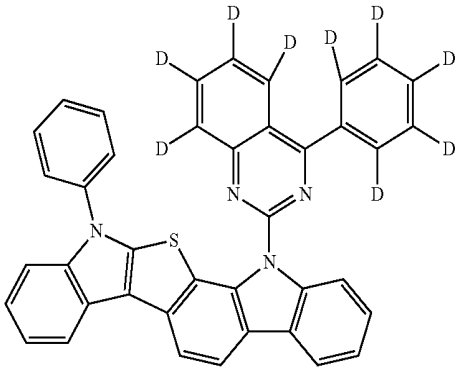

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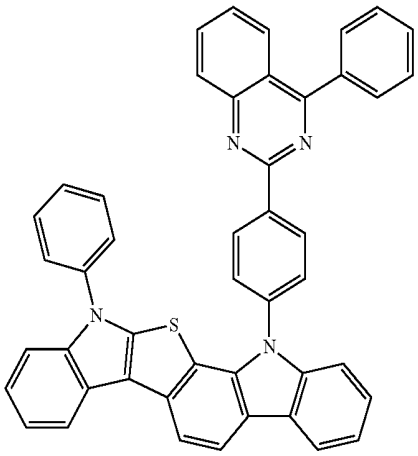

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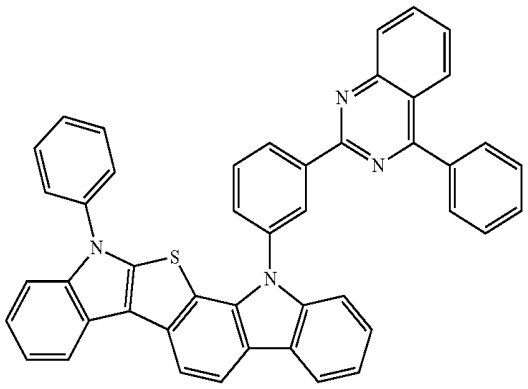

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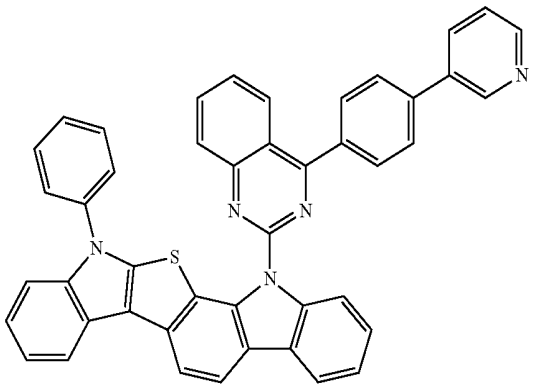

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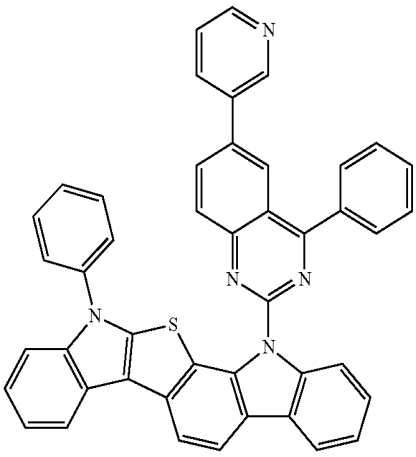

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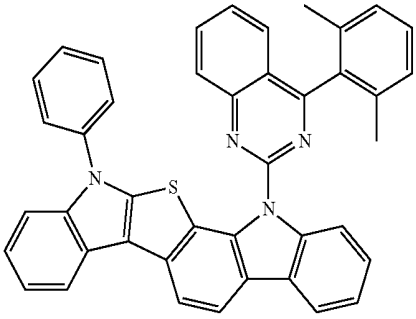

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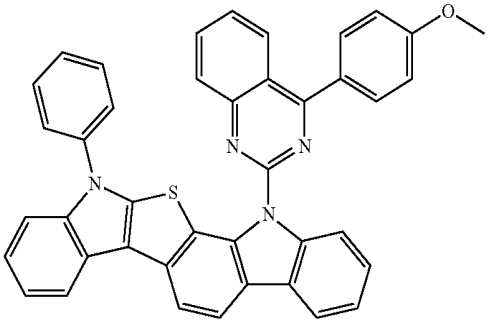

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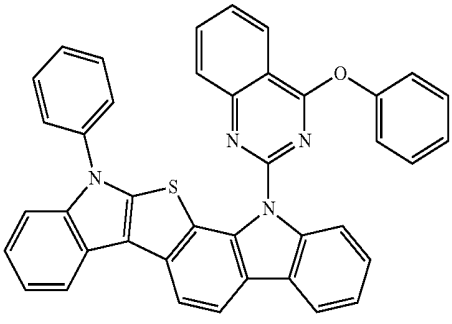

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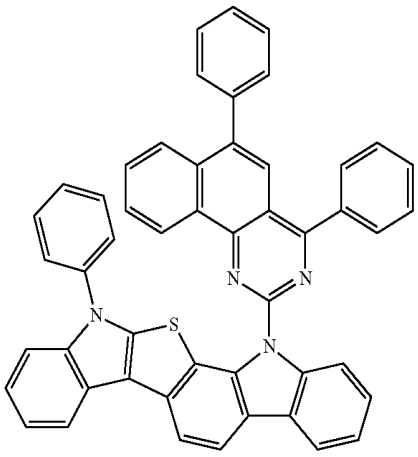

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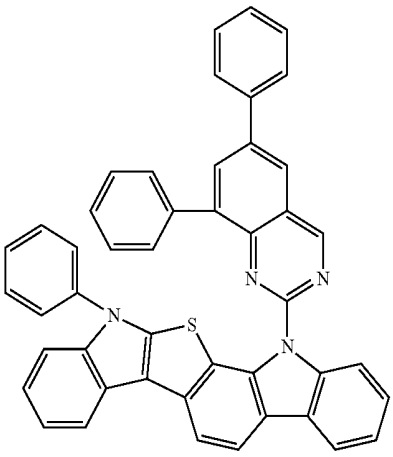

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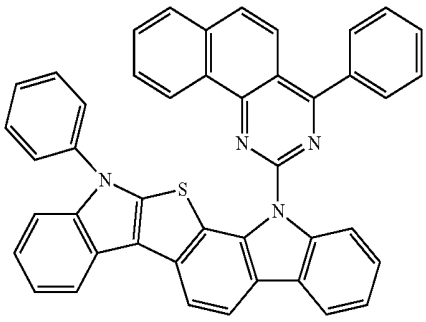

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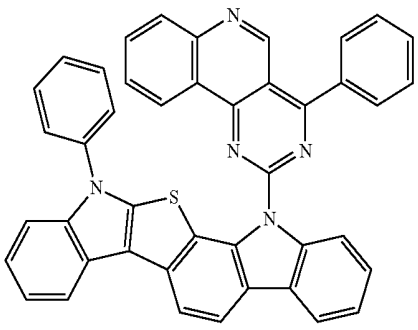

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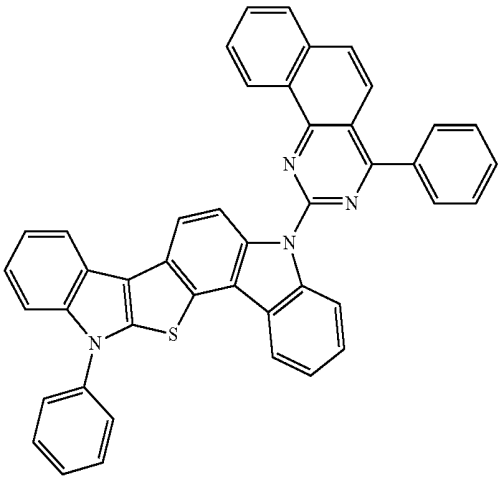

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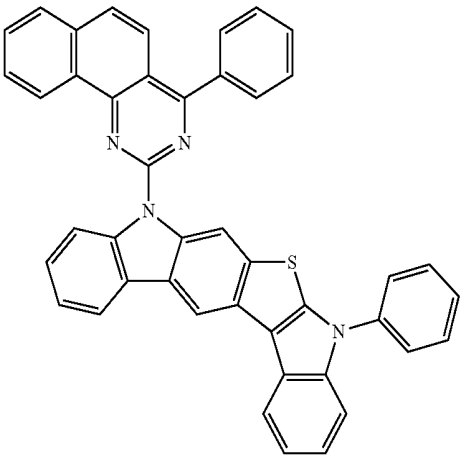

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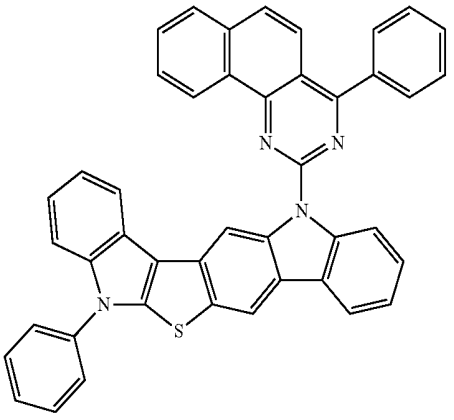

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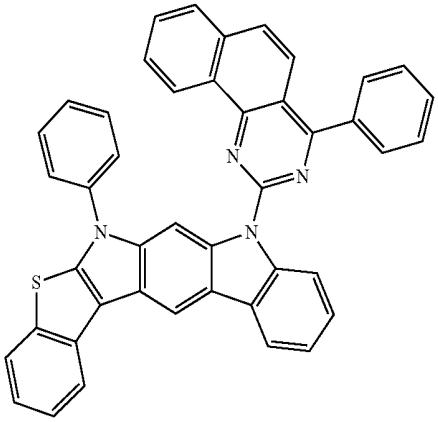

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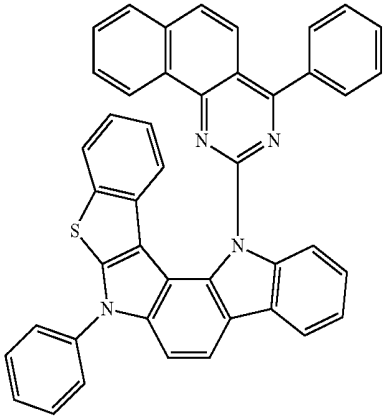

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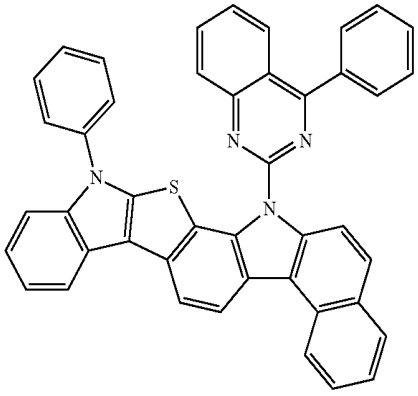

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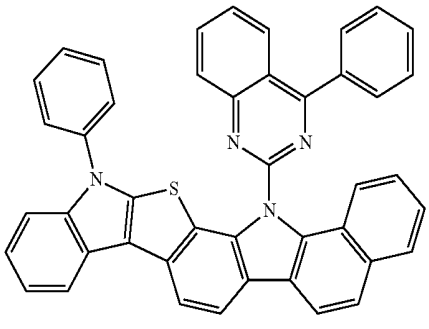

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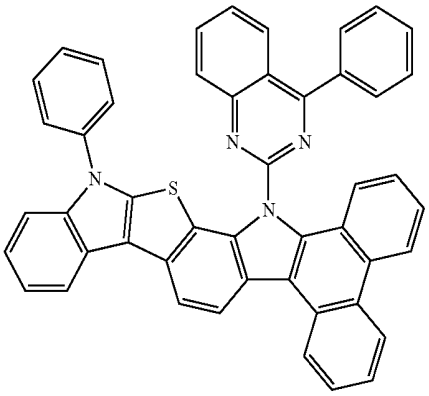

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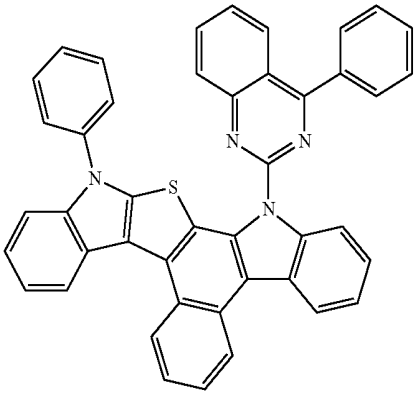

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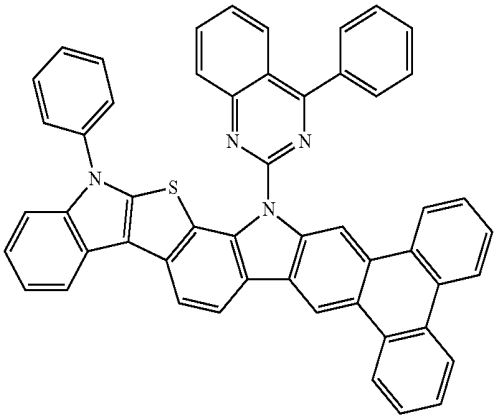

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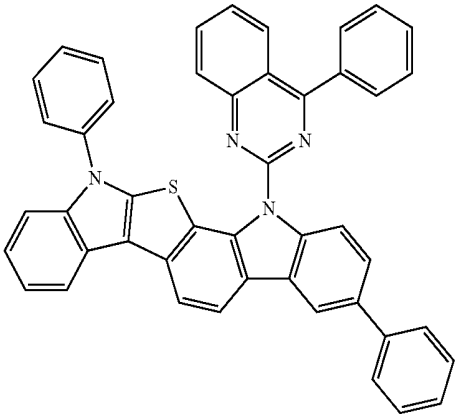

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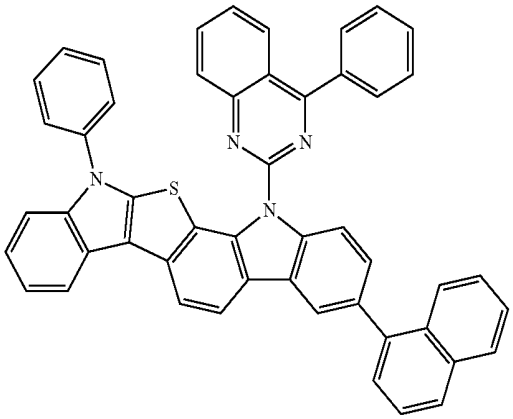

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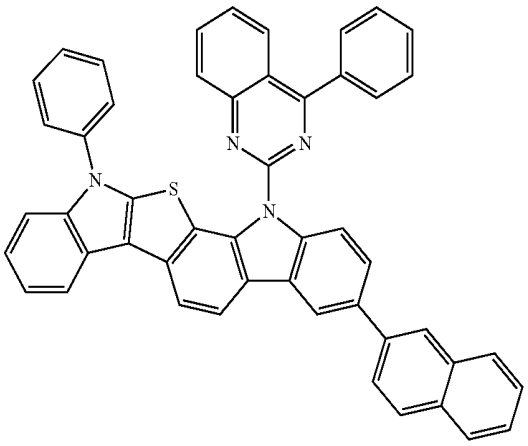

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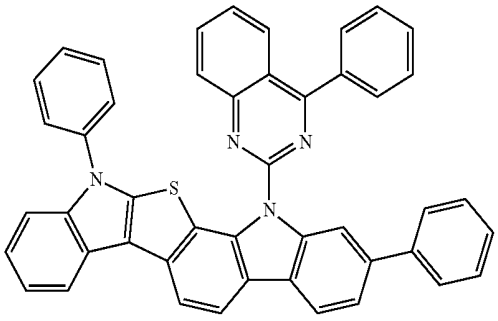

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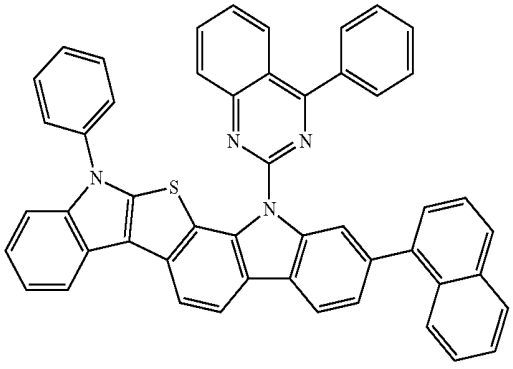

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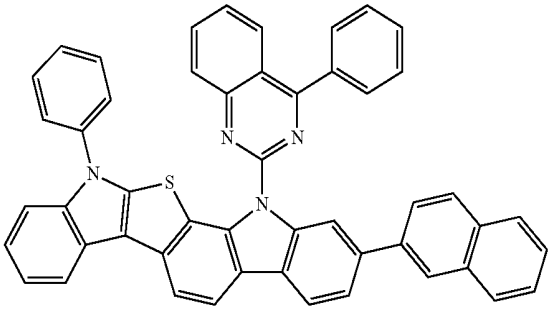

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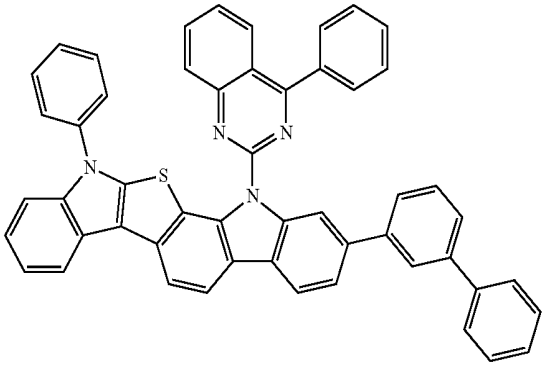

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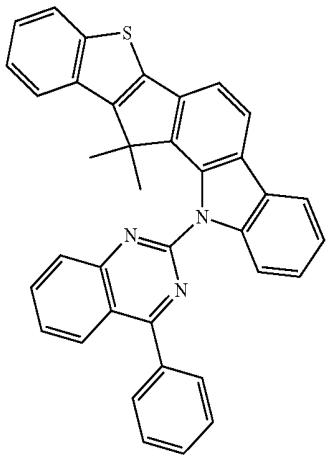

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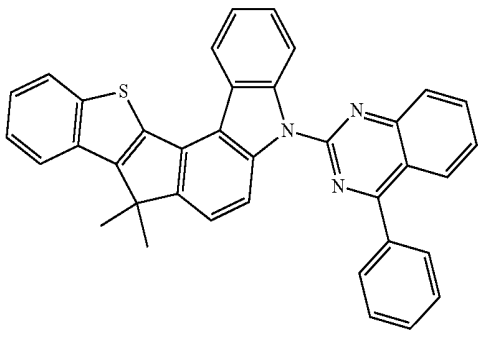

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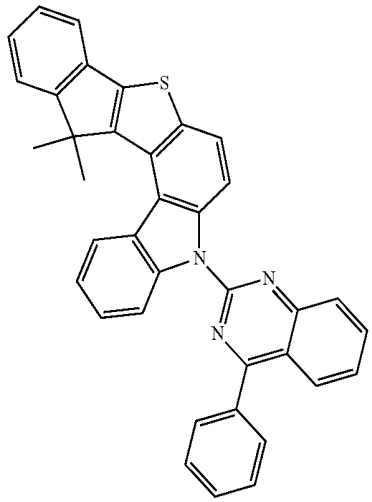

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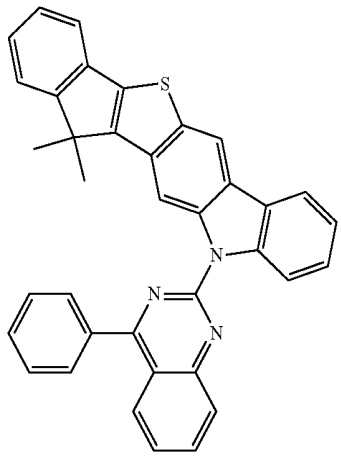

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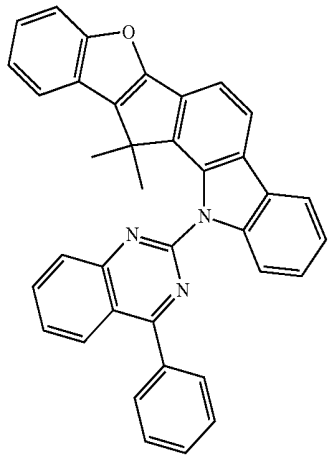

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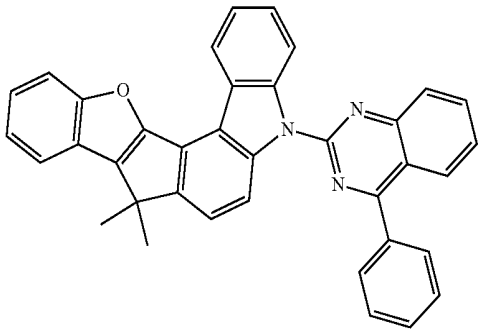

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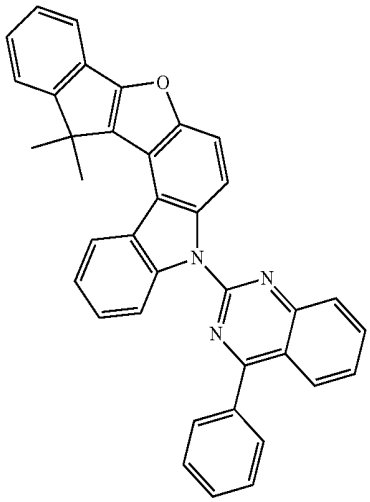

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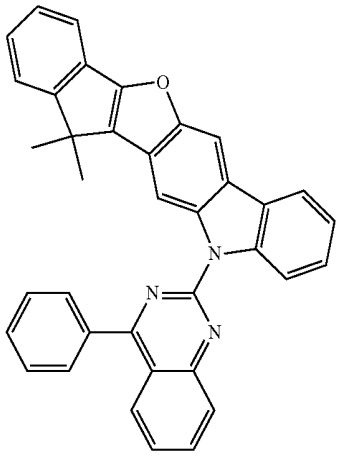

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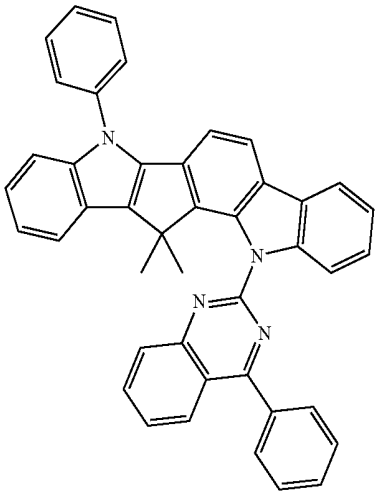

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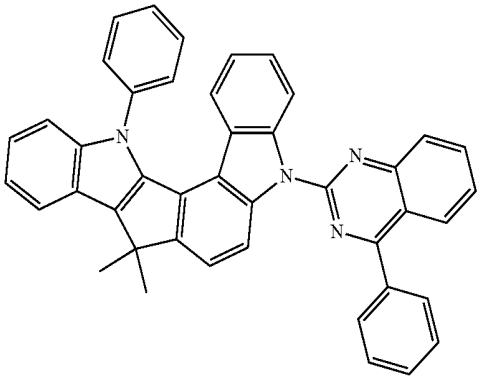

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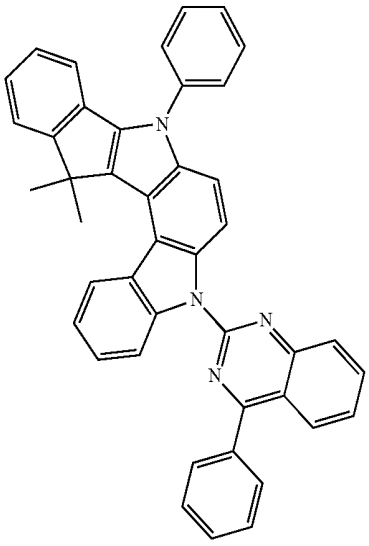

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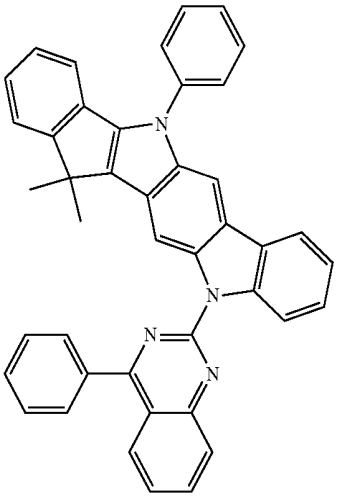

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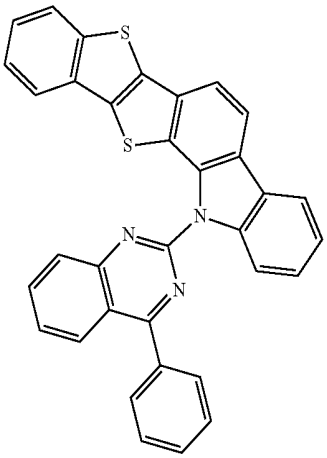

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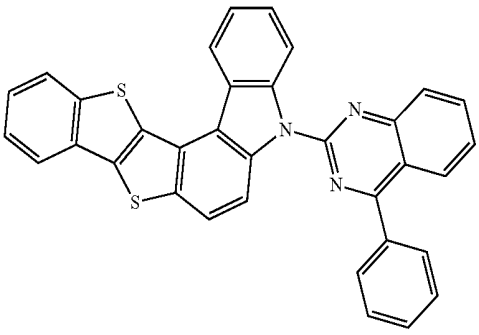

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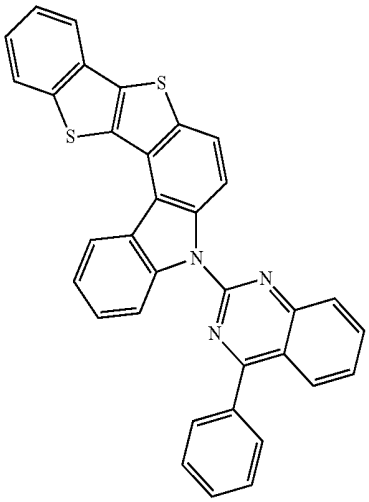

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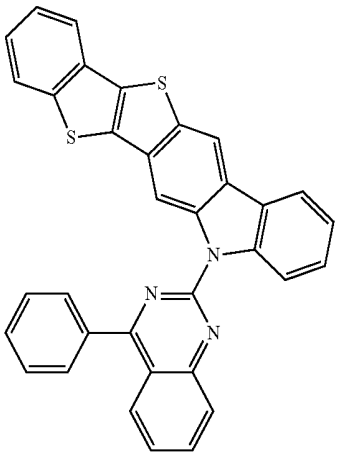

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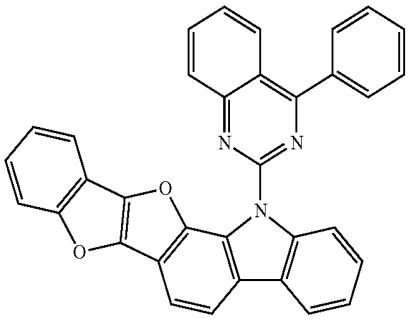

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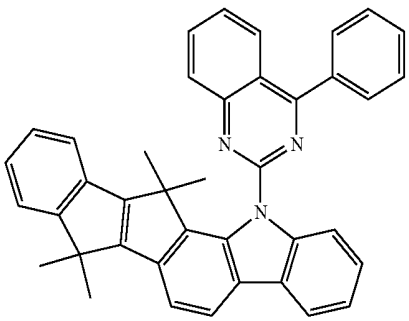

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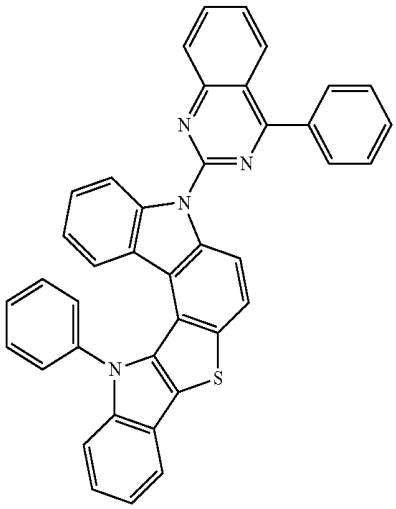

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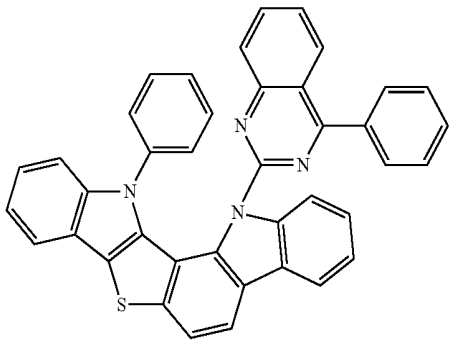

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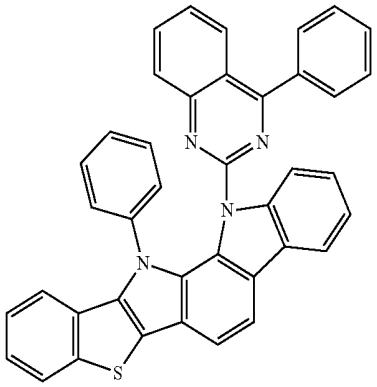

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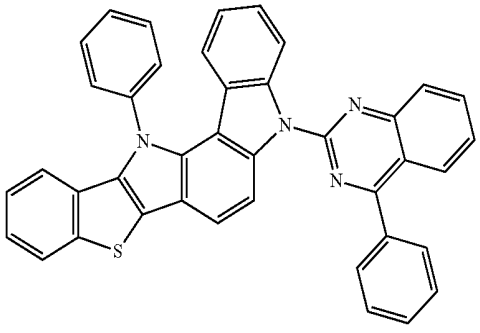

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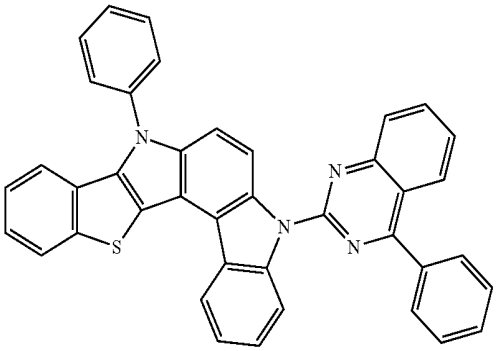

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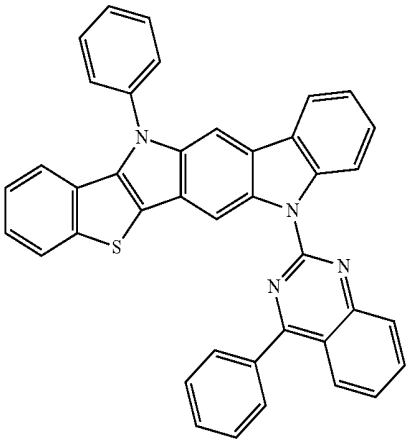

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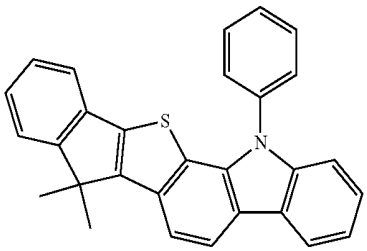

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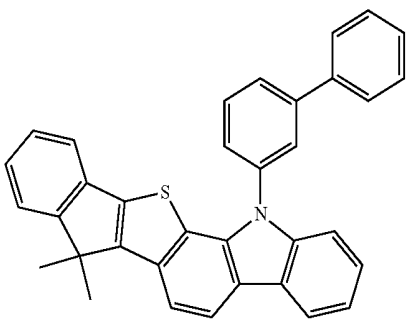

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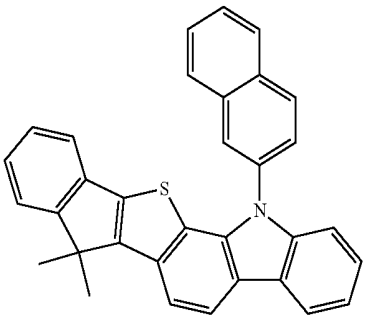

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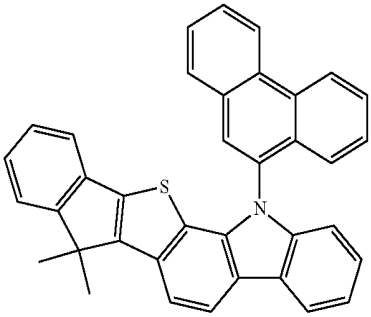

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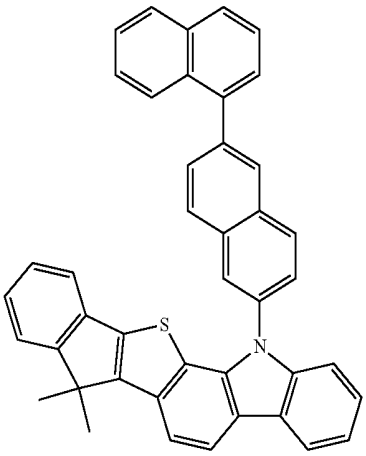

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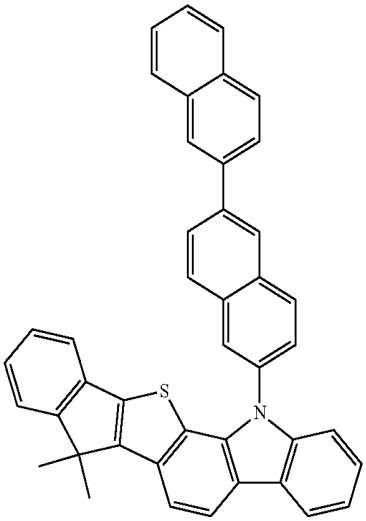

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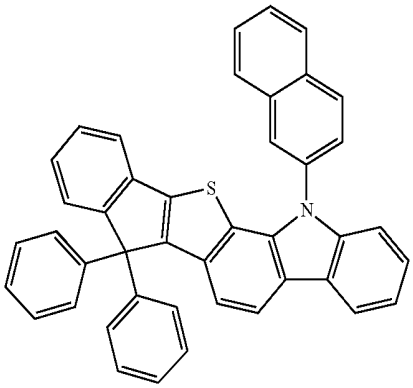

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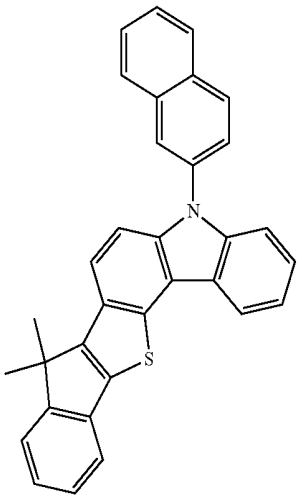

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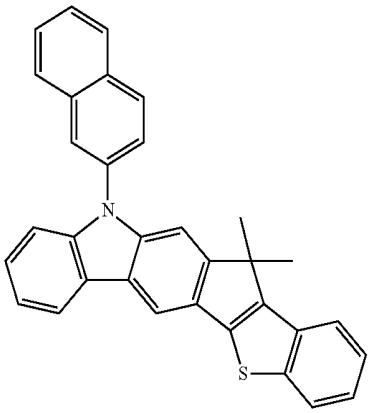

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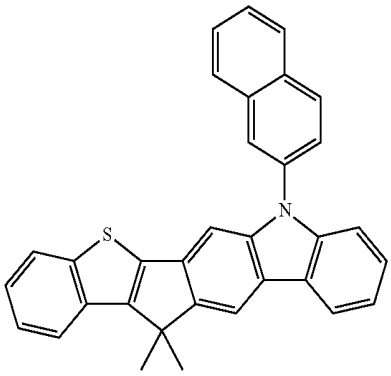

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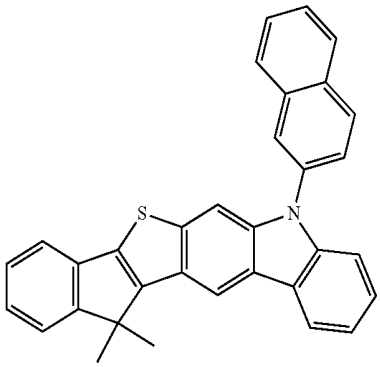

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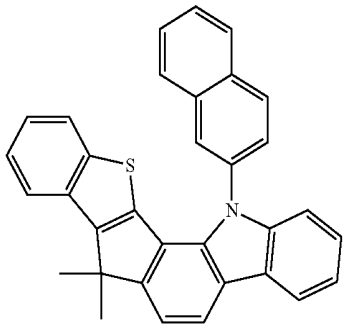

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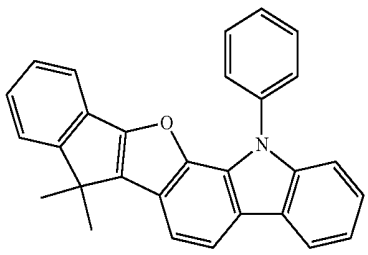

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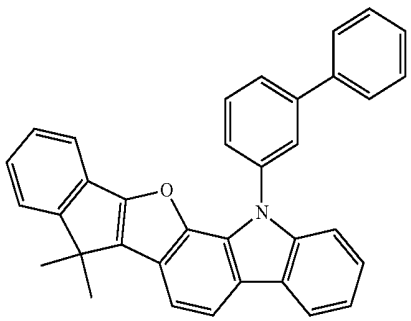

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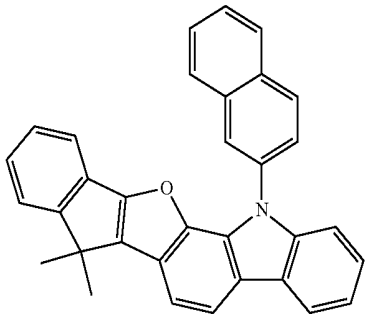

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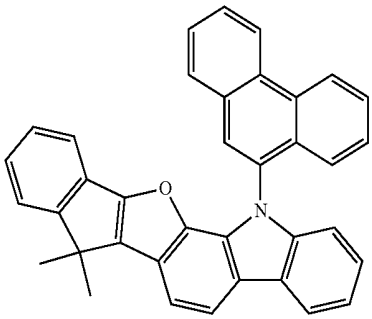

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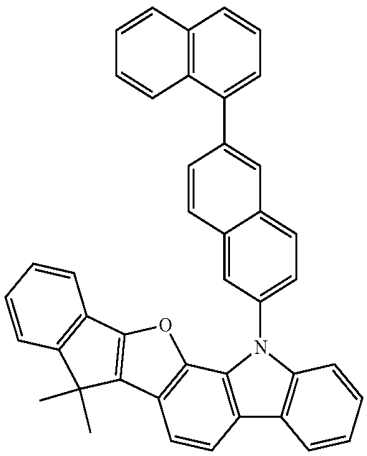

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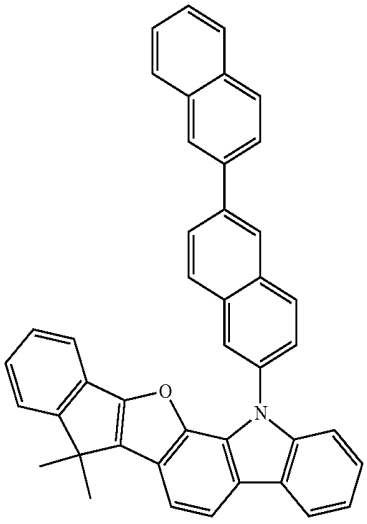

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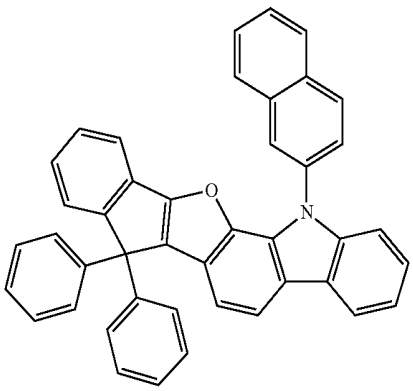

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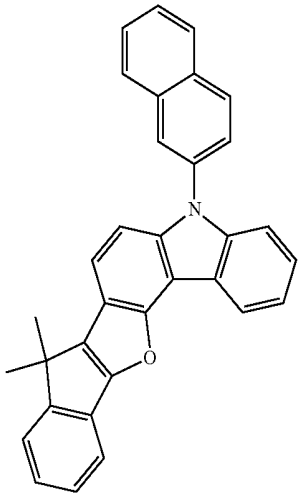

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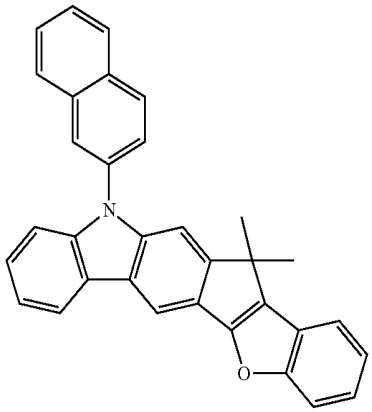

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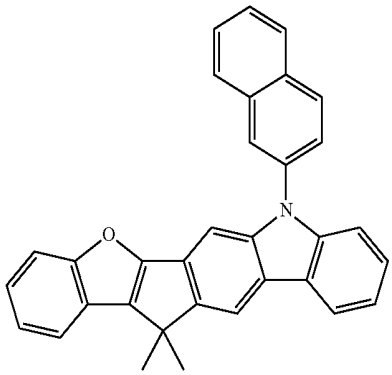

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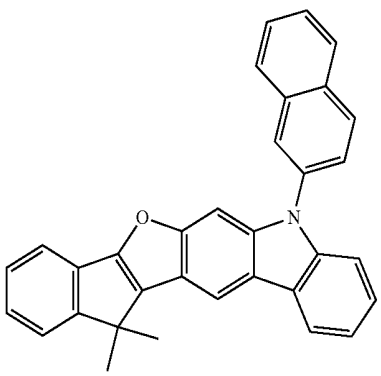

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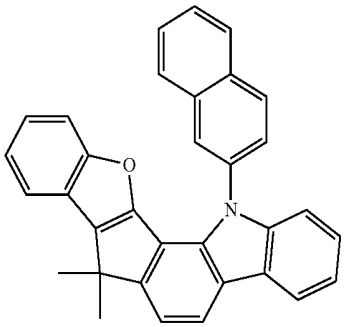

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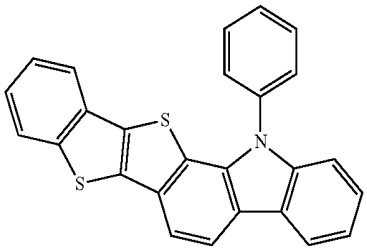

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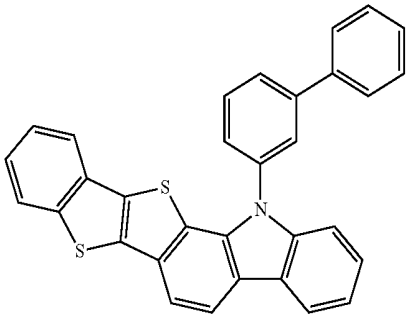

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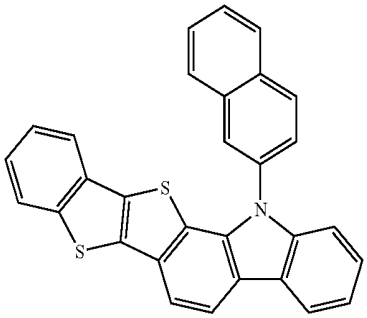

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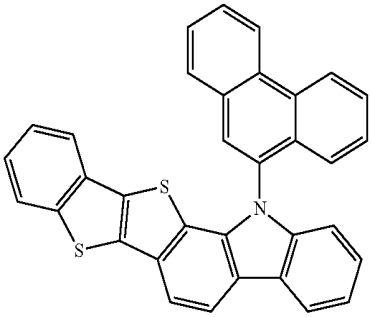

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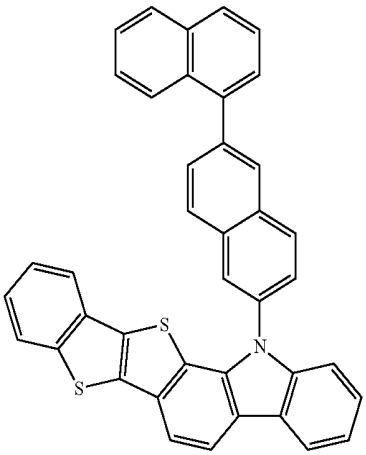

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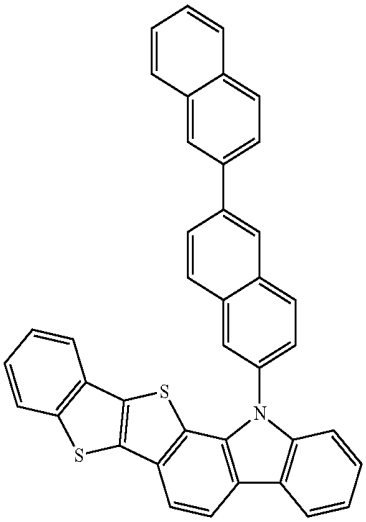

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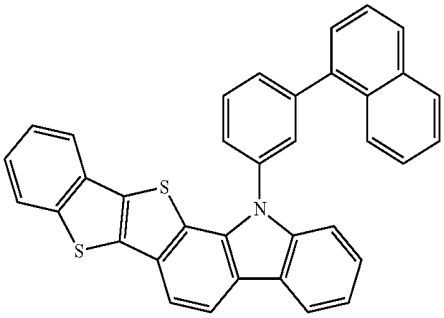

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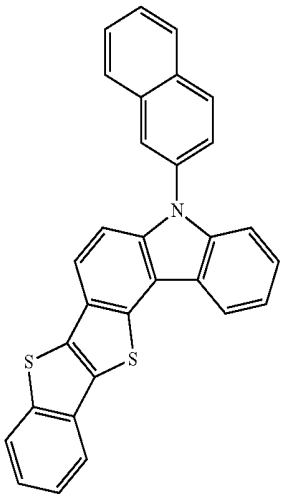

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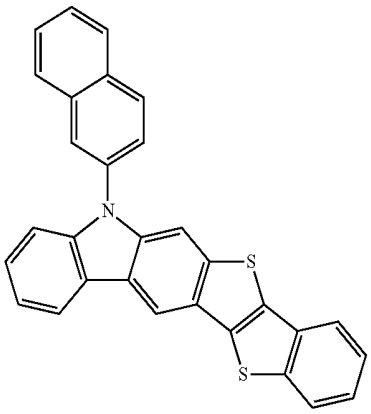

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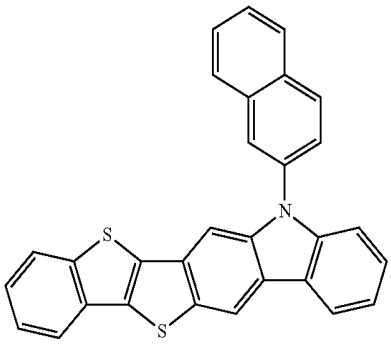

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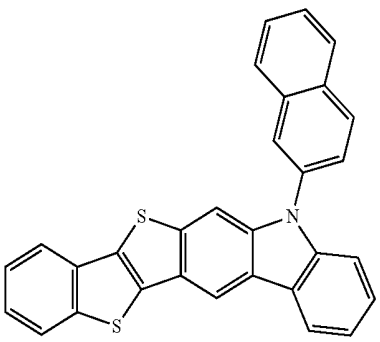

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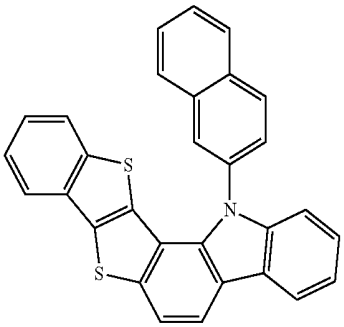

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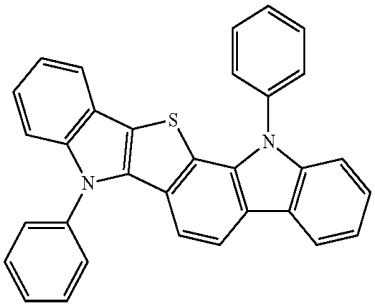

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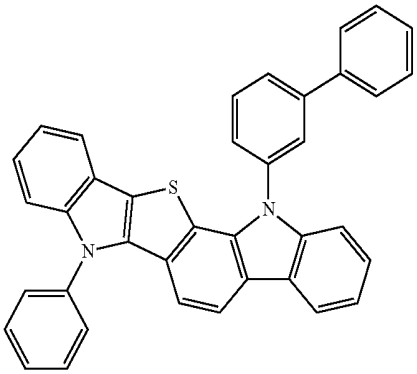

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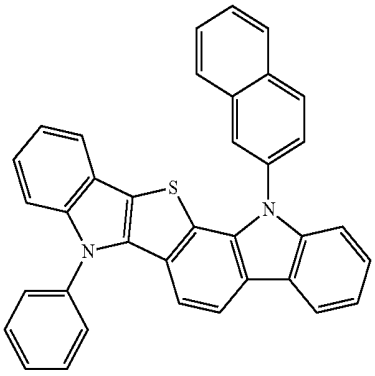

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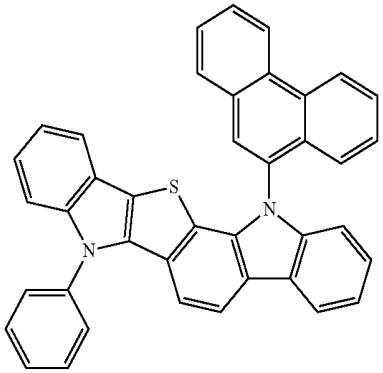

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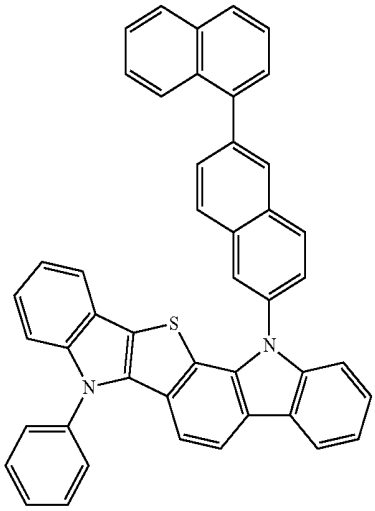

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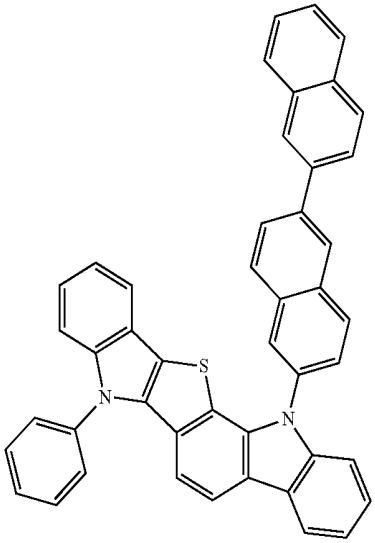

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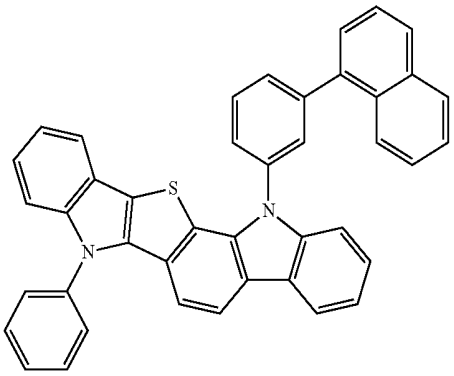

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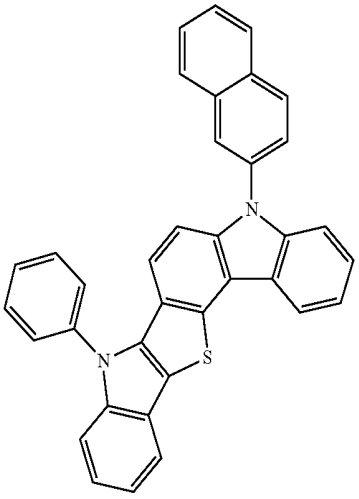

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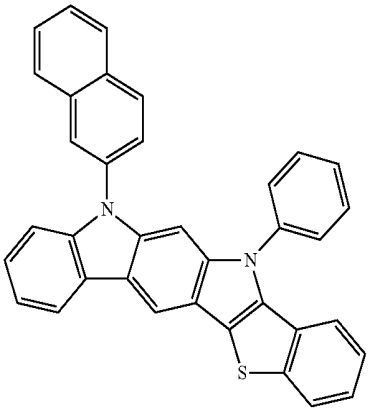

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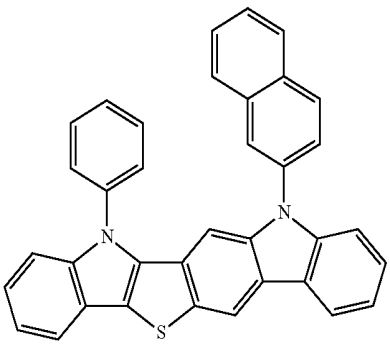

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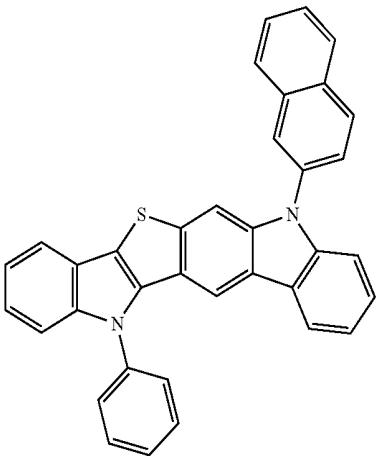

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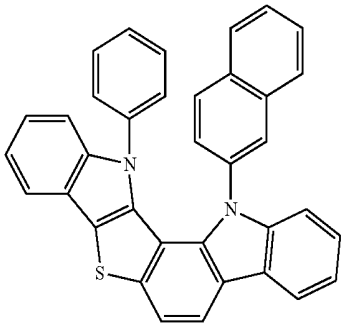

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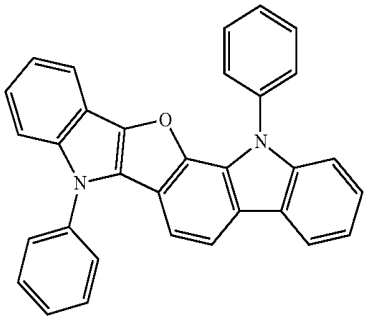

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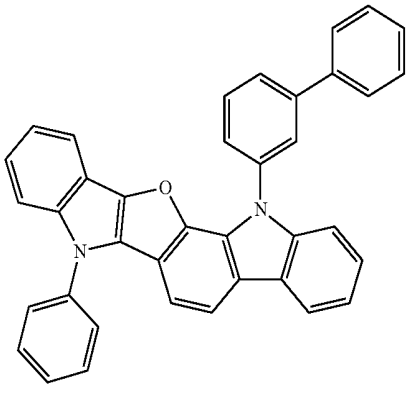

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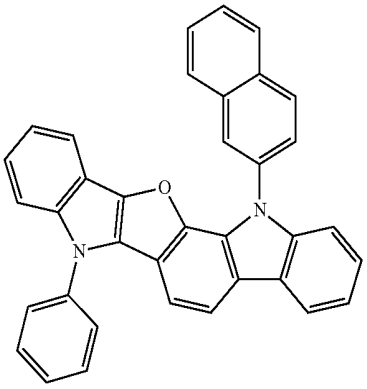

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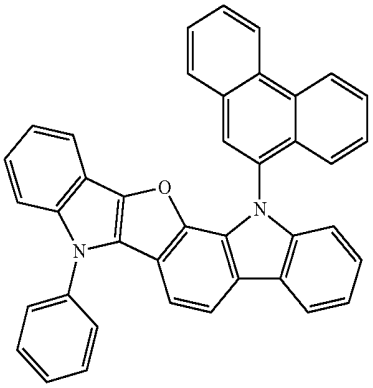

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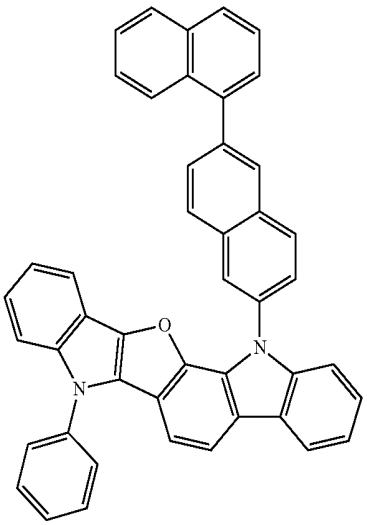

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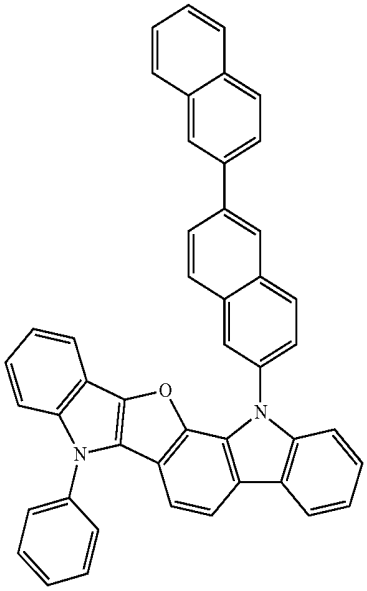

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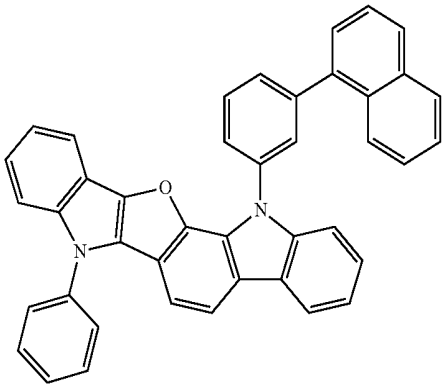

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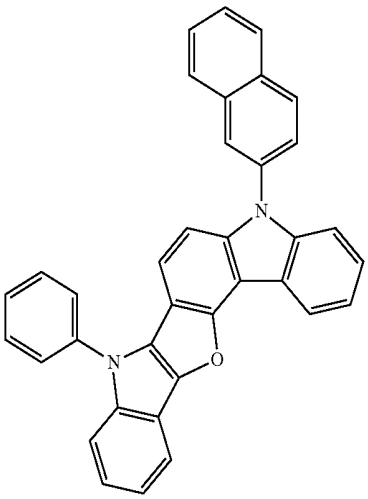

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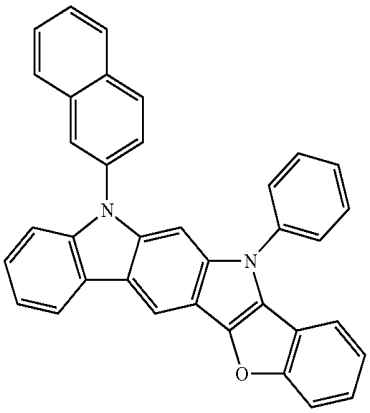

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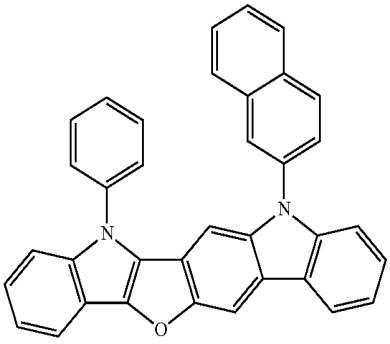

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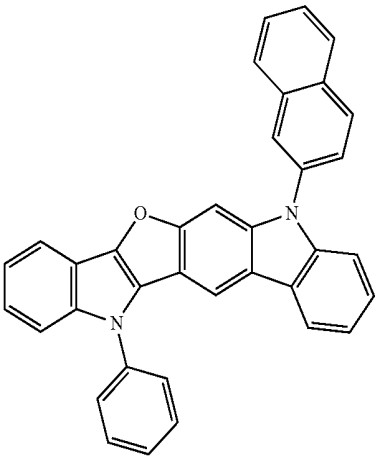

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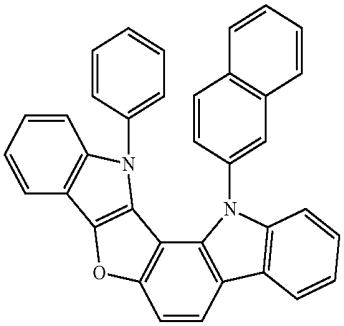

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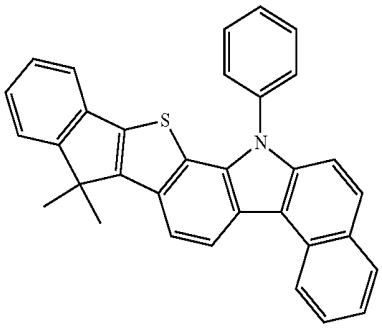

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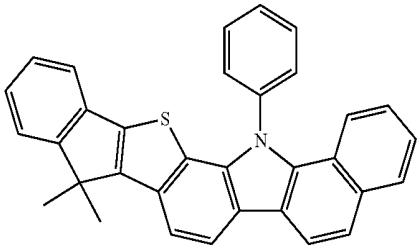

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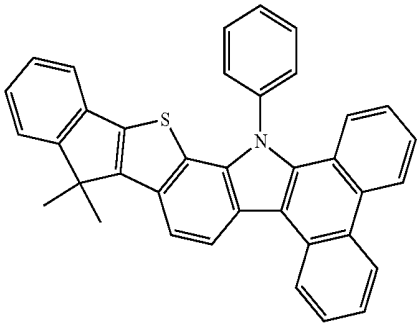

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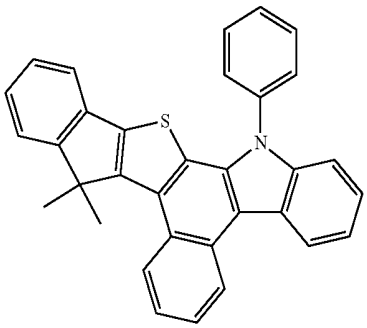

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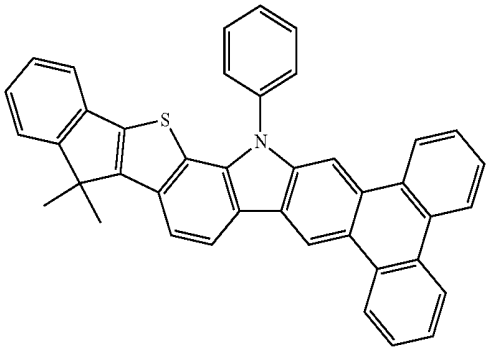

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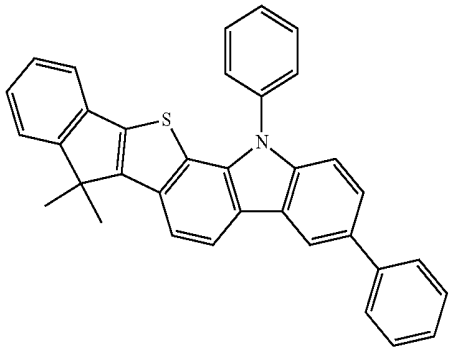

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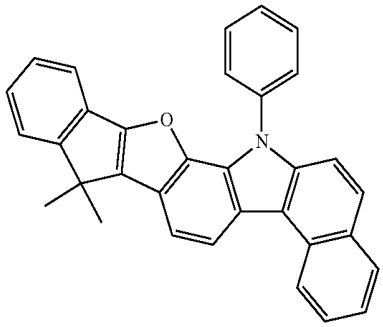

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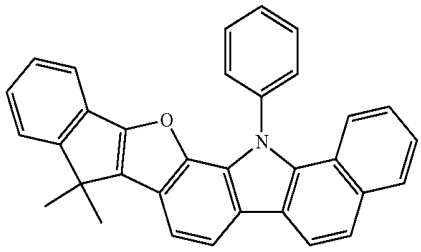

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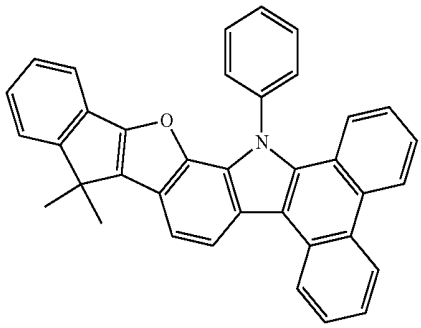

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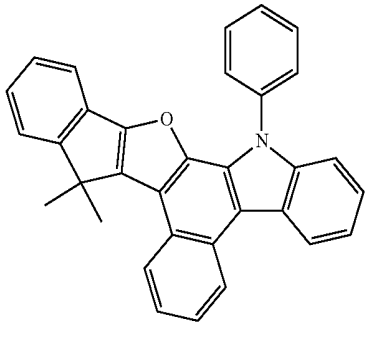

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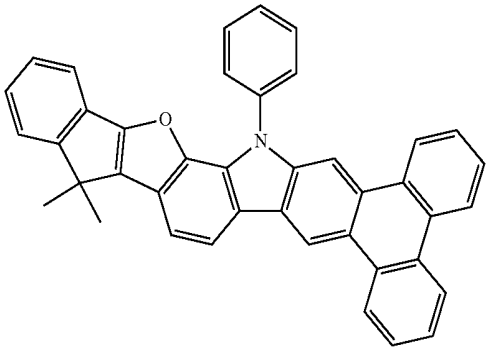

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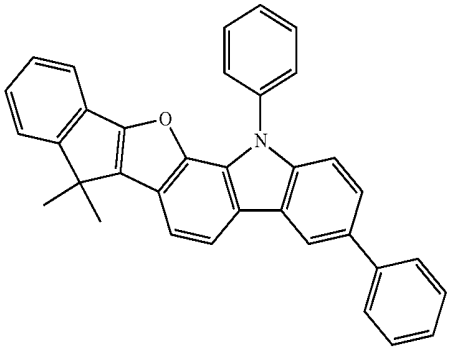

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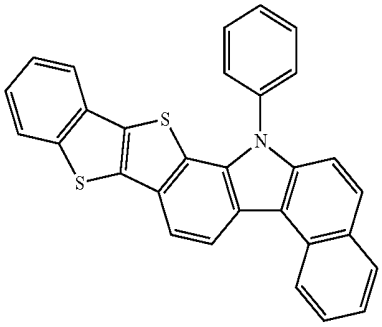

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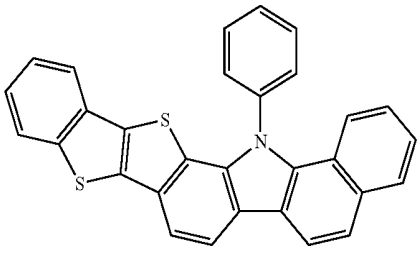

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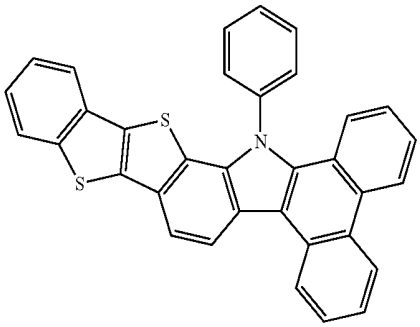

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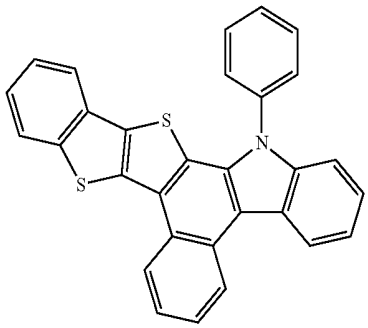

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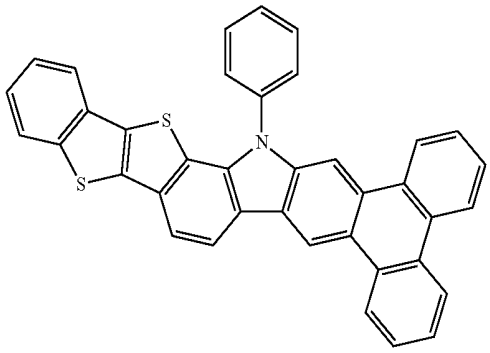

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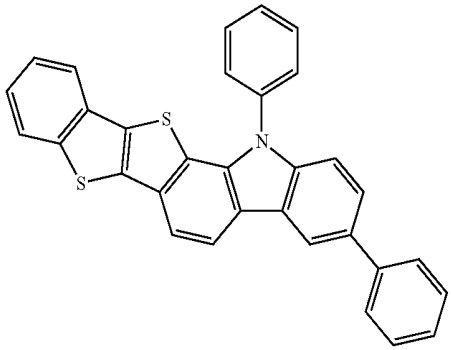

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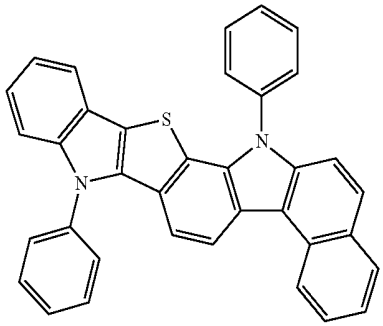

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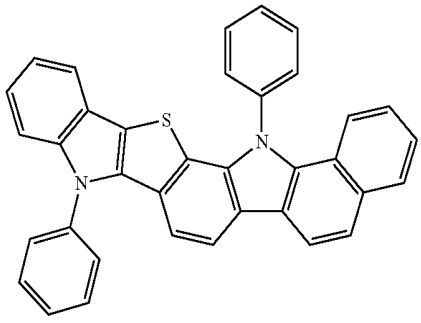

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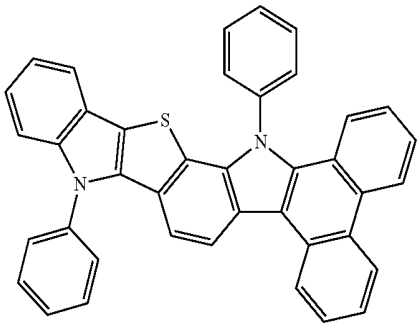

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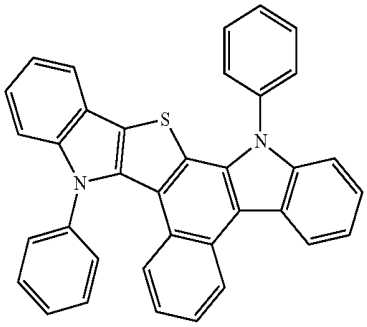

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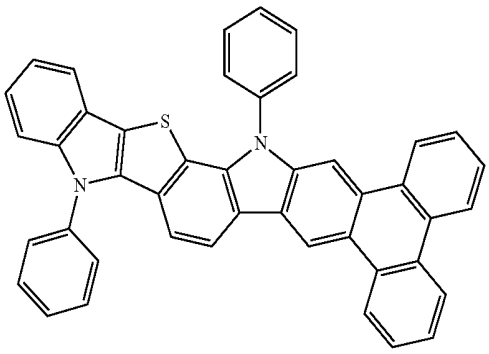

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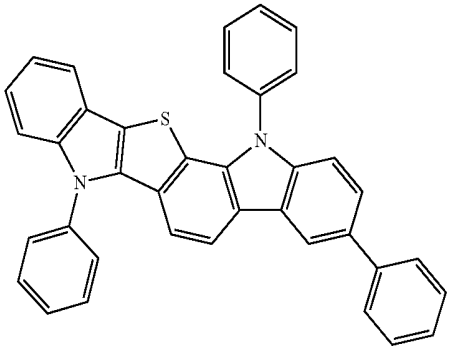

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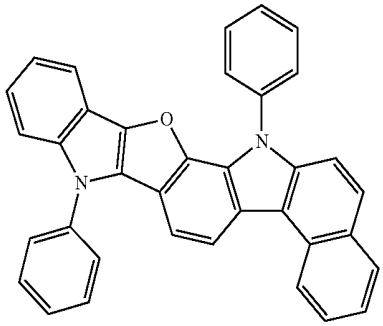

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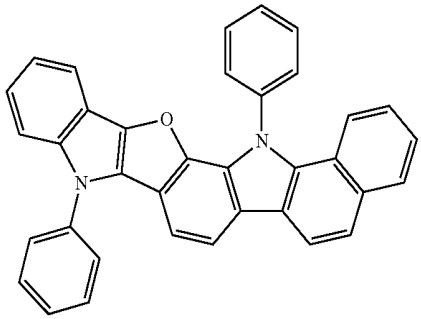

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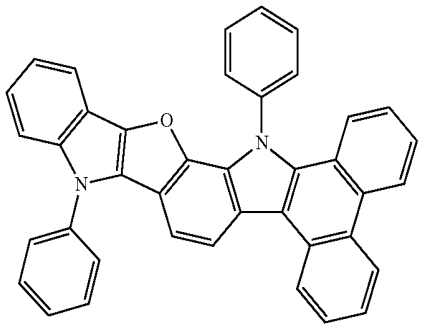

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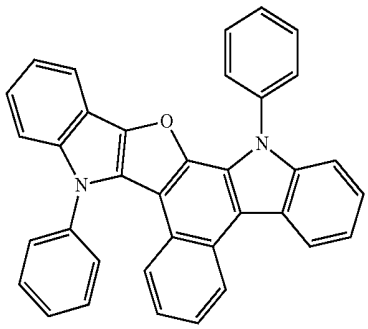

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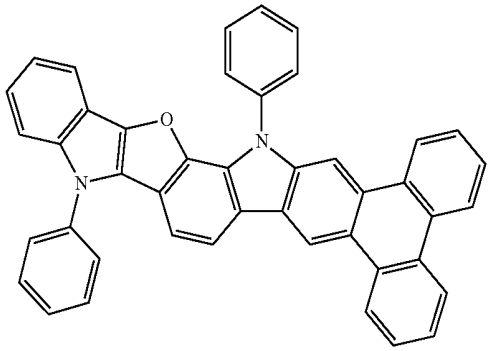

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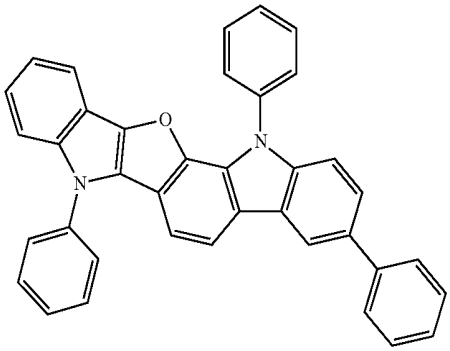

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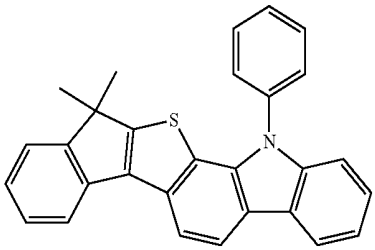

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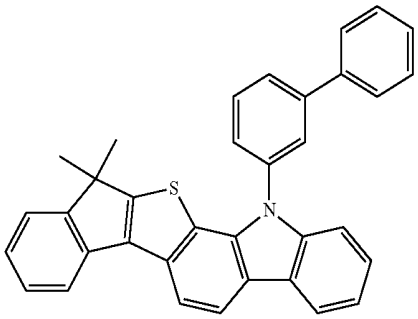

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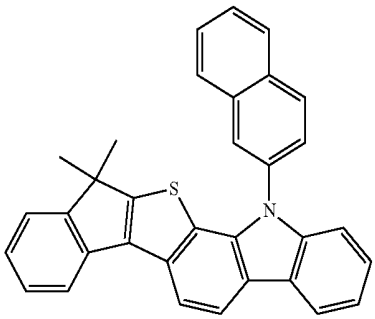

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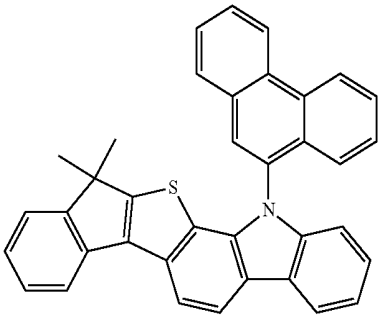

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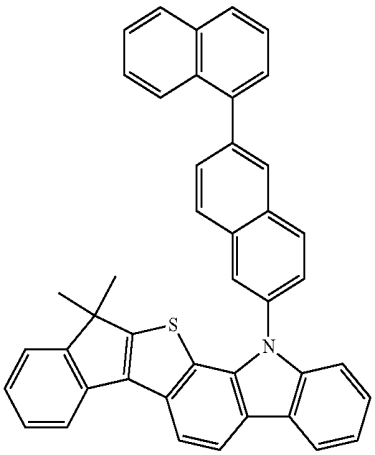

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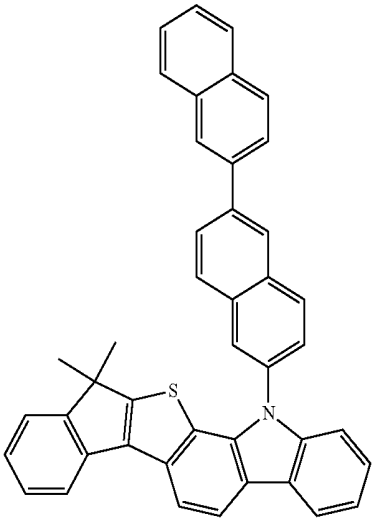

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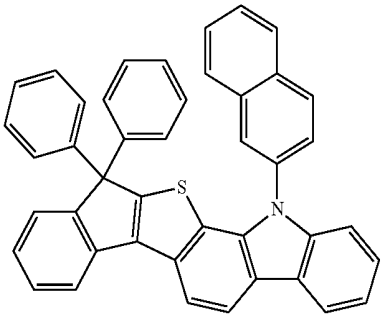

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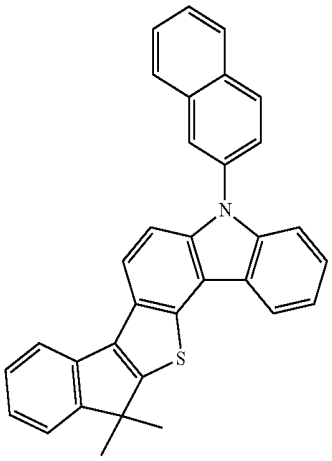

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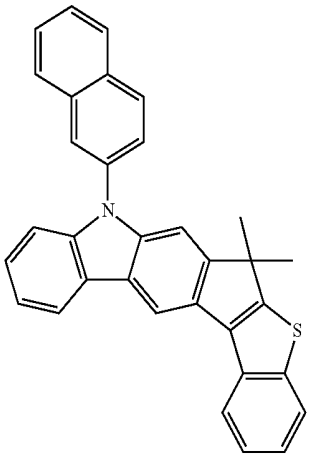

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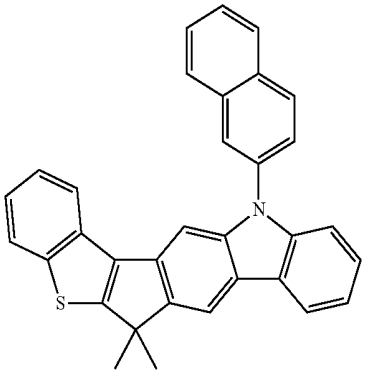

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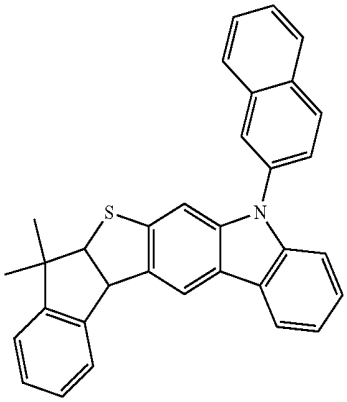

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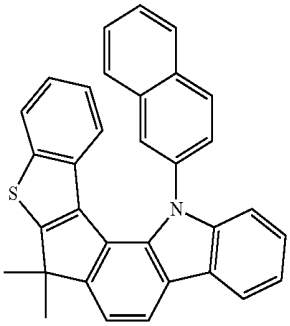

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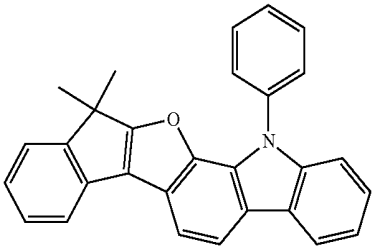

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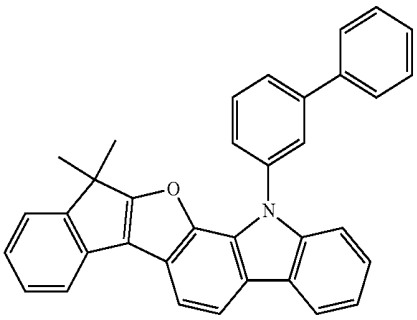

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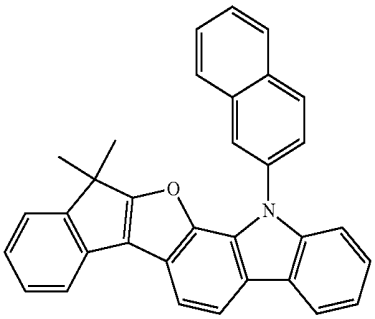

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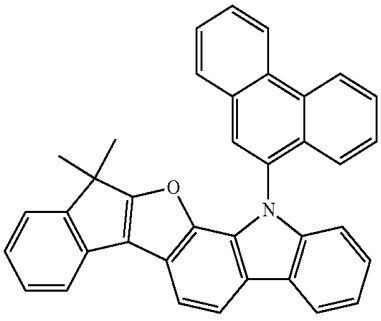

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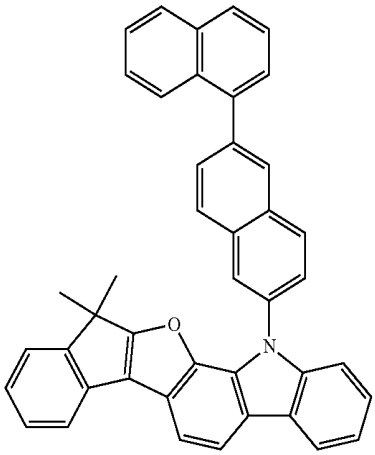

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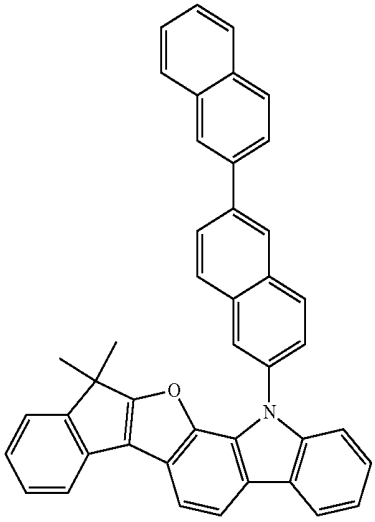

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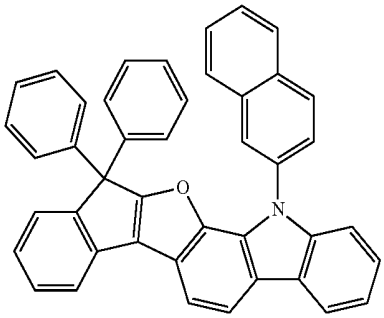

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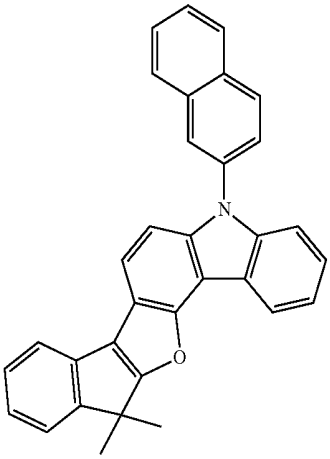

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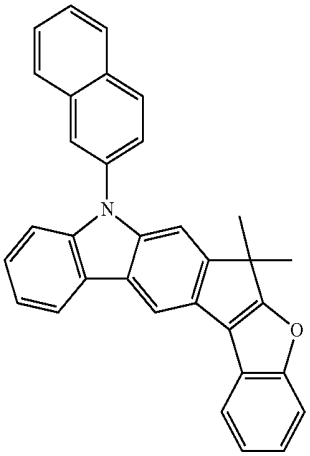

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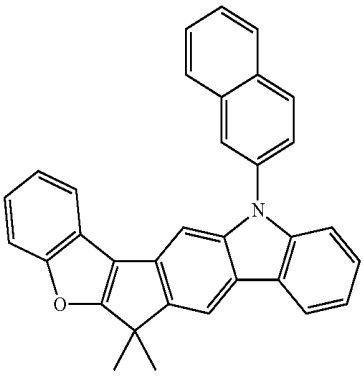

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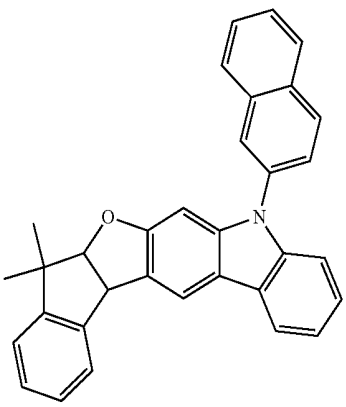

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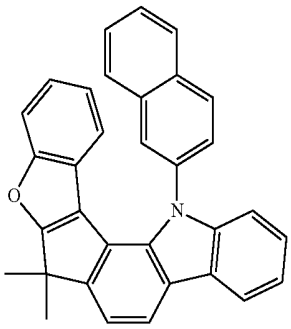

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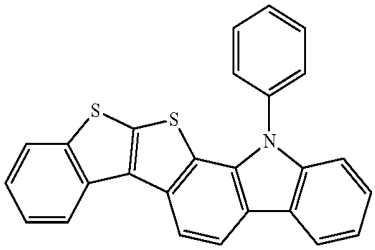

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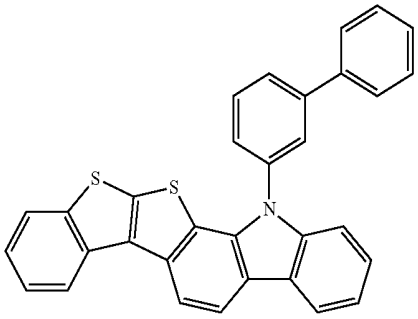

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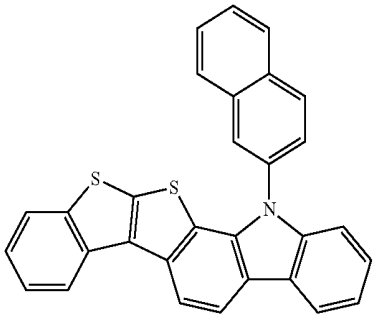

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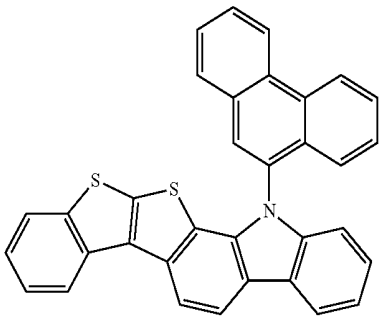

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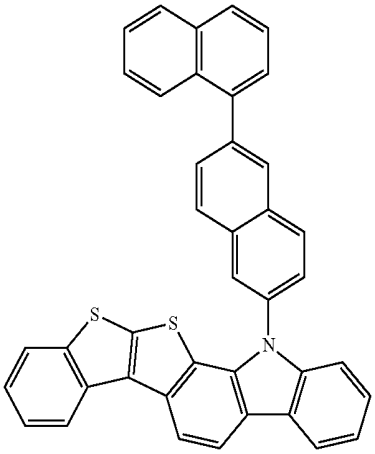

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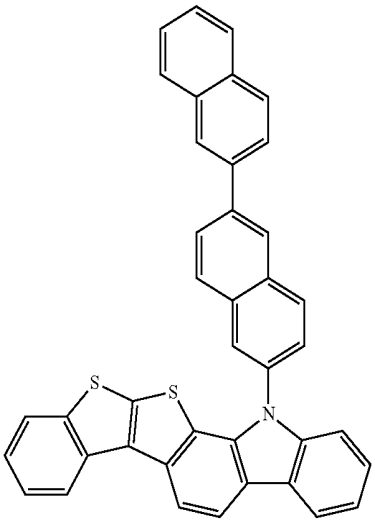

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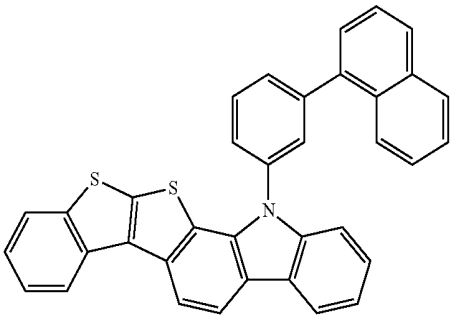

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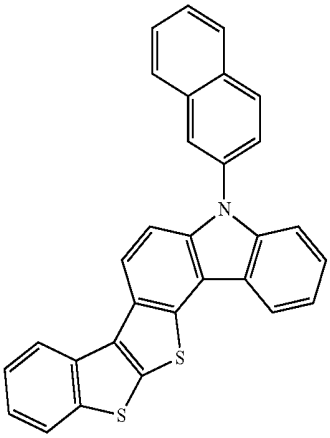

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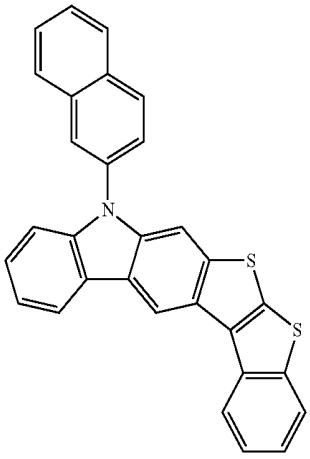

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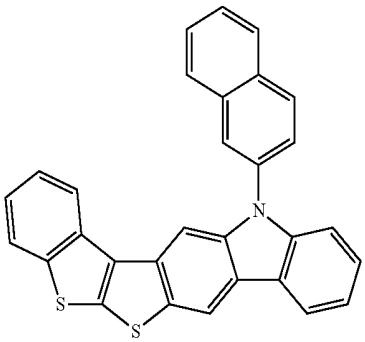

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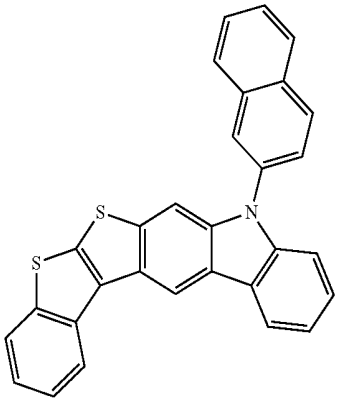

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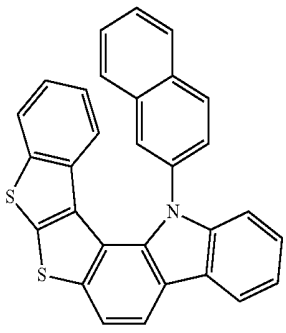

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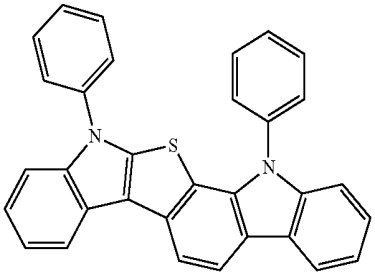

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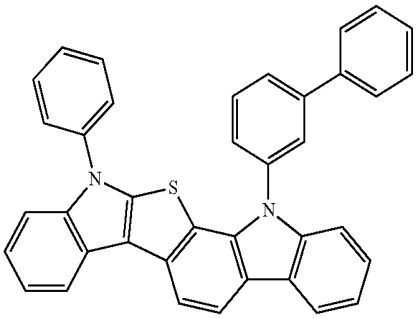

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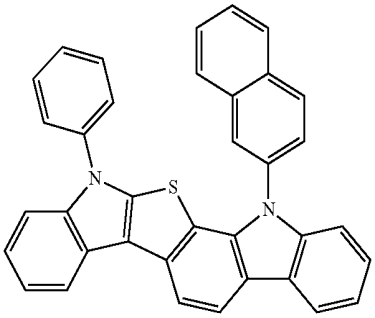

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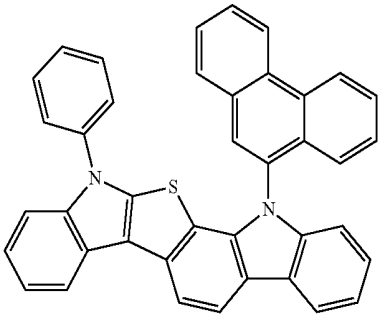

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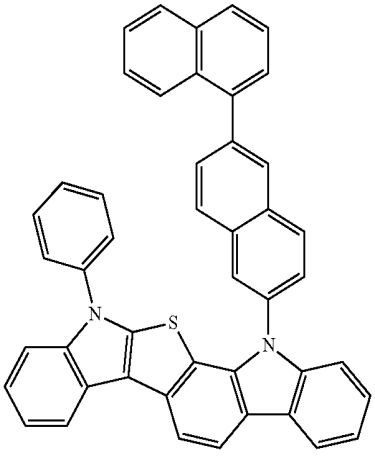

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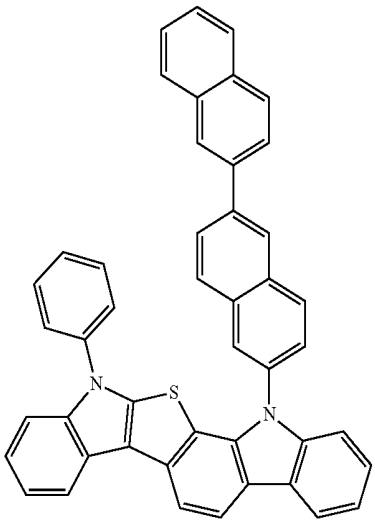

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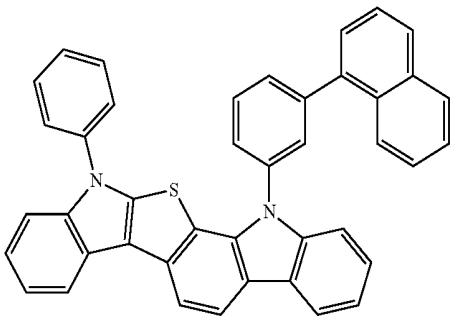

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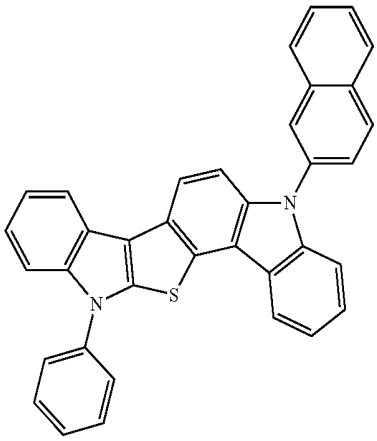

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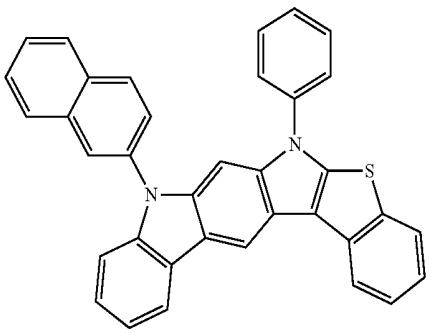

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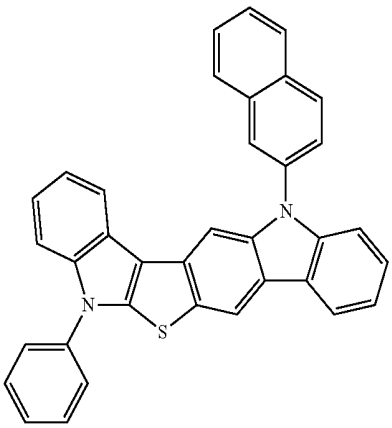

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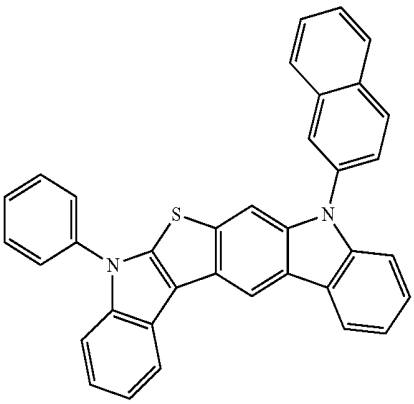

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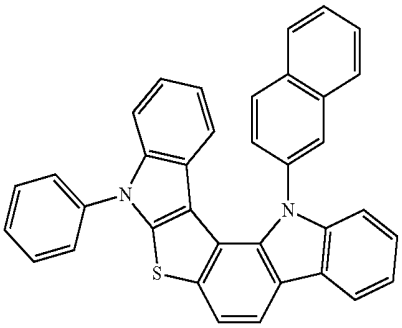

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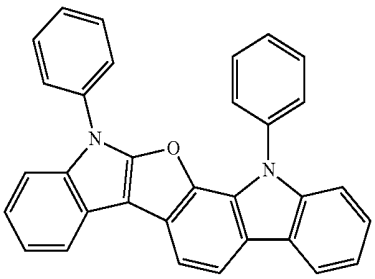

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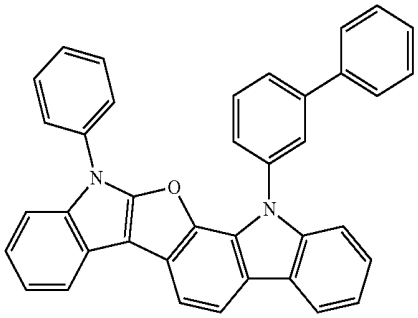

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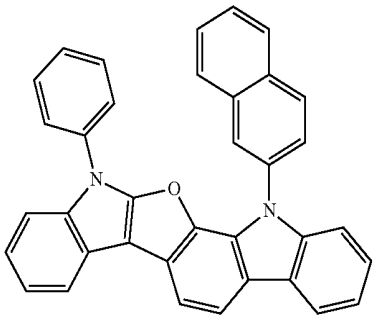

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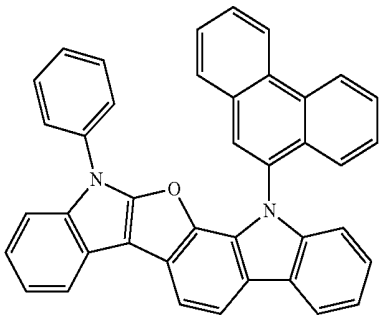

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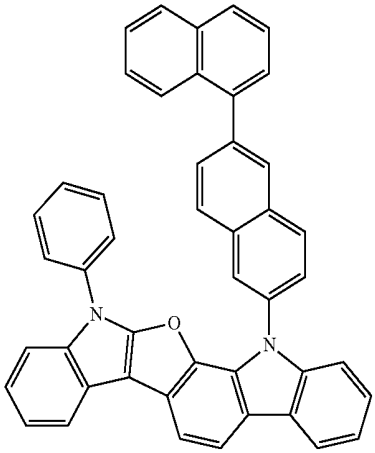

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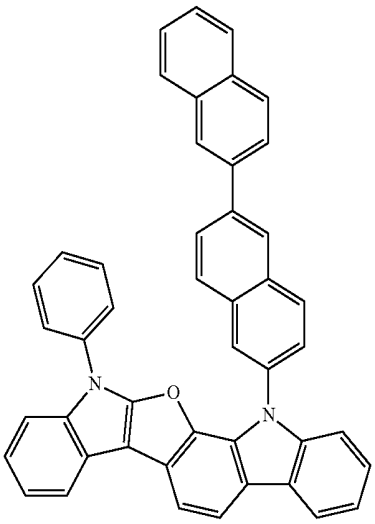

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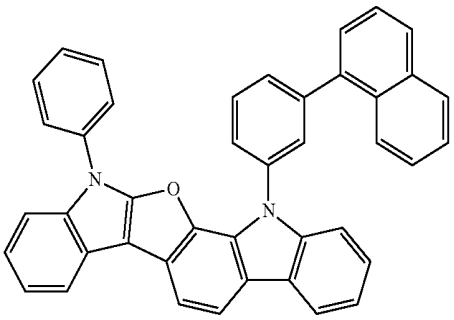

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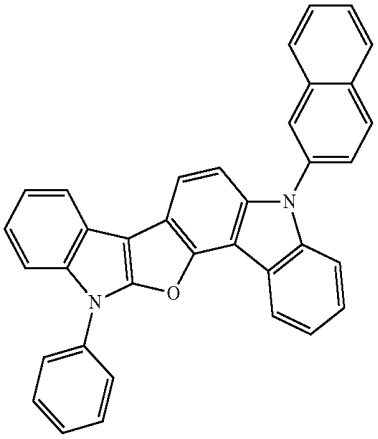

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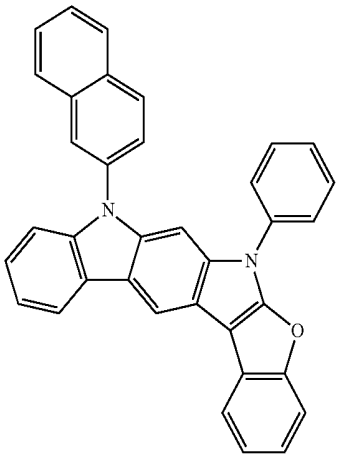

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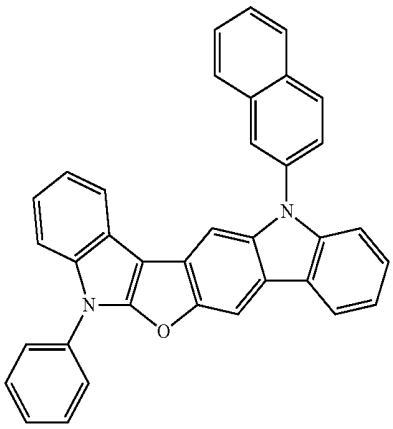

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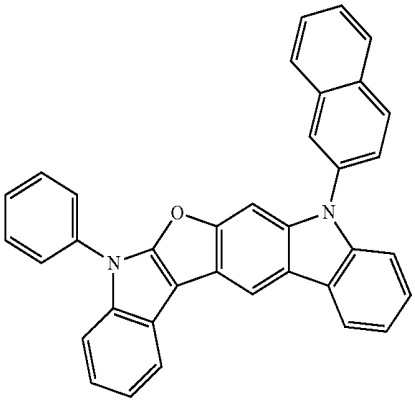

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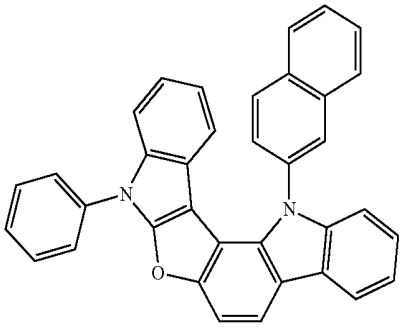

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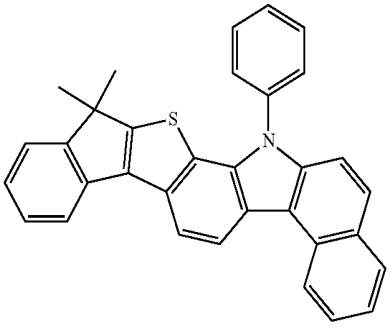

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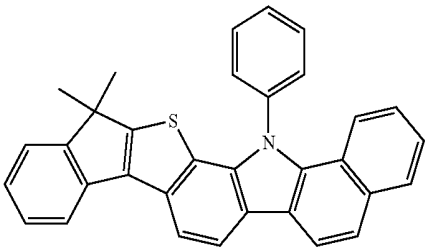

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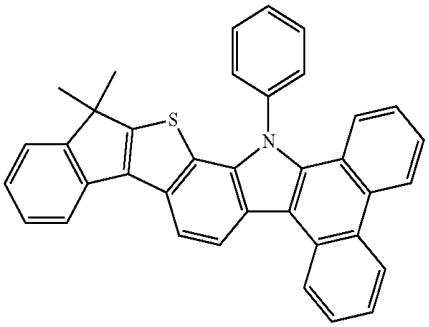

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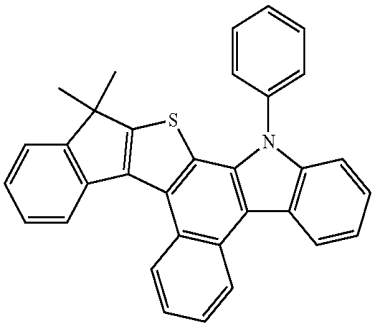

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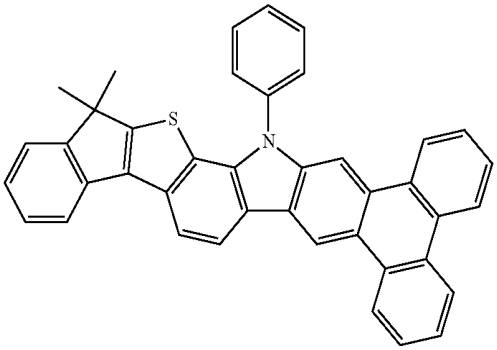

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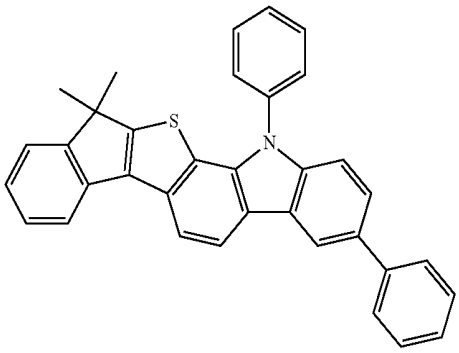

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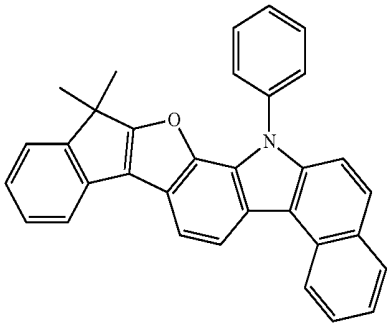

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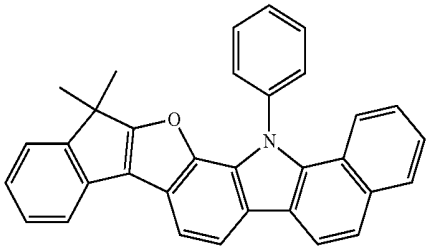

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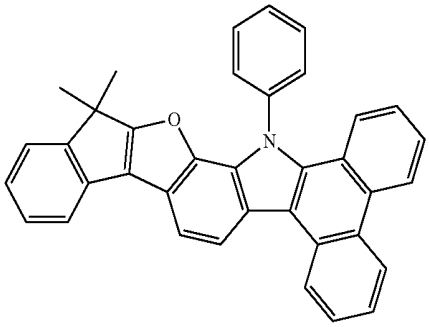

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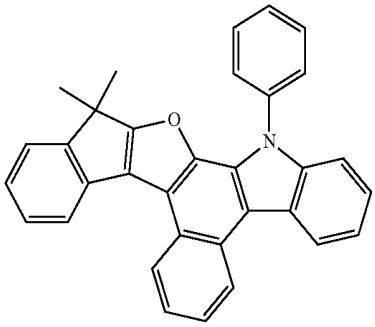

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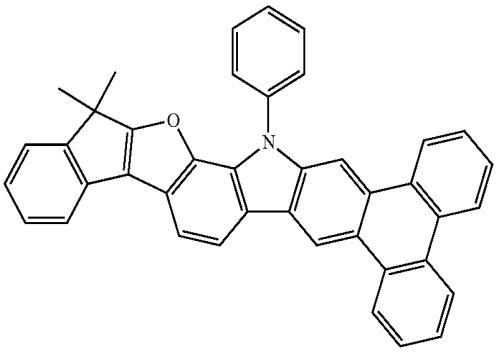

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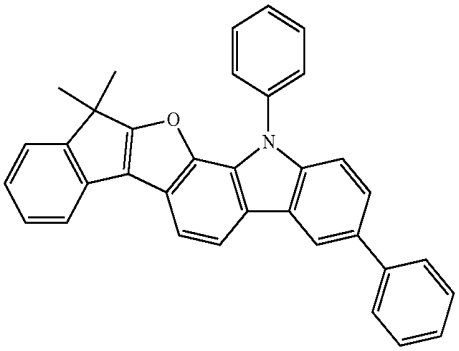

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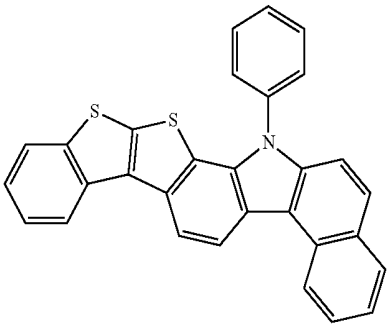

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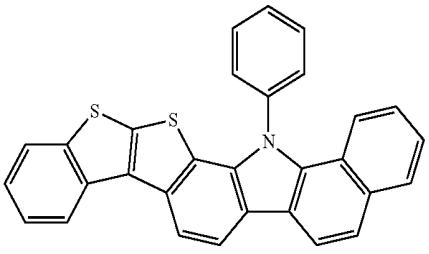

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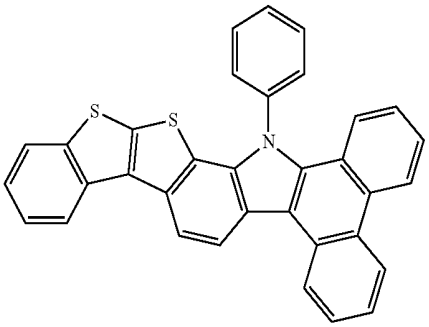

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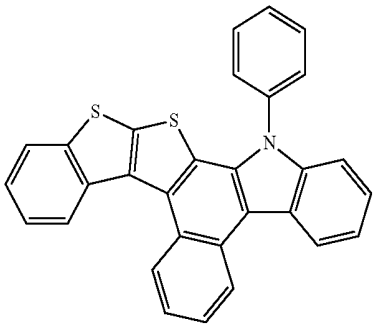

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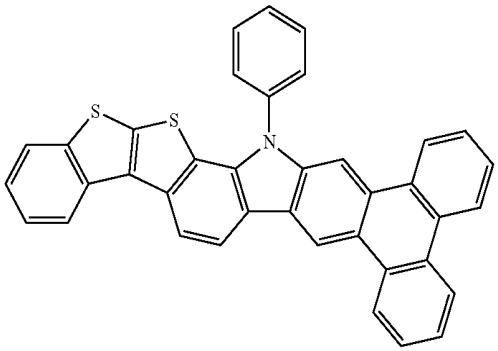

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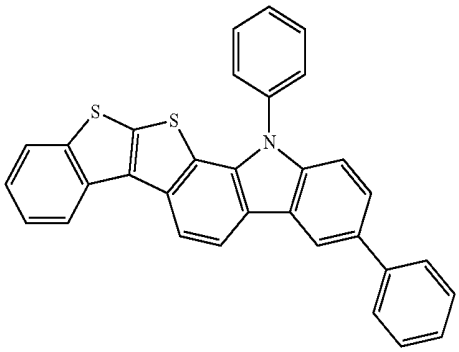

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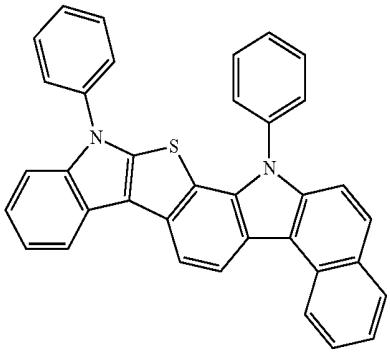

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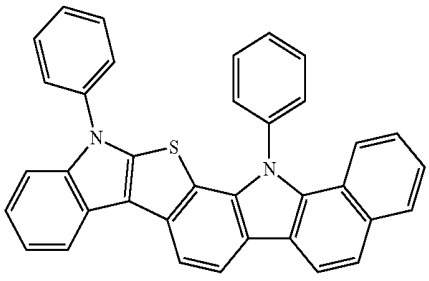

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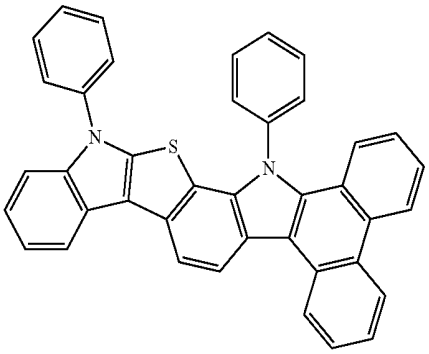

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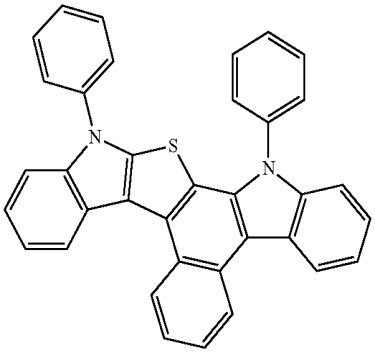

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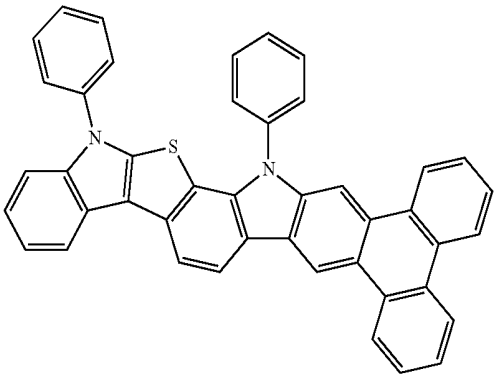

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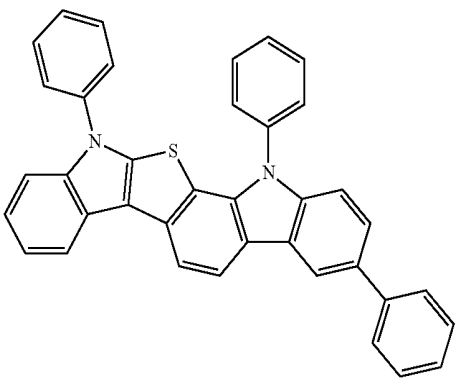

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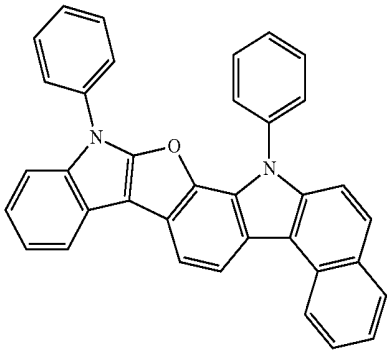

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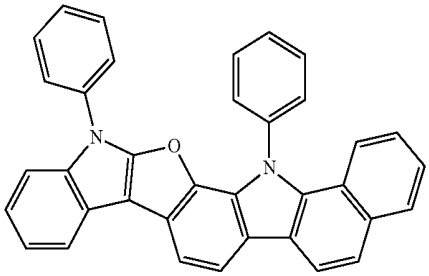

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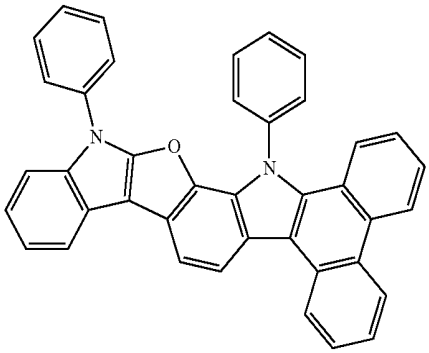

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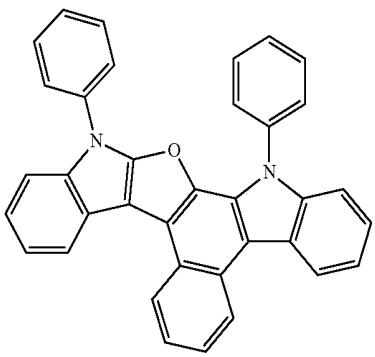

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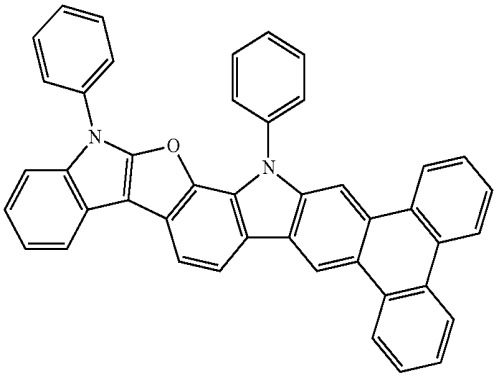

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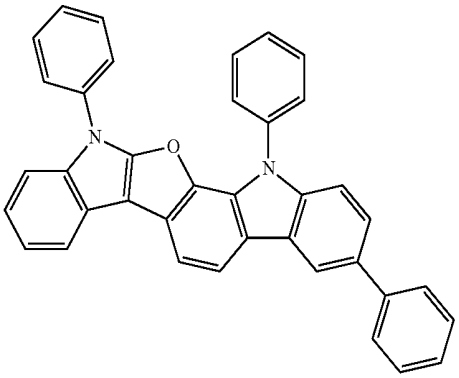

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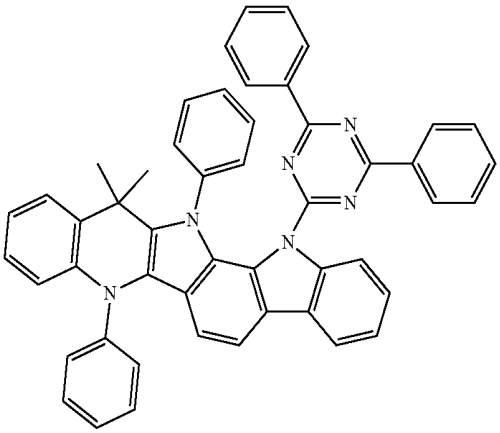

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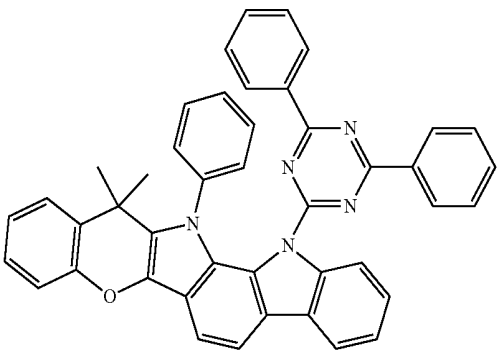

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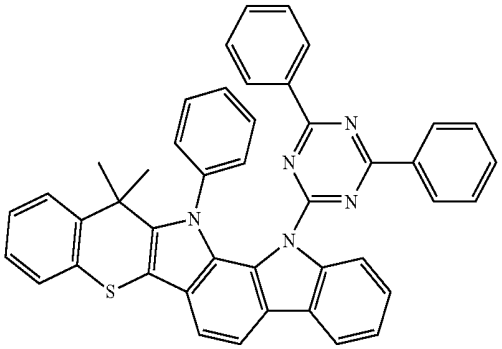

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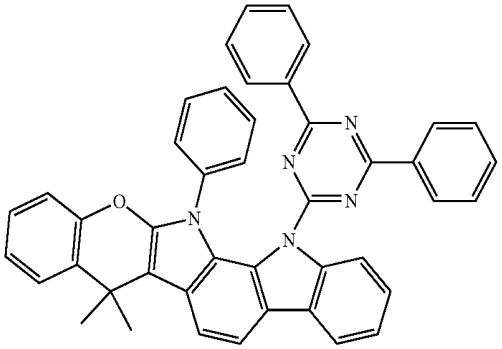

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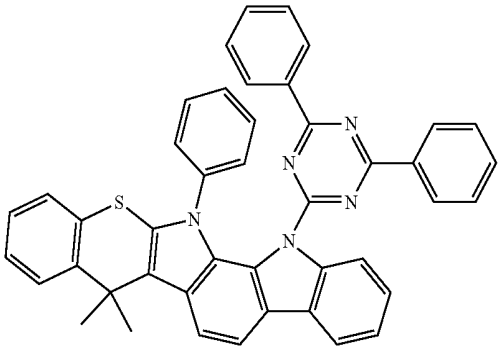

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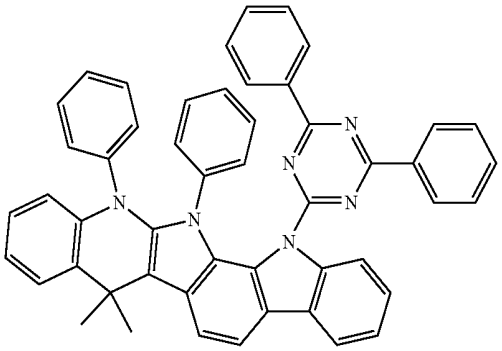

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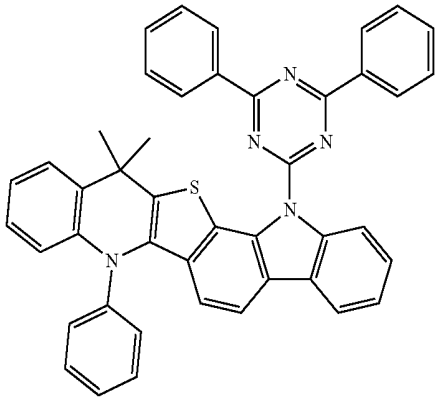

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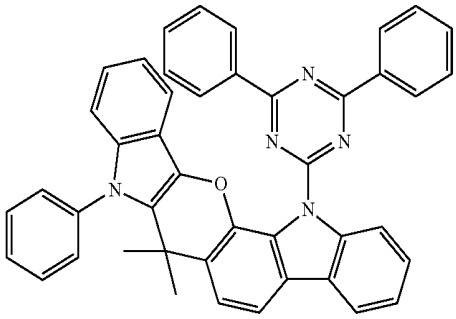

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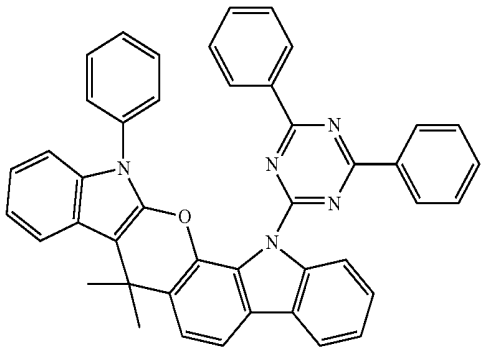

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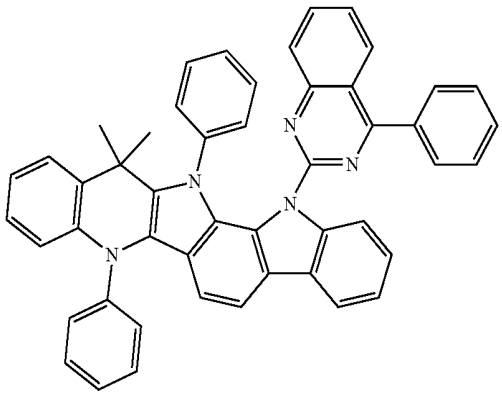

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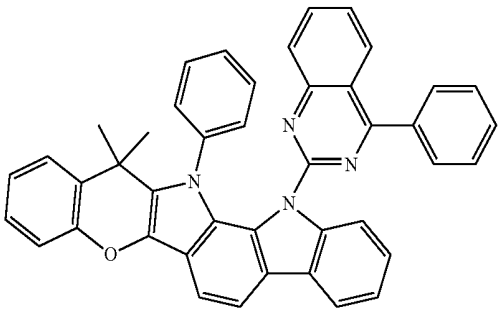

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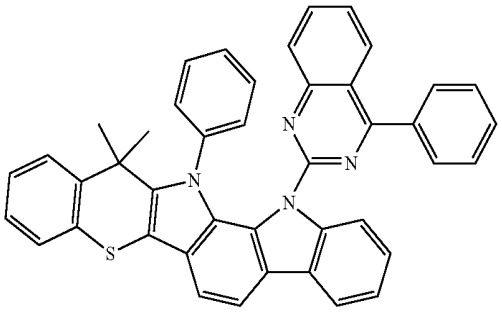

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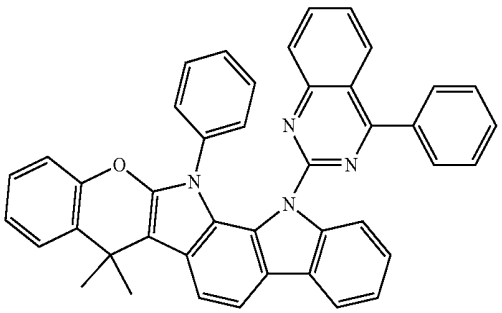

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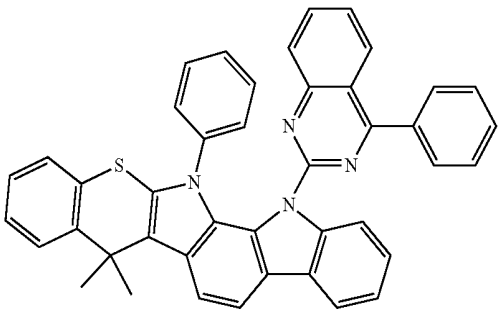

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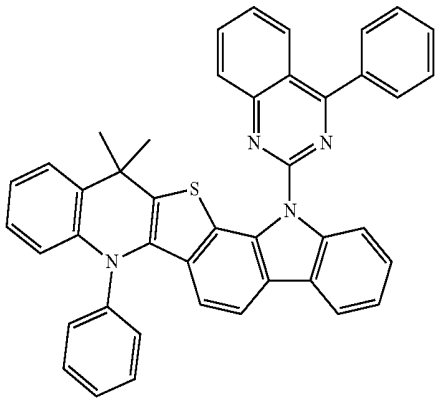

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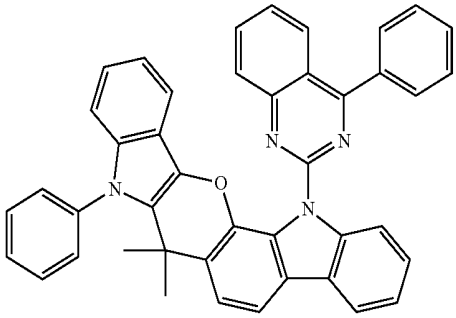

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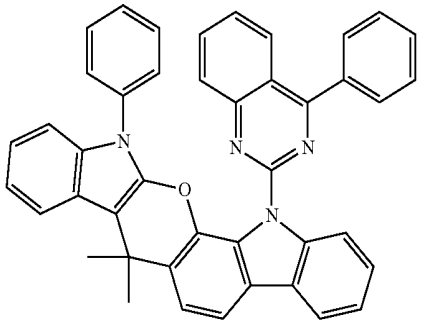

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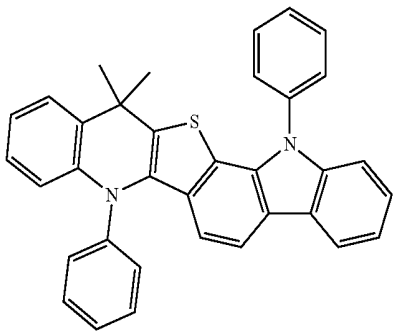

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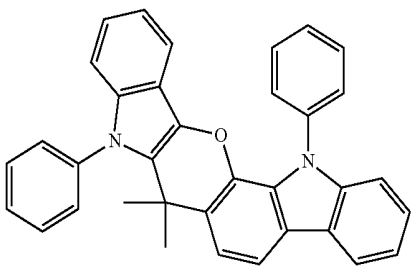

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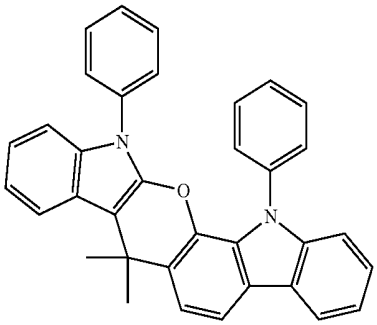

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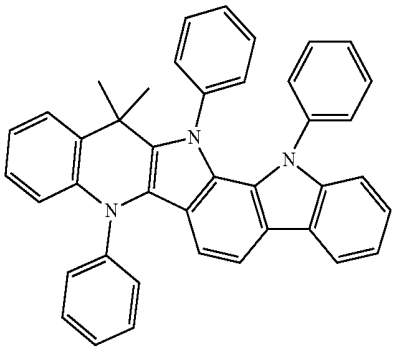

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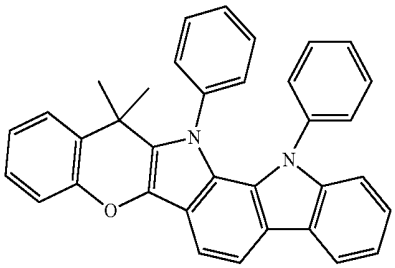

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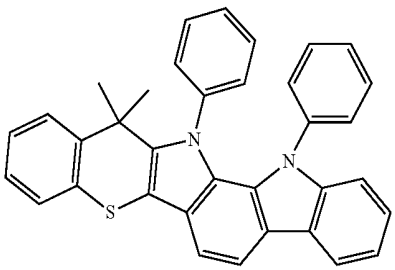

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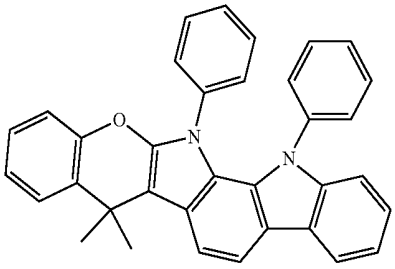

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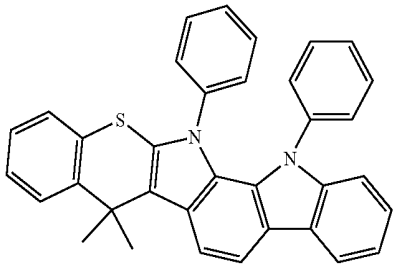

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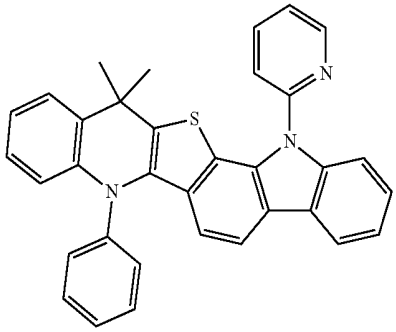

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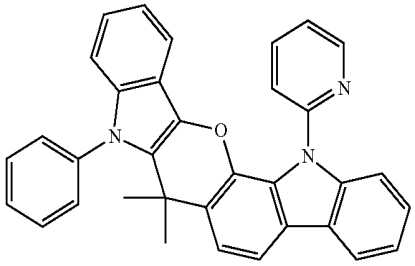

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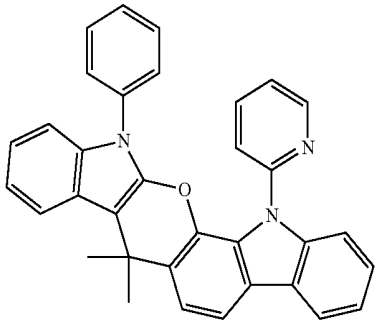

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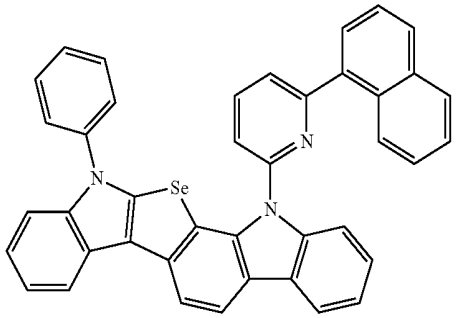

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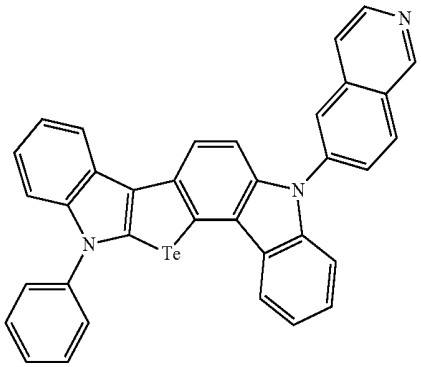

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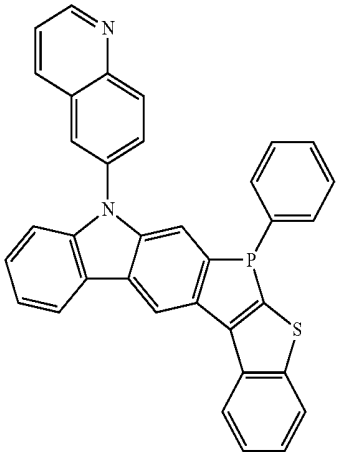

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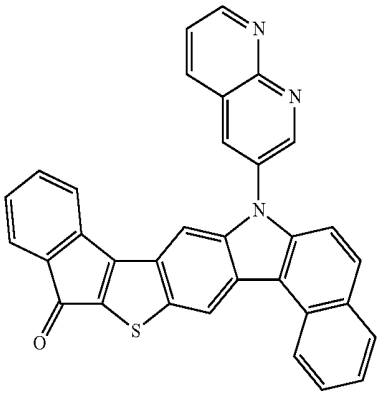

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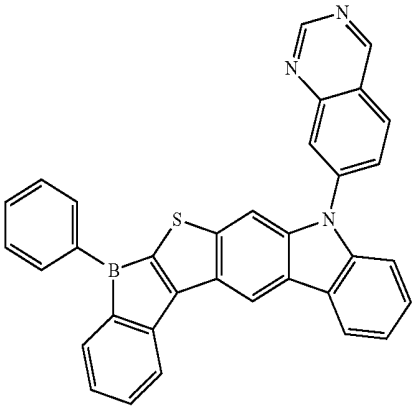

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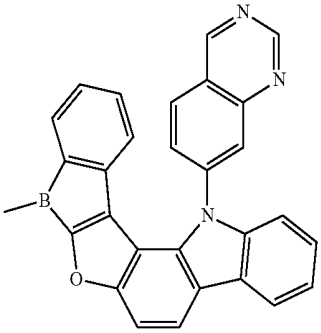

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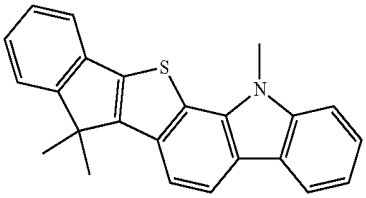

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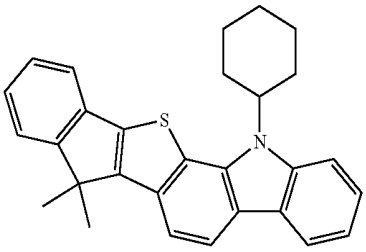

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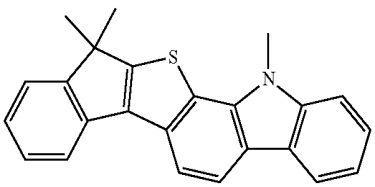

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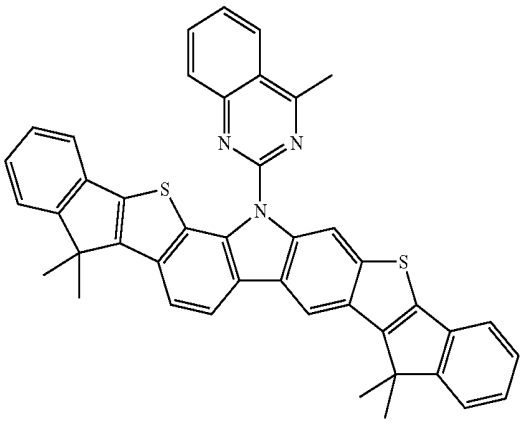

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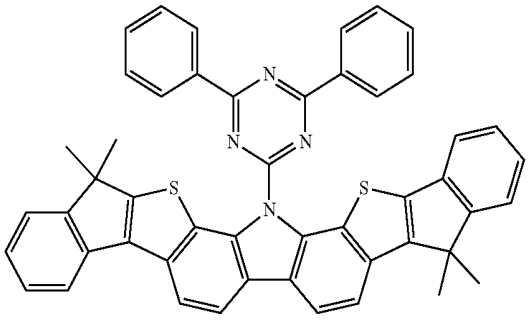

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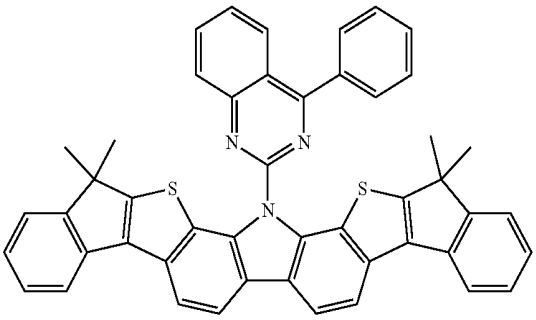

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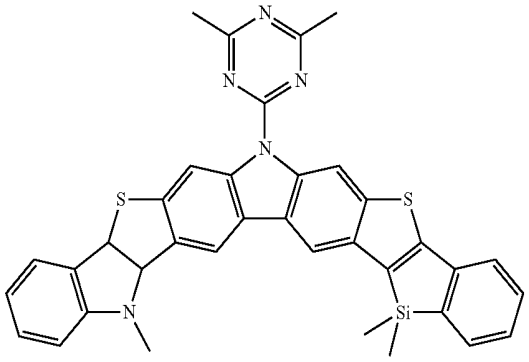

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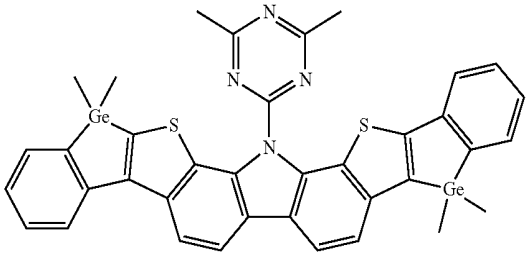

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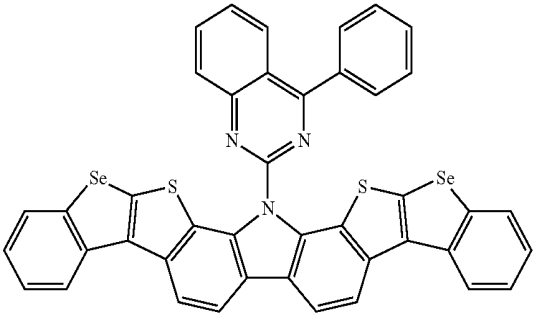

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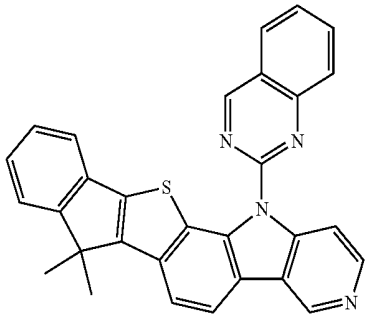

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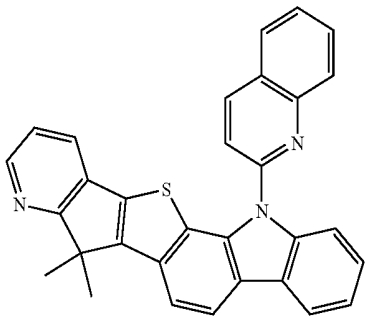

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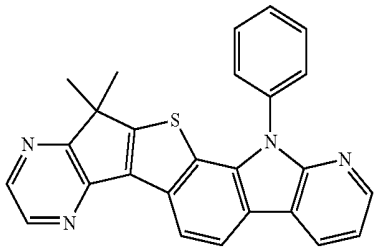

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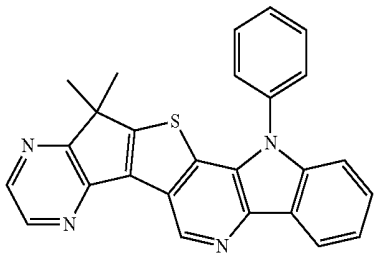

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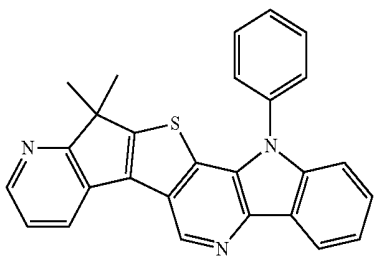

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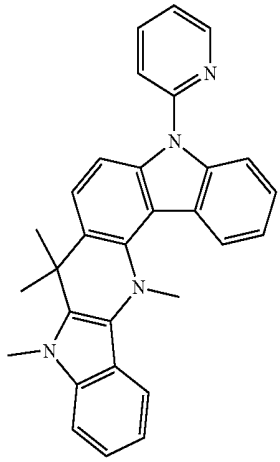

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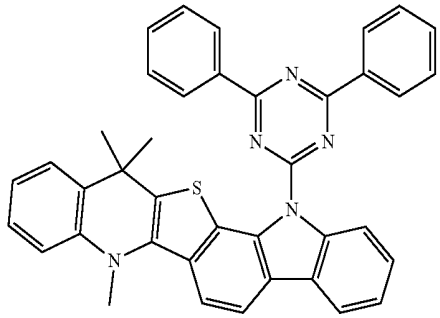

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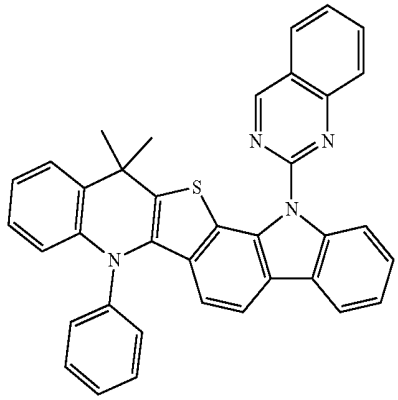

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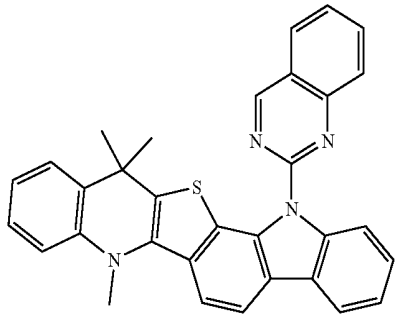

[0133] The heterocyclic compound of Formula 1 has a core structure of which free rotation is not easily allowed, and thus, in the case of forming a thin film according to a deposition method using the heterocyclic compound, the movement of electrons and/or holes may be facilitated. Accordingly, an organic light-emitting device including the heterocyclic compound may operate at a low driving voltage.

[0134] The heterocyclic compound of Formula 1 has a suitable triplet energy band gap for efficient phosphorescent emission, and accordingly, an organic light-emitting device including the heterocyclic compound may have high efficiency.

[0135] Aromatic rings are connected with each other (e.g., fused together) in the heterocyclic compound of Formula 1, and thus, charges may be widely distributed (upon a long conjugation length). In this regard, the heterocyclic compound may have excellent electrical stability, and accordingly, an organic light-emitting device including the heterocyclic compound may have a long lifespan.

[0136] Therefore, an organic light-emitting device including the heterocyclic compound of Formula 1 may have low driving voltage, high efficiency, and long lifespan characteristics.

[0137] The heterocyclic compound of Formula 1 may be synthesized according to synthesis methods generally available in the art. A method of synthesizing the heterocyclic compound may be understood by one of ordinary skill in the art by referring to Examples described below, but the present disclosure is not limited thereto.

[0138] The heterocyclic compound of Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the heterocyclic compound of Formula 1 may be included in an emission layer. Thus, in some embodiments, there is provided an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer disposed between the first electrode and the second electrode and including an emission layer, wherein the organic layer includes at least one of the heterocyclic compounds of Formula 1.

[0139] As used herein, the expression "(an organic layer) includes the heterocyclic compound" may be construed as meaning (an organic layer) may include one of the heterocyclic compound in a range of Formula 1 or at least two different heterocyclic compounds in a range of Formula 1.

[0140] For example, the organic layer may include, as the heterocyclic compound, Compound 1 only. Here, Compound 1 may be included in the emission layer of the organic light-emitting device. Alternatively, the organic layer may include, as the heterocyclic compound, Compound 1 and Compound 2. Here, Compound 1 and Compound 2 may be both included in a same layer (for example, in some embodiments Compound 1 and Compound 2 are both included in the emission layer), or may be included in different layers from each other (for example, in some embodiments Compound 1 is included in the emission layer while Compound 2 is included in an electron transport layer).

[0141] The organic layer may further include at least one of: i) a hole transport region between the first electrode and the emission layer and including at least one of a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer; and ii) an electron transport region

between the emission layer and the second electrode and including at least one of a hole blocking layer, an electron transport layer, and an electron injection layer.

[0142] As used herein, the term "organic layer" refers to a single and/or a plurality of layers disposed between the first electrode and the second electrode in the organic light-emitting device. A material included in the "organic layer" is not limited to an organic material.

[0143] The accompanying drawing is a schematic cross-sectional view of a structure of an organic light-emitting device **10** according to an example embodiment of the present disclosure. The organic light-emitting device **10** includes a first electrode **110**, an organic layer **150**, and a second electrode **190**.

[0144] Hereinafter, a structure of an organic light-emitting device according to an example embodiment and a method of manufacturing an organic light-emitting device according to an example embodiment will be described in connection with the accompanying drawing.

[0145] A substrate may be additionally disposed under the first electrode **110** or on the second electrode **190** in the organic light-emitting device **10**. The substrate may be a glass substrate or transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

[0146] The first electrode **110** may be formed by depositing or sputtering a material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for forming the first electrode **110** may be selected from materials having a high work function to facilitate hole injection. The first electrode **110** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. The material for forming the first electrode **110** may be an indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), or zinc oxide (ZnO), each having transparency and excellent conductivity. Alternatively, when the first electrode **110** is a semi-transmissive electrode or a reflective electrode, the material for forming the first electrode **110** may be at least one selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag).

[0147] The first electrode **110** may have a single-layer structure or a multi-layer structure including two or more layers. For example, the first electrode **110** may have a triple-layer structure of ITO/Ag/ITO, but embodiments are not limited thereto.

[0148] The organic layer **150** is disposed on the first electrode **110**. The organic layer **150** includes an emission layer.

[0149] The organic layer **150** may include a hole transport region that is disposed between the first electrode **110** and the emission layer. The organic layer **150** may further include an electron transport region that is disposed between the emission layer and the second electrode **190**.

[0150] The hole transport region may include at least one of a hole injection layer (HIL), a hole transport layer (HTL), and an electron blocking layer (EBL), and the electron transport region may include at least one of a hole blocking layer (HBL), an electron transport layer (ETL), and an electron injection layer (EIL), but embodiments are not limited thereto.

[0151] The hole transport region may have a single-layer structure formed of a single material, a single-layer structure formed of a plurality of different materials, or a multi-layer structure having a plurality of layers formed of a plurality of different materials.

[0152] For example, the hole transport region may have a single-layer structure formed of a plurality of different materials, or a structure of HIL/HTL, a structure of HIL/HTL/buffer layer, a structure of HIL/buffer layer, a structure of HTL/buffer layer, or a structure of HIL/HTL/EBL, wherein layers of each of the structures are sequentially stacked from the first electrode **110** in this stated order, but embodiments are not limited thereto.

[0153] When the hole transport region includes an HIL, the HIL may be formed on the first electrode **110** by using various suitable methods, such as vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, or laser-induced thermal imaging (LITI).

[0154] When the HIL is formed by vacuum deposition, the vacuum deposition may be performed at a deposition temperature in a range of about 100° C. to about 500° C., at a vacuum degree in a range of about 10^{-8} torr to about 10^{-3} torr, and at a deposition rate in a range of about 0.01 Å/sec to about 100 Å/sec, in consideration of a composition of a compound for forming the HIL and a structure of the suitable or desired HIL.

[0155] When the HIL is formed by spin coating, the spin coating may be performed at a coating rate in a range of about 2,000 rpm to about 5,000 rpm and at a temperature in a range of about 80° C. to about 200° C., in consideration of a composition of a compound for forming the HIL and a structure of the suitable or desired HIL.

[0156] When the hole transport region includes an HTL, the HTL may be formed on the first electrode **110** or on the HIL by using various suitable methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or LITI. When the HTL is formed by vacuum deposition or by spin coating, the deposition conditions or the coating conditions may be the same or substantially the same as (e.g., may be inferred based on) the deposition conditions or the coating conditions for forming the HIL.

[0157] The hole transport region may include, for example, at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, DNTPD, 4,4',4"-tris(N-carbazolyl) triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (Pani/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

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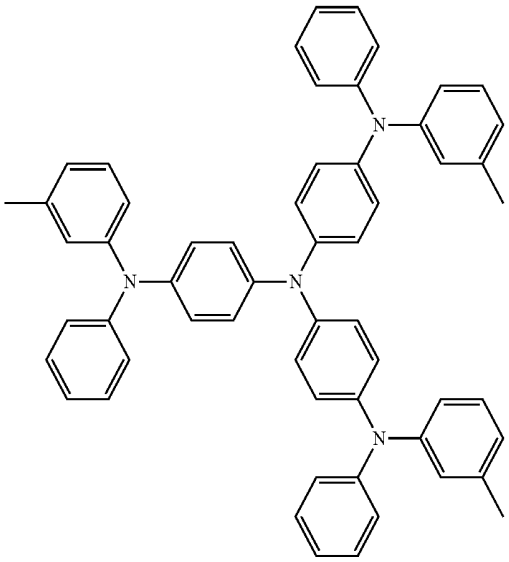
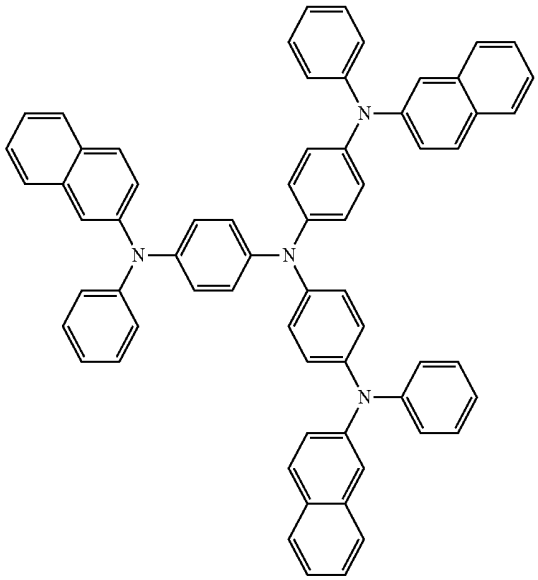


m-MTDATA



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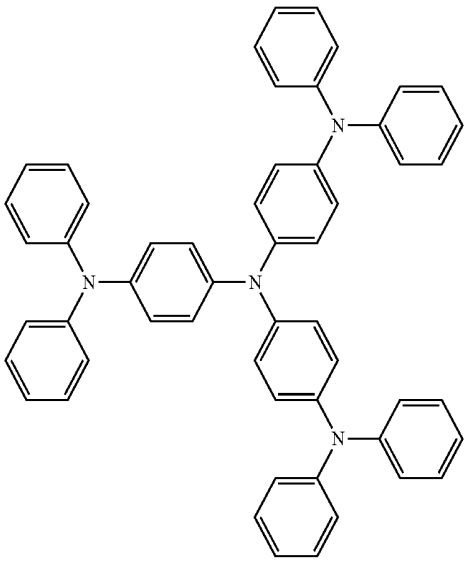
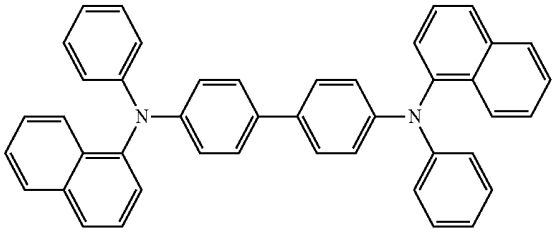
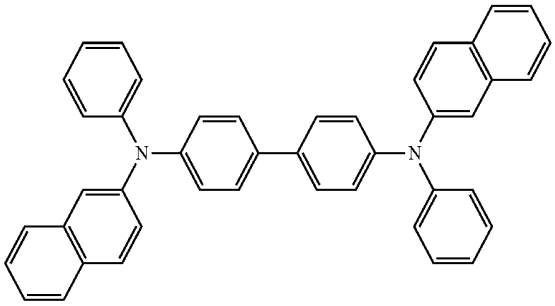


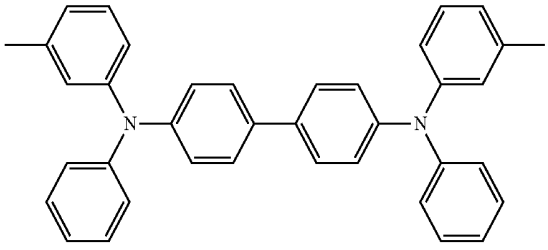
TDATA



NPB



β-NPB



TPD

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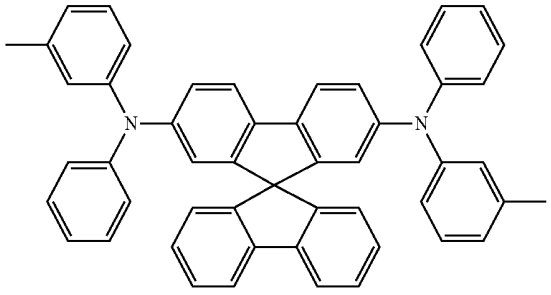
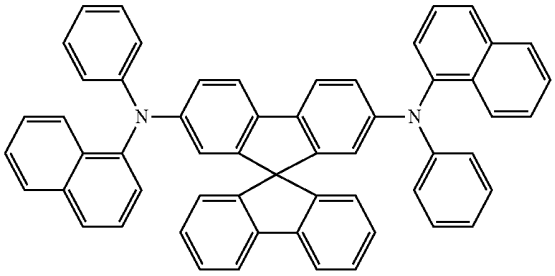
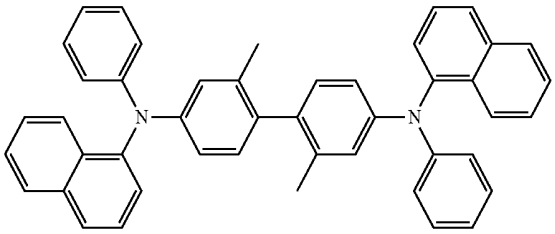


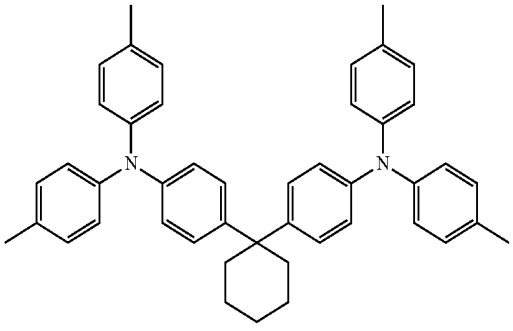
Spiro-TPD



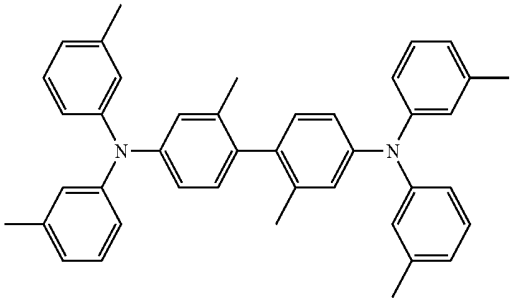
Spiro-NPB



methylated NPB



TAPC



HMTPD

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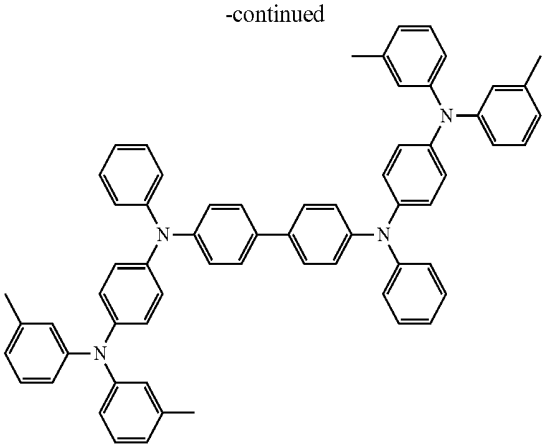
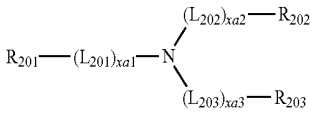
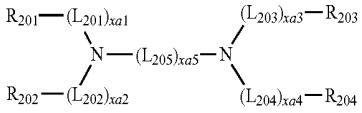


DNTPD

Formula 201



Formula 202



[0158] In Formulae 201 and 202,

[0159] L_{201} to L_{205} may be each independently the same as defined in connection with L_1 in the present specification (e.g., L_{201} to L_{205} may each independently be the same or substantially the same as described with respect to L_1);

[0160] xa1 to xa4 may be each independently selected from 0, 1, 2, and 3;

[0161] xa5 may be selected from 1, 2, 3, 4, and 5; and

[0162] R_{201} to R_{205} may be each independently the same as defined in connection with R_1 in the present specification (e.g., R_{201} to R_{205} may each independently be the same or substantially the same as described with respect to R_1).

[0163] For example, in Formulae 201 and 202,

[0164] L_{201} to L_{205} may be each independently selected from:

[0165] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0166] a phenylene group, a naphthalenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl

group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0167] xa1 to xa4 may be each independently 0, 1, or 2;

[0168] xa5 may be 1, 2 or 3; and

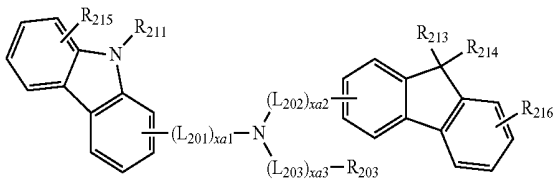
[0169] R_{201} to R_{205} may be each independently selected from:

[0170] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0171] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, but embodiments are not limited thereto.

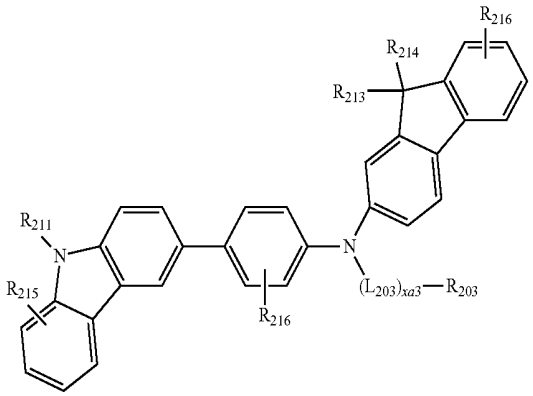
[0172] The compound represented by Formula 201 may be represented by Formula 201A:

Formula 201A



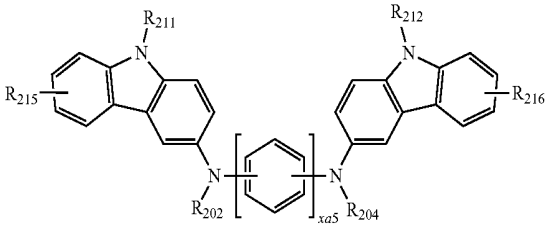
[0173] For example, the compound represented by Formula 201 may be represented by Formula 201A-1, but embodiments are not limited thereto:

Formula 201A-1



[0174] The compound represented by Formula 202 may be represented by Formula 202A, but embodiments are not limited thereto:

Formula 202A



[0175] In Formulae 201A, 201A-1, and 202A, L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} are the same as defined in the present specification (e.g., L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} may be the same or substantially the same as described with respect to Formulae 201 and 202), R_{211} and R_{212} are the same as defined in connection with R_{203} (e.g., R_{211} and R_{212} may be the same or substantially the same as R_{203} of Formulae 201 and 202), and R_{213} to R_{216} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0176] For example, in Formulae 201A, 201A-1 and 202A, L_{201} to L_{203} may be each independently selected from a phenylene group, a naphthylenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene

group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0177] a phenylene group, a naphthylenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0178] xa1 to xa3 may be each independently 0 or 1;

[0179] R_{203}, R_{211}, and R_{212} may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0180] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0181] R_{213} and R_{214} may be each independently selected from a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group;

[0182] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0183] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0184] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0185] R_{215} and R_{216} may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0186] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0187] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, and a triazinyl group; and

[0188] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a

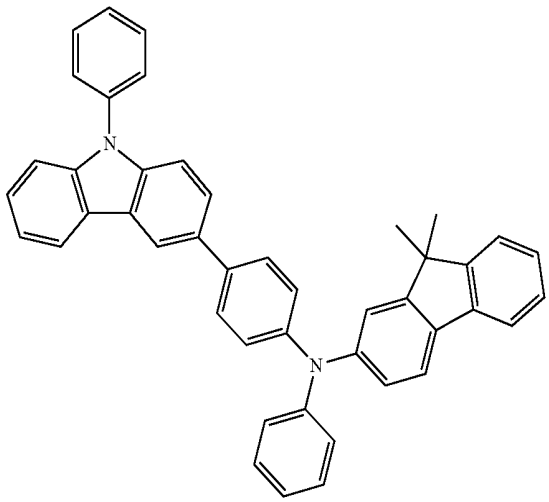
quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0189] xa5 may be 1 or 2.

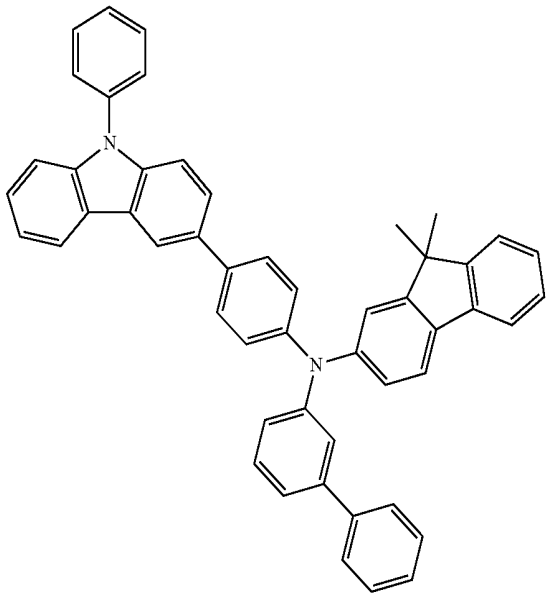
[0190] In Formulae 201A and 201A-1, R_{213} and R_{214} may be fused to each other (e.g., fused together) and form a saturated or unsaturated ring.

[0191] The compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20, but embodiments are not limited thereto.

HT1



HT2



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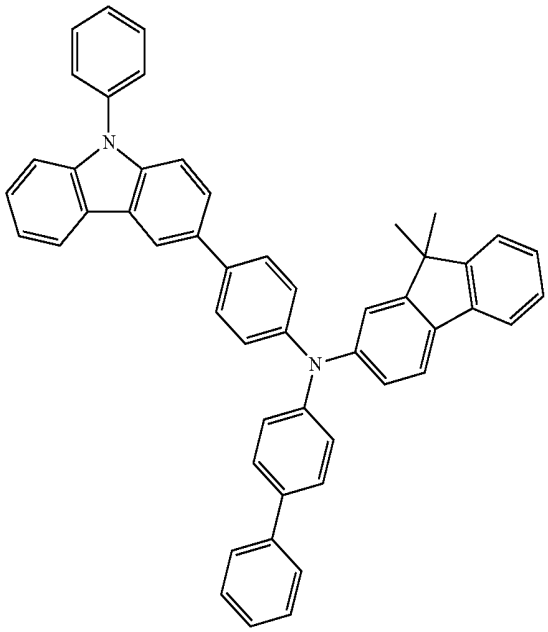
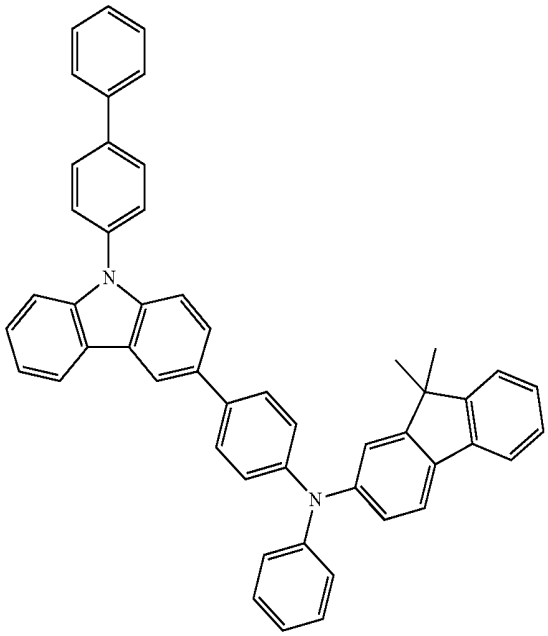
HT3



HT4



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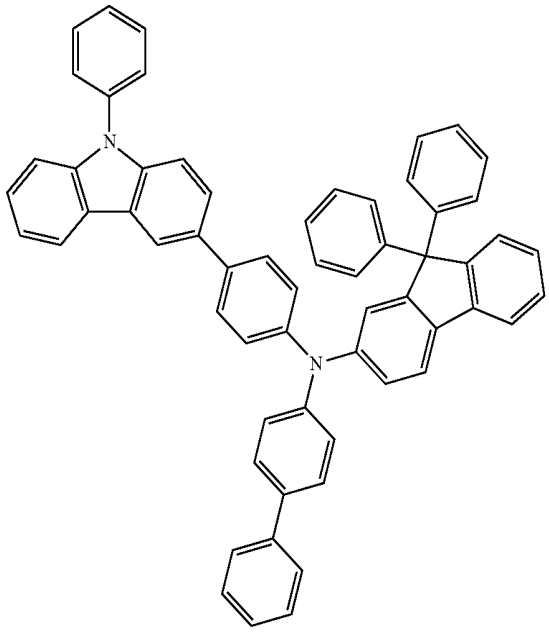
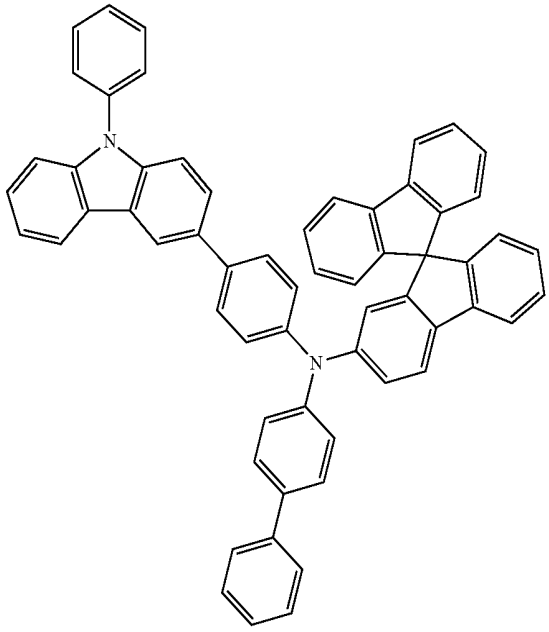
HT5



HT6



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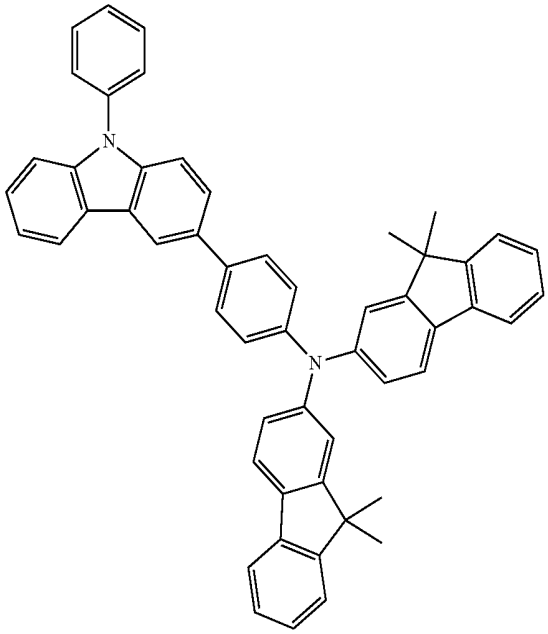
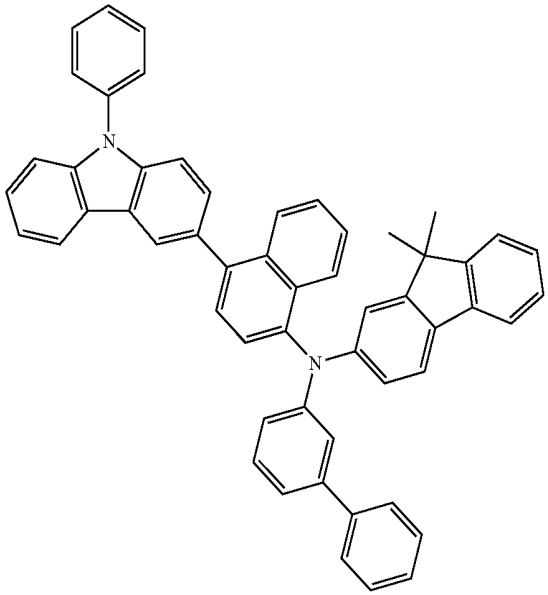
HT7



HT8



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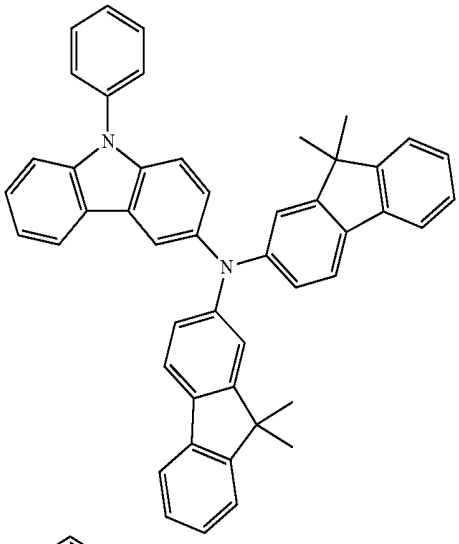
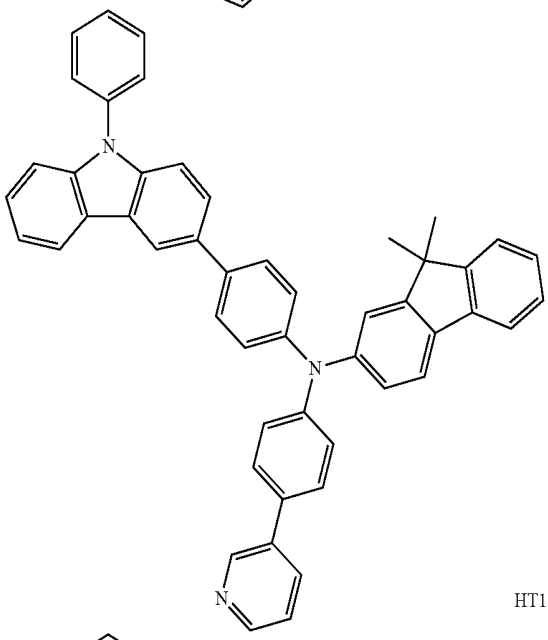
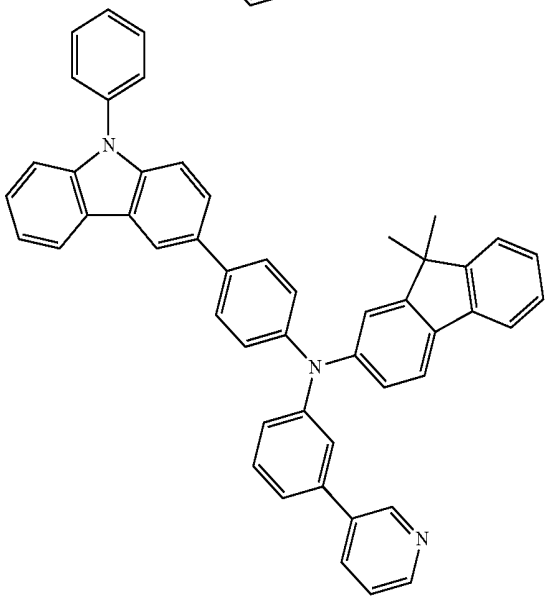
HT9



HT10



HT11



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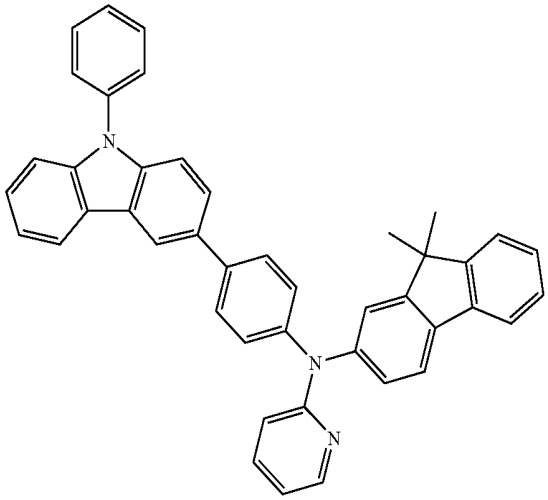
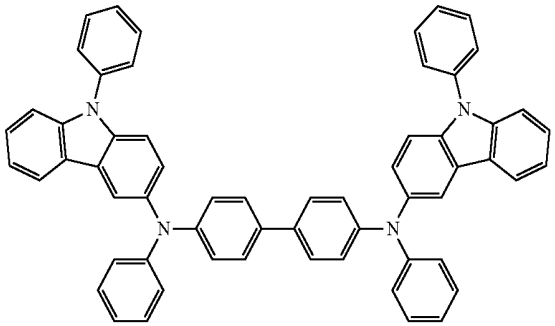
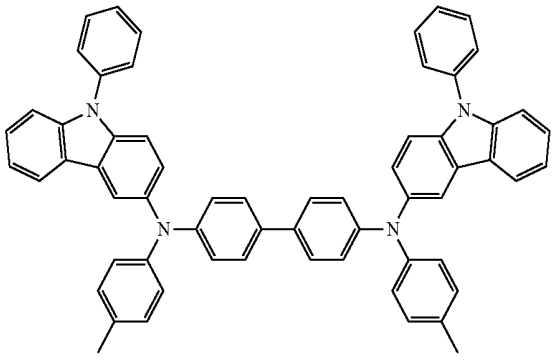
HT12



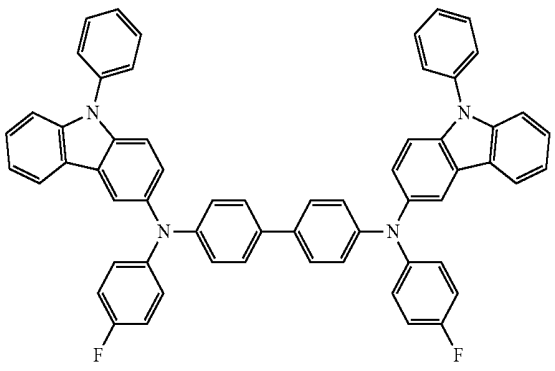
HT13



HT14



HT15



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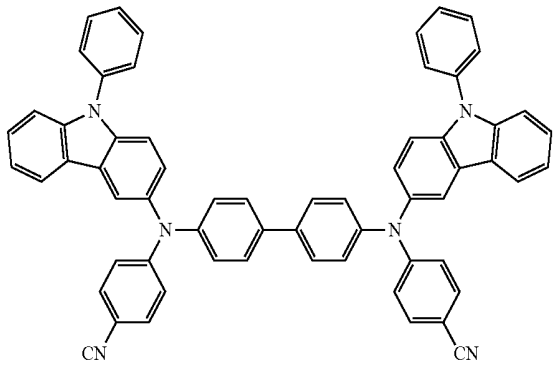
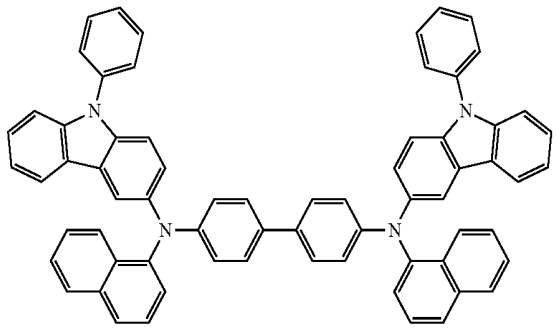
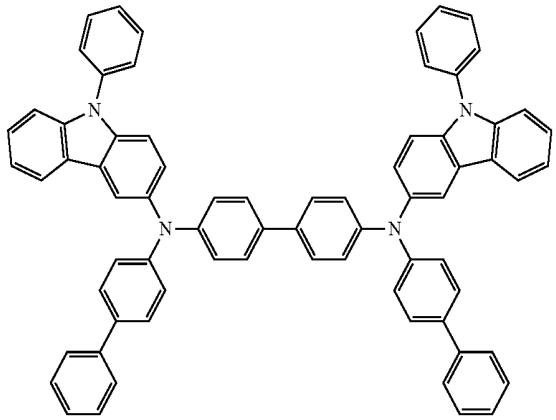
HT16



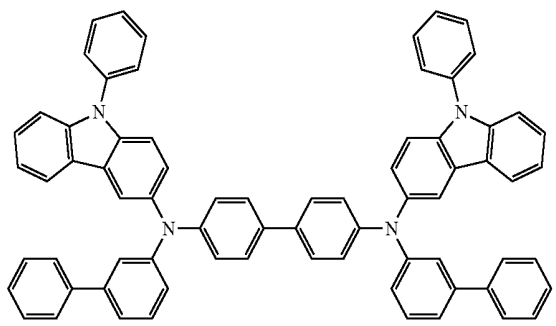
HT17



HT18



HT19



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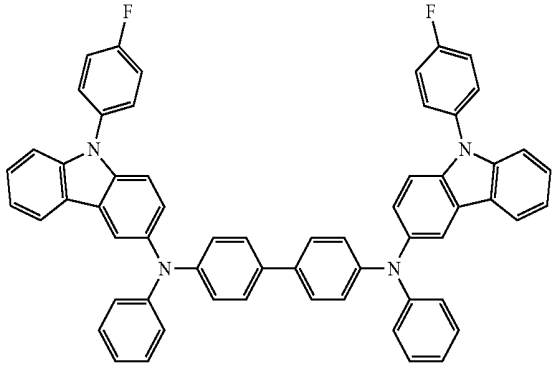
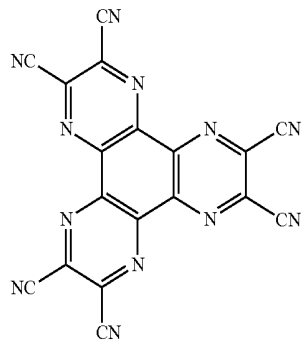
HT20



[0192] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes both an HIL and an HTL, a thickness of the HIL may be in a range of about 100 Å to about 10,000 Å, and, for example, about 100 Å to about 1,000 Å, and a thickness of the HTL may be in a range of about 50 Å to about 2,000 Å, and, for example, about 100 Å to about 1,500 Å. When thicknesses of the hole transport region, the HIL, and the HTL are within these ranges described above, hole transporting properties may be suitable or satisfactory without a substantial increase in a driving voltage.

[0193] The hole transport region may further include a charge-generating material to improve conductive properties in addition to the materials described above. The charge-generating material may be homogeneously or non-homogeneously dispersed throughout the hole transport region.

[0194] The charge-generating material may be, for example, a p-dopant. The p-dopant may be one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments are not limited thereto. For example, non-limiting examples of the p-dopant are a quinone derivative, such as tetracyanoquinonedimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenum oxide, and Compound HT-D1 illustrated below, but embodiments are not limited thereto.



Compound HT-D1

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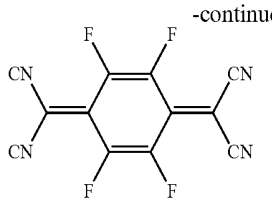


F4-TCNQ

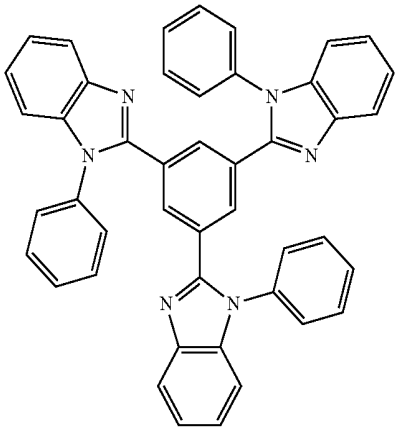
[0195] The hole transport region may further include, in addition to the HIL and the HTL, at least one of a buffer layer and an EBL. The buffer layer may compensate for an optical resonance distance of light according to a wavelength of the light emitted from the emission layer, and thus, may improve light-emission efficiency. In this regard, a material that is included in the hole transport region may be used as a material that is included in the buffer layer. The EBL may serve as a layer that reduces or prevents electrons from being injected from the electron transport region.

[0196] The emission layer may be formed on the first electrode **110** or on the hole transport region by using various suitable methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or LITI. When the emission layer is formed by vacuum deposition or by spin coating, the deposition conditions or the coating conditions may be the same or substantially the same as (e.g., may be inferred based on) the deposition conditions or the coating conditions for forming the HIL.

[0197] When the organic light-emitting device **10** is a full-color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, and a blue emission layer, according to an individual sub-pixel. Alternatively, the emission layer may have a structure of a red emission layer, a green emission layer, and a blue emission layer, each of which layers are sequentially stacked in the stated order. In this regard, a material emitting red light, a material emitting green light, and a material emitting blue light may have a mixed structure without having division of layers, thereby emitting white light.

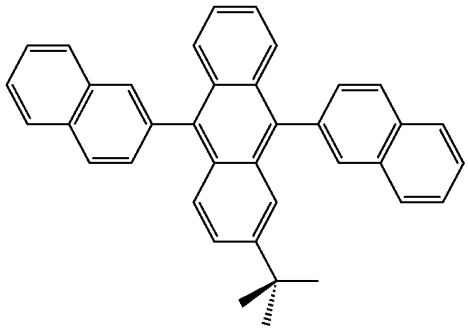
[0198] The emission layer may include a host and a dopant. The host may include at least one of the heterocyclic compounds of Formula 1.

[0199] The host may include, in addition to the heterocyclic compound of Formula 1, at least one of TPBi, TBADN, AND (also referred to as "DNA"), CBP, CDBP, and TCP:

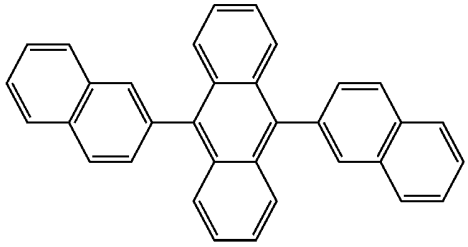


TPBi

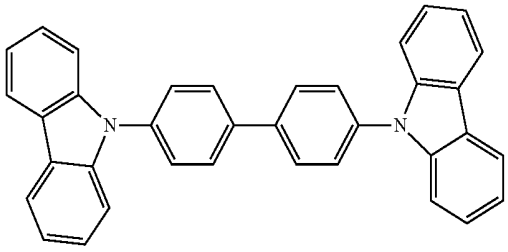
-continued



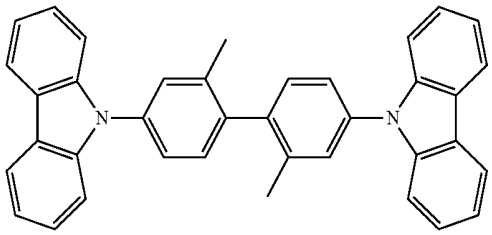
TBADN



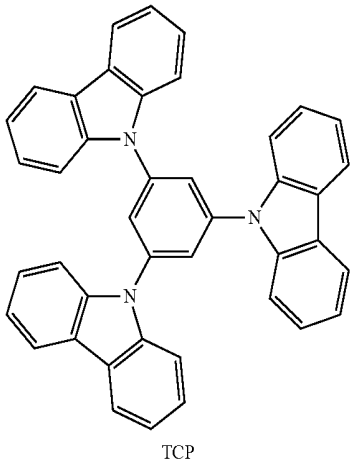
ADN



CBP



CDBP

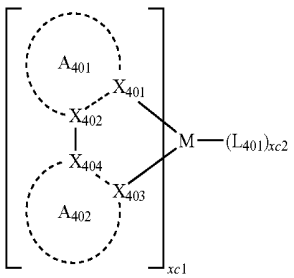


TCP

[0200] The dopant may include at least one of a fluorescent dopant and a phosphorescent dopant.

[0201] The phosphorescent dopant may include an organic metal complex represented by Formula 401:

Formula 401



[0202] In Formula 401,

[0203] M may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (TM);

[0204] X_{401} to X_{404} may be each independently N or C;

[0205] A_{401} and A_{402} rings may be each independently selected from a substituted or unsubstituted benzene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted fluorene, a substituted or unsubstituted spiro-fluorene, a substituted or unsubstituted indene, a substituted or unsubstituted pyrrole, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted imidazole, a substituted or unsubstituted pyrazole, a substituted or unsubstituted thiazole, a substituted or unsubstituted isothiazole, a substituted or unsubstituted oxazole, a substituted or unsubstituted isoxazole, a substituted or unsubstituted pyridine, a substituted or unsubstituted pyrazine, a substituted or unsubstituted pyrimidine, a substituted or unsubstituted pyridazine, a substituted or unsubstituted quinoline, a substituted or unsubstituted isoquinoline, a substituted or unsubstituted benzoquinoline, a substituted or unsubstituted quinoxaline, a substituted or unsubstituted quinazoline, a substituted or unsubstituted carbazole, a substituted or unsubstituted benzimidazole, a substituted or unsubstituted benzofuran, a substituted or unsubstituted benzothiophene, a substituted or unsubstituted isobenzothiophene, a substituted or unsubstituted benzoxazole, a substituted or unsubstituted isobenzoxazole, a substituted or unsubstituted triazole, a substituted or unsubstituted oxadiazole, a substituted or unsubstituted triazine, a substituted or unsubstituted dibenzofuran, and a substituted or unsubstituted dibenzothiophene;

[0206] at least one of substituents of the substituted benzene, the substituted naphthalene, the substituted fluorene, the substituted spiro-fluorene, the substituted indene, the substituted pyrrole, the substituted thiophene, the substituted furan, the substituted imidazole, the substituted pyrazole, the substituted thiazole, the substituted isothiazole, the substituted oxazole, the substituted isoxazole, the substituted pyridine, the substituted pyrazine, the substituted pyrimidine, the substituted pyridazine, the substituted quinoline, the substituted isoquinoline, the substituted benzoquinoline, the substituted quinoxaline, the substituted quinazoline, the substituted carbazole, the substituted benzimidazole, the substituted benzofuran, the substituted benzothiophene, the substituted isobenzothiophene, the substituted benzoxazole, the substituted isobenzoxazole, the substituted triazole, the substituted oxadiazole, the substituted triazine, the substituted dibenzofuran, and the substituted dibenzothiophene may be selected from:

[0207] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

[0208] a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60}aryloxy(aryloxy group, C_6-C_{60}arylthio(arylthio group, C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$N(Q_{401})(Q_{402})$, —$Si(Q_{403})(Q_{404})(Q_{405})$, and —$B(Q_{406})(Q_{407})$;

[0209] a C_3-C_{10} cycloalkyl group, a C_1-C_{10}heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0210] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxyl group or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$N(Q_{411})(Q_{412})$, —$Si(Q_{413})(Q_{414})(Q_{415})$, and —$B(Q_{416})(Q_{417})$; and

[0211] —$N(Q_{421})(Q_{422})$, —$Si(Q_{433})(Q_{434})(Q_{435})$, and —$B(Q_{426})(Q_{427})$

[0212] L_{401} may be an organic ligand;

[0213] xc1 may be 1, 2, or 3; and

[0214] xc2 may be 0, 1, 2, or 3,

[0215] wherein Q_{401} to Q_{407}, Q_{411} to Q_{417}, and Q_{421} to Q_{427} may be each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_1-C_{60} heteroaryl group.

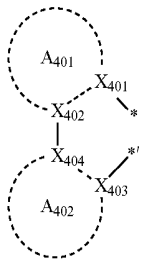
[0216] In an example embodiment, L_{401} may be a monovalent organic ligand, a divalent organic ligand, or a trivalent organic ligand. For example, L_{401} may be selected from a

halogen ligand (e.g., Cl or F), a diketone ligand (e.g., acetylacetonate, 1,3-diphenyl-1,3-propanedionate, 2,2,6,6-tetramethyl-3,5-heptanedionate, or hexafluoroacetonate, a carboxylic acid ligand (e.g., picolinate, dimethyl-3-pyrazolecarboxylate, or benzoate), a carbon monoxide ligand, an isonitrile ligand, a cyano ligand, and a phosphorus ligand (e.g., phosphine or phosphite), but is not limited thereto.

[0217] When A_{401} in Formula 401 has 2 or more substituents, 2 or more substituents of A_{401} may be bonded to each other to form a saturated ring or an unsaturated ring.

[0218] When A_{402} in Formula 401 has 2 or more substituents, 2 or more substituents of A_{402} may be bonded to each other to form a saturated ring or an unsaturated ring.

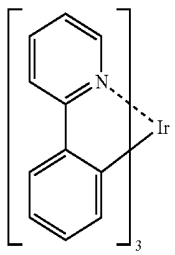
[0219] When xc1 in Formula 401 is 2 or more, a plurality of ligands



in Formula 401 may be identical to or different from each other. When xc1 in Formula 401 is 2 or more, A_{401} and A_{402} may be each independently bonded to A_{401} and A_{402} of other neighboring ligands, directly or via a linking group (e.g., a C_1-C_5 alkylene group, —N(R')— (wherein R' may be a C_1-C_{10} alkyl group or a C_6-C_{20} aryl group), or —C(=O)—).

[0220] The phosphorescent dopant may include at least one of Compounds PD1 to PD74, but is not limited thereto:

PD1



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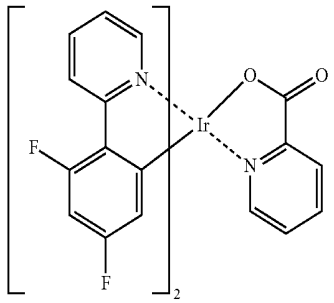

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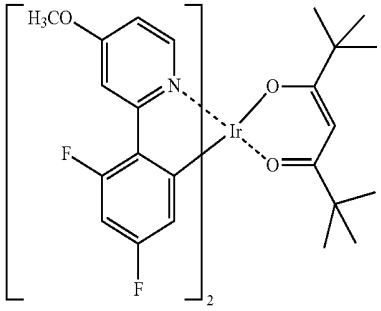

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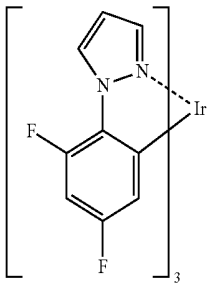

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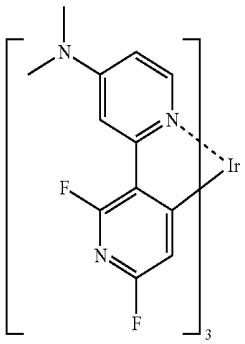

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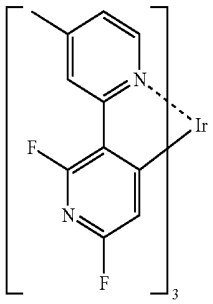

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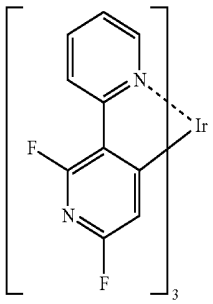

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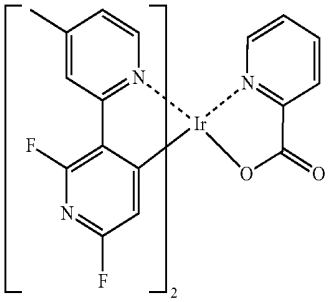

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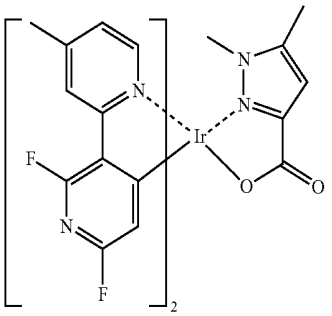

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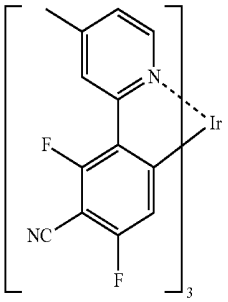

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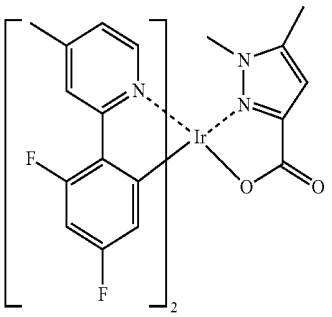

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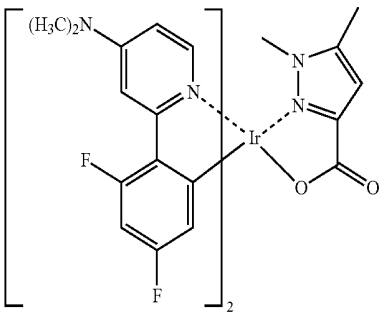

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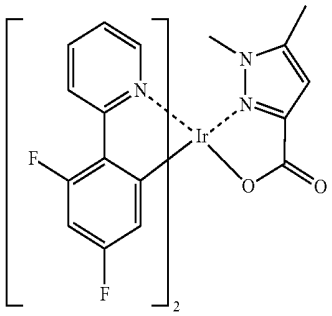

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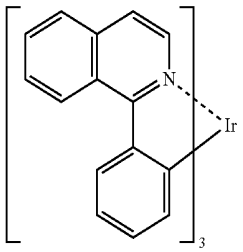

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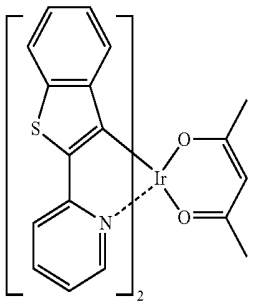

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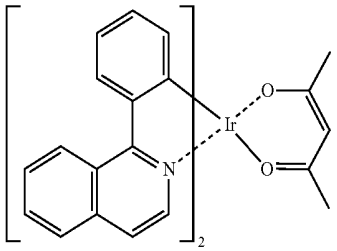

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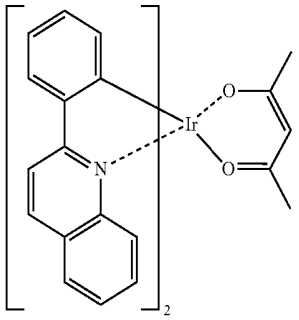

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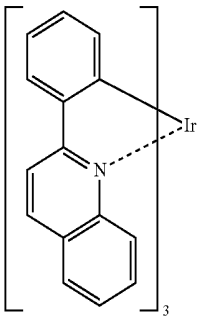

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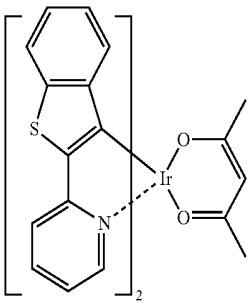

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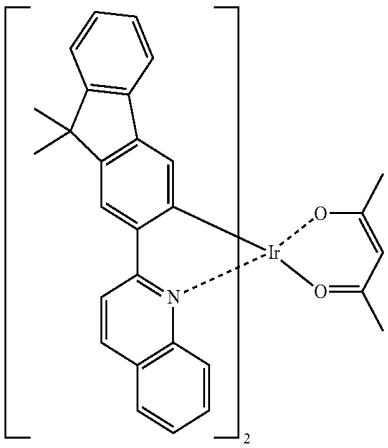

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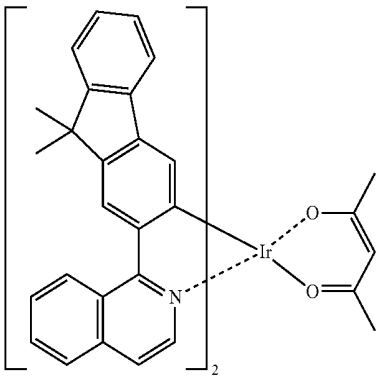

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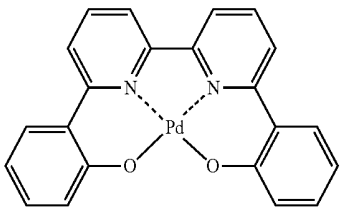

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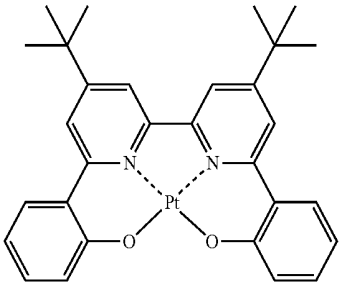

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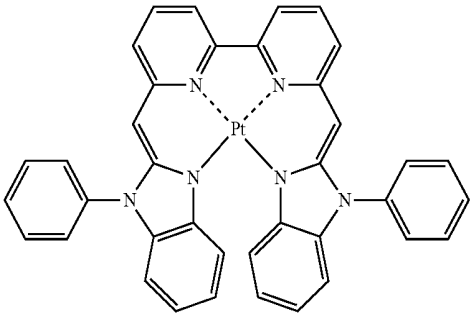

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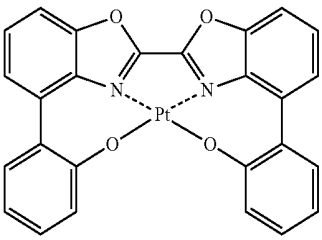

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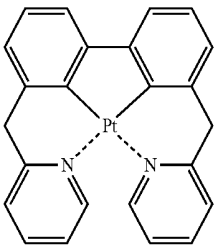

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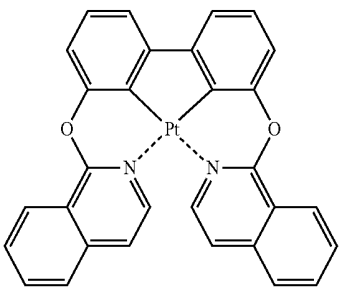

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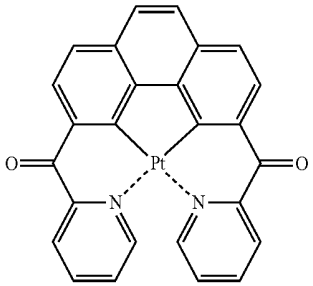

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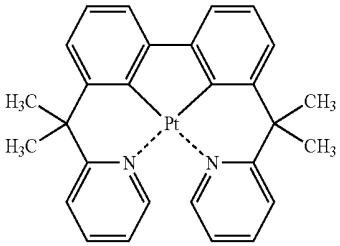

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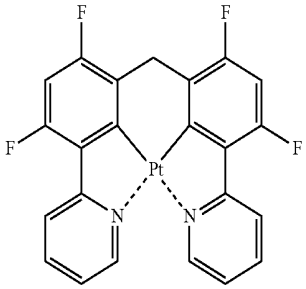

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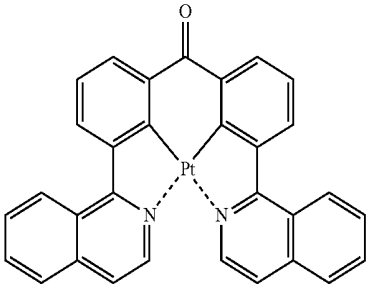

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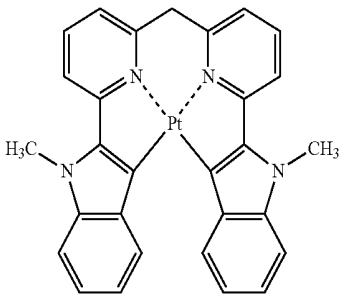

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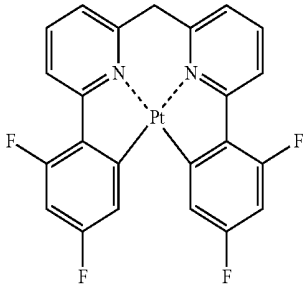

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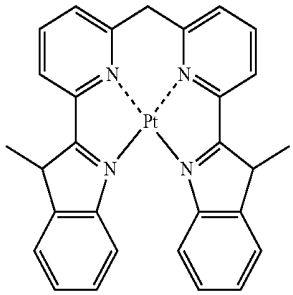

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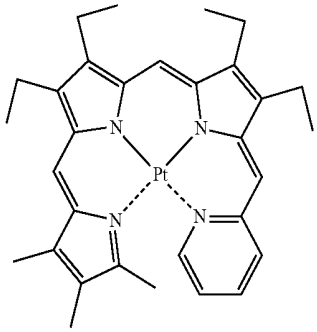

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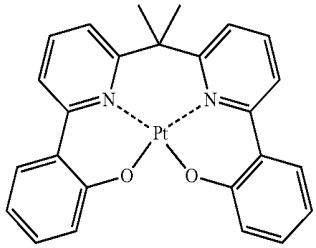

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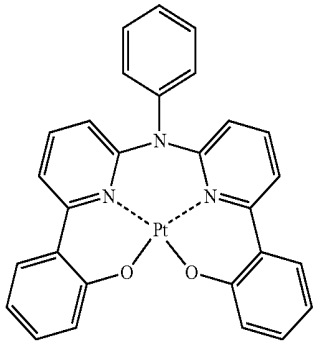

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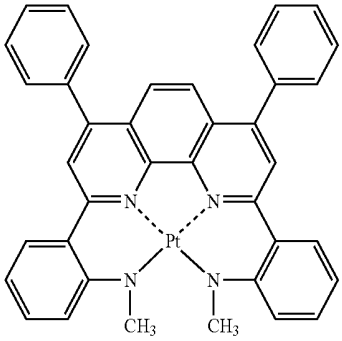

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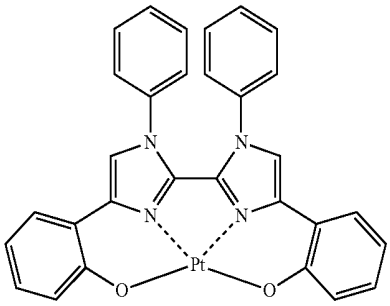

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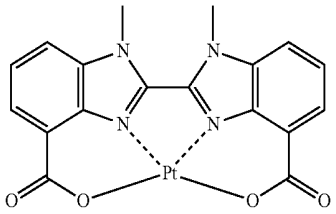

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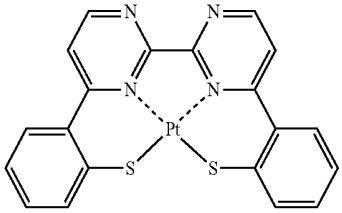

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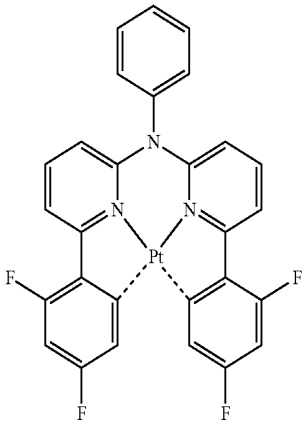

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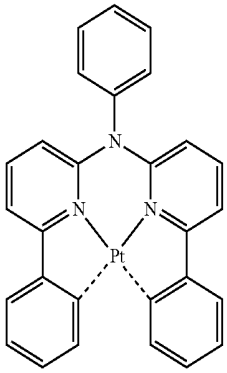

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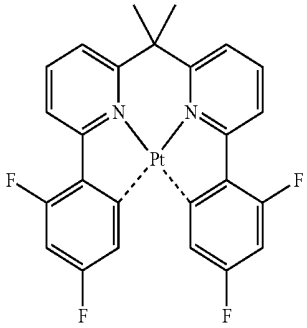

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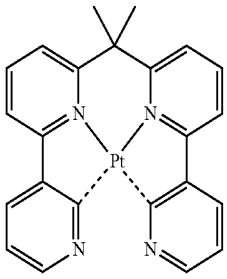

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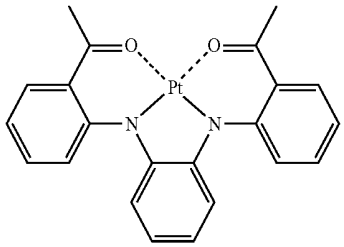

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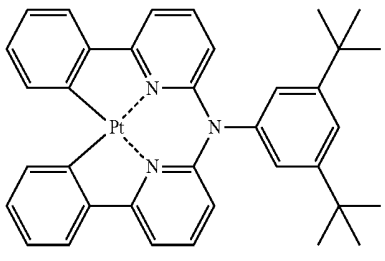

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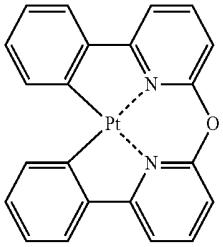
PD48



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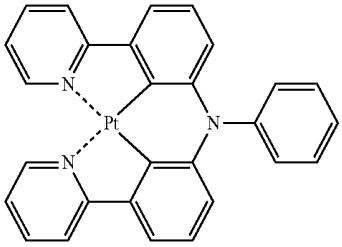

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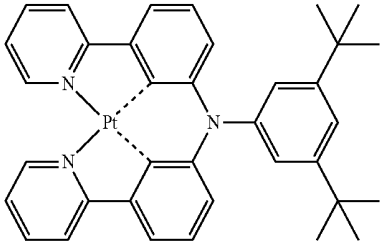

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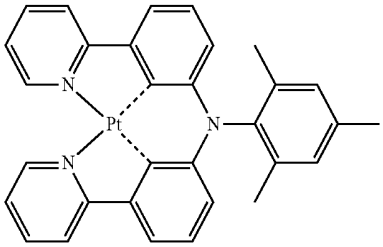

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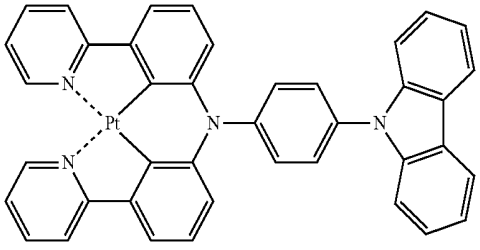

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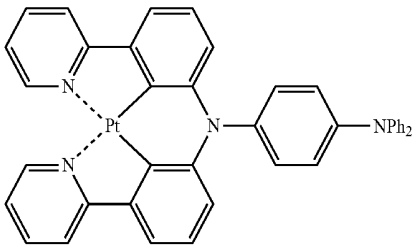

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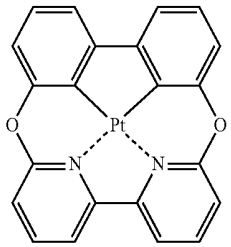

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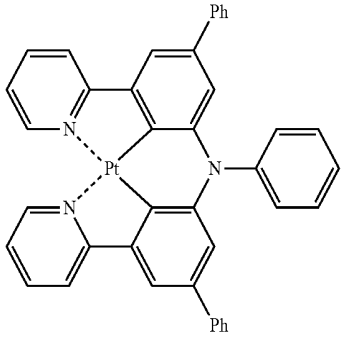

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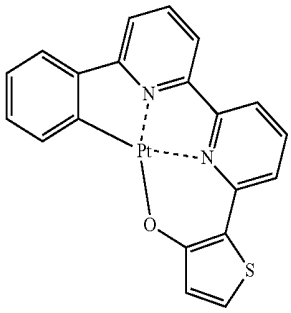

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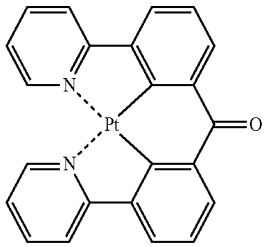

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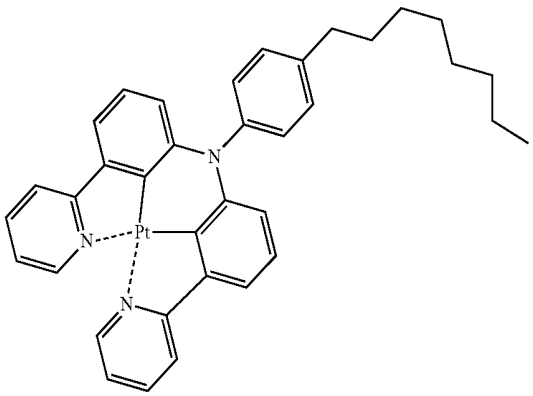

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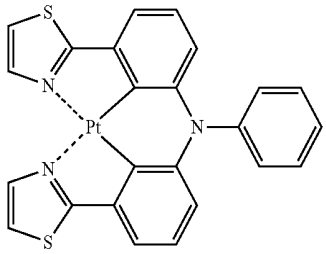
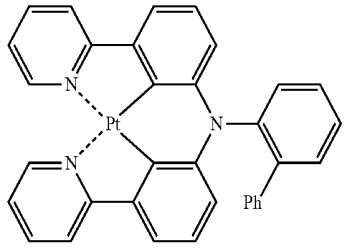
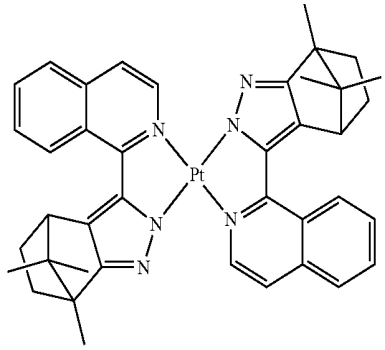
PD59



PD60



PD61



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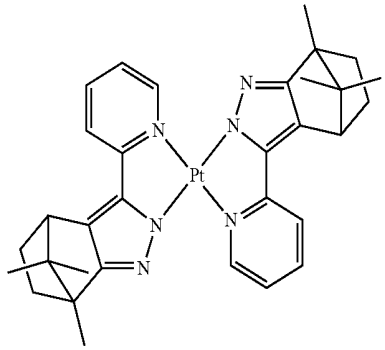

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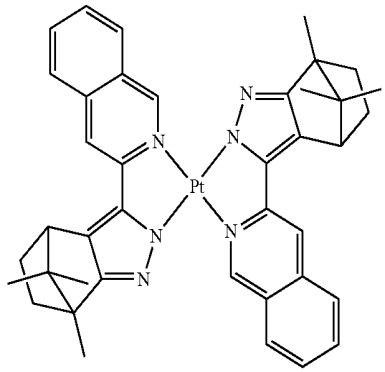

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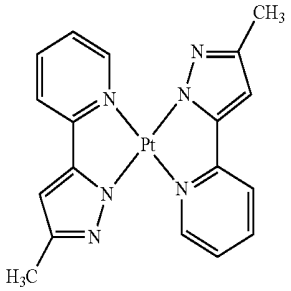
PD64



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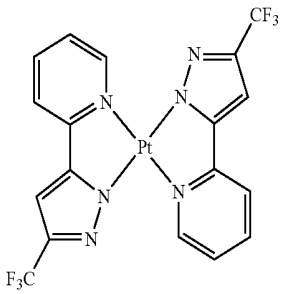

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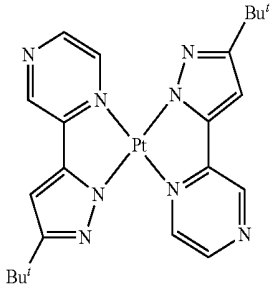

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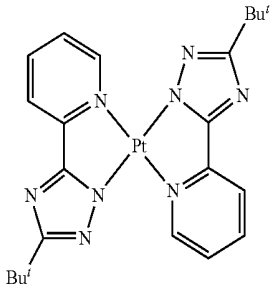

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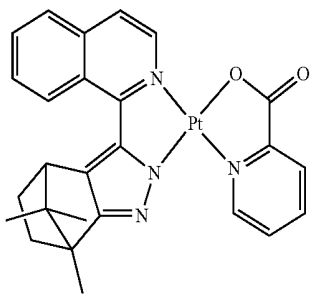

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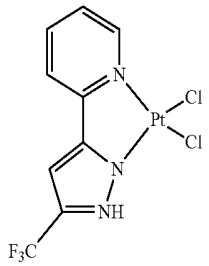
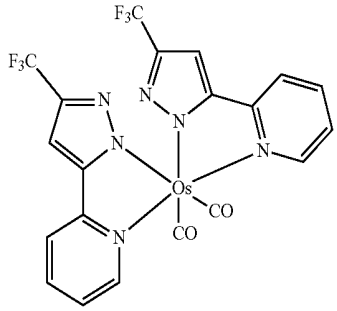
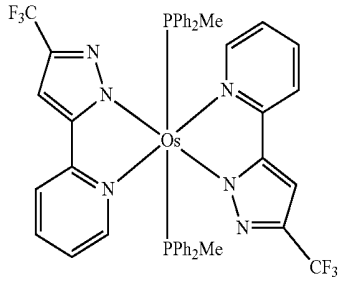
PD69



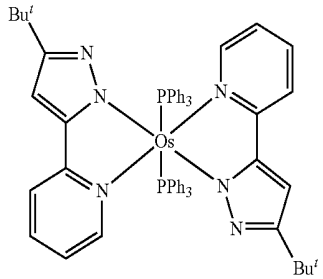
PD70



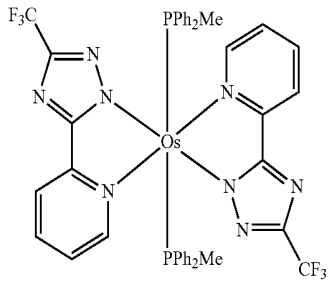
PD71



PD72



PD73



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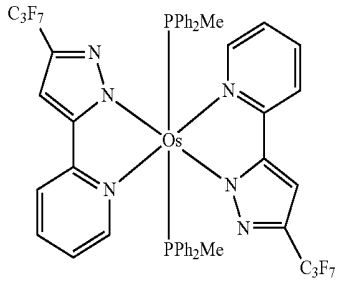
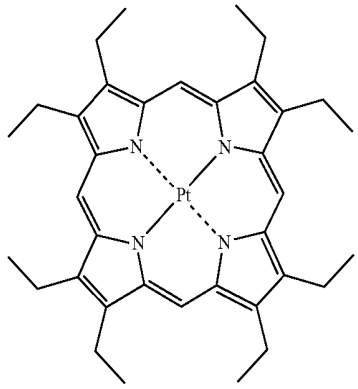
PD74



[0221] Alternatively, the phosphorescent dopant may include PtOEP:



PtOEP

[0222] An amount of the dopant included in the emission layer may be from about 0.01 to about 15 parts by weight, based on 100 parts by weight of the host, but is not limited thereto.

[0223] A thickness of the emission layer may be from about 100 Å to about 1,000 Å, e.g., about 200 Å to about 600 Å. When the thickness of the emission layer is within these ranges, excellent emission characteristics may be obtained without a substantial increase in driving voltage.

[0224] Next, the electron transport region may be disposed on the emission layer.

[0225] The electron transport region may include at least one of an HBL, an ETL, and an EIL, but embodiments are not limited thereto.

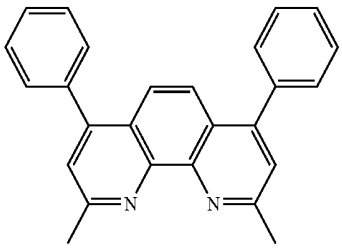
[0226] For example, the electron transport region may have a structure of ETL/EIL or a structure of HBL/ETL/EIL, each of which layers are sequentially stacked in the stated order from the emission layer, but embodiments are not limited thereto.

[0227] The electron transport region may include an HBL. When the emission layer includes a phosphorescent dopant, the HBL may serve as a layer that reduces or prevents triplet excitons or holes from being diffused into the ETL.

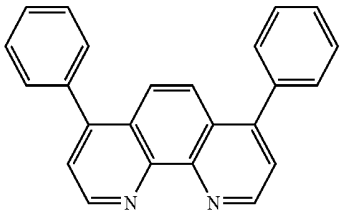
[0228] When the electron transport region includes the HBL, the HBL may be formed on the emission layer by using various suitable methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or LITI. When the HBL is formed by vacuum deposition or by spin coating, the deposition conditions or the coating conditions may be the same or substantially the same as (e.g., may

be inferred based on) the deposition conditions or the coating conditions for forming the HIL.

[0229] The HBL may include, for example, at least one of BCP and Bphen, but embodiments are not limited thereto.



BCP

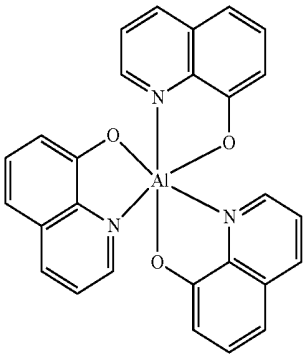


Bphen

[0230] A thickness of the HBL may be from about 20 Å to about 1,000 Å, e.g., about 30 Å to about 300 Å. When the thickness of the HBL is within these ranges, excellent hole blocking characteristics may be obtained without a substantial increase in driving voltage.

[0231] The electron transport region may include an ETL, and the ETL may be formed on the emission layer or on the HBL by using various suitable methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or LITI. When the ETL is formed by vacuum deposition or by spin coating, the deposition conditions or the coating conditions may be the same or substantially the same as (e.g., may be inferred based on) the deposition conditions or the coating conditions for forming the HIL.

[0232] The ETL may include at least one of BCP and Bphen above and Alq_3, Balq, TAZ, and NTAZ:



Alq3

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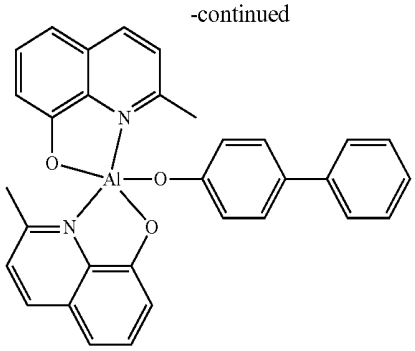
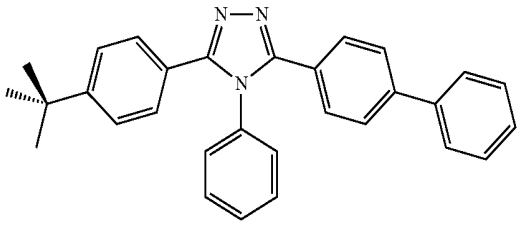
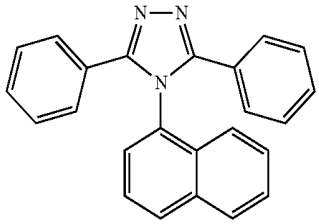


BAlq



TAZ



NTAZ

[0233] Alternatively, the ETL may include at least one of compounds represented by Formula 601:

$$Ar_{601}\text{-}[(L_{601})_{xe1}\text{-}E_{601}]_{xe2} \qquad \text{Formula 601}$$

[0234] In Formula 601,

[0235] Ar_{601} may be the same as defined in connection with Ar_{301} (e.g., Ar_{601} may be the same or substantially the same as described with respect to Ar_{301});

[0236] L_{601} may be the same as defined in connection with L_{201} (e.g., L_{601} may be the same or substantially the same as described with respect to L_{201});

[0237] E_{601} may be selected from:

[0238] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl

group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

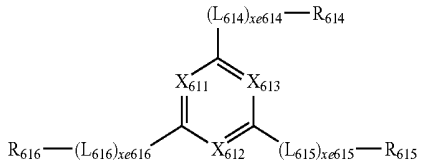
[0239] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group;

[0240] xe1 may be selected from 0, 1, 2, and 3; and

[0241] xe2 may be selected from 1, 2, 3, and 4.

[0242] Alternatively, the ETL may include at least one of compounds represented by Formula 602:

Formula 602



[0243] In Formula 602,

[0244] X_{611} may be N or C-$(L_{611})_{xe611}$-R_{611}; X_{612} may be N or C-$(L_{612})_{xe612}$-R_{612}; X_{613} may be N or C-$(L_{613})_{xe613}$-R_{613}, and at least one of X_{611} to X_{613} may be N;

[0245] L_{611} to L_{616} may be each independently the same as defined in connection with L_{201} in the present specification (e.g., L_{601} to L_{616} may each independently be the same or substantially the same as described with respect to L_{201});

[0246] R_{611} to R_{616} may be each independently selected from:

[0247] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

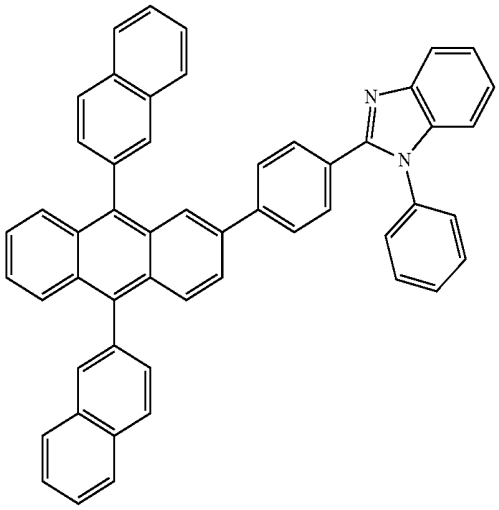
[0248] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0249] xe611 to xe616 may be each independently selected from 0, 1, 2, and 3.

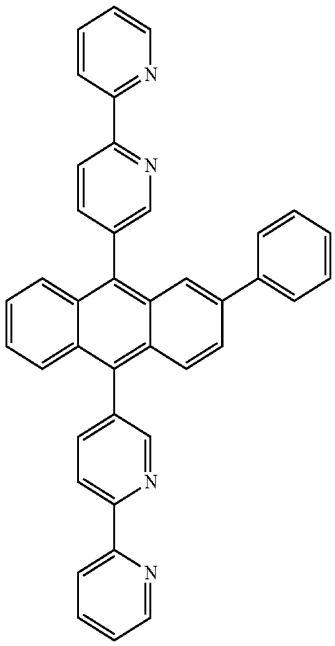
[0250] The compound represented by Formula 601 and the compound represented by 602 may include at least one of Compounds ET1 to ET16:

-continued

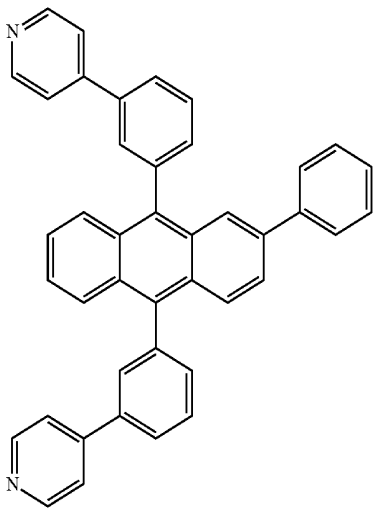
ET1



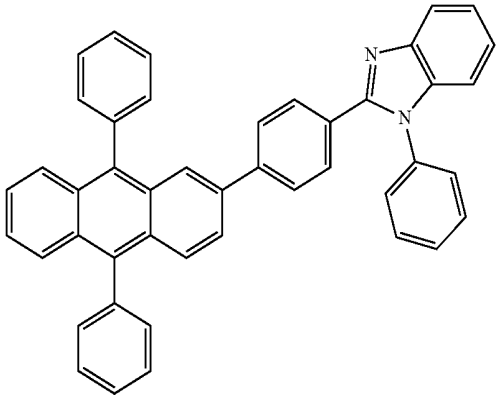
ET2



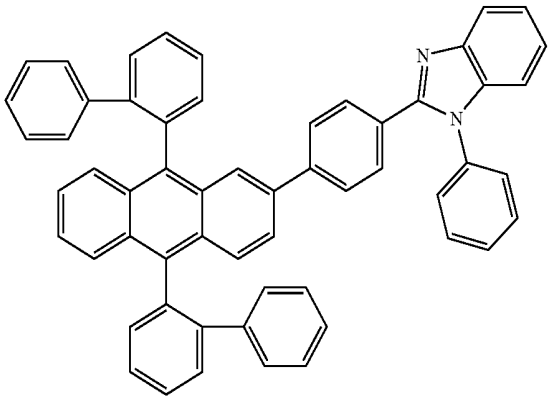
ET3



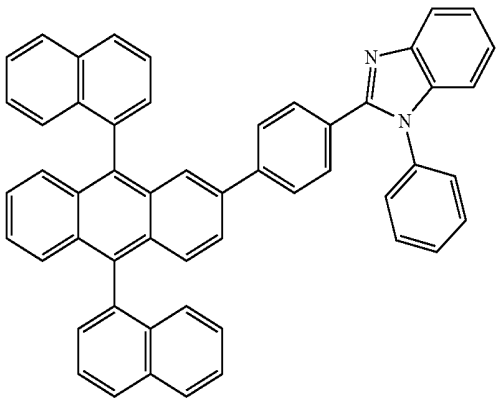
ET4



ET5



ET6



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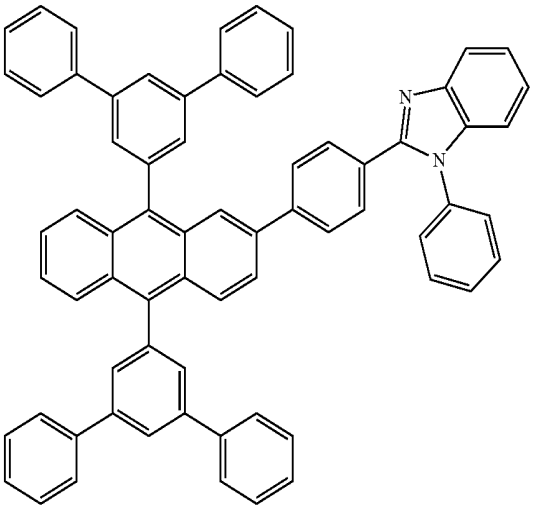
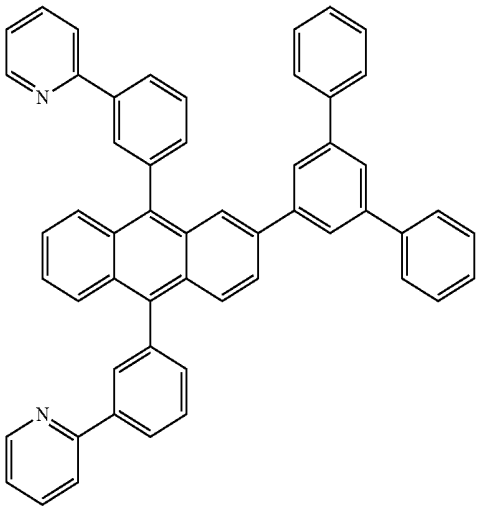
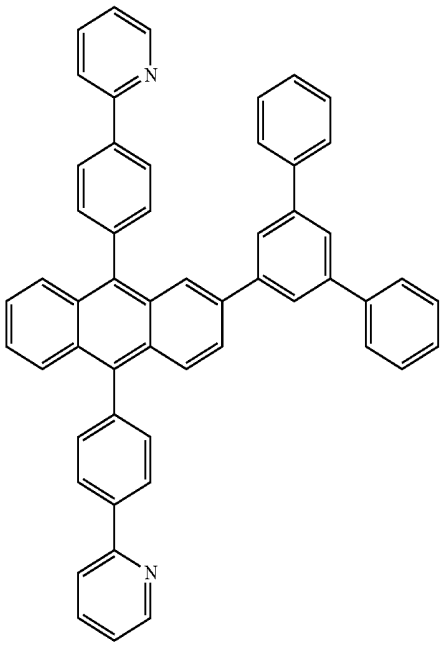
ET7



ET8



ET9



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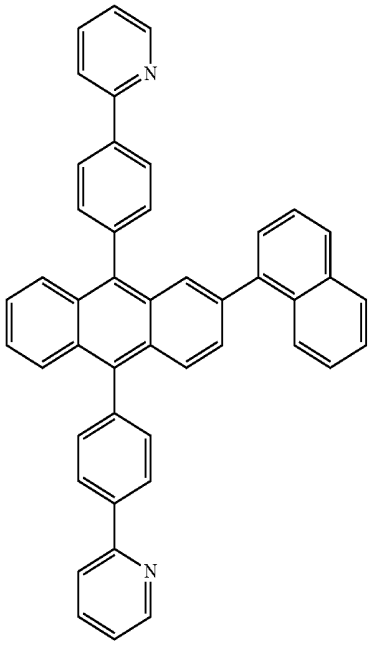
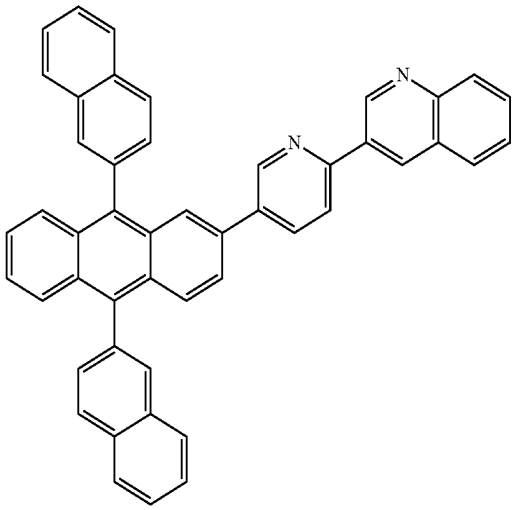
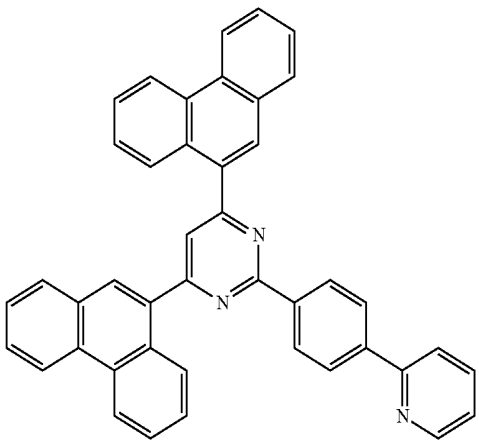
ET10



ET11



ET12



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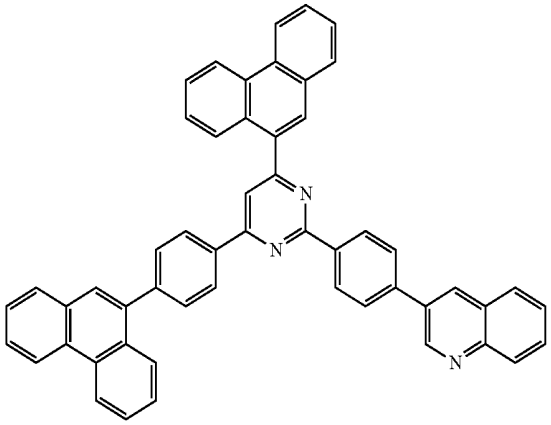
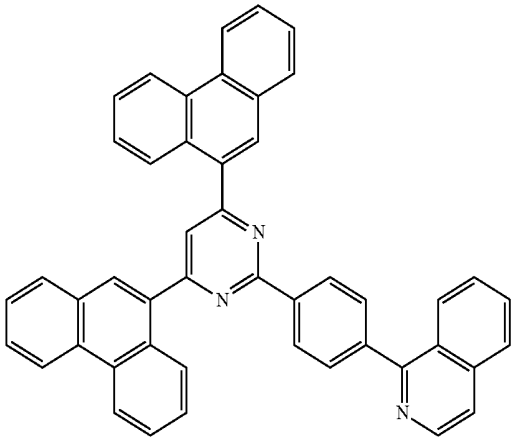
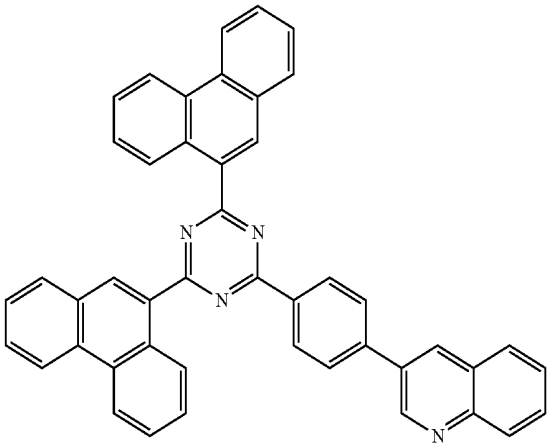
ET13



ET14



ET15



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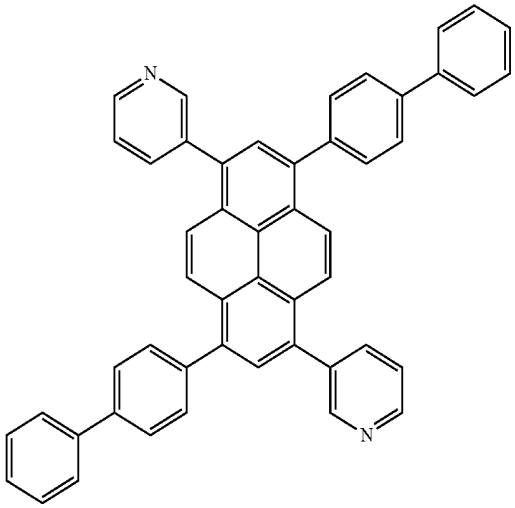
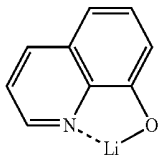
ET16



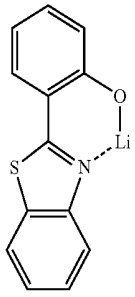
[0251] A thickness of the ETL may be from about 100 Å to about 1,000 Å, e.g., about 150 Å to about 500 Å. When the thickness of the ETL is within these ranges, excellent electron transporting characteristics may be obtained without a substantial increase in driving voltage.

[0252] The ETL may further include, in addition to the materials described above, a metal-containing material.

[0253] The metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (e.g., lithium quinolate (LiQ)) or ET-D2.



ET-D1



ET-D2

[0254] The electron transport region may include an EIL that facilitates electron injection from the second electrode **190**.

[0255] The EIL may be formed on the ETL by using various suitable methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or LITI. When the EIL is formed by vacuum deposition or by spin coating, the deposition conditions or the coating conditions may be the same or substantially the same as (e.g., may be

inferred based on) the deposition conditions or the coating conditions for forming the HIL.

[0256] The EIL may include at least one selected from LiF, NaCl, CsF, Li_2O, BaO, and LiQ.

[0257] A thickness of the EIL may be from about 1 Å to about 100 Å, e.g., about 3 Å to about 90 Å. When the thickness of the EIL is within these ranges, suitable or satisfactory electron injecting characteristics may be obtained without a substantial increase in driving voltage.

[0258] The second electrode **190** may be disposed on the organic layer **150**. The second electrode **190** may be a cathode, which is an electron injection electrode. Here, a material for forming the second electrode **190** may be a material having a low work function, such as a metal, an alloy, an electrically conductive compound, or a mixture thereof. Detailed examples of the material for forming the second electrode **190** may include lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag). Alternatively, the material for forming the second electrode **190** may include ITO or IZO. The second electrode **190** may be a semi-transmissive electrode or a transmissive electrode.

[0259] Hereinbefore, the organic light-emitting device is described in connection with the accompanying drawing, but embodiments are not limited thereto.

[0260] A C_1-C_{60} alkyl group as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and detailed examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. A C_1-C_{60} alkylene group as used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

[0261] A C_1-C_{60} alkoxy group as used herein refers to a monovalent group represented by $—OA_{101}$ (wherein A_{101} is the C_1-C_{60} alkyl group), and detailed examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0262] A C_2-C_{60} alkenyl group as used herein refers to a hydrocarbon group formed by substituting at least one carbon double bond in a main chain (e.g., the middle) or terminal end of the C_2-C_{60} alkyl group, and detailed examples thereof include an ethenyl group, a propenyl group, and a butenyl group. A C_2-C_{60} alkenylene group as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group.

[0263] A C_2-C_{60} alkynyl group as used herein refers to a hydrocarbon group formed by substituting at least one carbon triple bond in a main chain (e.g., the middle) or terminal end of the C_2-C_{60} alkyl group, and detailed examples thereof are an ethynyl group and a propynyl group. A C_2-C_{60}alkynylene group as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group.

[0264] A C_3-C_{10} cycloalkyl group as used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms, and detailed examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C_3-C_{10} cycloalkylene group used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkyl group.

[0265] A C_1-C_{10} heterocycloalkyl group as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and detailed examples thereof include a tetrahydrofuranyl group and a tetrahydrothiophenyl group. A C_1-C_{10} heterocycloalkylene group as used herein refers to a divalent group having the same structure as the C_1-C_{10} heterocycloalkyl group.

[0266] A C_3-C_{10} cycloalkenyl group as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in the ring thereof and does not have aromaticity (e.g., the ring is not aromatic), and detailed examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C_3-C_{10} cycloalkenylene group as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

[0267] A C_1-C_{10} heterocycloalkenyl group as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Detailed examples of the C_1-C_{10} heterocycloalkenyl group include a 2,3-hydrofuranyl group and a 2,3-hydrothiophenyl group. A C_1-C_{10} heterocycloalkenylene group as used herein refers to a divalent group having the same structure as the C_1-C_{10} heterocycloalkenyl group.

[0268] A C_6-C_{60} aryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C_6-C_{60} arylene group as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C_6-C_{60} aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, these rings may be fused to each other (e.g., fused together).

[0269] A C_1-C_{60} heteroaryl group as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. A C_1-C_{60} heteroarylene group as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. Detailed examples of the C_1-C_{60} heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_1-C_{60} heteroaryl group and the C_1-C_{60} heteroarylene group each include two or more rings, these rings may be fused to each other (e.g., fused together).

[0270] A C_6-C_{60} aryloxy group as used herein indicates $—OA_{102}$ (wherein A_{102} is the C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group as used herein indicates $—SA_{103}$ (wherein A_{103} is the C_6-C_{60} aryl group).

[0271] A monovalent non-aromatic condensed polycyclic group (e.g., a group having 8 to 60 carbon atoms) as used herein refers to a monovalent group that has two or more rings condensed to each other, has carbon atoms only as a ring-forming atom, and has non-aromaticity in the entire molecular structure (e.g., the entire molecular structure is not aromatic). A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. A divalent non-aromatic condensed polycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0272] A monovalent non-aromatic condensed heteropolycyclic group (e.g., a group having 1 to 60 carbon atoms) as used herein refers to a monovalent group that has two or more

rings condensed to each other, has heteroatoms as a ring-forming atom selected from N, O, P, and S, in addition to C, and has non-aromaticity in the entire molecular structure (e.g., the entire molecular structure is not aromatic). A detailed example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. A divalent non-aromatic condensed heteropolycyclic group used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0273] At least one of substituent of the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0274] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a —C_{60} alkoxy group;

[0275] a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a —C_{60} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$;

[0276] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0277] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

[0278] —$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$, and —$B(Q_{36})(Q_{37})$,

[0279] wherein Q_{ii} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{37} may be each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0280] For example, at least one of substituents of the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0281] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group;

[0282] a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a C_1-C_{30} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent

non-aromatic condensed heteropolycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$;

[0283] a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylene group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, cyclooctyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group;

[0284] a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylene group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, cyclooctyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group and a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a C_1-C_{30} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

[0285] —$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$, and —$B(Q_{36})(Q_{37})$,

[0286] wherein Q_{ii} to Q_{17} and Q_{31} to Q_{37} may be each independently from a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylene group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a hydrogen, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, cyclooctyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group, but embodiments are not limited thereto.

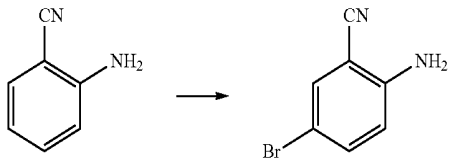
[0287] Hereinafter, an organic light-emitting device according to an embodiment will be described in detail with reference to Synthesis Examples and Examples. The term "B was used instead of A" used in describing Synthesis Examples denotes that a molar equivalent of A was identical (or substantially the same) to a molar equivalent of B.

EXAMPLE

Synthesis Example 1

Synthesis of Compound 4

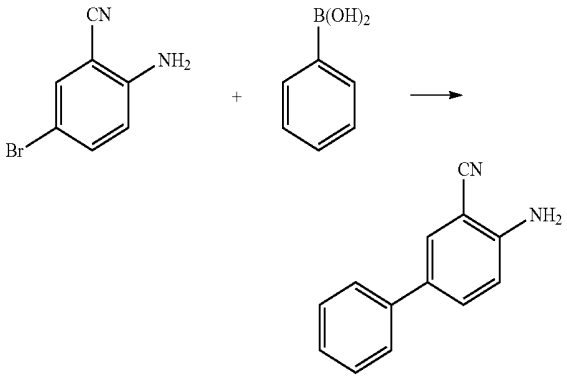
[0288] 1) Reaction Scheme 1-1: Synthesis of Intermediate 1-a



1-a

[0289] 35.1 g (297 mmol) of 2-aminobenzonitrile, 55.56 g (312 mmol) of N-bromosuccinimide, and 350 mL of dimethylformamide were placed in a 1 L reactor, and then, stirred for 4 hours. After distilled water was added thereto, solid residues obtained by filtering the reaction solution were separated-purified by chromatography, so as to obtain 54.2 g (yield: 92.6%) of Intermediate 1-a.

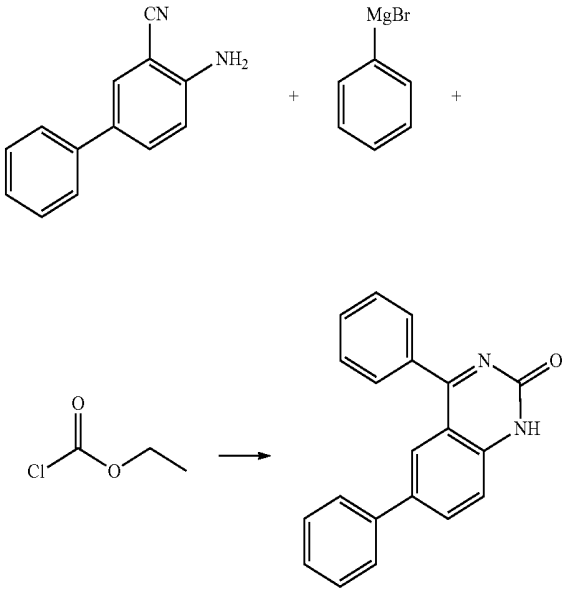
[0290] 2) Reaction Scheme 1-2: Synthesis of Intermediate 1-b



1-b

[0291] 50 g (254 mmol) of Intermediate 1-a, 40.2 g (330 mmol) of phenylboronic acid, 13.3 g (12.0 mmol) of tetrakis (triphenylphosphine)palladium, 70.1 g (508 mmol) of potassium carbonate, 250 mL of 1,4-dioxane, 250 mL of toluene, and 100 mL of distilled water were placed in a 2 L reactor, and then, stirred at a temperature of 100° C. for 12 hours. The reaction solution was cooled to room temperature, and then, extracted using ethylacetate. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 45 g (yield: 91%) of Intermediate 1-b.

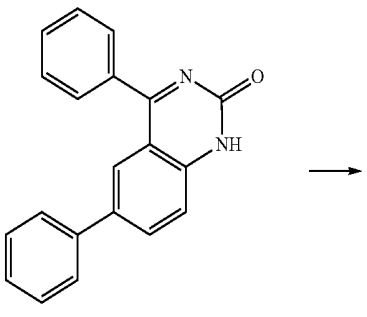
[0292] 3) Reaction Scheme 1-3: Synthesis of Intermediate 1-c



1-c

[0293] 45.0 g (232 mmol) of Intermediate 1-b and 450 mL of tetrahydrofuran were placed in a 2 L reactor, and then, stirred. After the reaction solution was cooled to 0° C., 88.2 mL (487 mmol) of 3M phenylmagnesiumbromide was added dropwise thereto, and then, the mixed solution was refluxed for 3 hours. After the refluxed solution was cooled to 0° C., a solution in which 44.3 g (732 mmol) of ethylchloroformate was dissolved with 200 ml of tetrahydrofuran was added dropwise thereto, and then, the mixed solution was refluxed for 2 hours. After the refluxed solution was cooled to 0° C., a saturated ammonium chloride aqueous solution was added thereto, and then, extracted using ethylacetate and water. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 46 g (yield: 80%) of Intermediate 1-c.

[0294] 4) Reaction Scheme 1-4: Synthesis of Intermediate 1-d



1-c

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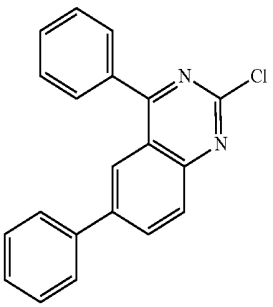
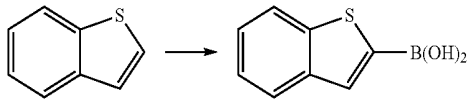


1-d

[0295] 40 g (134 mmol) of Intermediate 1-c and 500 mL of phosphorus oxycloride were placed in a 2 L reactor, and then, refluxed for 5 hours. After the reaction solution was cooled to 0° C., distilled water was added dropwise thereto. Solid residues obtained by filtering the reaction solution were separated-purified by chromatography, so as to obtain 30.5 g (yield: 70.6%) of Intermediate 1-d.

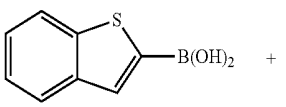
[0296] 5) Reaction Scheme 1-5: Synthesis of Intermediate 1-e



1-e

[0297] 144 g (554 mmol) of benzothiophene and 1,000 mL of tetrahydrofuran were added in a 2 L reactor, and then, cooled to −78° C. 415 mL of n-butyllithium (1.6M hexane solution) was added dropwise thereto, and then, the mixed solution was stirred for 1 hour. After the reaction solution was stirred for 12 hours when warmed up to room temperature, the reaction solution was cooled to −78° C. again. 80.3 mL (664 mmol) of trimethylborate was added dropwise thereto, and then, the reaction solution was stirred for 2 hours when warmed up to room temperature. The reaction solution was cooled to 0° C. again, and then, 2N hydrochloric acid solution was added thereto. The mixed solution was extracted using ethylacetate and distilled water. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 86 g (yield: 87.3%) of Intermediate 1-e.

[0298] 6) Reaction Scheme 1-6: Synthesis of Intermediate 1-f



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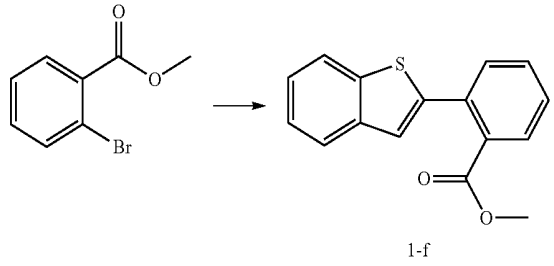
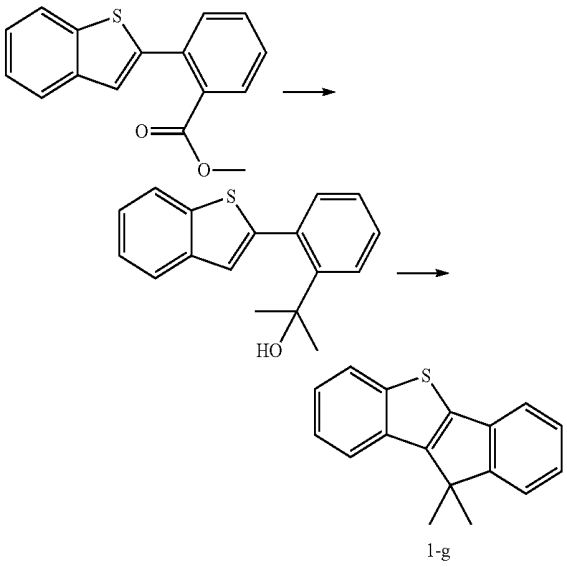


1-f

[0299] 75 g (349 mmol) of 2-bromo methylbenzoate, 80.7 g (453 mmol) of Intermediate 1-e, 10.1 g (9 mmol) of tetrakis (triphenylphosphine)palladium, 120.5 g (872 mmol) of potassium carbonate, 370 mL of 1,4-dioxane, 370 mL of toluene, and 160 mL of distilled water were placed in a 2 L reactor, and then, stirred at a temperature of 100° C. for 12 hours. The reaction solution was cooled to room temperature, and then, extracted using ethylacetate. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 80 g (yield: 85.9%) of Intermediate 1-f.

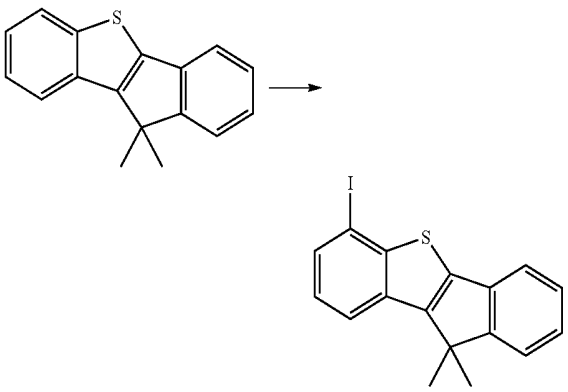
[0300] 7) Reaction Scheme 1-7: Synthesis of Intermediate 1-g



1-g

[0301] 80 g (298 mmol) of Intermediate 1-f and 800 mL of tetrahydrofuran were placed in a 2 L reactor, and then, stirred. After the reaction solution was cooled to 0° C., 348 mL (1,043 mmol) of 3M methylmagnesiumbromide was added dropwise thereto, and then, the mixed solution was refluxed for 3 hours. A saturated ammonium chloride aqueous solution was added thereto, and then, the mixed solution was extracted using ethylacetate and water. After an organic layer obtained therefrom was concentrated under reduced pressure, 270 mL of phosphoric acid was added thereto, and then, stirred for 12 hours. The organic layer was extracted using methylene chloride and distilled water, concentrated under reduced pressure, and separated-purified by chromatography, so as to obtain 55 g (yield: 78.1%) of Intermediate 1-g.

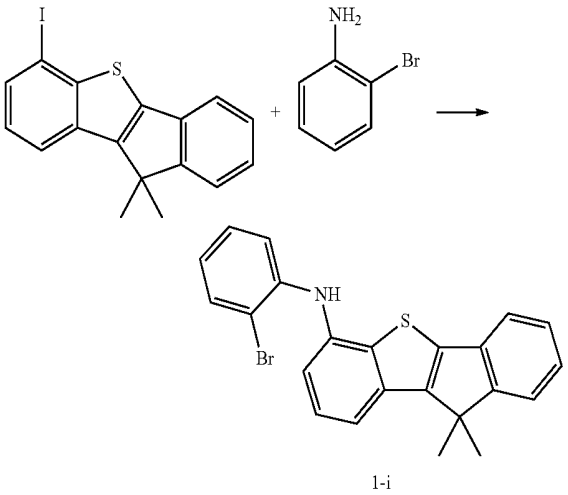
[0302] 8) Reaction Scheme 1-8: Synthesis of Intermediate 1-h



1-h

[0303] 110 g (439 mmol) of Intermediate 1-g and 1,100 mL of tetrahydrofuran were placed in a 2 L reactor, and then, stirred. After the reaction solution was cooled to −78° C., 302 mL (483 mmol) of n-butyllithium (1.6M hexane solution) was added dropwise thereto, and then, the mixed solution was stirred for 1 hour when warmed up to room temperature. 134 g (530 mmol) of iodine was added thereto, and then, the mixed solution was stirred for 2 hours when warmed up to room temperature. A sodium thiosulfate aqueous solution was added thereto, and the mixed solution was extracted using ethylacetate and distilled water. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 127 g (yield: 76.9%) of Intermediate 1-h.

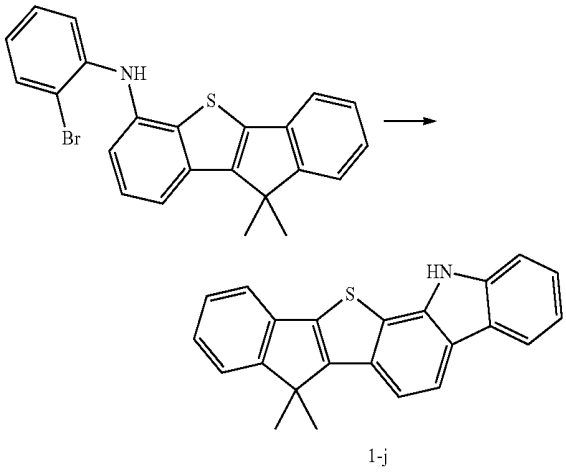
[0304] 9) Reaction Scheme 1-9: Synthesis of Intermediate 1-i



1-i

[0305] 127 g (338 mmol) of Intermediate 1-h, 70 g (407 mmol) of 2-bromoaniline, 0.9 g (4 mmol) of dipalladium acetate, 7.1 g (12 mmol) of xantphos, 154 g (472 mmol) of cesium carbonate, and 1,000 mL of toluene were placed in a 2 L reactor, and then, stirred for 12 hours. After the reaction solution was filtered at a high temperature, residues obtained therefrom were concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 100 g (yield: 70%) of Intermediate 1-i.

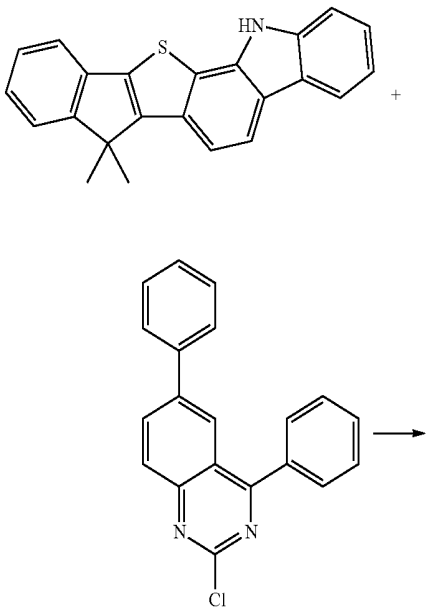
[0306] 10) Reaction Scheme 1-10: Synthesis of Intermediate 1-j



1-j

[0307] 75 g (178 mmol) of Intermediate 1-I, 1.3 g (4 mmol) of tricyclohexylphosphine tetrafluoroborate, 0.4 g (2 mmol) of dipalladium acetate, 49.3 g (357 mmol) of potassium carbonate, and 1,000 mL of toluene were placed in a 2 L reactor, and then, refluxed for 12 hours. After the reaction solution was filtered at a high temperature, residues obtained therefrom were concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 50 g (yield: 82.6%) of Intermediate 1-j.

[0308] 11) Reaction Scheme 1-11: Synthesis of Compound 4



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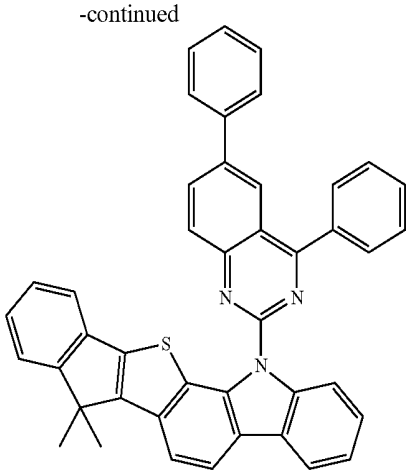


4

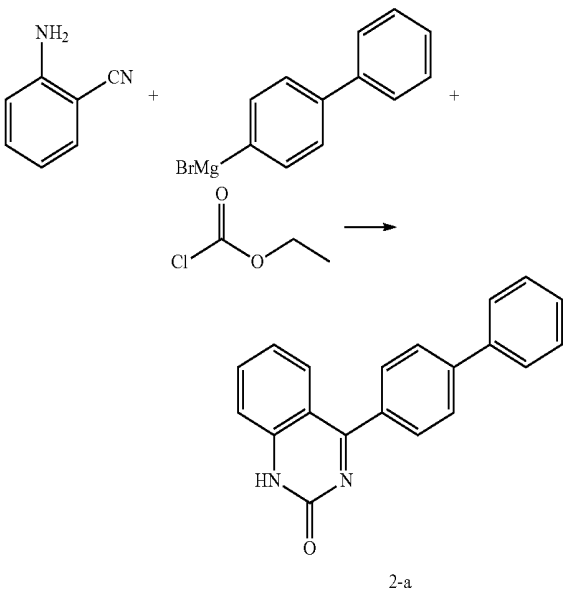
[0309] 10 g (29 mmol) of Intermediate 1-j, 12.1 g (33 mmol) of Intermediate 1-d, 0.5 g (0.6 mmol) of tris(dibenzylideneacetone)dipalladium, 0.9 g (3 mmol) of tri-tert-butylphosphonium tetrafluoroborate, 5.7 g (60 mmol) of sodium tert-butoxide, and 70 mL of xylene were placed in a 300 mL reactor, and then, refluxed for 12 hours. After the mixed solution was filtered at a high temperature, residues obtained therefrom were concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 7 g (yield: 38.3%) of Compound 4.

[0310] MS $[M]^+$: 620

Synthesis Example 2

Synthesis of Compound 7

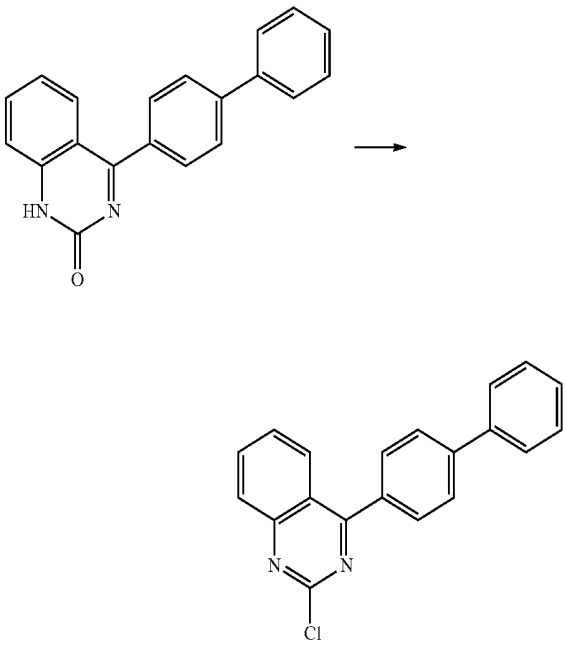
[0311] 1) Reaction Scheme 2-1: Synthesis of Intermediate 2-a



2-a

[0312] 43.7 g (yield: 77.6%) of Intermediate 2-a was obtained in the same manner as in Synthesis Example 1, except that 2-aminobenzonitrile was used instead of Intermediate 1-b of Reaction Scheme 1-3 in Synthesis Example 1 and 4-biphenylmagnesiumbromide was used instead of 3M phenylmagnesiumbromide.

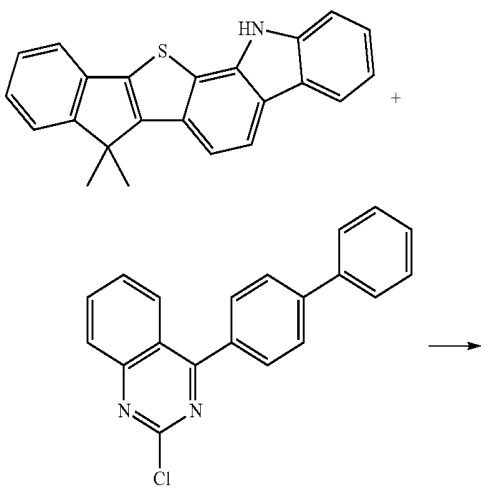
[0313] 2) Reaction Scheme 2-2: Synthesis of Intermediate 2-b



2-b

[0314] 29.7 g (yield: 80.2%) of Intermediate 2-b was obtained in the same manner as in Synthesis Example 1, except that Intermediate 2-a was used instead of Intermediate 1-c of Reaction Scheme 1-4 in Synthesis Example 1.

[0315] 3) Reaction Scheme 2-3: Synthesis of Compound 7



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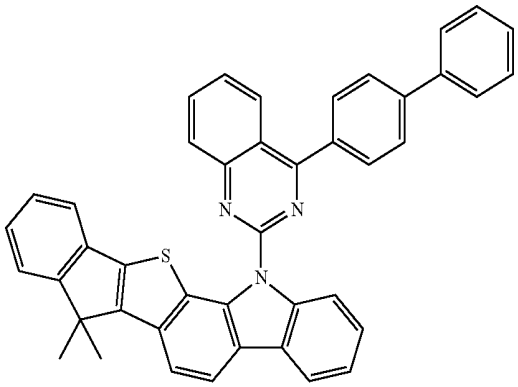


7

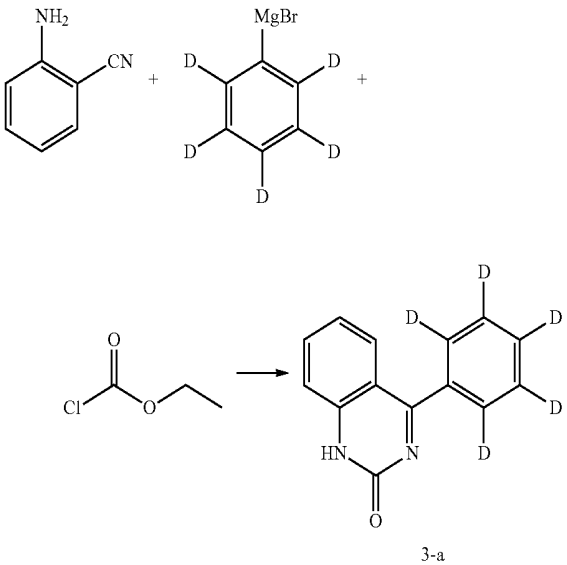
[0316] 6.7 g (yield: 36.7%) of Compound 7 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 2-b was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0317] MS $[M]^+$: 620

Synthesis Example 3

Synthesis of Compound 12

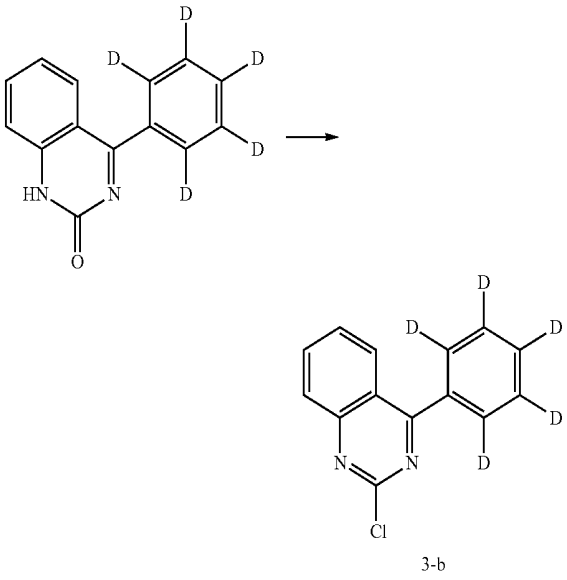
[0318] 1) Reaction Scheme 3-1: Synthesis of Intermediate 3-a



3-a

[0319] 51 g (yield: 78.3%) of Intermediate 3-a was obtained in the same manner as in Synthesis Example 1, except that 2-aminobenzonitrile was used instead of Intermediate 1-b of Reaction Scheme 1-3 in Synthesis Example 1 and phenyl-d5-magnesiumbromide was used instead of 3M phenylmagnesiumbromide.

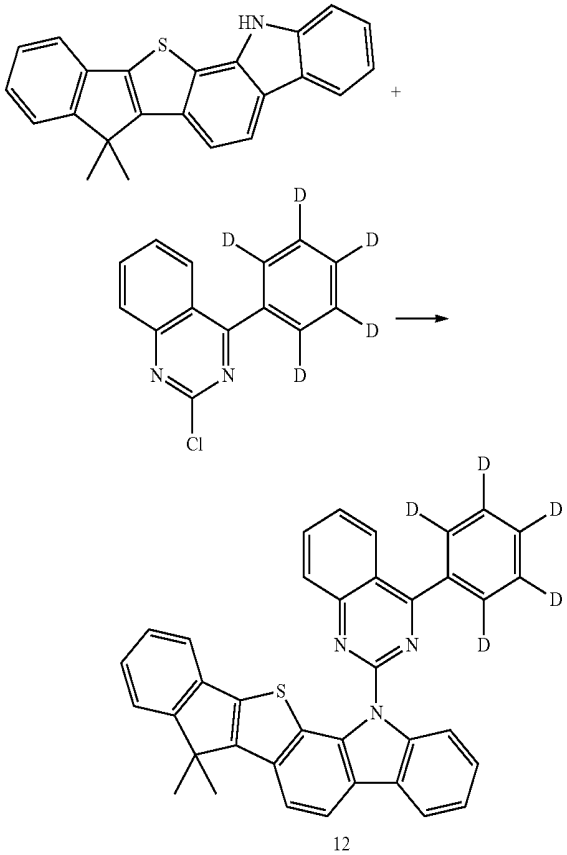
[0320] 2) Reaction Scheme 3-2: Synthesis of Intermediate 3-b



3-b

[0321] 31 g (yield: 57.8%) of Intermediate 3-b was obtained in the same manner as in Synthesis Example 1, except that Intermediate 3-a was used instead of Intermediate 1-c of Reaction Scheme 1-4 in Synthesis Example 1.

[0322] 3) Reaction Scheme 3-3: Synthesis of Compound 12



12

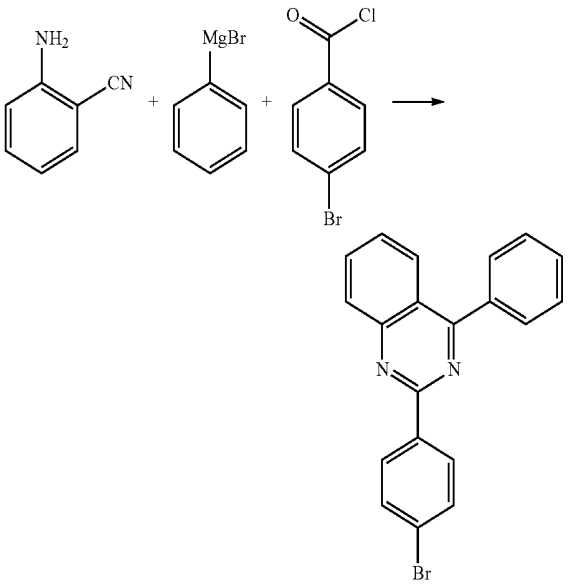
[0323] 8.4 g (yield: 31.7%) of Compound 12 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 3-b was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0324] MS $[M]^+$: 549

Synthesis Example 4

Synthesis of Compound 15

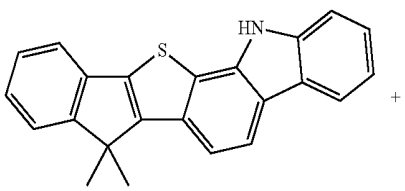
[0325] 1) Reaction Scheme 4-1: Synthesis of Intermediate 4-a



4-a

[0326] 20.0 g (169 mmol) of 2-aminobenzonitrile and 200 mL of tetrahydrofuran were placed in a 1 L reactor, and 113 mL (339 mmol) 3M phenylmagnesiumbromide was slowly added dropwise thereto. The mixed solution was refluxed for 3 hours. After it was confirmed that 2-aminobenzonitrile was removed from the reactor, the reaction solution was cooled to 0° C., and a solution in which 44.58 g (0.203 mmol) of 4-bromobenzoyl chloride was dissolved with 200 mL of tetrahydrofuran was slowly added dropwise thereto. The mixed solution was refluxed for 2 hours. An ammoniumchloride aqueous solution was added to the reactor, and the reaction solution was extracted using ethylacetate and water. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 25 g (yield: 40.8%) of Intermediate 4-a.

[0327] 2) Reaction Scheme 4-2: Synthesis of Compound 15



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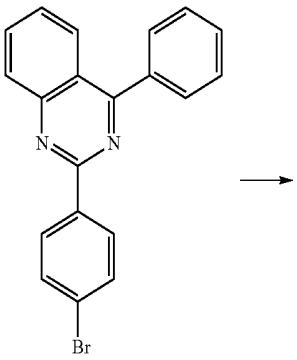
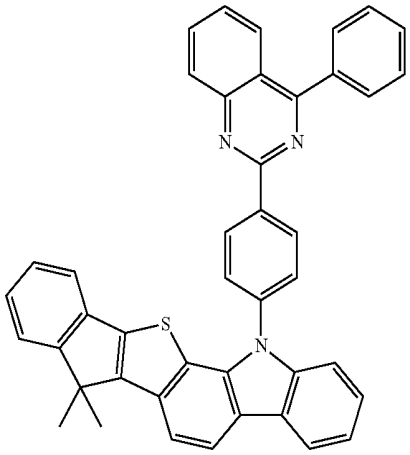




15

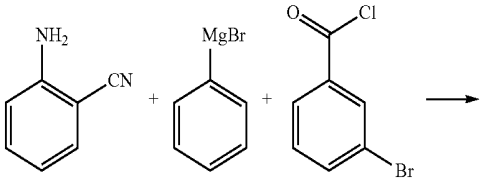
[0328] 5.2 g (yield: 27.6%) of Compound 15 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 4-a was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0329] MS $[M]^+$: 620

Synthesis Example 5

Synthesis of Compound 16

[0330] 1) Reaction Scheme 5-1: Synthesis of Intermediate 5-a



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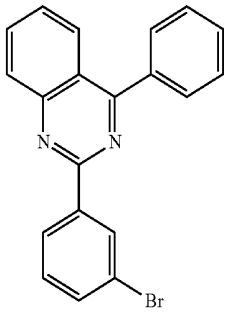
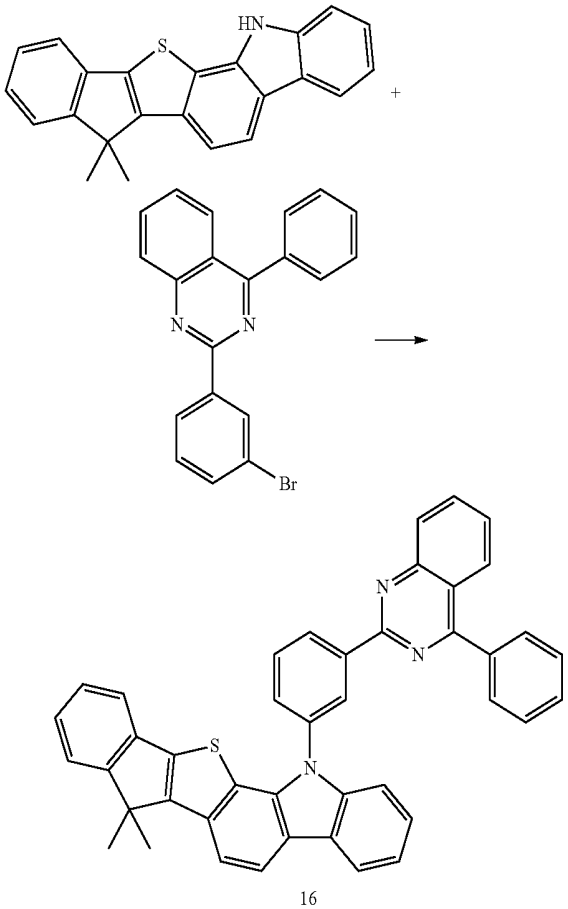


5-a

[0331] 37 g (yield: 60.3%) of Intermediate 5-a was obtained in the same manner as in Synthesis Example 1, except that 3-bromobenzoyl chloride was used instead of 4-bromobenzoyl chloride of Reaction Scheme 4-1 in Synthesis Example 4.

[0332] 2) Reaction Scheme 5-2: Synthesis of Compound 16



16

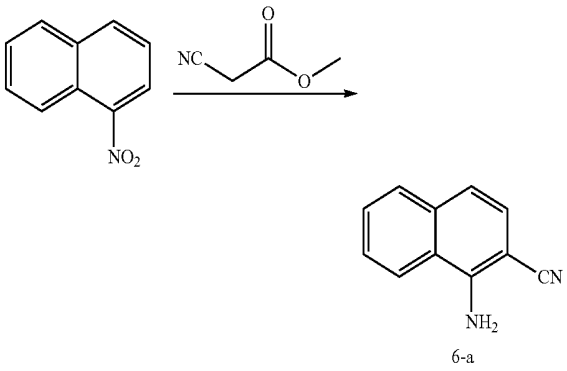
[0333] 8.4 g (yield: 31.8%) of Compound 16 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 5-a was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0334] MS $[M]^+$: 620

Synthesis Example 6

Synthesis of Compound 24

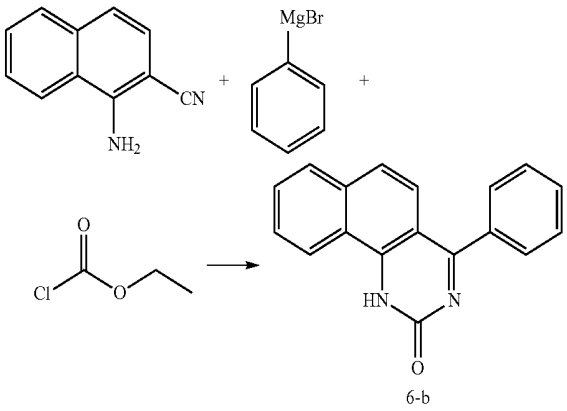
[0335] 1) Reaction Scheme 6-1: Synthesis of Intermediate 6-a



6-a

[0336] 139.8 g (1.236 mol) of ethyl cyanoacetate, 29.5 g (0.453 mol) of potassium cyanide, 46.2 g (0.824 mol) of potassium hydroxide, and 920 mL of dimethylformamide were placed in a 2 L reactor, and then, stirred at a temperature of 10° C. for 20 minutes. 92 g (412 mol) of 1-nitronaphthalene was added thereto, and the mixed solution was stirred at a temperature of 60° C. for 4 hours. After a solvent was concentrated in the reactor, 600 mL of a 10% sodium hydroxide aqueous solution was added thereto. The mixed solution was stirred under reflux for 1 hour. Solid residues obtained by filtering the reaction solution were separated-purified by chromatography using methylene chloride and heptane, so as to obtain 50 g (yield: 60%) of Formula 6-a.

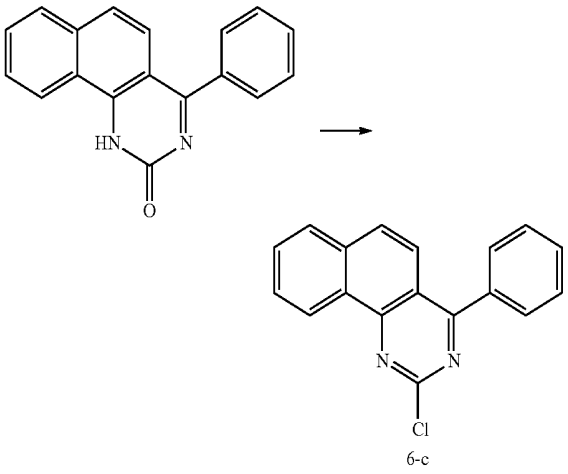
[0337] 2) Reaction Scheme 6-2: Synthesis of Intermediate 6-b



6-b

[0338] 50 g (yield: 60%) of Intermediate 6-a was obtained in the same manner as in Synthesis Example 1, except that Intermediate 6-1 of Reaction Scheme 6-1 was used instead of Intermediate 1-b of Reaction Scheme 1-3.

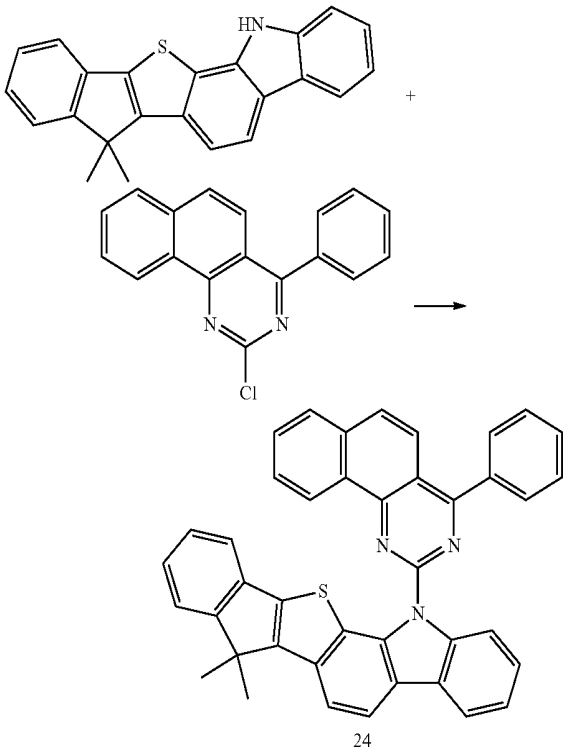
[0339] 3) Reaction Scheme 6-3: Synthesis of Intermediate 6-c



6-c

[0340] 30.5 g (yield: 70.6%) of Intermediate 6-c was obtained in the same manner as in Synthesis Example 1, except that Intermediate 6-b was used instead of Intermediate 1-c of Reaction Scheme 1-4 in Synthesis Example 1.

[0341] 4) Reaction Scheme 6-4: Synthesis of Compound 24



24

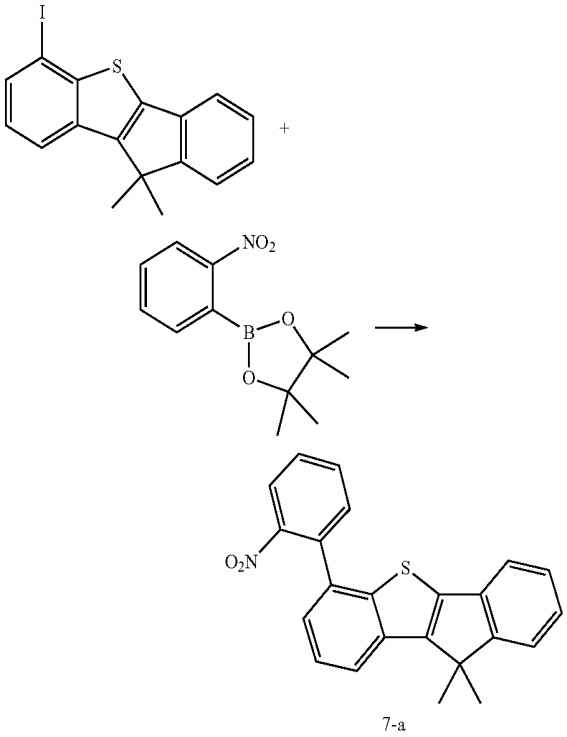
[0342] 6.8 g (yield: 35.1%) of Compound 24 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 6-c was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0343] MS $[M]^+$: 594

Synthesis Example 7

Synthesis of Compound 26

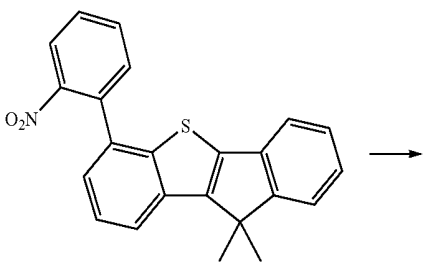
[0344] 1) Reaction Scheme 7-1: Synthesis of Intermediate 7-a



7-a

[0345] 28 g (74 mmol) of Intermediate 1-h, 24.1 g (97 mmol) of 2-nitrophenylborate, 2.2 g (0.19 mmol) of tetrakis (triphenylphosphine)palladium, 25.7 g (186 mmol) of potassium carbonate, 140 mL of 1,4-dioxane, 140 mL of toluene, and 50 mL of distilled water were placed in a reactor, and then, stirred at a temperature of 100° C. for 12 hours. After the completion of the reaction, the reaction solution was cooled to room temperature, and then, extracted using ethylacetate. An organic layer obtained therefrom was concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 20.7 g (yield: 74.9%) of Intermediate 7-a.

[0346] 2) Reaction Scheme 7-2: Synthesis of Intermediate 7-b



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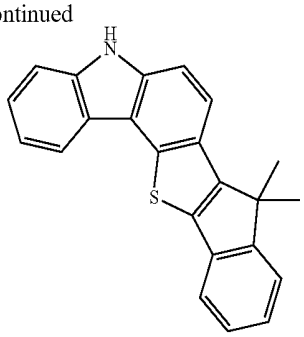
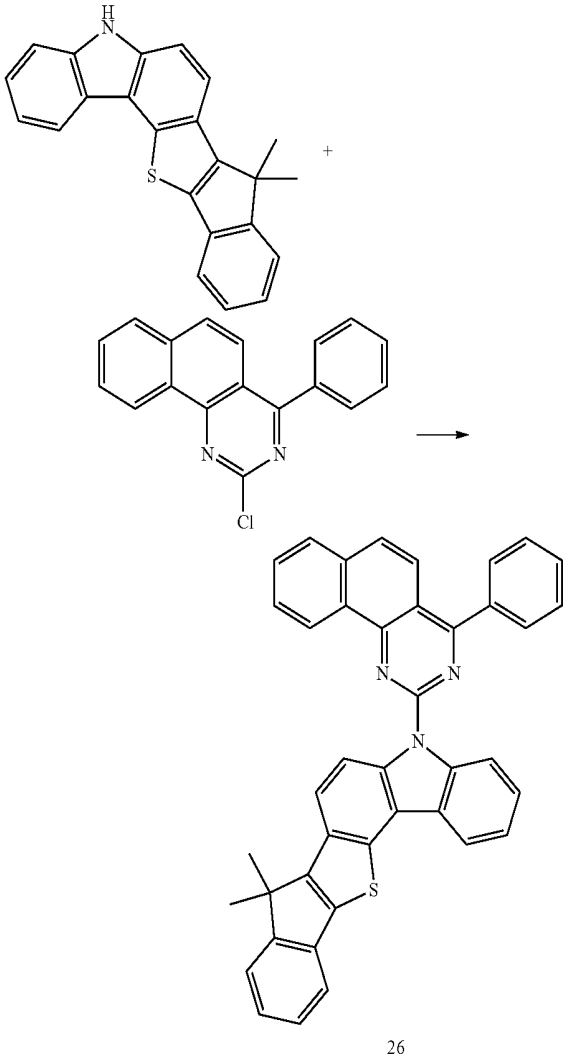


7-b

[0347] 20.7 g (27 mmol) of Intermediate 7-a, 21.2 g (81 mmol) of triphenylphosphine, and 200 mL of dichlorobenzene were placed in a reactor, and then, refluxed for 12 hours. After the completion of the reaction, the reaction solution, which was in a hot condition, was filtered under reduced pressure. The filtered solution was dried under reduced pressure, and then, separated-purified by chromatography, so as to obtain 12.9 g (yield: 68.2%) of Intermediate 1-I.

[0348] 3) Reaction Scheme 7-3: Synthesis of Compound 26



26

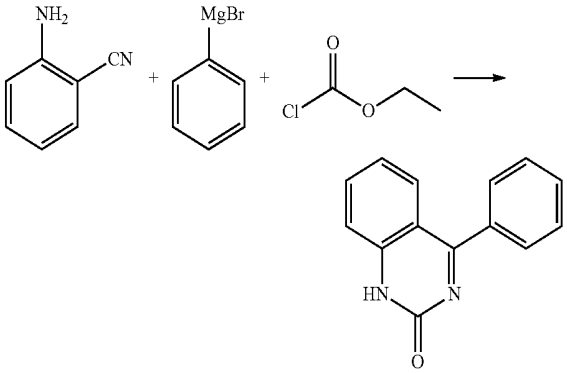
[0349] 26 9.3 g (yield: 34.8%) of Compound 26 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 7-b and Intermediate 6-c were used instead of Intermediate 1-j and Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1, respectively.

[0350] MS $[M]^+$: 594

Synthesis Example 8

Synthesis of Compound 33

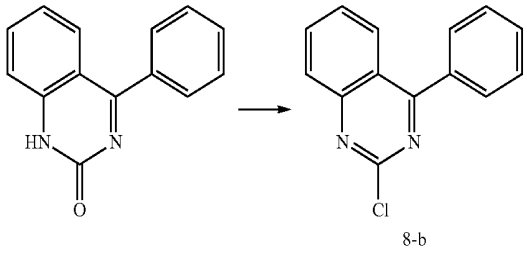
[0351] 1) Reaction Scheme 8-1: Synthesis of Intermediate 8-a



8-a

[0352] 48.2 g (yield: 75.7%) of Intermediate 8-a was obtained in the same manner as in Synthesis Example 1, except that 2-aminobenzonitrile was used instead of Intermediate 1-b of Reaction Scheme 1-3 in Synthesis Example 1.

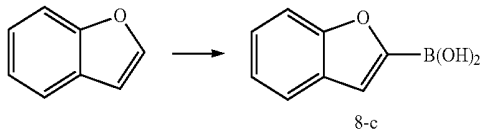
[0353] 2) Reaction Scheme 8-2: Synthesis of Intermediate 8-b



8-b

[0354] 32.1 g (yield: 68.4%) of Intermediate 8-b was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-a was used instead of Intermediate 1-c of Reaction Scheme 1-4 in Synthesis Example 1.

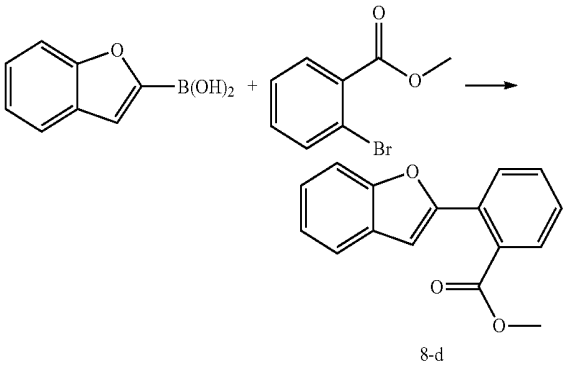
[0355] 3) Reaction Scheme 8-3: Synthesis of Intermediate 8-c



8-c

[0356] 123.4 g (yield: 87.4%) of Intermediate 8-c was obtained in the same manner as in Synthesis Example 1, except that benzofuran was used instead of benzothiophene of Reaction Scheme 1-5 in Synthesis Example 1.

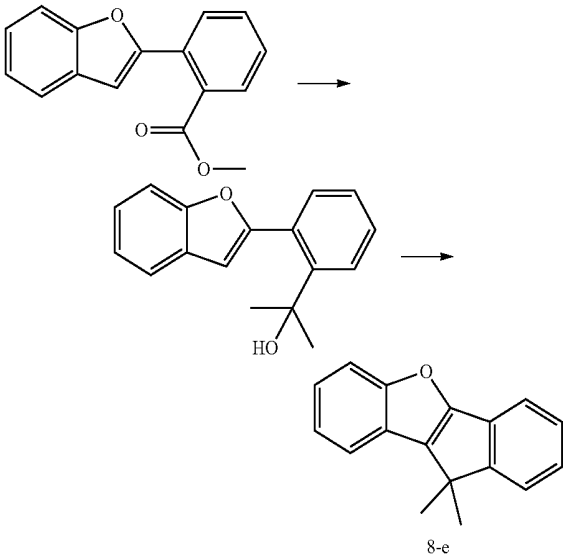
[0357] 4) Reaction Scheme 8-4: Synthesis of Intermediate 8-d



8-d

[0358] 106.2 g (yield: 79.3%) of Intermediate 8-d was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-c was used instead of Intermediate 1-e of Reaction Scheme 1-6 in Synthesis Example 1.

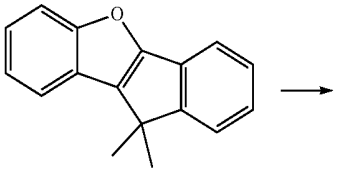
[0359] 5) Reaction Scheme 8-5: Synthesis of Intermediate 8-e



8-e

[0360] 84.3 g (yield: 75.5%) of Intermediate 8-e was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-d was used instead of Intermediate 1-f of Reaction Scheme 1-7 in Synthesis Example 1.

[0361] 6) Reaction Scheme 8-6: Synthesis of Intermediate 8-f



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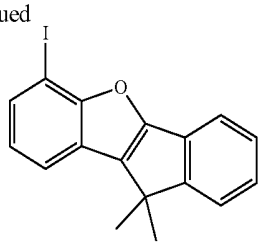
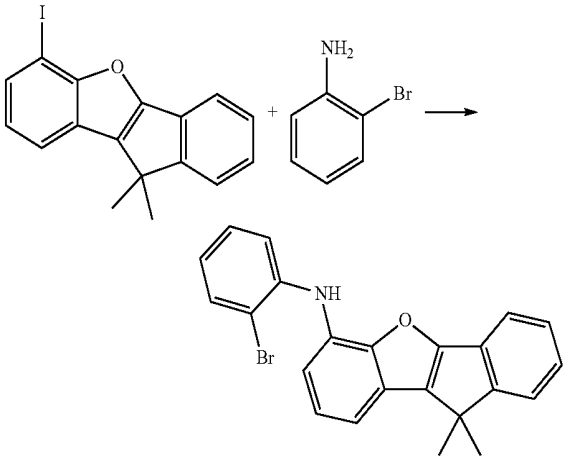


8-f

[0362] 110.6 g (yield: 80.9%) of Intermediate 8-f was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-d was used instead of Intermediate 1-g of Reaction Scheme 1-8 in Synthesis Example 1.

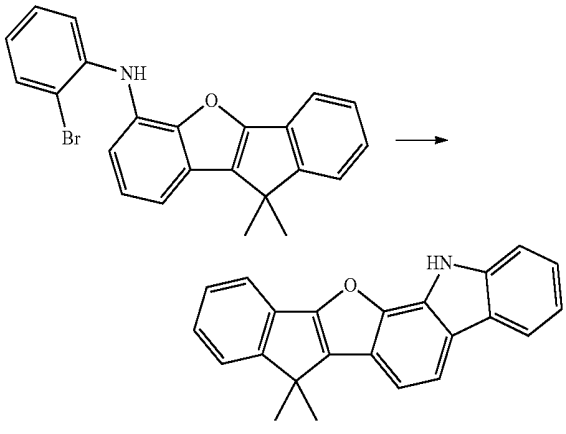
[0363] 7) Reaction Scheme 8-7: Synthesis of Intermediate 8-g



8-g

[0364] 85.3 g (yield: 74.5%) of Intermediate 8-g was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-f was used instead of Intermediate 1-h of Reaction Scheme 1-9 in Synthesis Example 1.

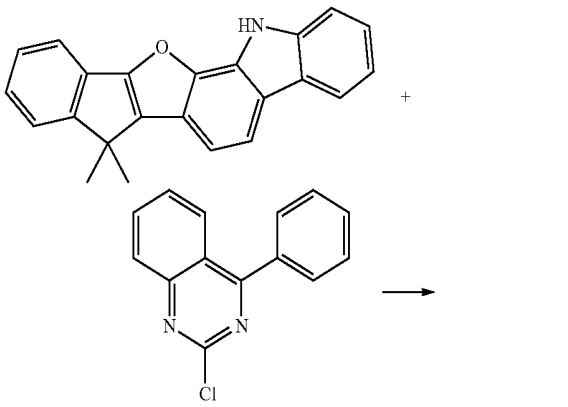
[0365] 8) Reaction Scheme 8-8: Synthesis of Intermediate 8-h



8-h

[0366] 31.5 g (yield: 74.2%) of Intermediate 8-h was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-g was used instead of Intermediate 1-i of Reaction Scheme 1-10 in Synthesis Example 1.

[0367] 9) Reaction Scheme 8-9: Synthesis of Compound 33



33

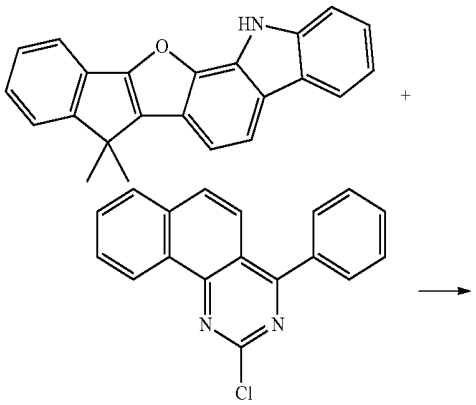
[0368] 6.2 g (yield: 31.8%) of Compound 33 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-b and Intermediate 8-h were used instead of Intermediate 1-d and Intermediate 1-j of Reaction Scheme 1-11 in Synthesis Example 1, respectively.

[0369] MS $[M]^+$: 528

Synthesis Example 9

Synthesis of Compound 34

[0370] 1) Reaction Scheme 9-1: Synthesis of Compound 34



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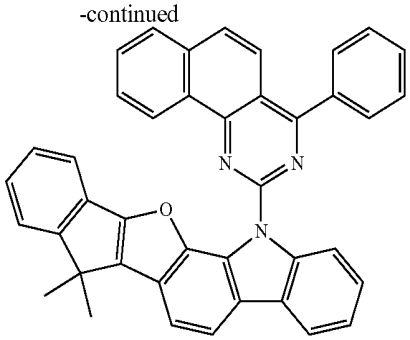


34

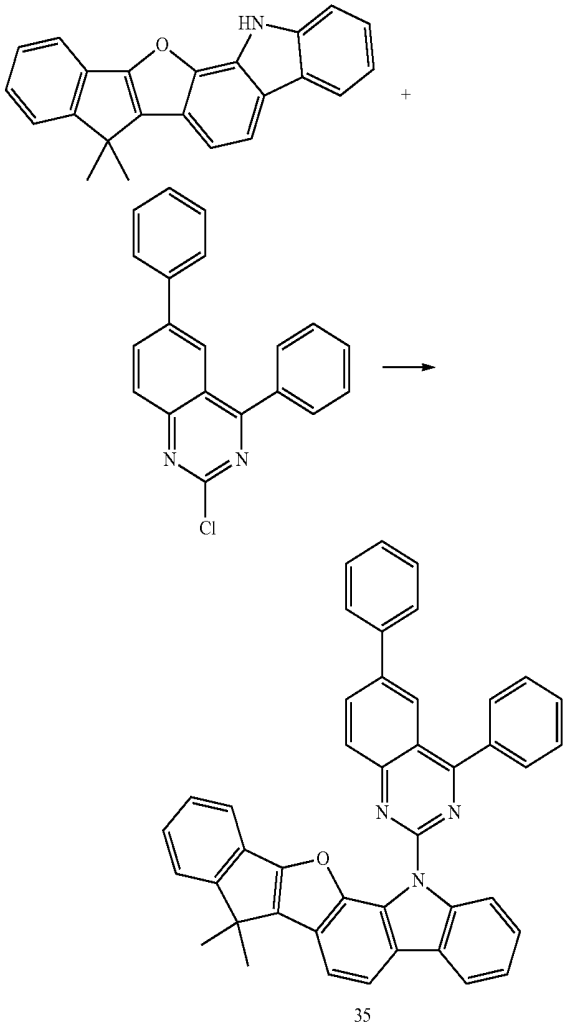
[0371] 8.6 g (yield: 29.7%) of was obtained in the same manner as in Synthesis Example 1, except that Intermediate 6-c was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0372] MS $[M]^+$: 578

Synthesis Example 10

Synthesis of Compound 35

[0373] 1) Reaction Scheme 10-1: Synthesis of Compound 35



35

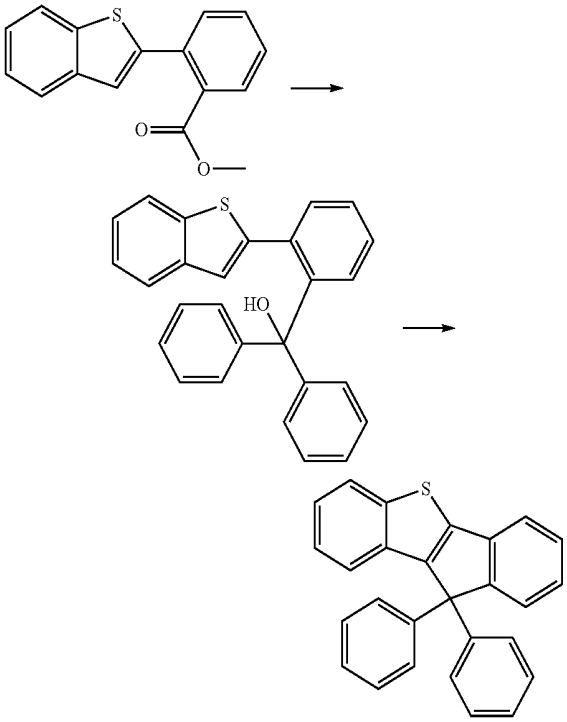
[0374] 7.2 g (yield: 28.5%) of Compound 35 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 8-h was used instead of Intermediate 1-j of Reaction Scheme 1-11 in Synthesis Example 1.

[0375] MS $[M]^+$: 578

Synthesis Example 11

Synthesis of Compound 44

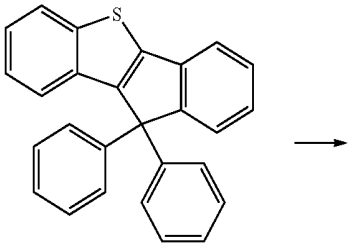
[0376] 1) Reaction Scheme 11-1: Synthesis of Intermediate 11-a



11-a

[0377] 42.7 g (yield: 80.6%) of Intermediate 11-a was obtained in the same manner as in Synthesis Example 1, except that 3M phenylmagnesiumbromide was used instead of 3M methylmagnesiumbromide of Reaction Scheme 1-7 in Synthesis Example 1.

[0378] 2) Reaction Scheme 11-2: Synthesis of Intermediate 11-b



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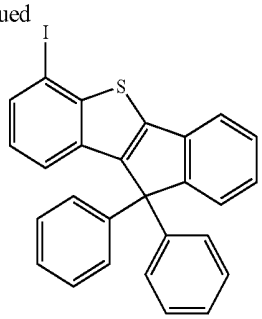
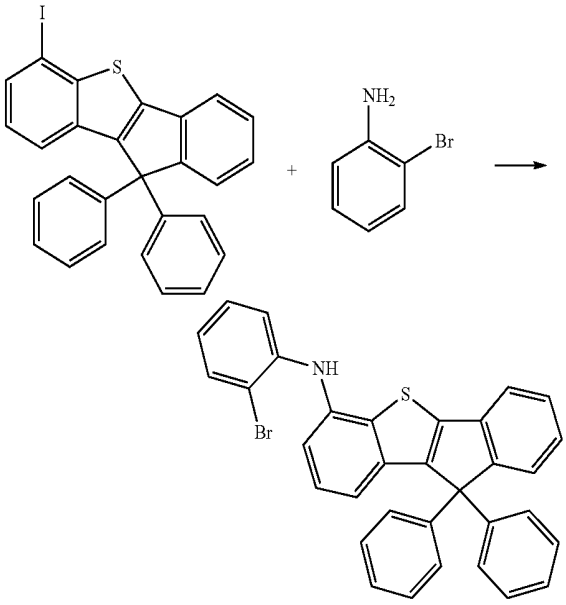


11-b

[0379] 49.3 g (yield: 76.4%) of Intermediate 11-b was obtained in the same manner as in Synthesis Example 1, except that Intermediate 11-a was used instead of Intermediate 1-g of Reaction Scheme 1-8 in Synthesis Example 1.

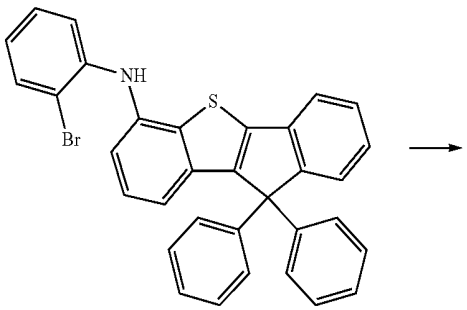
[0380] 31 Reaction Scheme 11-3: Synthesis of Intermediate 11-c



11-c

[0381] 37.2 g (yield: 69.7%) of Intermediate 11-c was obtained in the same manner as in Synthesis Example 1, except that Intermediate 11-b was used instead of Intermediate 1-h of Reaction Scheme 1-9 in Synthesis Example 1.

[0382] 4) Reaction Scheme 11-4: Synthesis of Intermediate 11-d



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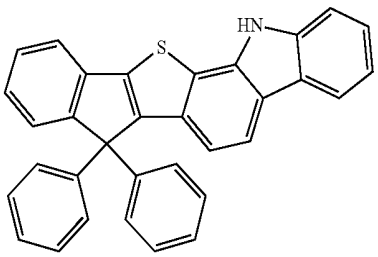
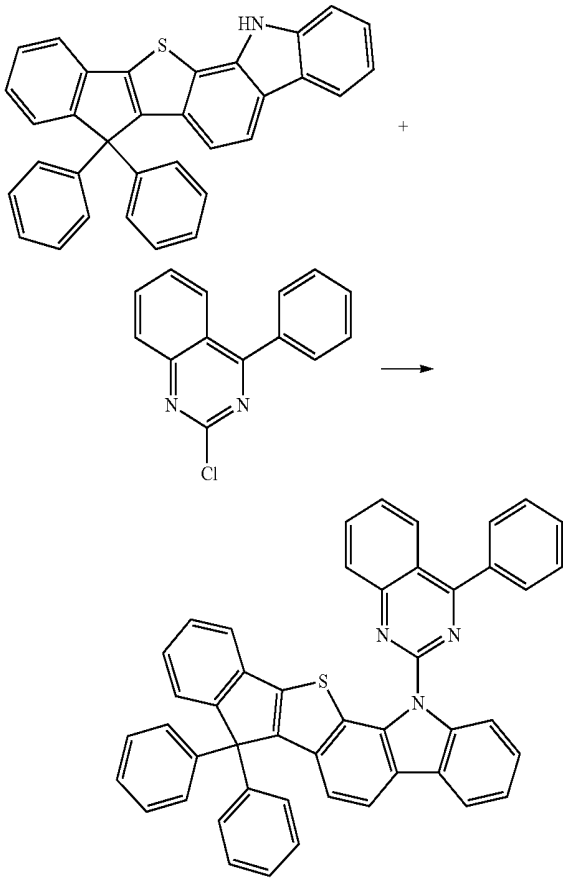


11-d

[0383] 27.3 g (yield: 70.4%) of Intermediate 11-d was obtained in the same manner as in Synthesis Example 1, except that Intermediate 11-c was used instead of Intermediate 1-i of Reaction Scheme 1-10 in Synthesis Example 1.

[0384] 5) Reaction Scheme 11-5: Synthesis of Compound 44



44

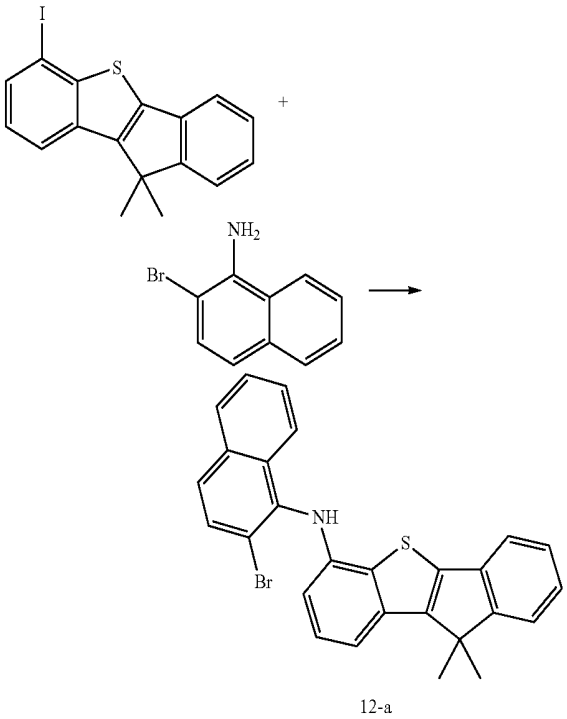
[0385] 6.7 g (yield: 37.4%) of Compound 44 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 11-d was used instead of Intermediate 1-j of Reaction Scheme 1-11 in Synthesis Example 1.

[0386] MS $[M]^+$: 668

Synthesis Example 12

Synthesis of Compound 47

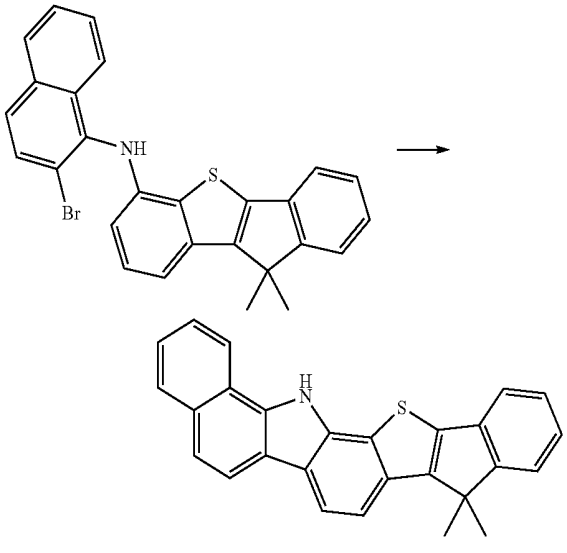
[0387] 1) Reaction Scheme 12-1: Synthesis of Intermediate 12-a



12-a

[0388] 35.7 g (yield: 73.1%) of Intermediate 12-a was obtained in the same manner as in Synthesis Example 1, except that 2-bromo-1-naphthaleneamine was used instead of 2-bromoaniline of Reaction Scheme 1-9 in Synthesis Example 1.

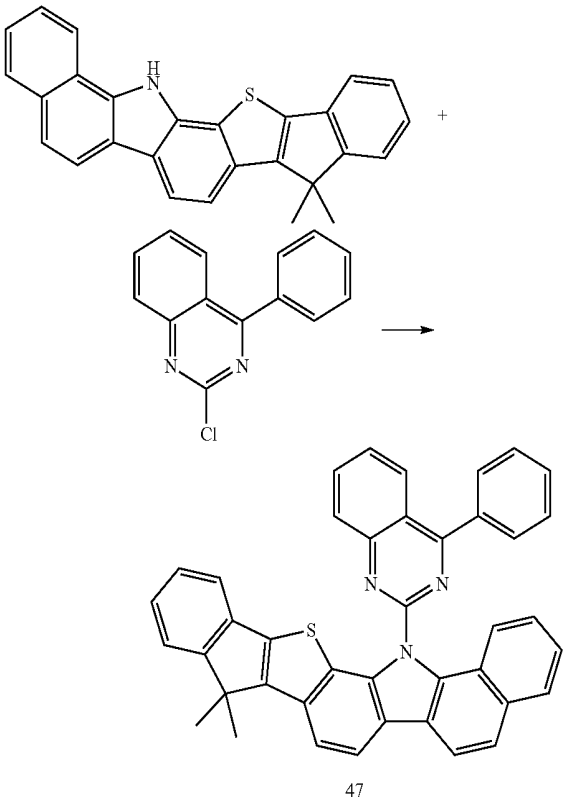
[0389] 2) Reaction Scheme 12-2: Synthesis of Intermediate 12-b



12-b

[0390] 29.5 g (yield: 68.4%) of Intermediate 12-b was obtained in the same manner as in Synthesis Example 1, except that Intermediate 12-a was used instead of Intermediate 1-i of Reaction Scheme 1-10 in Synthesis Example 1.

[0391] 3) Reaction Scheme 12-3: Synthesis of Compound 47



47

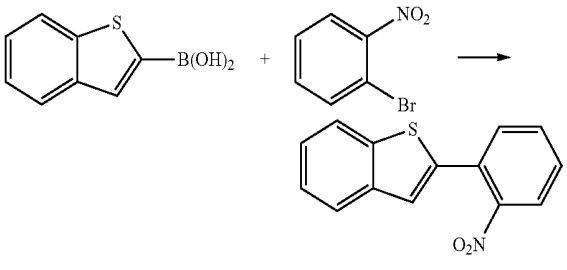
[0392] 4.8 g (yield: 41.9%) of Compound 47 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 12-b was used instead of Intermediate 1-j of Reaction Scheme 1-11 in Synthesis Example 1.

[0393] MS $[M]^+$: 594

Synthesis Example 13

Synthesis of Compound 123

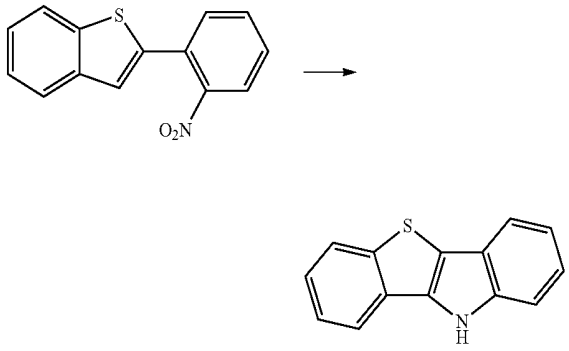
[0394] 1) Reaction Scheme 13-1: Synthesis of Intermediate 13-a



13-a

[0395] 65 g (yield: 64.3%) of Intermediate 13-a was obtained in the same manner as in Synthesis Example 1, except that 1-bromo-2-nitrobenzene was used instead of 2-bromo methylbenzoate of Reaction Scheme 1-6 in Synthesis Example 1.

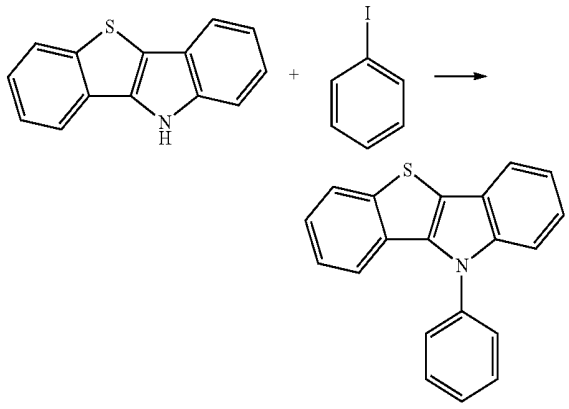
[0396] 2) Reaction Scheme 13-2: Synthesis of Intermediate 13-b



13-b

[0397] 47 g (yield: 82.7%) of Intermediate 13-b was obtained in the same manner as in Synthesis Example 1, except that Intermediate 13-a was used instead of Intermediate 7-a of Reaction Scheme 7-2 in Synthesis Example 7.

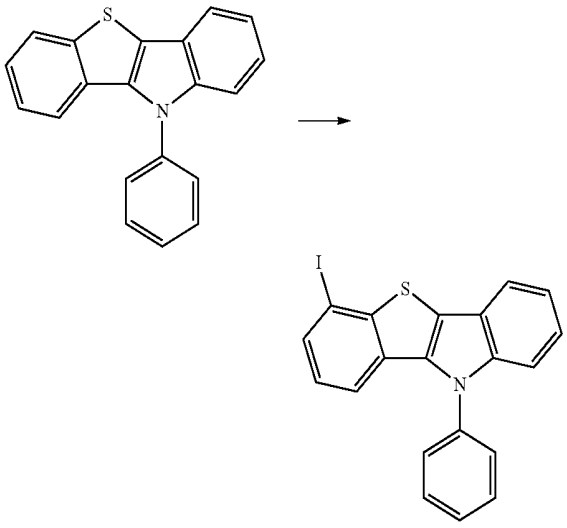
[0398] 3) Reaction Scheme 13-3: Synthesis of Intermediate 13-c



13-c

[0399] 43.1 g (193 mmol) of Intermediate 13-b, 47.3 g (232 mmol) of iodobenzene, 1.8 g (10 mmol) of iodinecopper, 86.1 g of potassium phosphate, 46.3 g (405 mmol) of 1,2-cyclohexyldiamine, and 430 mL of 1,4-dioxane were placed in a 1 L reactor, and then, stirred at a temperature of 100° C. for 12 hours. After the reaction solution was filtered at a high temperature, residues obtained therefrom were concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 56 g (yield: 96.9%) of Intermediate 11-c.

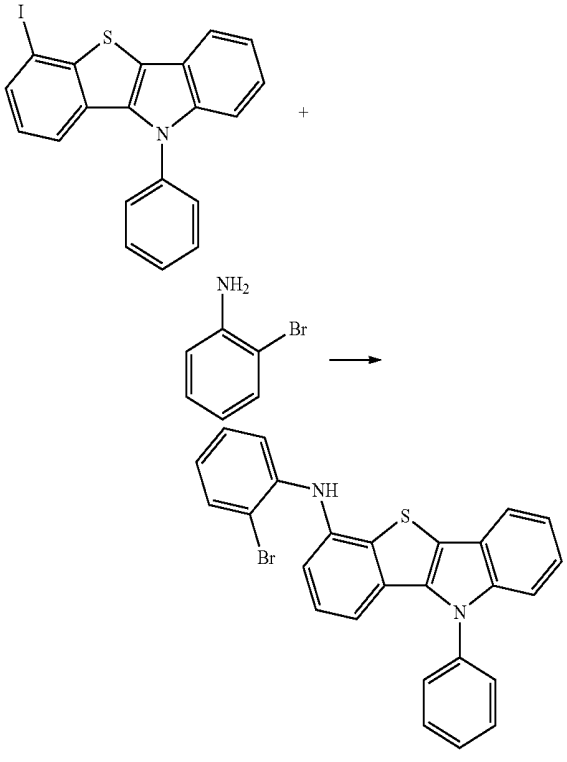
[0400] 4) Reaction Scheme 13-4: Synthesis of Intermediate 13-d



13-d

[0401] 64.2 g (yield: 76.8%) of Intermediate 13-d was obtained in the same manner as in Synthesis Example 1, except that Intermediate 13-c was used instead of Intermediate 1-g of Reaction Scheme 1-8 in Synthesis Example 1.

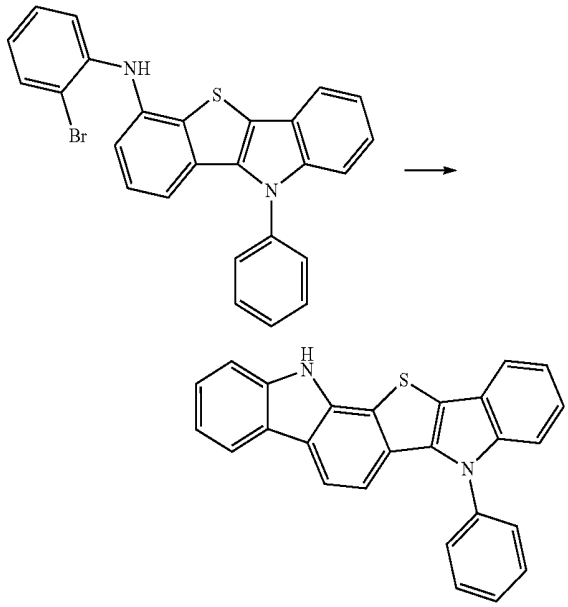
[0402] 5) Reaction Scheme 13-5: Synthesis of Intermediate 13-e



13-e

[0403] 28.1 g (yield: 71.6%) of Intermediate 13-e was obtained in the same manner as in Synthesis Example 1, except that Intermediate 13-d was used instead of Intermediate 1-h of Reaction Scheme 1-9 in Synthesis Example 1.

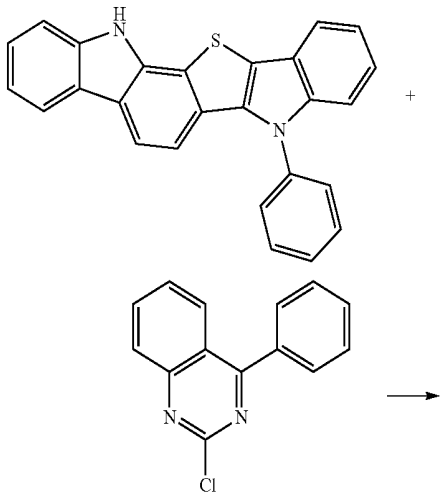
[0404] 6) Reaction Scheme 13-6: Synthesis of Intermediate 13-f



13-f

[0405] 18.9 g (yield: 69.4%) of Intermediate 13-f was obtained in the same manner as in Synthesis Example 1, except that Intermediate 13-e was used instead of Intermediate 1-i of Reaction Scheme 1-10 in Synthesis Example 1.

[0406] 7) Reaction Scheme 13-7: Synthesis of Compound 123



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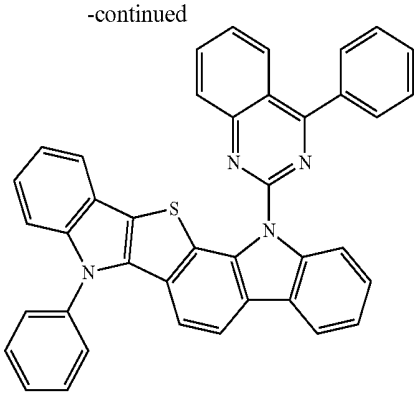


123

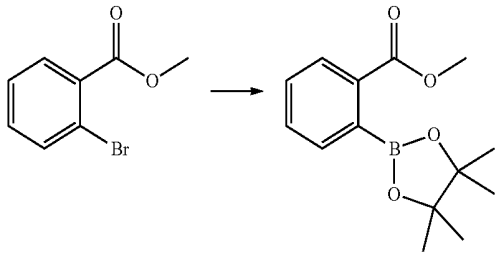
[0407] 4.3 g (yield: 42.9%) of Compound 123 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 13-f was used instead of Intermediate 1-j of Reaction Scheme 1-11 in Synthesis Example 1.

[0408] MS $[M]^+$: 593

Synthesis Example 14

Synthesis of Compound 165

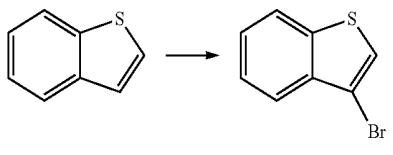
[0409] 1) Reaction Scheme 14-1: Synthesis of Intermediate 14-a



14-a

[0410] 100 g (465 mmol) of 2-bromoethylacetate, 177.1 g (698 mmol) of bis(pinacolato)diboron, 10.2 g (14 mmol) of [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium, 136.9 g (1395 mmol) of potassium acetate, and 1,000 mL of toluene were placed in a 2 L reactor, and then, refluxed for 12 hours. After the reaction solution was filtered at a high temperature, residues obtained therefrom were concentrated under reduced pressure and separated-purified by chromatography, so as to obtain 96 g (yield: 78.8%) of Intermediate 14-a.

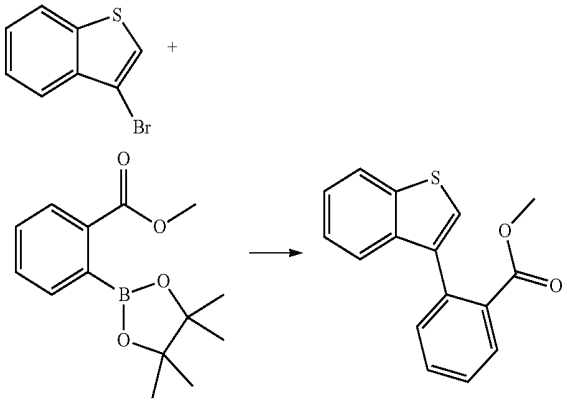
[0411] 2) Reaction Scheme 14-2: Synthesis of Intermediate 14-b



14-b

[0412] 35 g (261 mmol) of benzothiophene and 350 mL of tetrahydrofuran were placed in a 1 L reactor, and then, stirred. After the reaction solution was cooled to 0° C., 55.7 g (313 mmol) of N-bromosuccinimide was added thereto, and then, stirred for 1 hour. After the reaction solution was stirred for 12 hours when warmed up to room temperature, a sodium thiosulfite aqueous solution was added thereto. The mixed solution was extracted using ethylacetate and distilled water, and then, an organic layer was obtained therefrom was separated. The organic layer was concentrated under reduced pressure, so as to obtain 43 g (yield: 63.4%) of Intermediate 14-b.

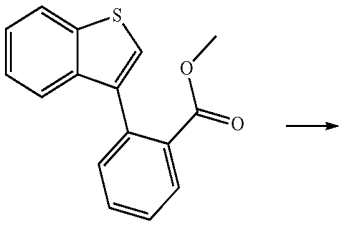
[0413] 3) Reaction Scheme 14-3: Synthesis of Intermediate 14-c



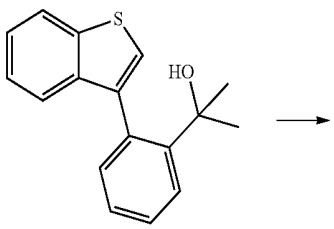
14-c

[0414] 33 g (yield: 65.3%) of Intermediate 14-c was obtained in the same manner as in Synthesis Example 1, except that Intermediate 14-b and Intermediate 14-a were used instead of 2-bromo methylbenzoate and Intermediate 1-e of Reaction Scheme 1-6 in Synthesis Example 1, respectively.

[0415] 4) Reaction Scheme 14-4: Synthesis of Intermediate 14-d



14-c



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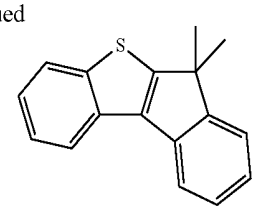
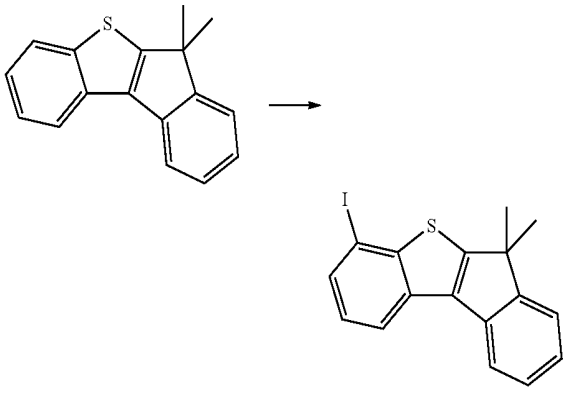


14-d

[0416] 42 g (yield: 73.8%) of Intermediate 14-d was obtained in the same manner as in Synthesis Example 1, except that Intermediate 14-c was used instead of Intermediate 1-g of Reaction Scheme 1-8 in Synthesis Example 1.

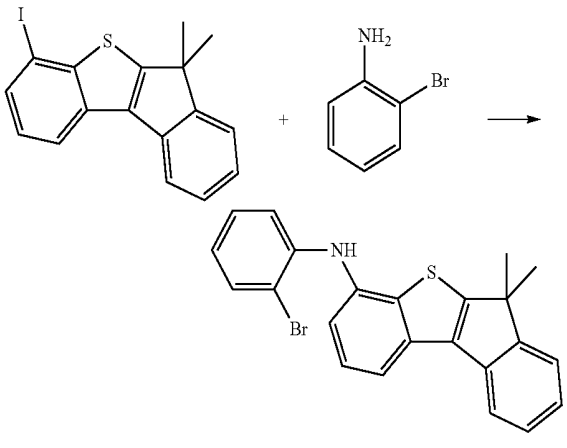
[0417] 5) Reaction Scheme 14-5: Synthesis of Intermediate 14-e



14-e

[0418] 50 g (yield: 75.3%) of Intermediate 14-e was obtained in the same manner as in Synthesis Example 1, except that Intermediate 14-d was used instead of Intermediate 1-g of Reaction Scheme 1-8 in Synthesis Example 1.

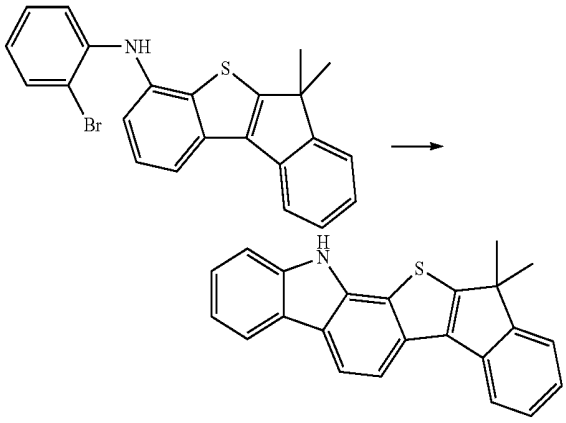
[0419] 6) Reaction Scheme 14-6: Synthesis of Intermediate 14-f



14-f

[0420] 45 g (yield: 76.2%) of Intermediate 14-f was obtained in the same manner as in Synthesis Example 1, except that Intermediate 14-e was used instead of Intermediate 1-h of Reaction Scheme 1-9 in Synthesis Example 1.

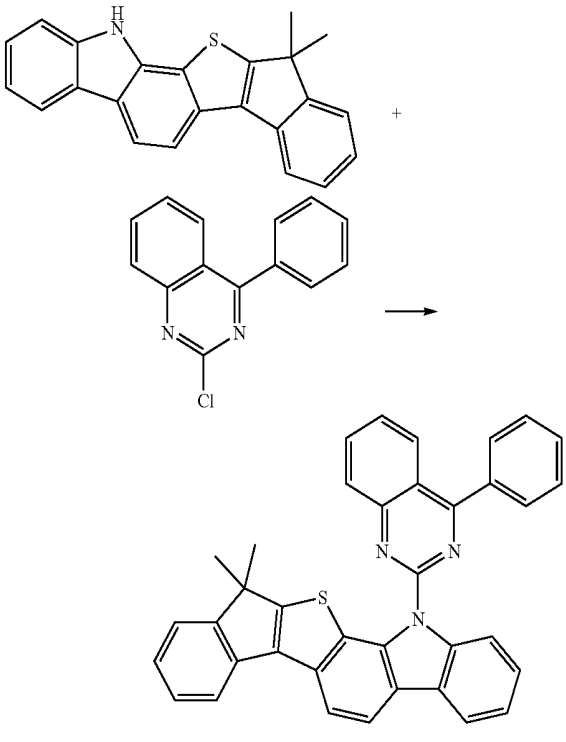
[0421] 7) Reaction Scheme 14-7: Synthesis of Intermediate 14-g



14-g

[0422] 25 g (yield: 67.1%) of Intermediate 14-g was obtained in the same manner as in Synthesis Example 1, except that Intermediate 14-f was used instead of Intermediate 1-i of Reaction Scheme 1-10 in Synthesis Example 1.

[0423] 8) Reaction Scheme 14-8: Synthesis of Compound 165



165

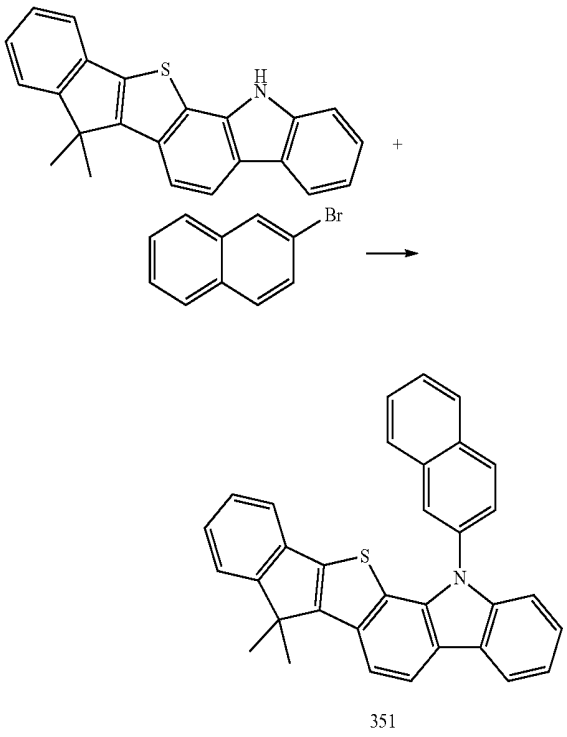
[0424] 6.3 g (yield: 43.8%) of Compound 165 was obtained in the same manner as in Synthesis Example 1, except that Intermediate 13-g was used instead of Intermediate 1-j of Reaction Scheme 1-11 in Synthesis Example 1.

[0425] MS $[M]^+$: 544

Synthesis Example 15

Synthesis of Compound 351

[0426] 1) Reaction Scheme 15-1: Synthesis of Compound 351



351

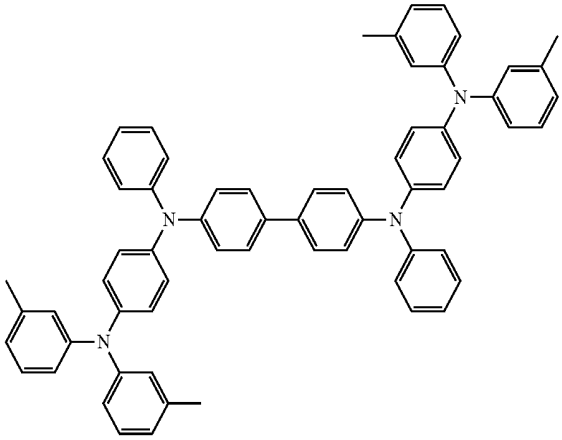
[0427] 5.4 g (yield: 46.7%) of Compound 351 was obtained in the same manner as in Synthesis Example 1, except that 2-bromonaphthalene was used instead of Intermediate 1-d of Reaction Scheme 1-11 in Synthesis Example 1.

[0428] MS $[M]^+$: 466

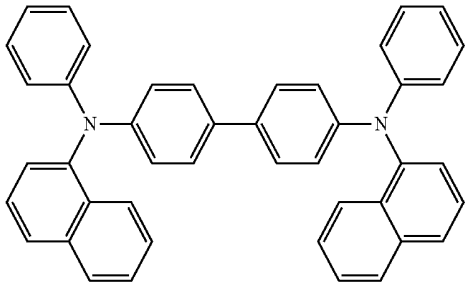
Example 1

[0429] An ITO glass substrate was patterned to have a light-emitting area cut into a size of 2 mm×2 mm, and then, cleaned. After the ITO glass substrate was mounted on a vacuum chamber base that is set to have a base pressure of 1×10^{-6} torr, DNTPD (700 Å), NPB (300 Å), Compound 3:RD-1 (at a weight ratio of 90:10) (300 Å), Compound ET16:Liq (at a weight ratio of 1:1) (250 Å), Liq (10 Å), and Al (1,000 Å) were sequentially cast on the ITO glass substrate in the stated order, thereby manufacturing an organic light-emitting device on the ITO glass substrate.

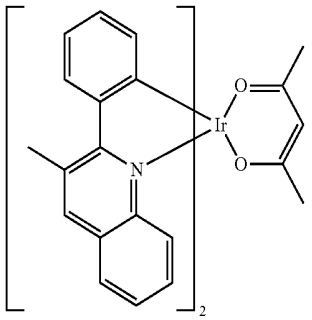
[0430] The structures of DNTPD, NPB, RD-1, Compound ET16, and Liq are as follows:



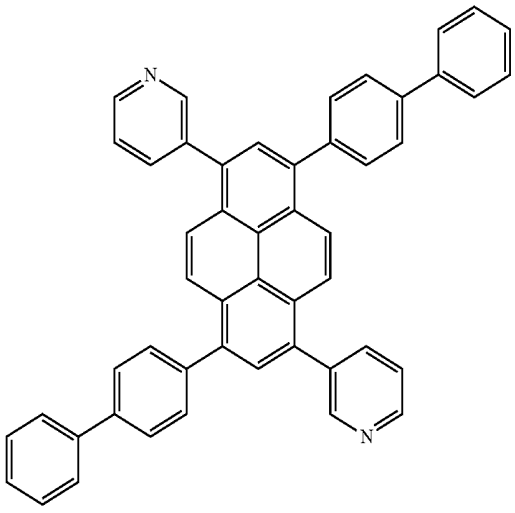
DNTPD



NPB



RD-1



ET16

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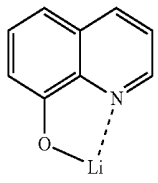


Liq

Example 2

[0431] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 4 was used instead of Compound 3 in the formation of the emission layer.

Example 3

[0432] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 7 was used instead of Compound 3 in the formation of the emission layer.

Example 4

[0433] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 9 was used instead of Compound 3 in the formation of the emission layer.

Example 5

[0434] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 10 was used instead of Compound 3 in the formation of the emission layer.

Example 6

[0435] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 15 was used instead of Compound 3 in the formation of the emission layer.

Example 7

[0436] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 16 was used instead of Compound 3 in the formation of the emission layer.

Example 8

[0437] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 24 was used instead of Compound 3 in the formation of the emission layer.

Example 9

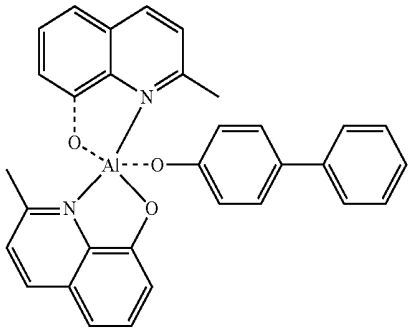
[0438] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 33 was used instead of Compound 3 in the formation of the emission layer.

Example 10

[0439] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 165 was used instead of Compound 3 in the formation of the emission layer.

Comparative Example 1

[0440] An organic light-emitting device was manufactured in the same manner as in Example 1, except that BAlq was used instead of Compound 3 in the formation of the emission layer emission layer.



BAlq

Evaluation Example 1

[0441] Driving voltages, luminance, color coordinates, and lifespans (T95) of the organic light-emitting devices prepared in Examples 1 to 10 and Comparative Example 1 were evaluated, and the results are shown in Table 1below. The expression "T95" as used herein refers to time required to reach 95% of luminance when initial luminance is considered as 100% (with respect to a current density of 3,000 cd/m^2).

TABLE 1

Division	Host	Driving voltage (V)	Luminance (Cd/m^2)	Efficiency (Cd/A)	CIEx	CIEy	T95 (hour)
Comparative Example 1	BAlq	6.2	1470	14.7	0.665	0.334	40
Example 1	Compound 3	4.3	2500	25.0	0.665	0.334	540
Example 2	Compound 4	4.1	2010	20.1	0.665	0.334	500
Example 3	Compound 7	4.1	2290	22.9	0.665	0.334	400
Example 4	Compound 9	4.7	2500	25.0	0.666	0.333	500
Example 5	Compound 10	4.4	2510	25.1	0.665	0.334	540

TABLE 1-continued

Division	Host	Driving voltage (V)	Luminance (Cd/m^2)	Efficiency (Cd/A)	CIEx	CIEy	T95 (hour)
Example 6	Compound 15	4.2	2430	24.3	0.664	0.335	380
Example 7	Compound 16	3.7	2120	21.2	0.665	0.334	370
Example 8	Compound 24	4.3	2470	24.7	0.665	0.334	400
Example 9	Compound 33	4.1	2130	21.3	0.665	0.335	320
Example 10	Compound 165	4.1	2000	20.0	0.665	0.335	400

[0442] Referring to Table 1, it was confirmed that the organic light-emitting devices of Examples 1 to 10 had excellent driving voltages, luminance, and lifespan than compared to those of the organic light-emitting device of Comparative Example 1.

[0443] As described above, according to one or more of the above example embodiments, an organic light-emitting device including a heterocyclic compound may provide low driving voltage, high luminance, high efficiency, and long lifespan characteristics.

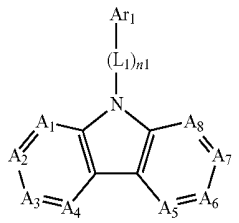
[0444] It should be understood that example embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each example embodiment should typically be considered as available for other similar features or aspects in other example embodiments.

[0445] While one or more example embodiments have been described with reference to the accompanying drawing, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

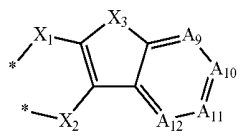
What is claimed is:

1. A heterocyclic compound represented by Formula 1:

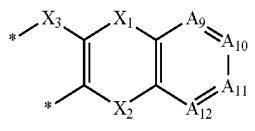
Formula 1



Formula 1a



Formula 1b



wherein, in Formulae 1, 1a, and 1b,

A_1 is selected from CR_1 and nitrogen (N), A_2 is selected from CR_2 and N, A_3 is selected from CR_3 and N, A_4 is selected from CR_4 and N, A_5 is selected from CR_5 and N, A_6 is selected from CR_6 and N, A_7 is selected from CR_7 and N, A_8 is selected from CR_8 and N, A_9 is selected from CR_9 and N, A_{10} is selected from CR_{10} and N, A_{11} is selected from C_{R11} and N, and A_{12} is selected from CR_{12} and N;

two adjacent groups among A_1 to A_8 are each independently connected with a respective * of Formulae 1a or 1b to form a ring, wherein each * is a carbon atom of Formula 1;

L_1 is selected from a substituted or unsubstituted C_3-C_{10}cycloalkylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene, a substituted or unsubstituted C_3-C_{10} cycloalkenylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene, a substituted or unsubstituted C_6-C_{60} arylene, a substituted or unsubstituted C_1-C_{60} heteroarylene, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

n1 is selected from 0, 1, 2, 3, and 4;

X_1 is selected from a single bond, $C(R_{13})(R_{14})$, $N(R_{13})$, O, S, Se, Te, Po, $Si(R_{13})(R_{14})$, $Ge(R_{13})(R_{14})$, $P(R_{13})$, $P(R_{13})(=O)$, C=O, and $B(R_{13})$;

X_2 is selected from a single bond, $C(R_{15})(R_{16})$, $N(R_{15})$, O, S, Se, Te, Po, $Si(R_{15})(R_{16})$, $Ge(R_{15})(R_{16})$, $P(R_{15})$, $P(R_{15})(=O)$, C=O, and $B(R_{15})$;

X_3 is selected from $C(R_{17})(R_{18})$, $N(R_{17})$, O, S, Se, Te, Po, $Si(R_{17})(R_{18})$, $Ge(R_{17})(R_{18})$, $P(R_{17})$, $P(R_{17})(=O)$, C=O, and $B(R_{17})$;

Ar_1 and R_1 to R_{18} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsub-

stituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group;

two adjacent groups among R_1 to R_{18} are optionally connected with each other to form a ring;

at least one substituent of the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{11})(Q_{12})$, $—Si(Q_{13})(Q_{14})(Q_{15})$, and $—B(Q_{16})(Q_{17})$;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{21})(Q_{22})$, $—Si(Q_{23})(Q_{24})(Q_{25})$, and $—B(Q_{26})(Q_{27})$; and

$—N(Q_{31})(Q_{32})$, $—Si(Q_{33})(Q_{34})(Q_{35})$, and $—B(Q_{36})(Q_{37})$,

wherein Q_{11} to Q_{17}, Q_{21} to Q_{27} and Q_{31} to Q_{37} are each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_1-C_{60} alkoxy group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

2. The heterocyclic compound of claim **1**, wherein L_1 is selected from:

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spirofluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, a benzofuranylene group, a benzothiophenylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, and a dibenzocarbazolylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a

heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, a benzofuranylene group, a benzothiophenylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, and a dibenzocarbazolylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, and an imidazopyridinyl group.

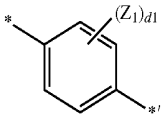
3. The heterocyclic compound of claim **1**, wherein L_1 is selected from:

a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group and a triazinylene group; and

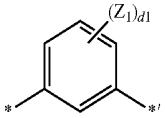
a naphthylene group, a pyridinylene group, a pyrimidinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a benzoquinazolinylene group and a triazinylene group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group.

4. The heterocyclic compound of claim **1**, wherein L_1 is selected from groups represented by Formulae 3-1 to 3-22:

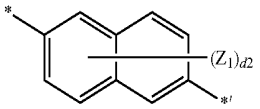
3-1



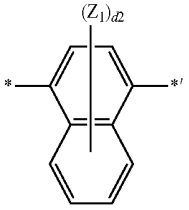
3-2



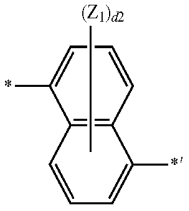
3-3



3-4



3-5



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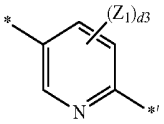
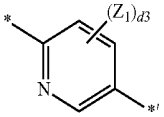
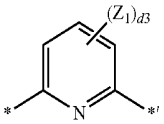
3-6



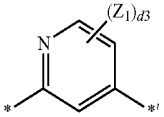
3-7



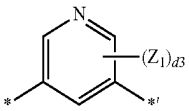
3-8



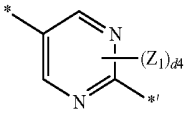
3-9



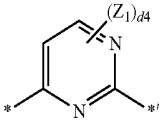
3-10



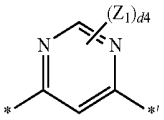
3-11



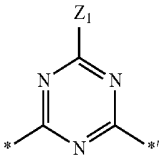
3-12



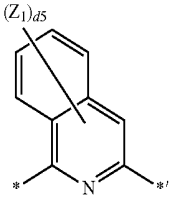
3-13



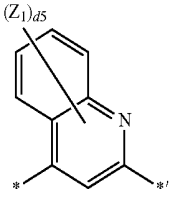
3-14



3-15



3-16



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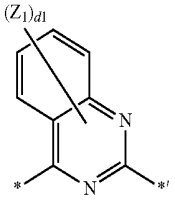
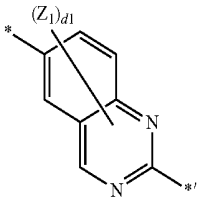
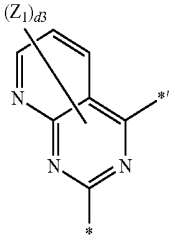
3-17



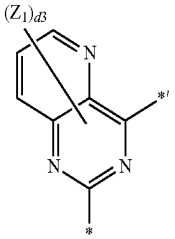
3-18



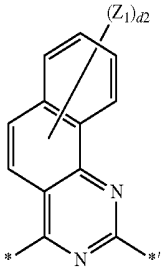
3-19



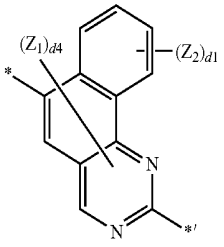
3-20



3-21



3-22



wherein, in Formulae 3-1 to 3-22,

Z_1 and Z_2 are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

d1 is selected from 1, 2, 3, and 4;

d2 is selected from 1, 2, 3, 4, 5, and 6;

d3 is selected from 1, 2, and 3;

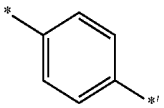
d4 is selected from 1 and 2;

d5 is selected from 1, 2, 3, 4, and 5; and

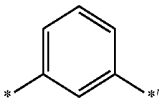
* and *' are each independently a binding site to a neighboring atom.

5. The heterocyclic compound of claim **1**, wherein L_1 is selected from groups represented by Formulae 4-1 to 4-22:

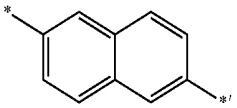
4-1



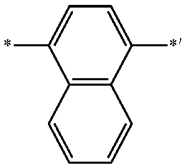
4-2



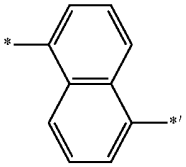
4-3



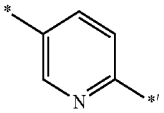
4-4



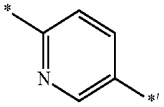
4-5



4-6



4-7



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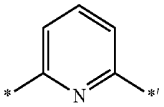

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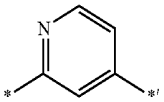

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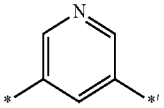

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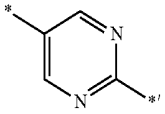

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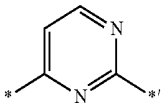

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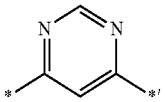

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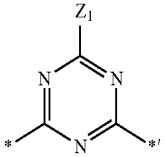

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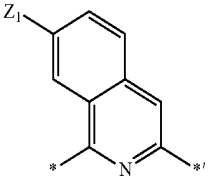

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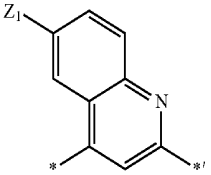

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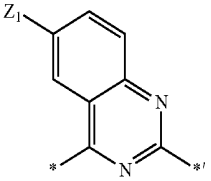

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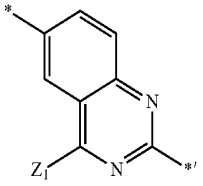

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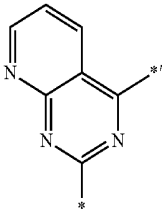

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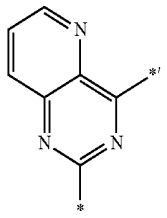

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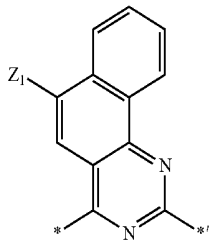
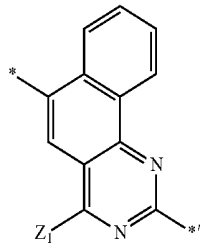


4-22



wherein, in Formulae 4-1 to 4-22,

Z_1 is selected from a hydrogen, a deuterium, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

* and *' are each independently a binding site to a neighboring atom.

6. The heterocyclic compound of claim **1**, wherein n is selected from 0, 1, and 2.

7. The heterocyclic compound of claim **1**, wherein X_1 and X_2 are each independently selected from a single bond, oxygen (O), and sulfur (S).

8. The heterocyclic compound of claim **1**, wherein X_3 is selected from $C(R_{17})(R_{18})$ and $N(R_{17})$.

9. The heterocyclic compound of claim **1**, wherein Ar_1 is selected from:

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovaleny group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosililolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosililolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one of a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl

group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

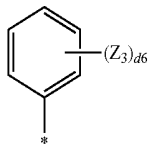
10. The heterocyclic compound of claim **1**, wherein Ar_1 is selected from:

a methyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group; and

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group.

11. The heterocyclic compound of claim **1**, wherein Ar_1 is selected from groups represented by Formulae 5-1 to 5-48:

5-1



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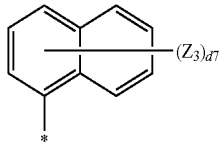

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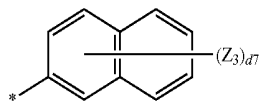

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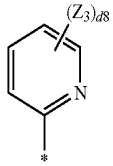

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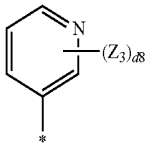

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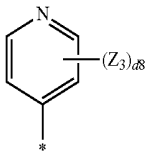

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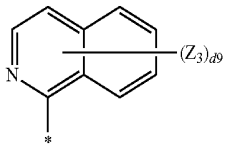

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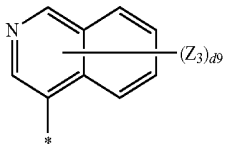

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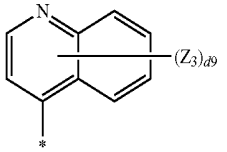

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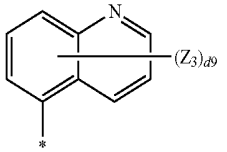

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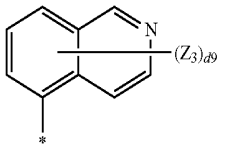

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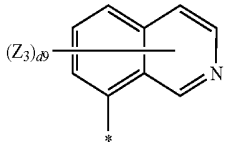

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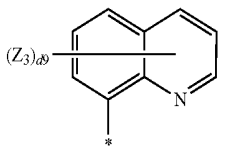

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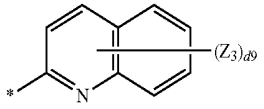

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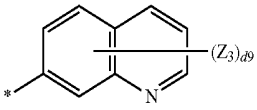

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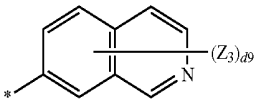

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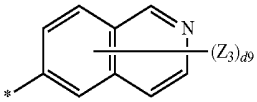

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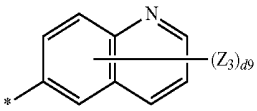

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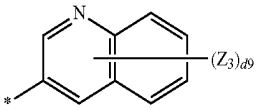

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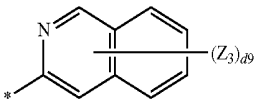

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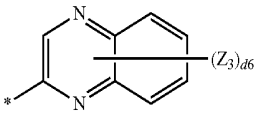

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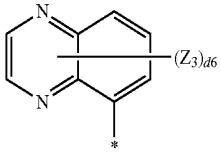

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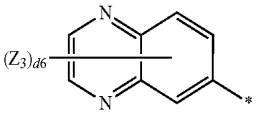

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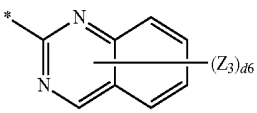

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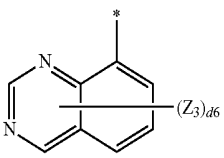

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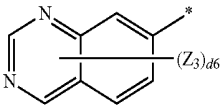

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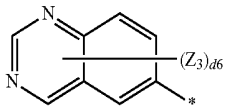
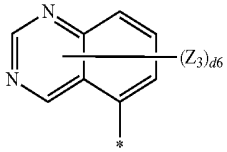
5-27



5-28



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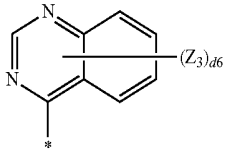

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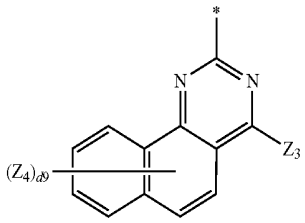

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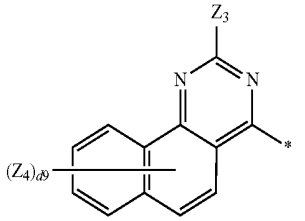

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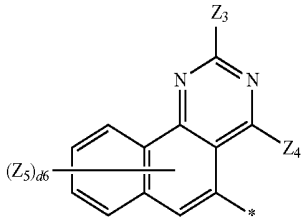

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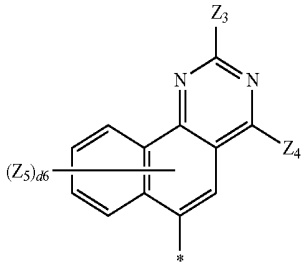

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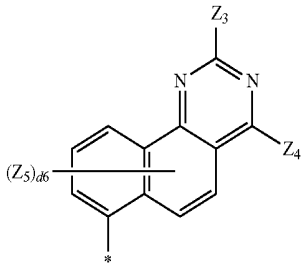

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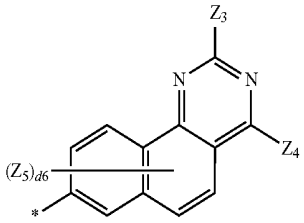

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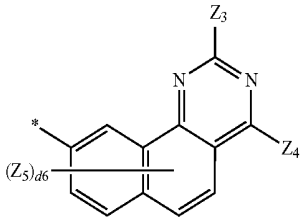

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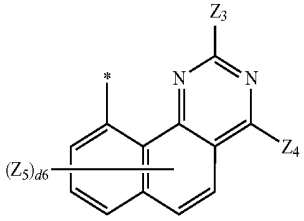

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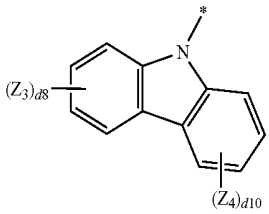

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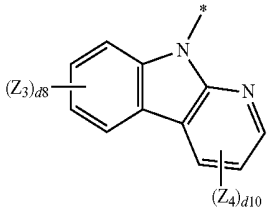

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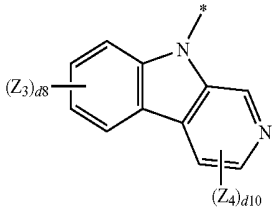

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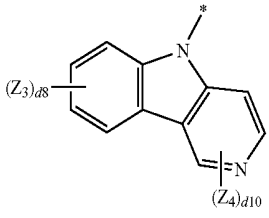

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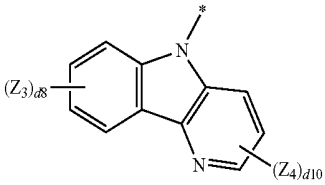
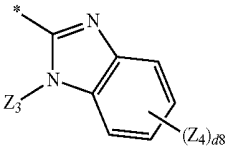
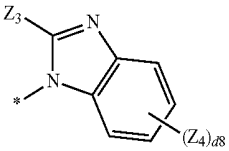
5-42



5-43



5-44



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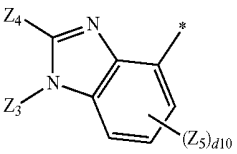

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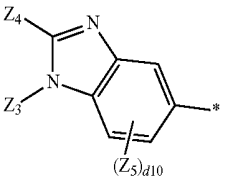

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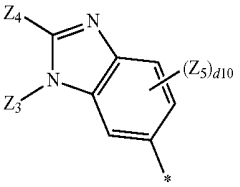
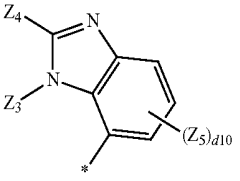


5-48



wherein, in Formulae 5-1 to 5-48,

Z_3 to Z_5 are each independently selected from a hydrogen, a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

d6 is selected from 1, 2, 3, 4, and 5;

d7 is selected from 1, 2, 3, 4, 5, 6, and 7;

d8 is selected from 1, 2, 3, and 4;

d9 is selected from 1, 2, 3, 4, 5, and 6; and

* is a binding site to a neighboring atom.

12. The heterocyclic compound of claim **1**, wherein R_1 to R_{18} are each independently selected from:

a hydrogen, a deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

a phenyl group, a naphthyl group, and a pyridinyl group, each substituted with at least one of a phenyl group, a naphthyl group, and a pyridinyl group.

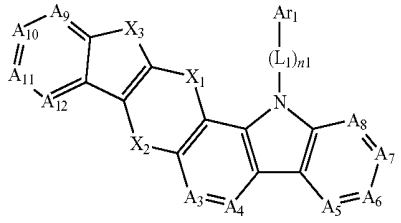
13. The heterocyclic compound of claim **1**, wherein R_1 to R_{18} are each independently selected from:

a hydrogen, a methyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

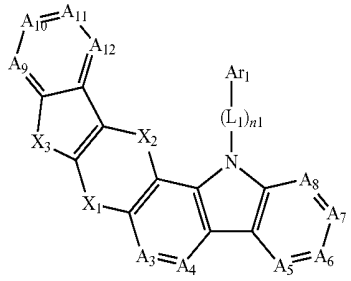
a phenyl group substituted with a phenyl group.

14. The heterocyclic compound of claim **1**, wherein the heterocyclic compound is represented by one of Formulae 1-1 to 1-12:

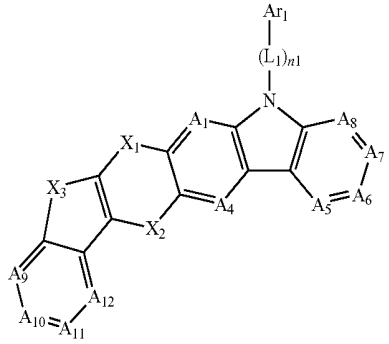
1-1



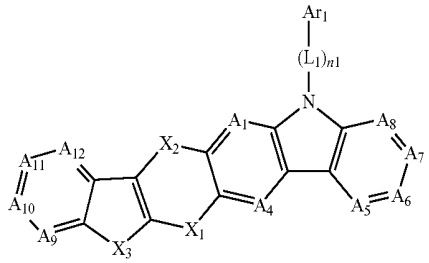
1-2



1-3



1-4



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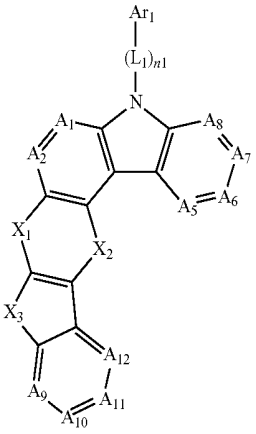
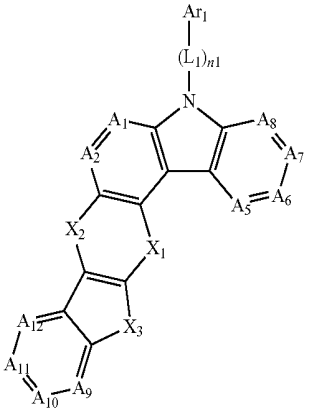
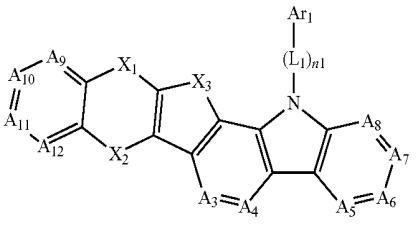
1-5



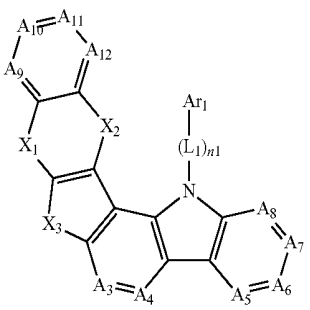
1-6



1-7



1-8



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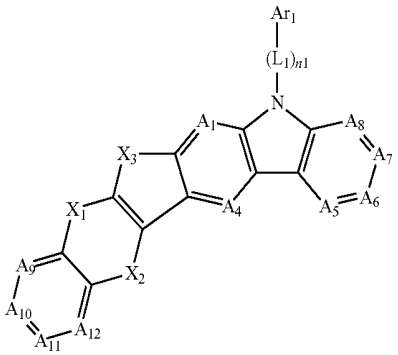
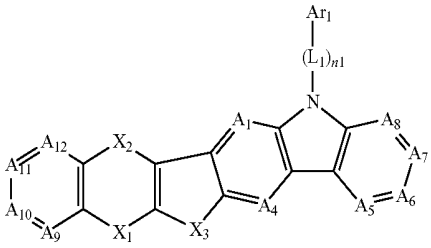
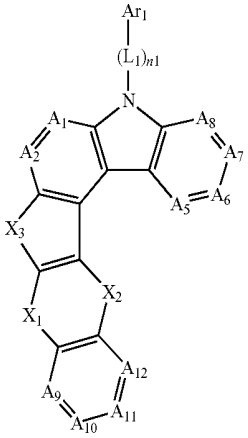
1-9



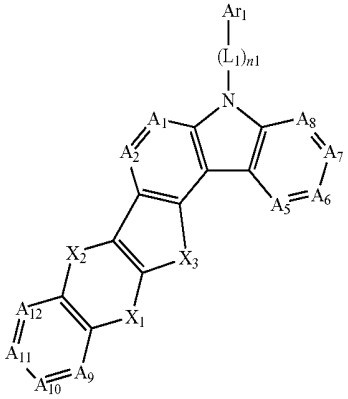
1-10



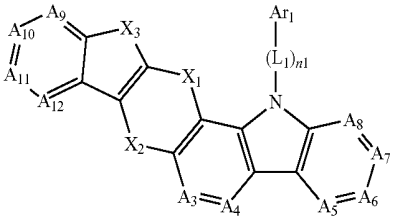
1-11



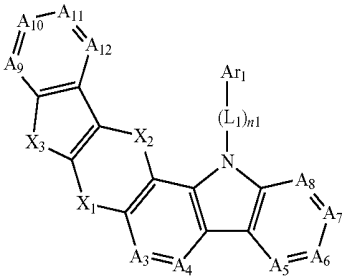
1-12



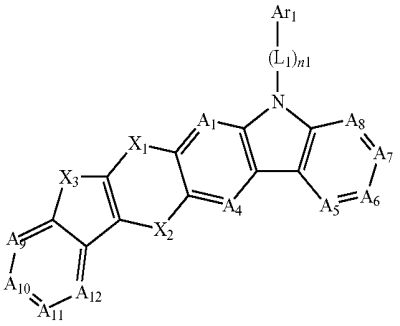
1-1



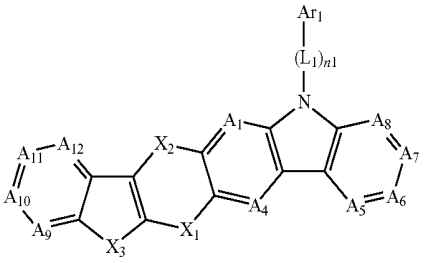
1-2



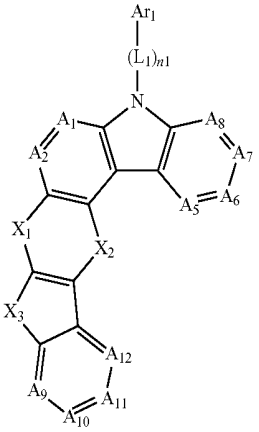
1-3



1-4



1-5



wherein, in Formulae 1-1 to 1-12,

A_1 to A_{12}, L_1, n1, X_1, X_2, X_3, Ar_1 and R_1 to R_{12} are the same as defined in connection with Formulae 1, 1a, and 1b.

15. The heterocyclic compound of claim **1**, wherein the heterocyclic compound is represented by one of Formulae 1-1 to 1-12:

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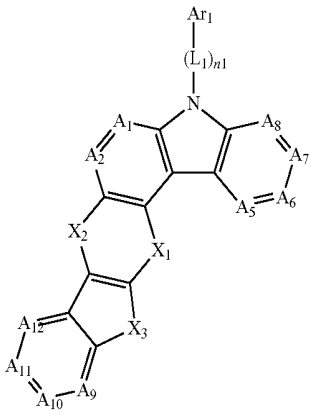
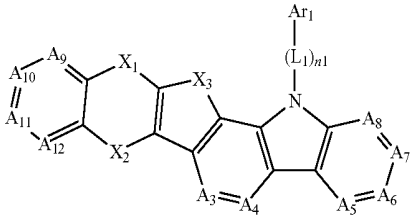
1-6



1-7



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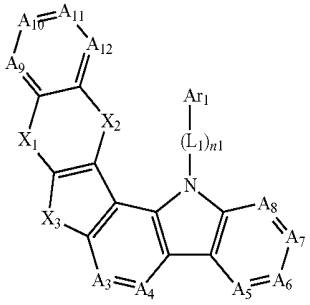

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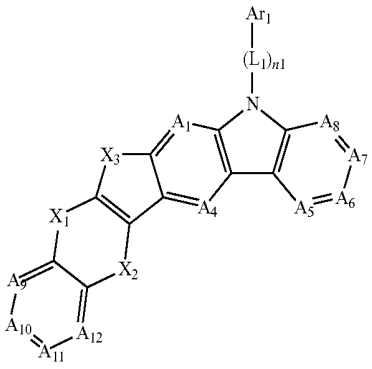
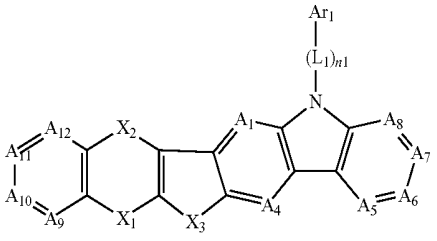


1-10



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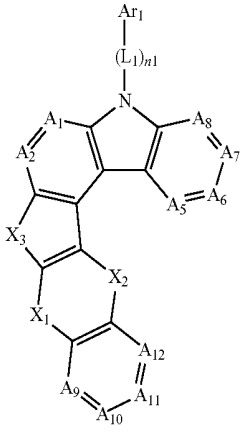
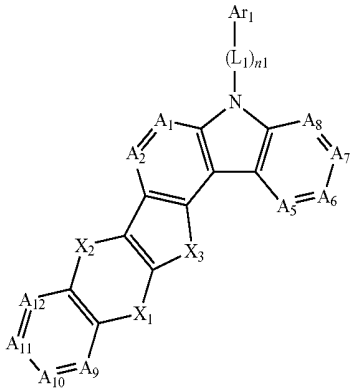
1-11



1-12



wherein, in Formulae 1-1 to 1-12,

A_1 is selected from CR_1 and N, A_2 is selected from CR_2 and N, A_3 is selected from CR_3 and N, A_4 is selected from CR_4 and N, A_5 is selected from CR_5 and N, A_6 is selected from CR_6 and N, A_7 is selected from CR_7 and N, A_8 is selected from CR_8 and N, A_9 is selected from CR_9 and N, A_{10} is selected from CR_{10} and N, A_{11} is selected from CR_{11} and N, and A_{12} is selected from CR_{12} and N;

L_1 is selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene, a substituted or unsubstituted C_3-C_{10} cycloalkenylene, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene, a substituted or unsubstituted C_6-C_{60} arylene, a substituted or unsubstituted C_1-C_{60} heteroarylene, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

n1 is selected from 0, 1, and 2;

X_1 and X_2 are each independently selected from O and S;

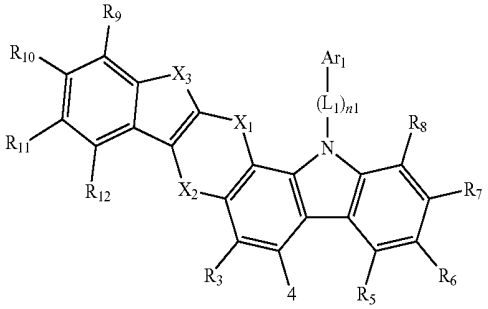
X_3 is selected from $C(R_{17})(R_{18})$ and $N(R_{17})$; and

Ar_1 and R_1 to R_{18} are each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy

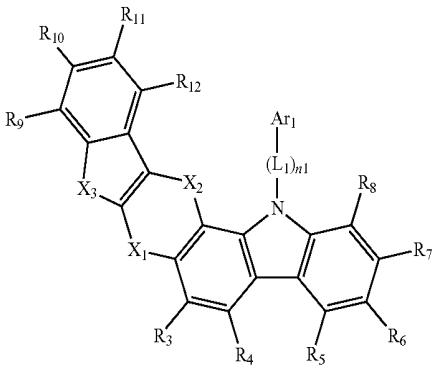
group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

16. The heterocyclic compound of claim **1**, wherein the heterocyclic compound is represented by one of Formulae 1-21 to 1-32:

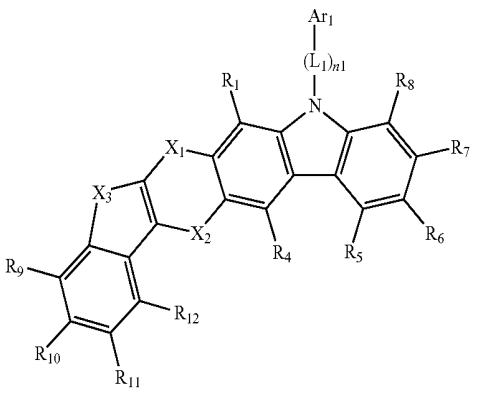
1-21



1-22



1-23



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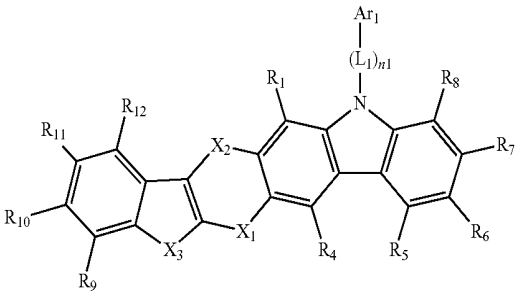
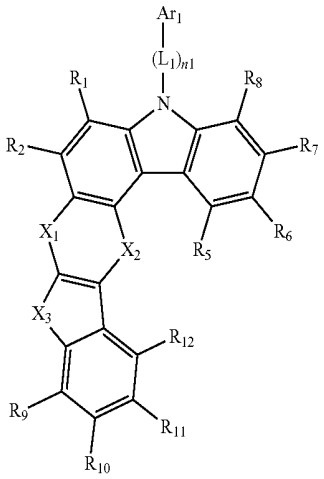
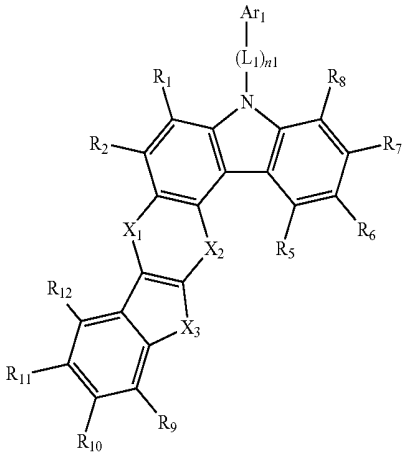
1-24



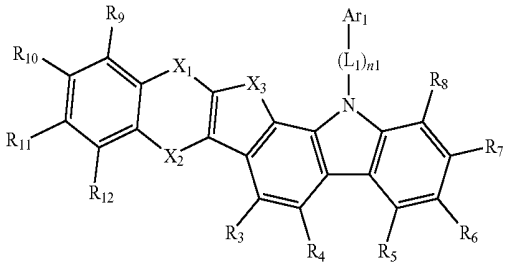
1-25



1-26



1-27



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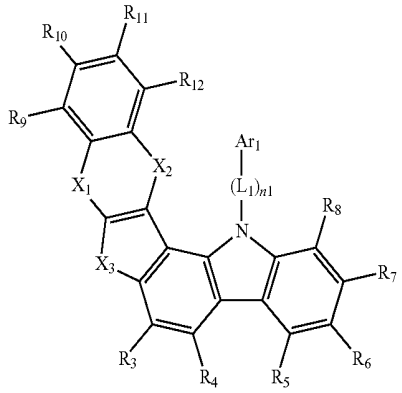
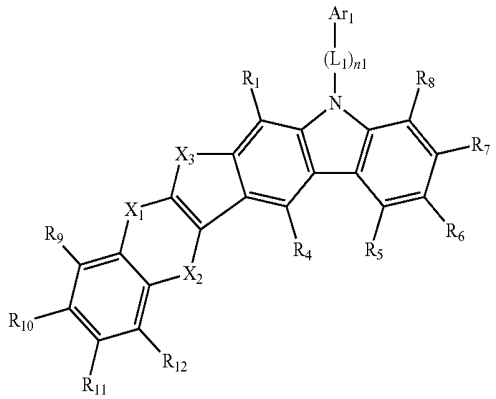
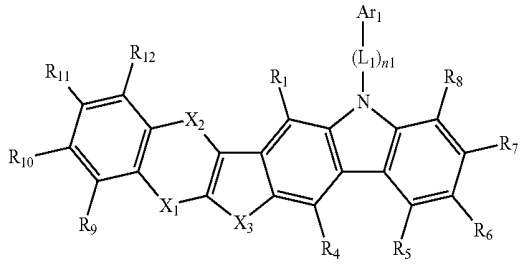
1-28



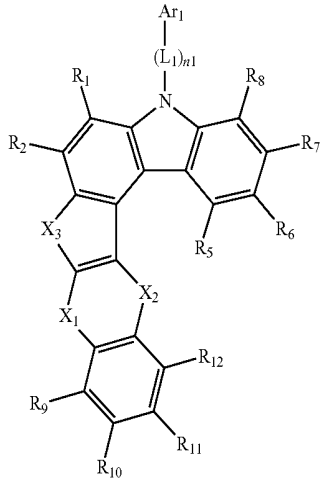
1-29



1-30



1-31



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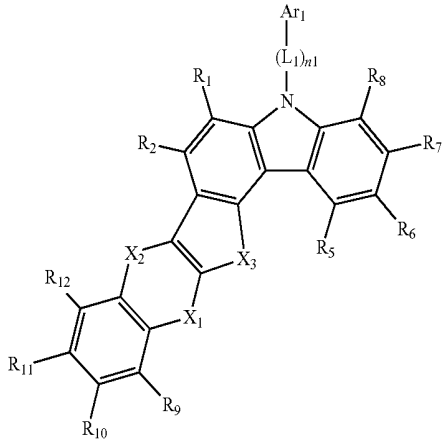
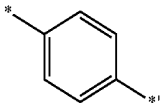
1-32



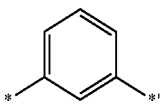
wherein, in Formulae 1-21 to 1-32,

L_1 is selected from groups represented by Formulae 4-1 to 4-18;

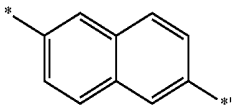
4-1



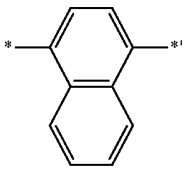
4-2



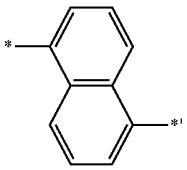
4-3



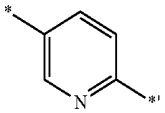
4-4



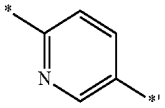
4-5



4-6



4-7



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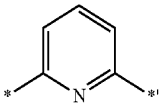
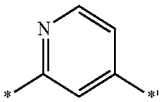
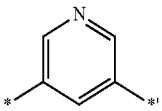
4-8



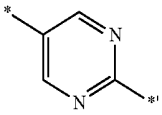
4-9



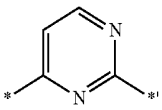
4-10



4-11



4-12



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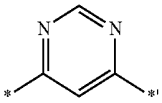
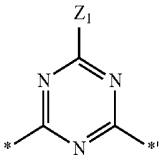
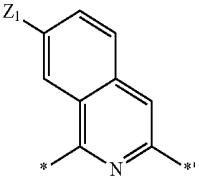


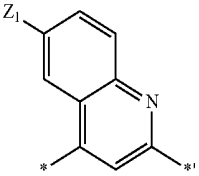
4-14



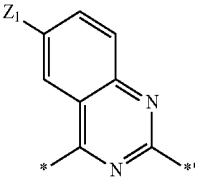
4-15



4-16



4-17



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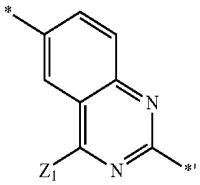
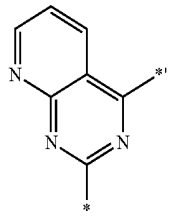
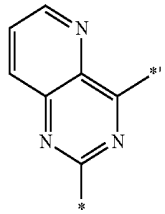
4-18



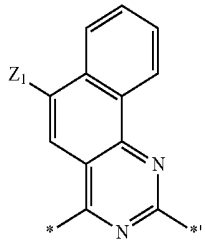
4-19



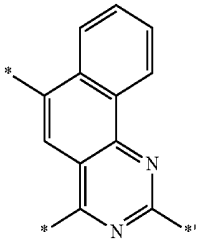
4-20



4-21



4-22



wherein, in Formulae 4-1 to 4-22,

Z_1 is selected from a hydrogen, a deuterium, a methyl group, an ethyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

* and *' are each independently a binding site to a neighboring atom;

n is selected from 0, 1, and 2;

X_1 and X_2 are each independently selected from O and S;

X_3 is selected from $C(R_{17})(R_{18})$ and $N(R_{17})$;

Ar_1 is selected from:

a methyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group; and

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a pyridoindolyl group, a quinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a benzimidazolyl group, and a triazinyl group, each substituted with at least one of a deuterium, —F, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a tert-butyl group, a methoxy group, an ethoxy group, a tert-butoxy group, a phenoxy group, a phenylthio group, a phenyl group, a naphthyl group, and a pyridinyl group;

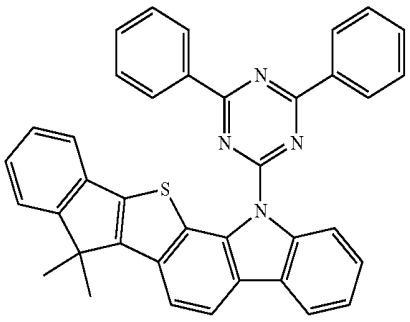
R_1 to R_{18} are each independently selected from:

a hydrogen, a deuterium, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, a phenyl group, a naphthyl group, and a pyridinyl group; and

a phenyl group, a naphthyl group, and a pyridinyl group, each substituted with at least one of a phenyl group, a naphthyl group, and a pyridinyl group.

17. The heterocyclic compound of claim **1**, wherein the heterocyclic compound is any one of Compounds 2 to 580:

2



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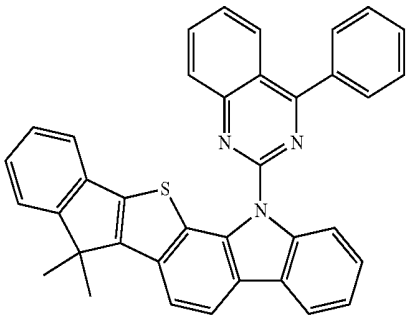

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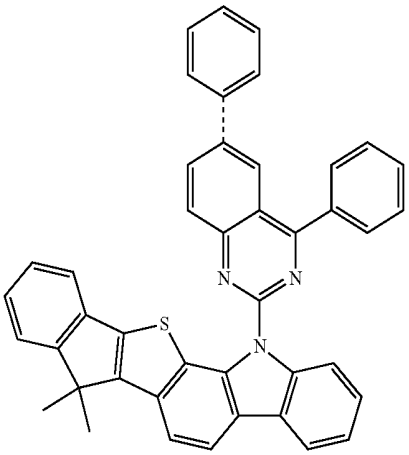
4



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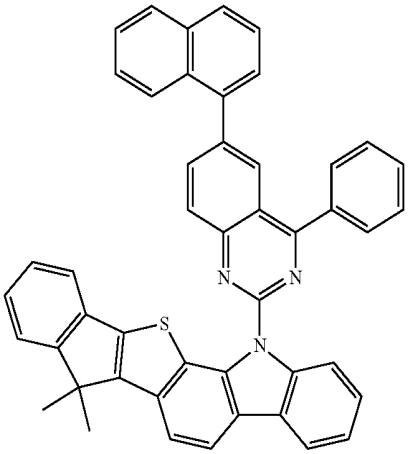

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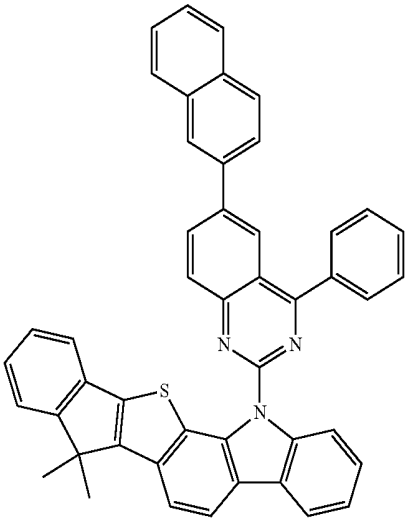

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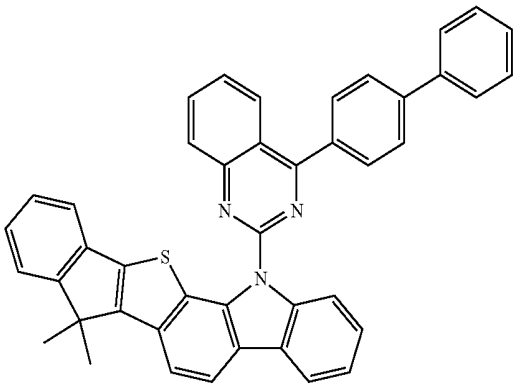
7



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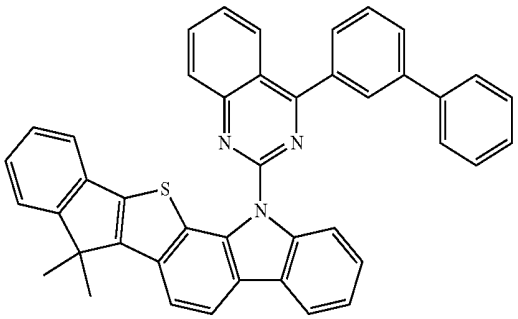
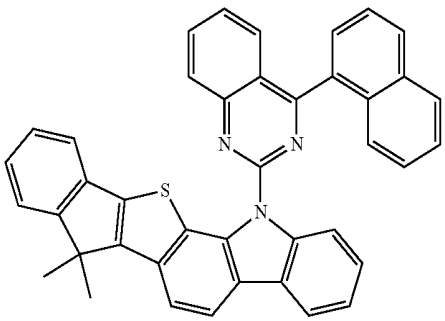


9



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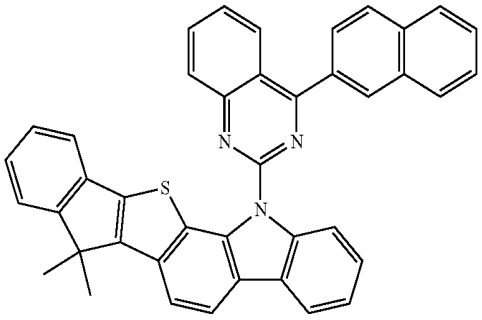

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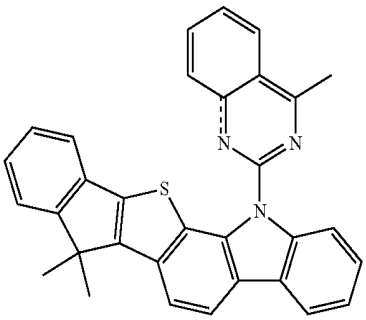

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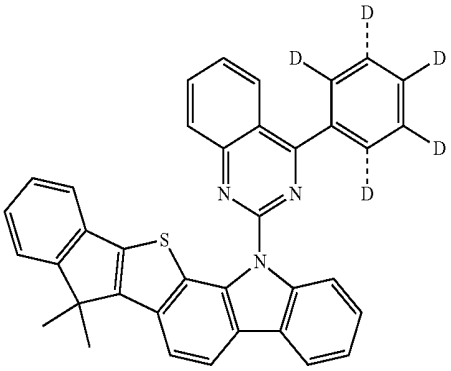

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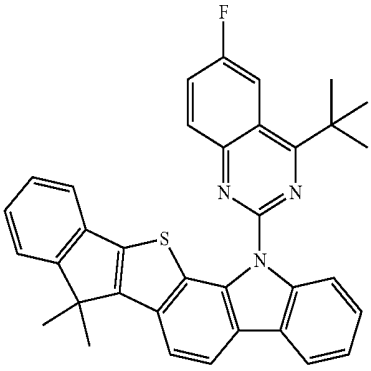

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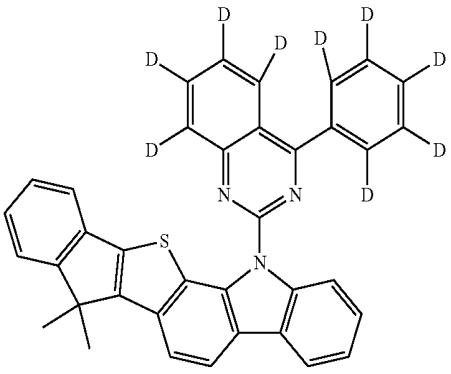

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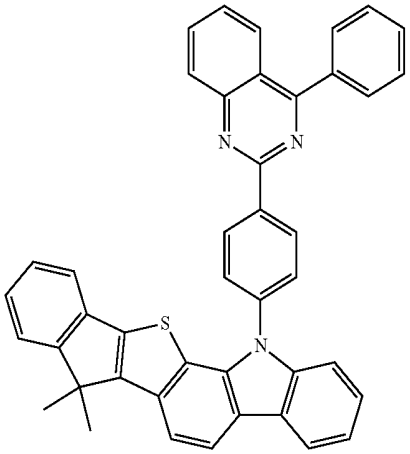

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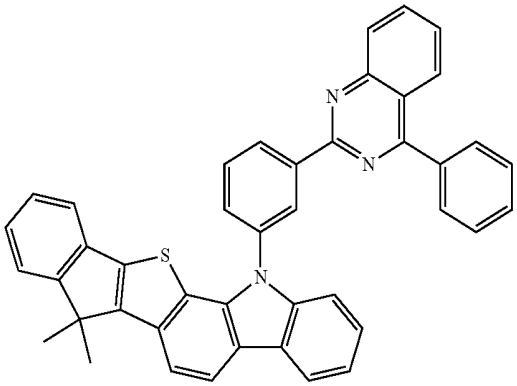

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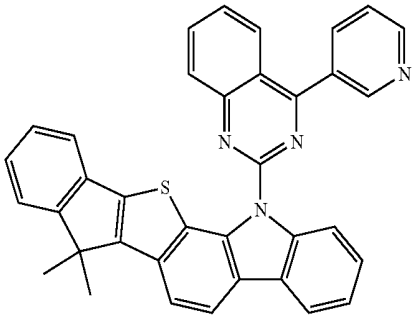

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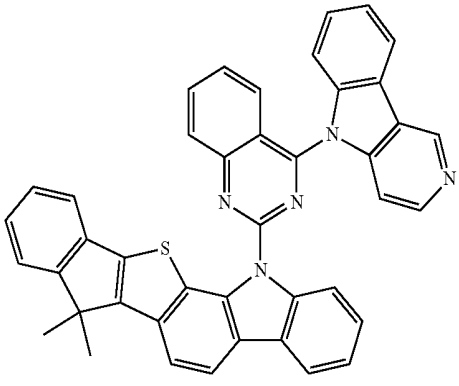

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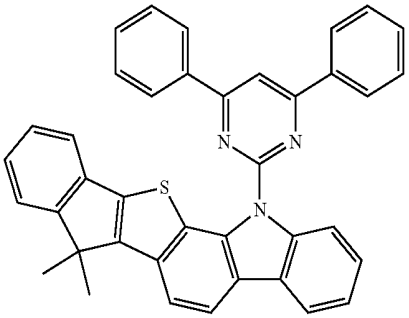

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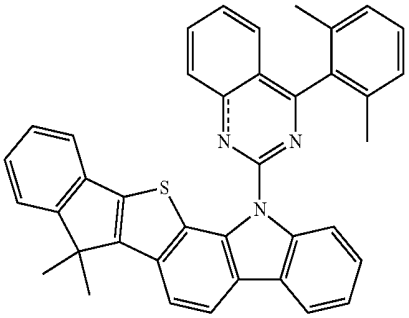

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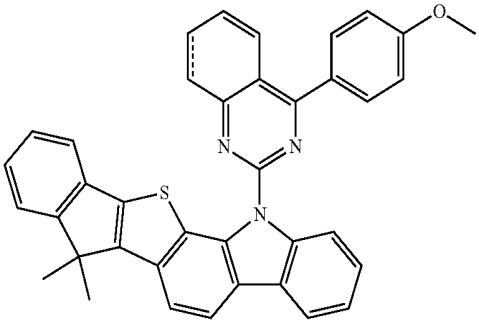

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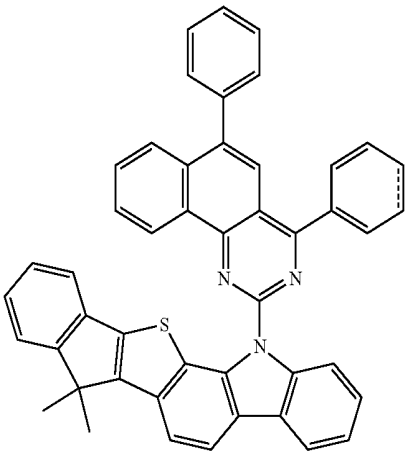

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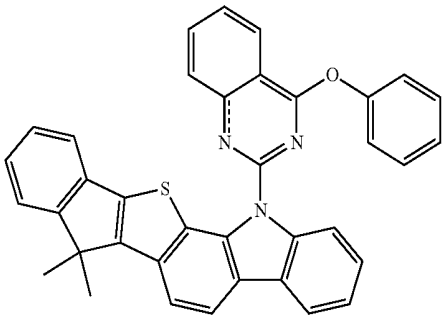

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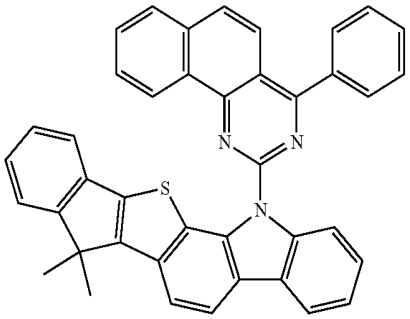

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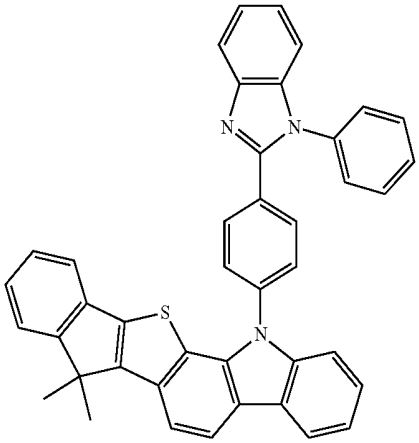

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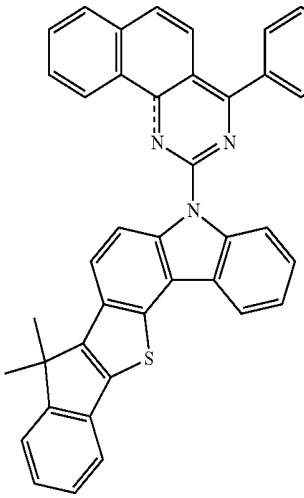

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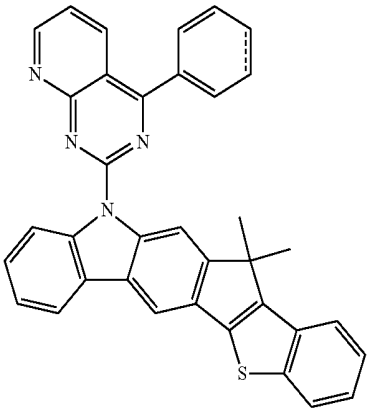

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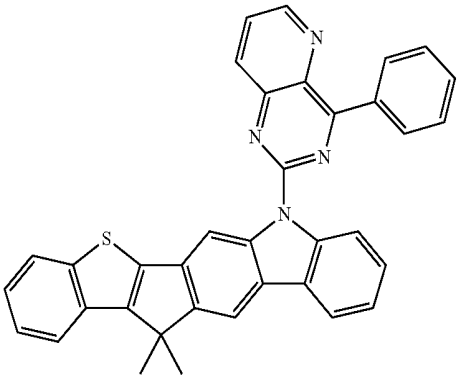

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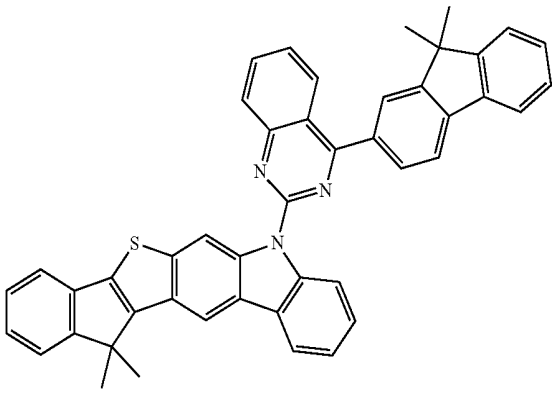

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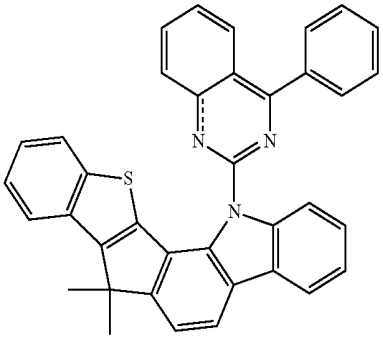

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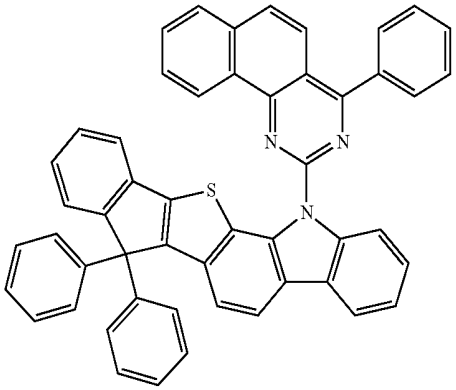

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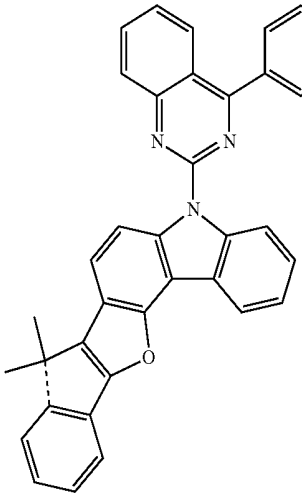

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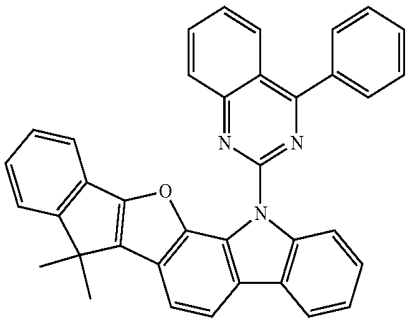

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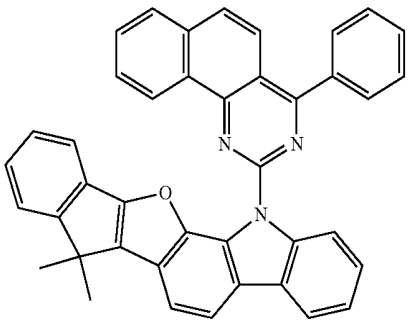

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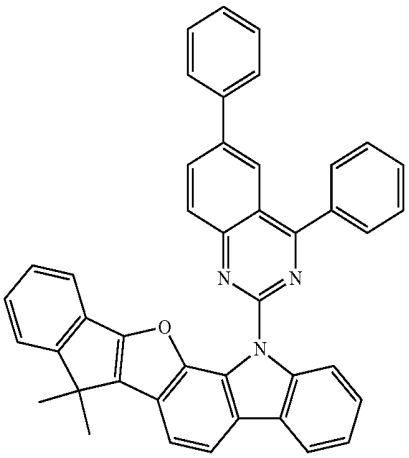

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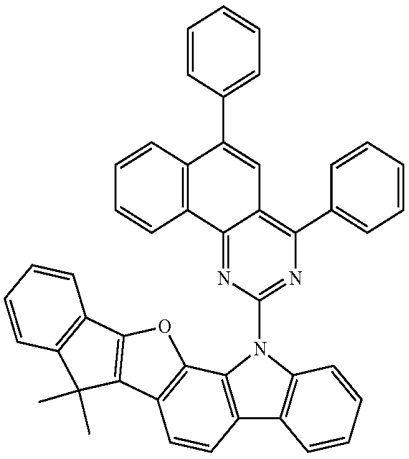

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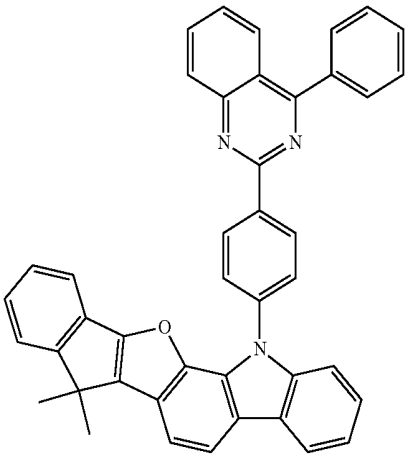

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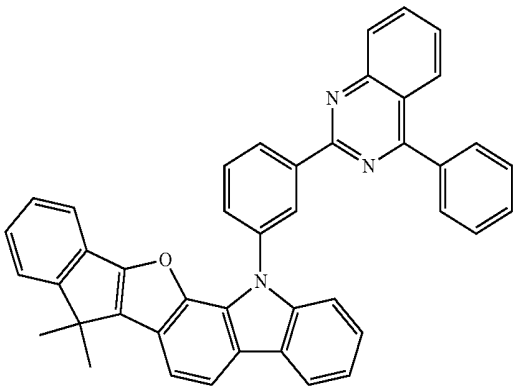

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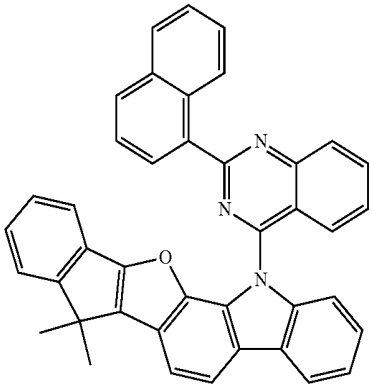

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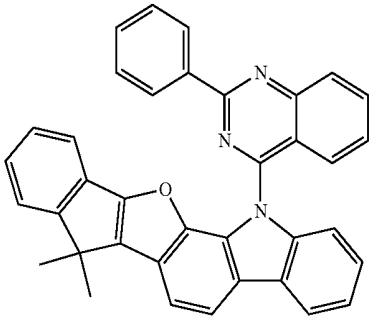

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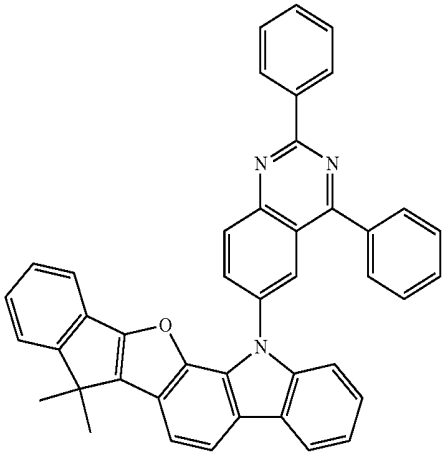

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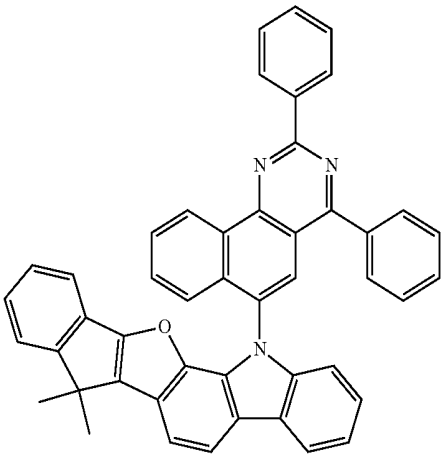

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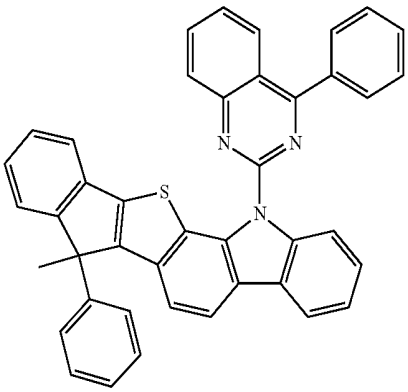

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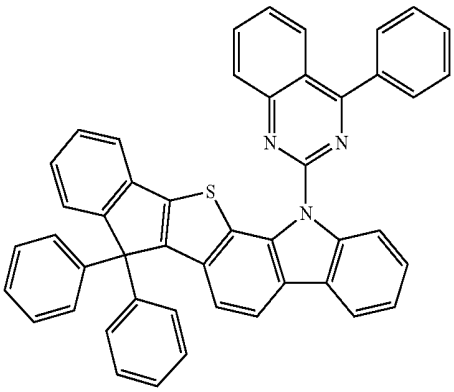

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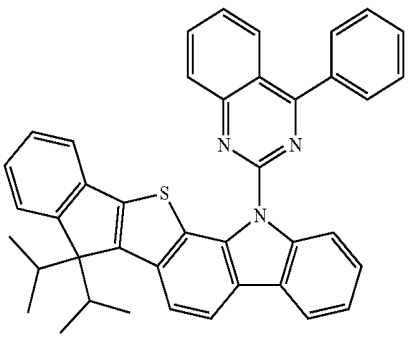

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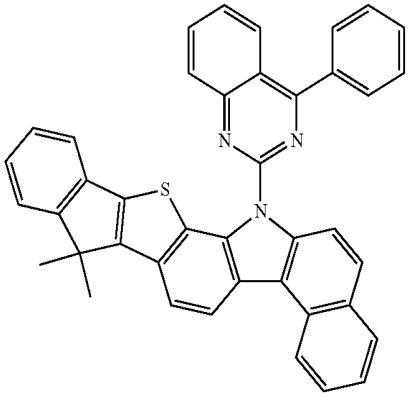

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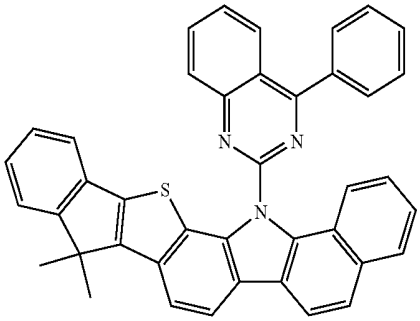

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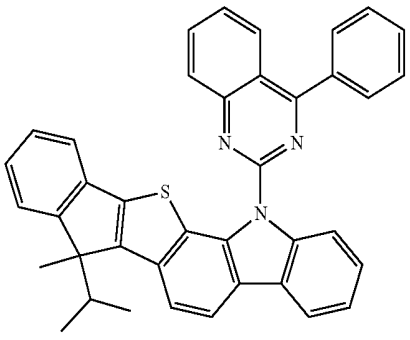

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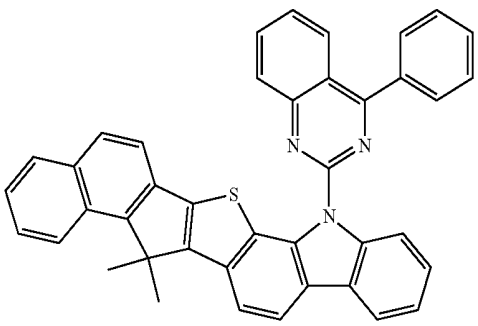

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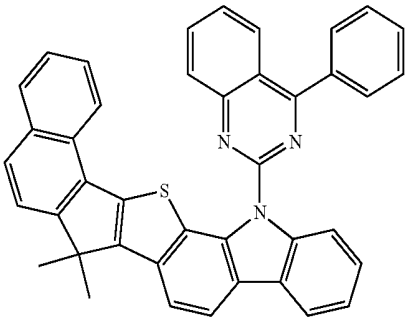

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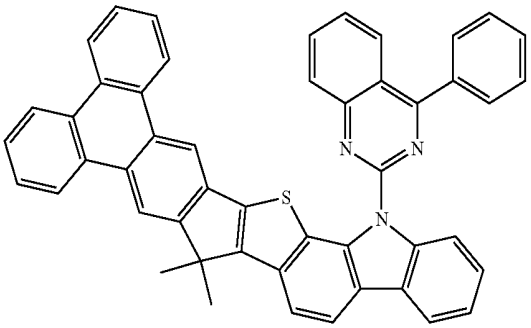

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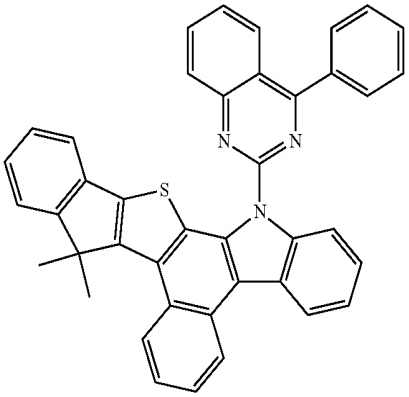

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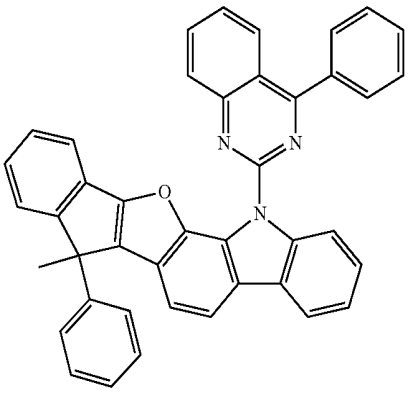

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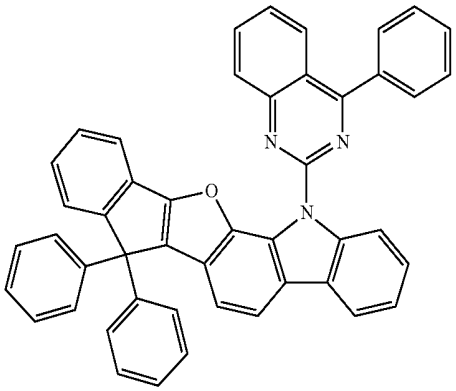

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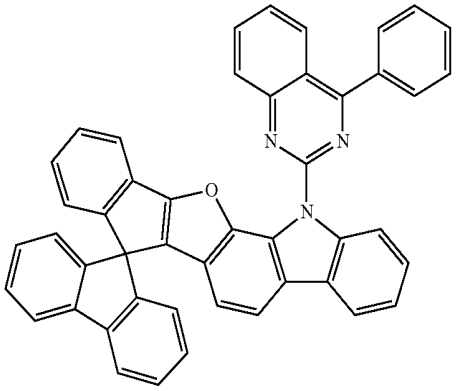

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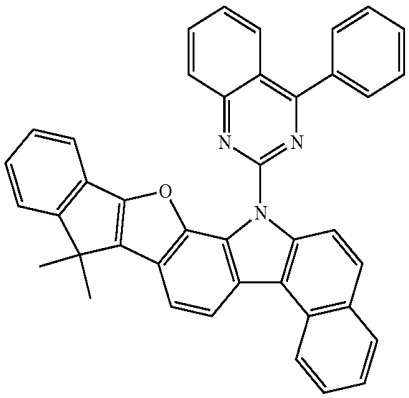

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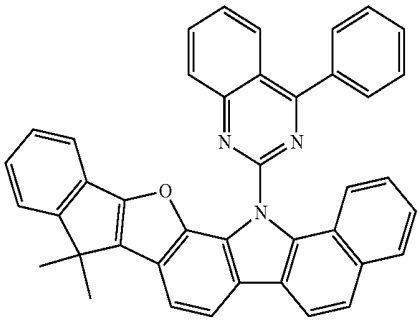

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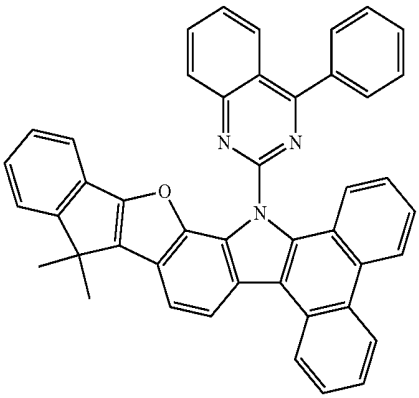

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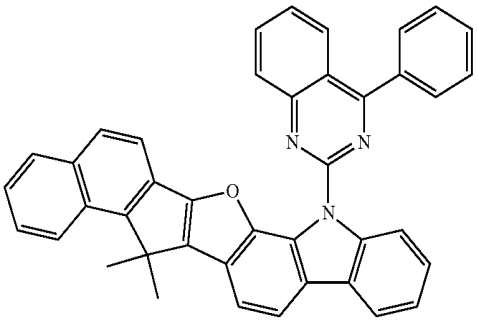

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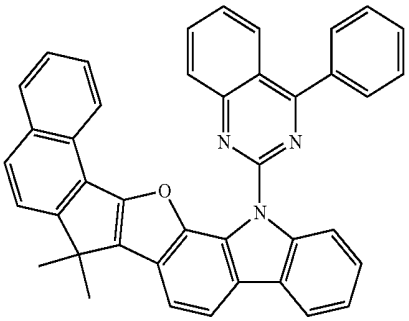

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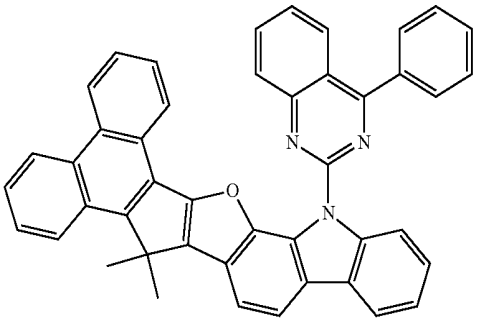

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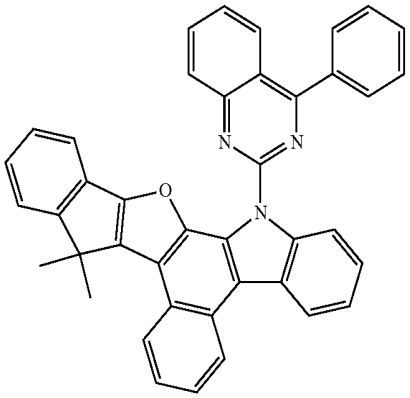

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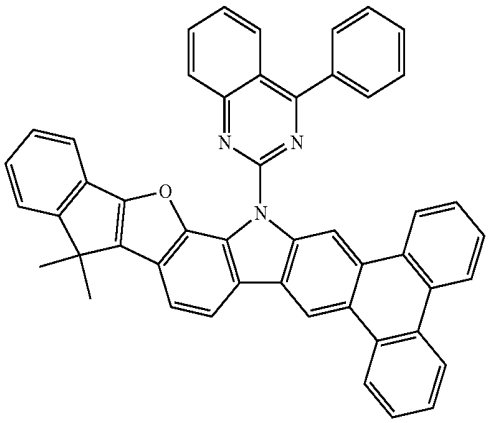

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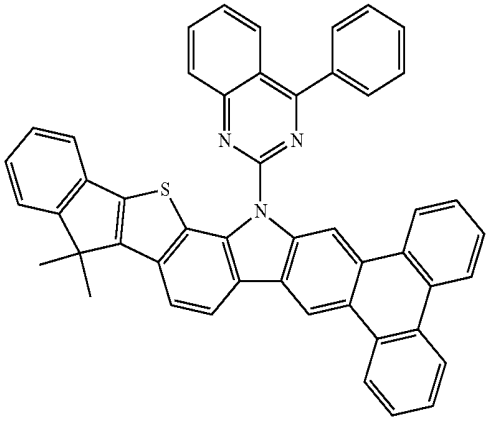

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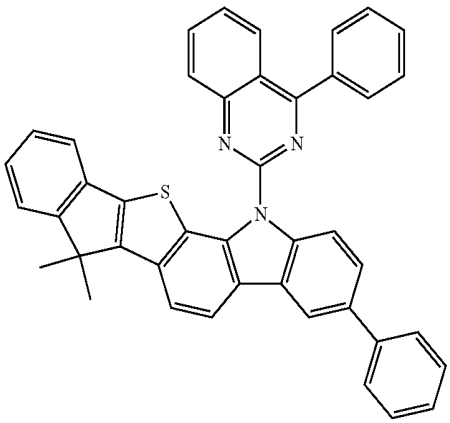

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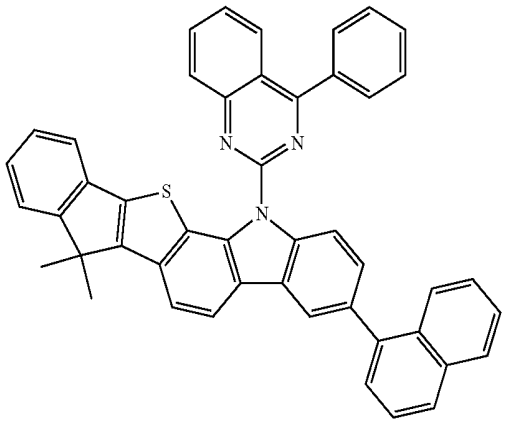

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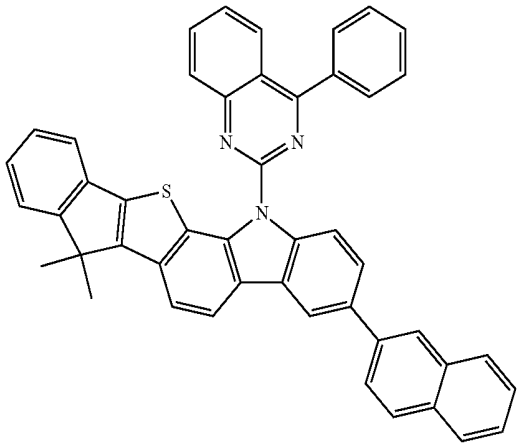

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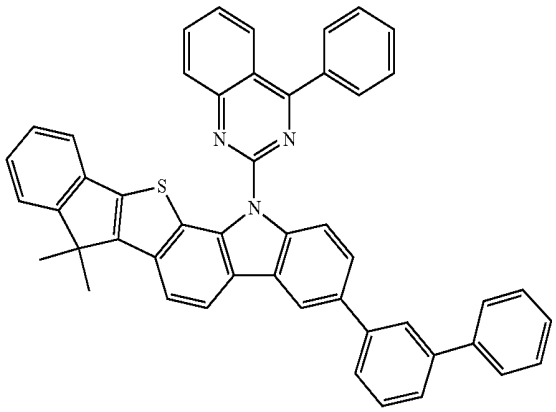

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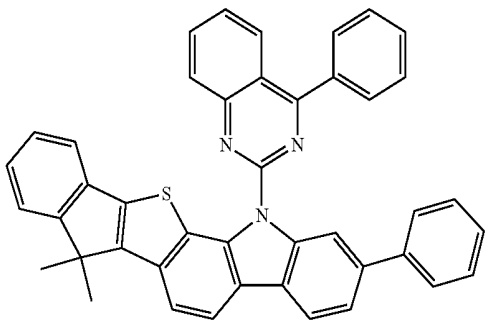

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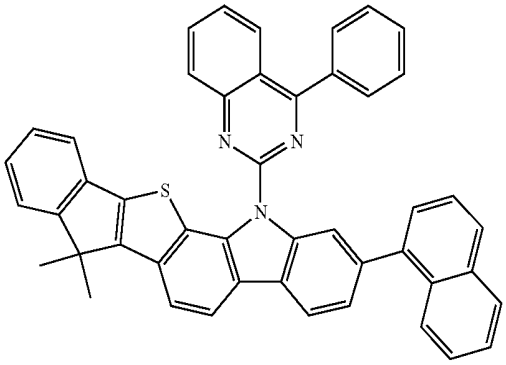

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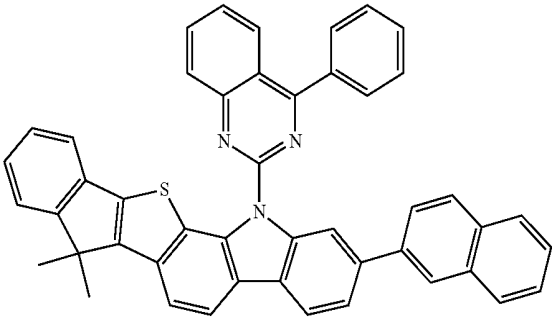

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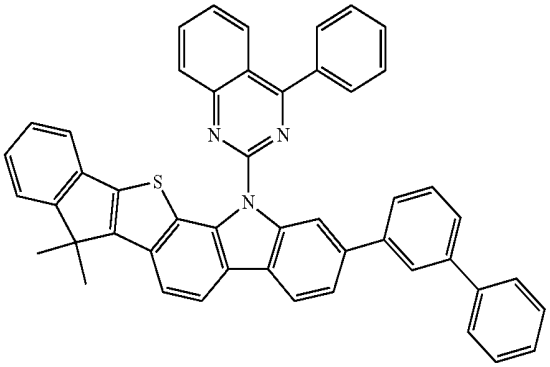

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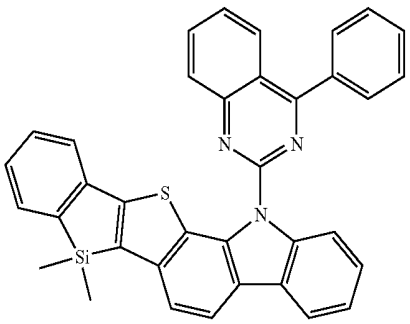

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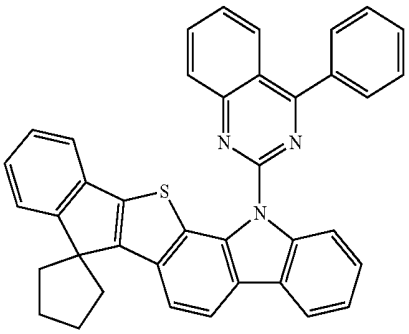

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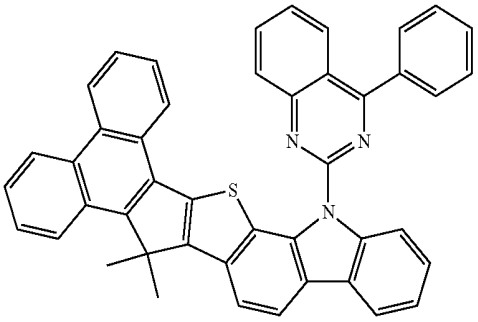

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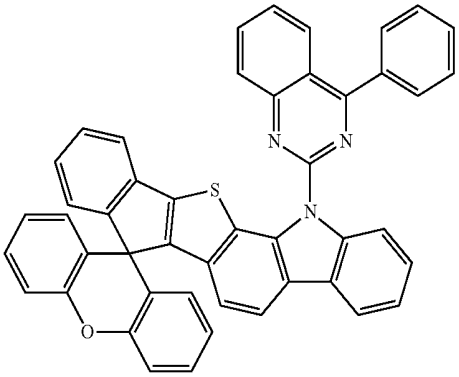

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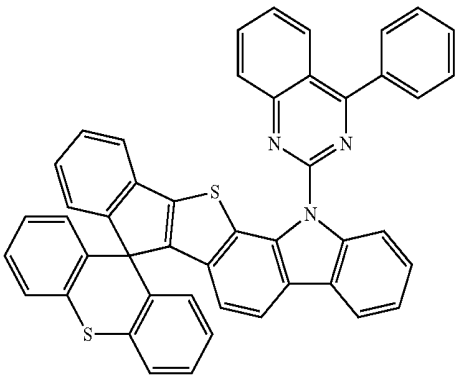

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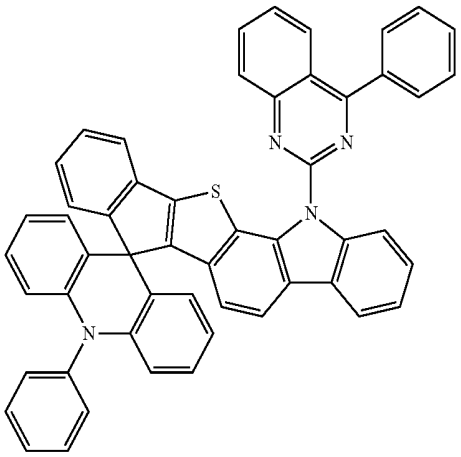

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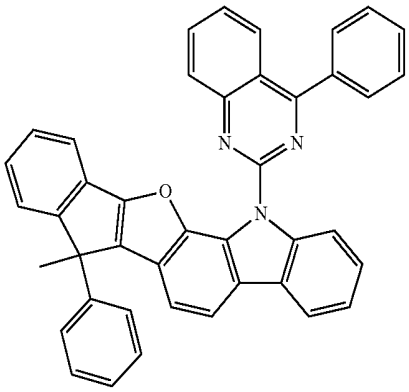

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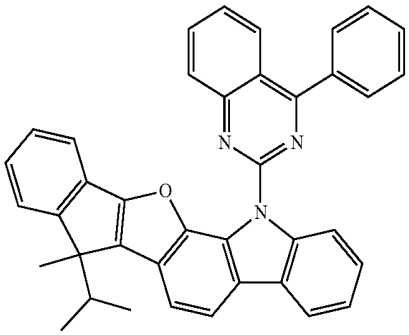

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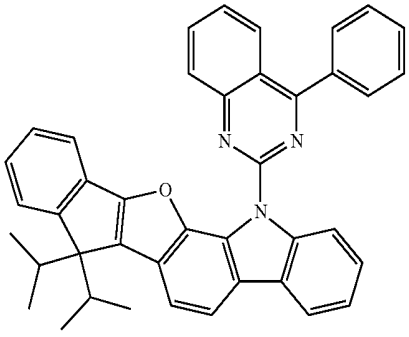

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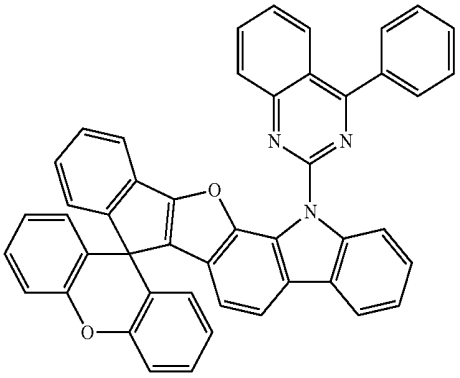

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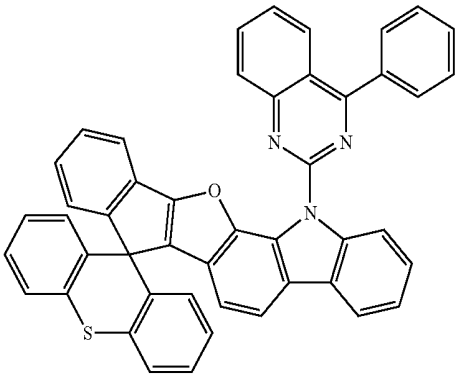

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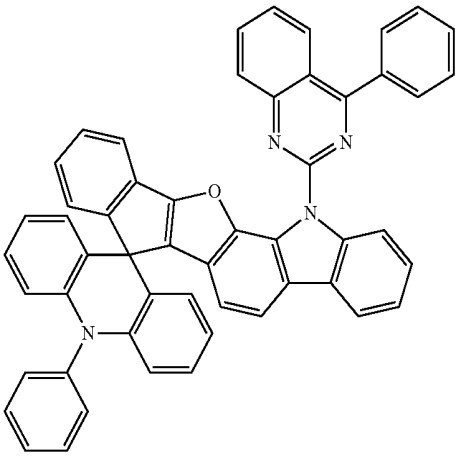

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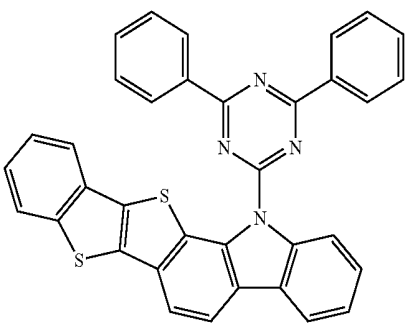

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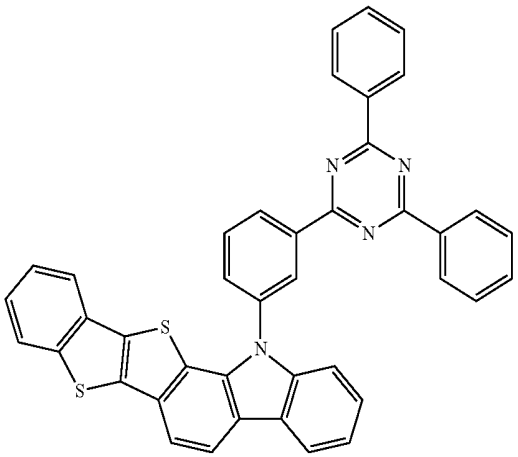

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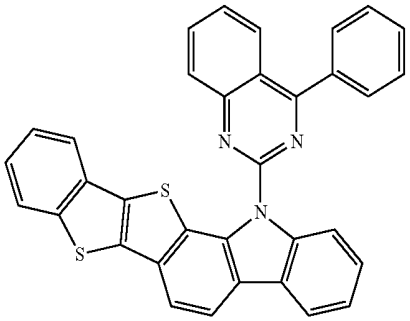

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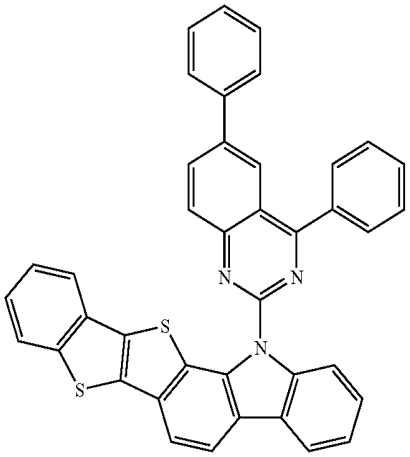

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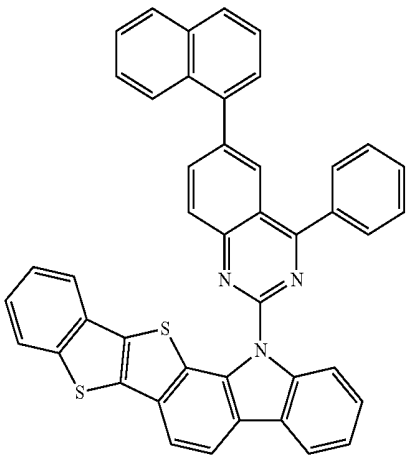

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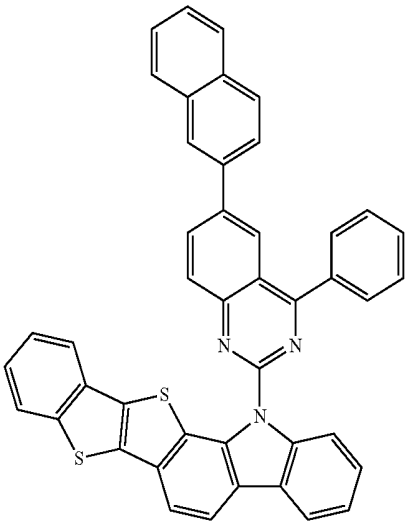

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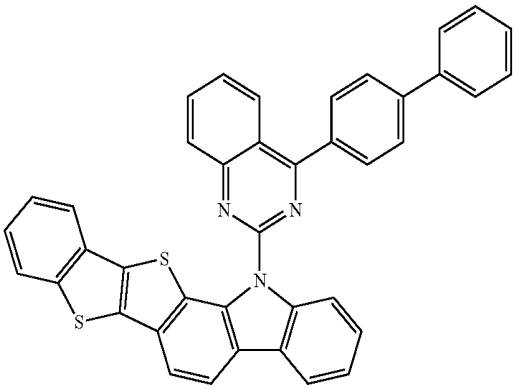

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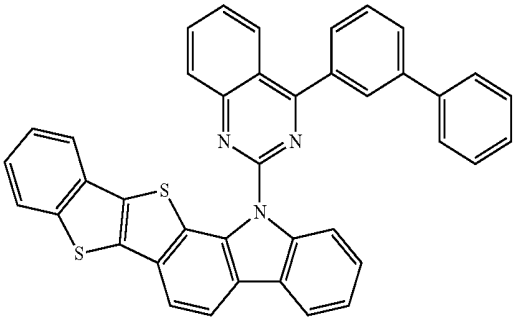

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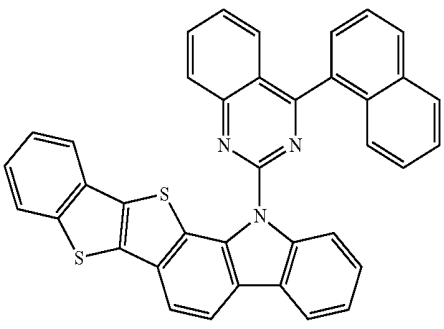

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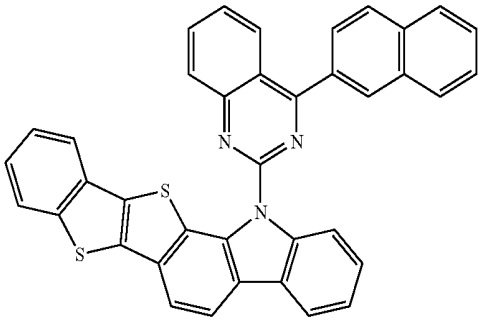

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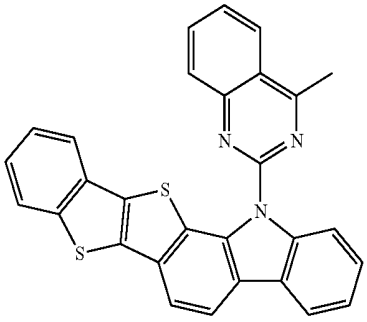

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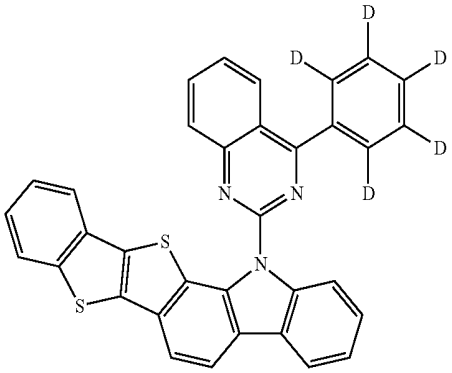

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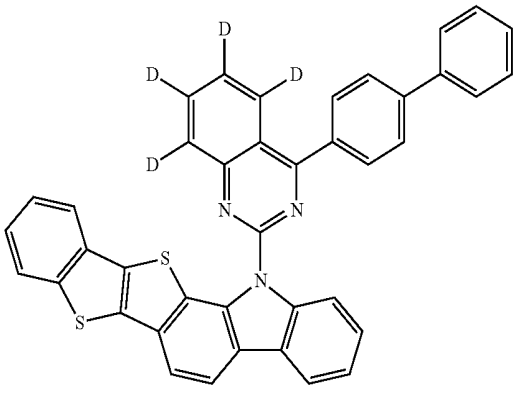

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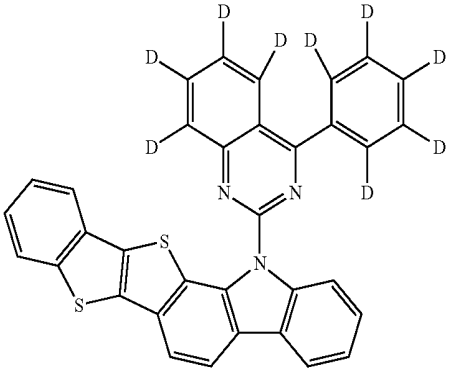

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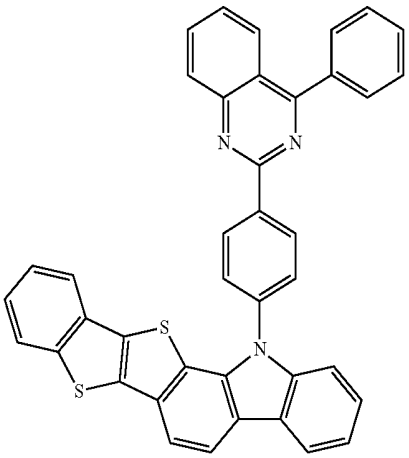

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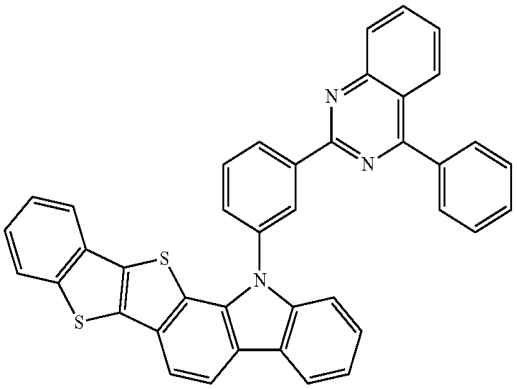

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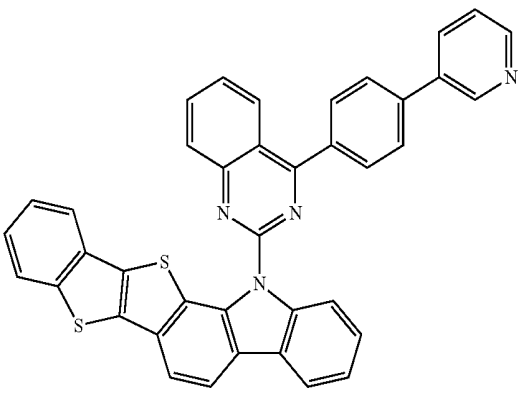

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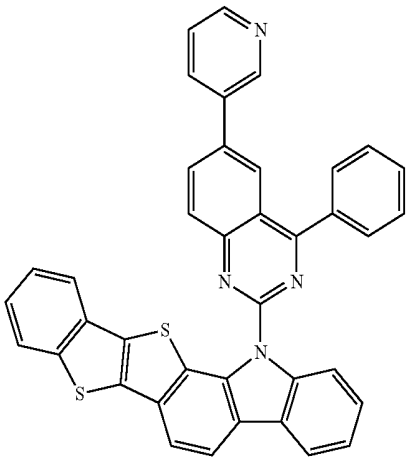

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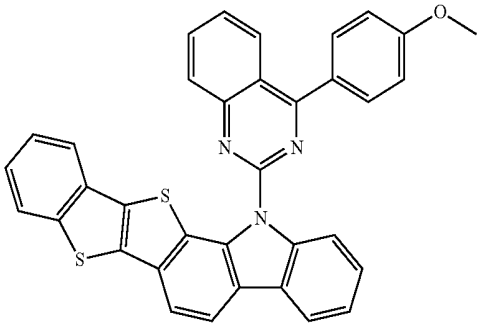

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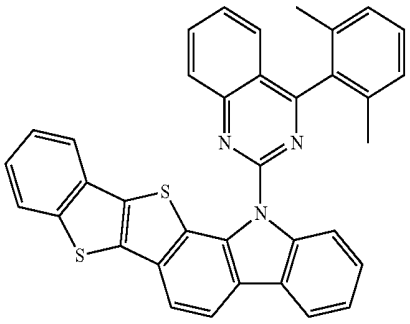

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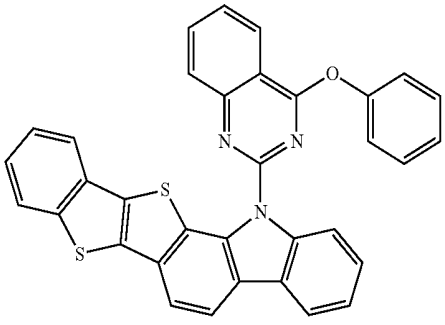

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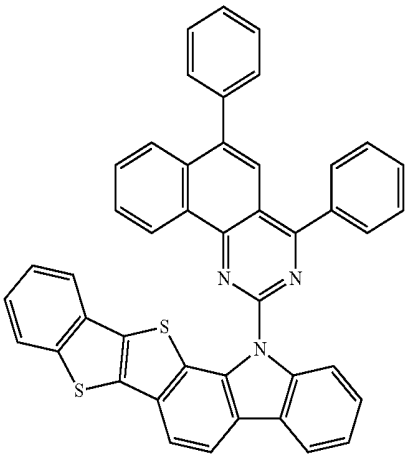

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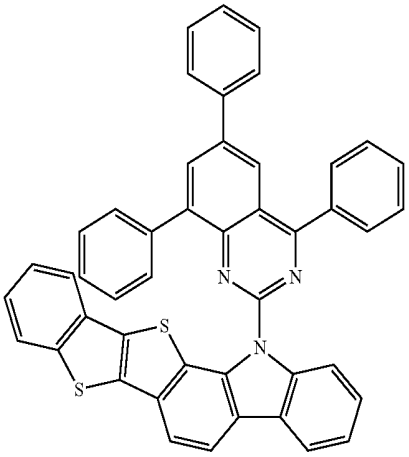

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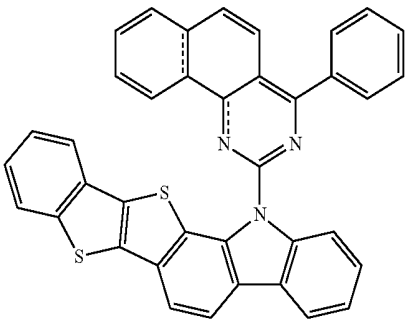

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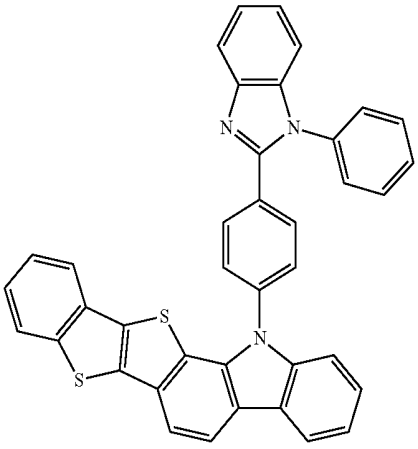

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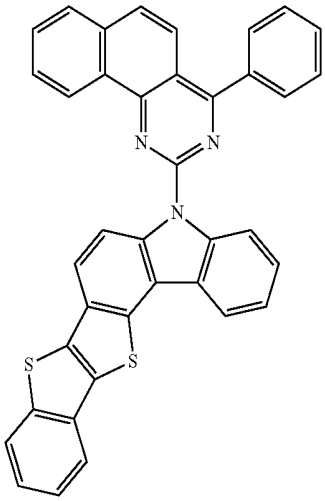

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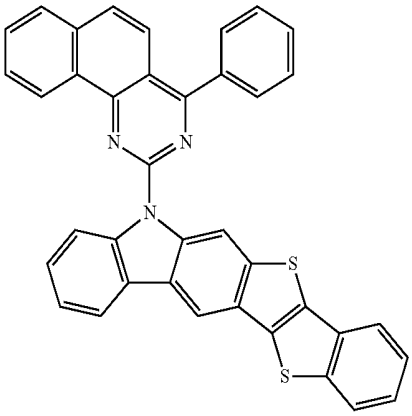

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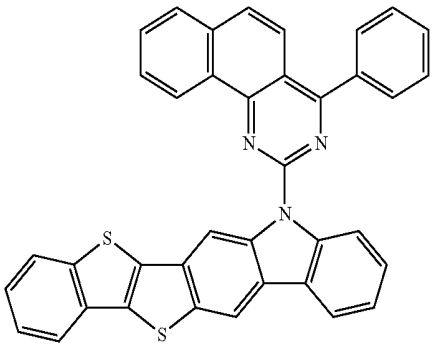

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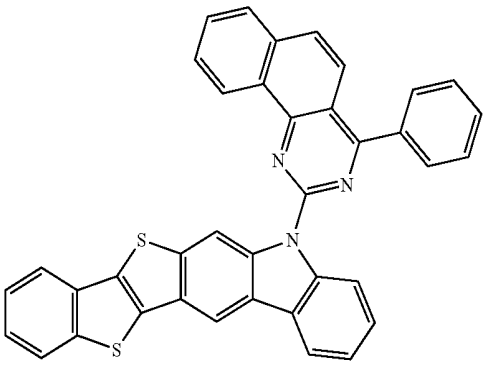

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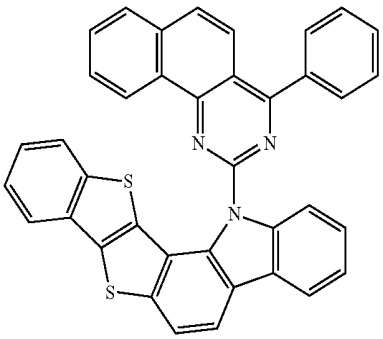

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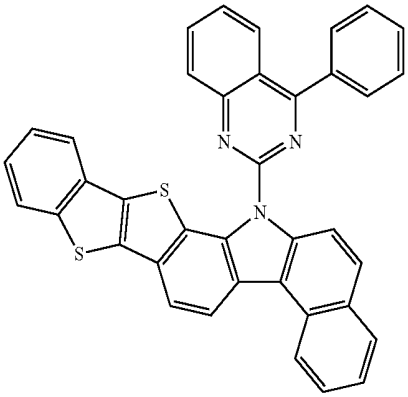

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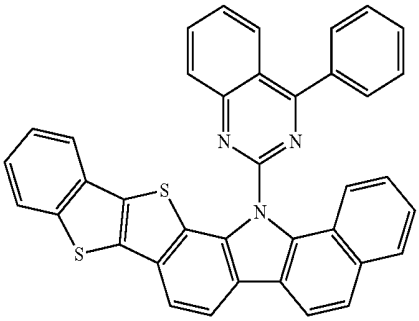

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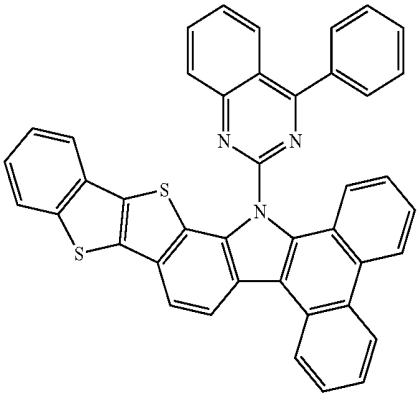

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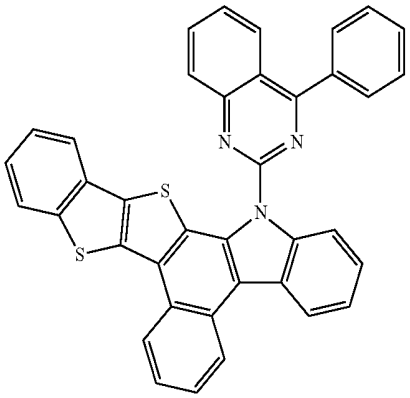

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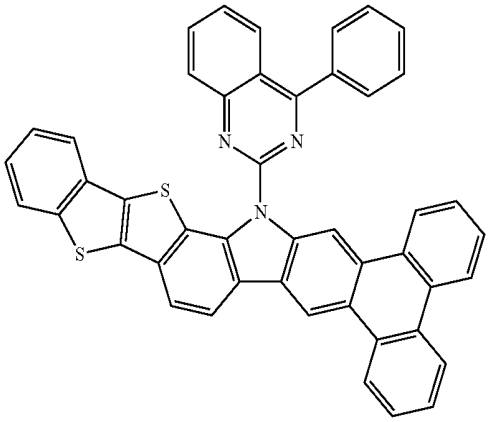

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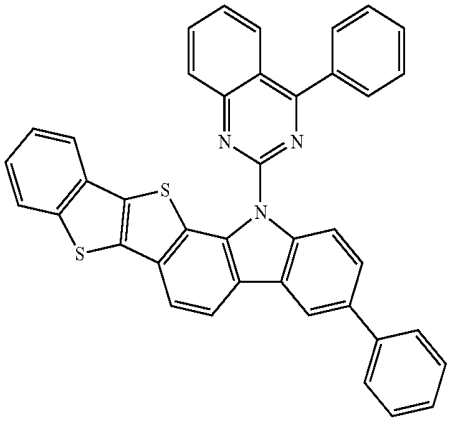

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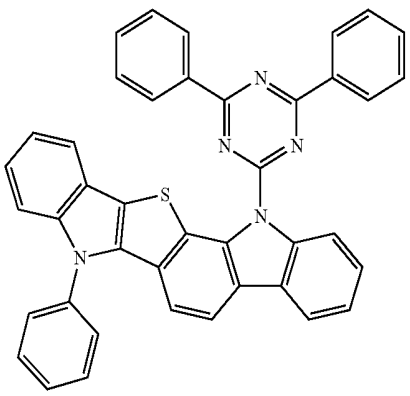

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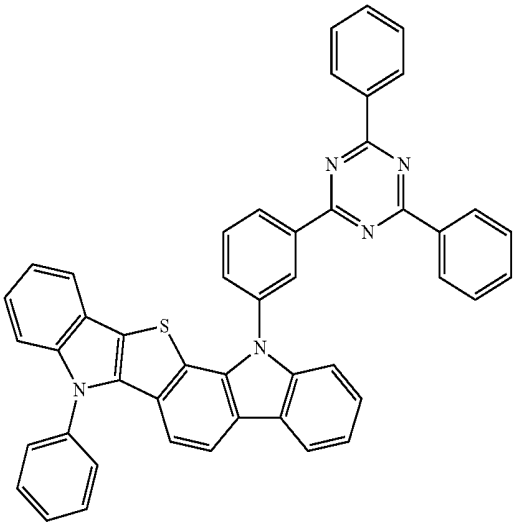

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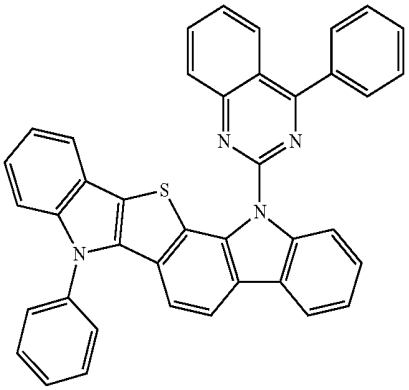

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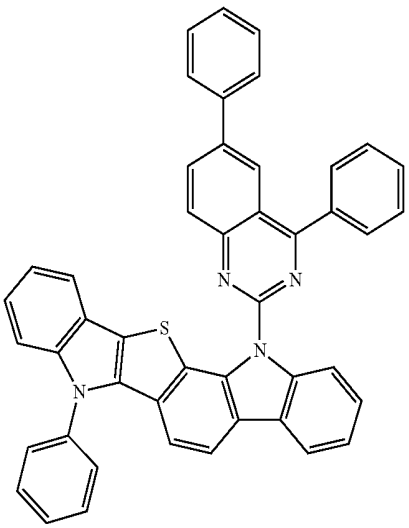

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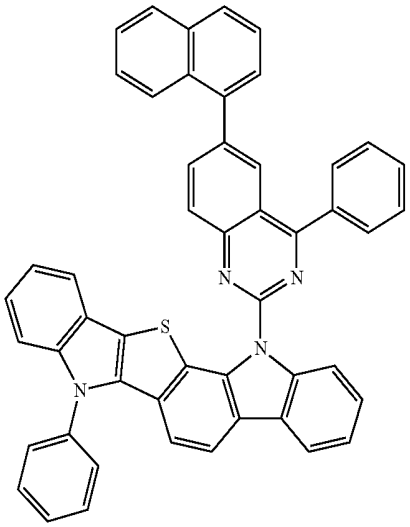

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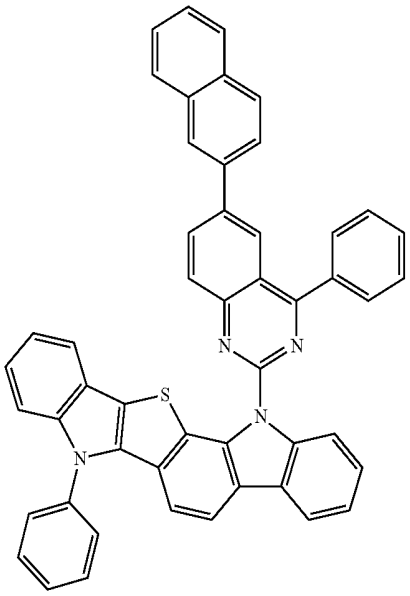

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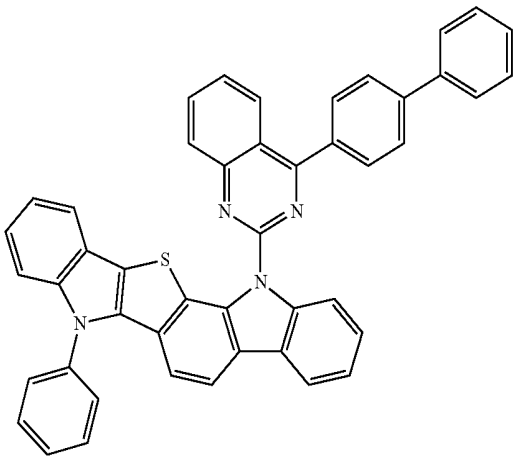

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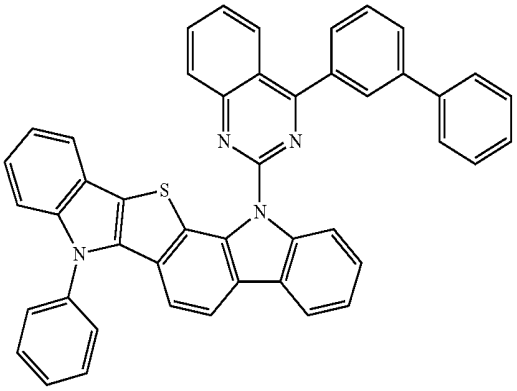

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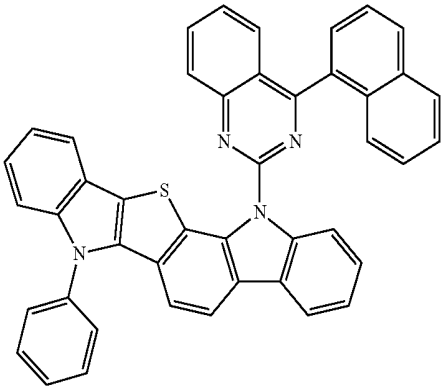

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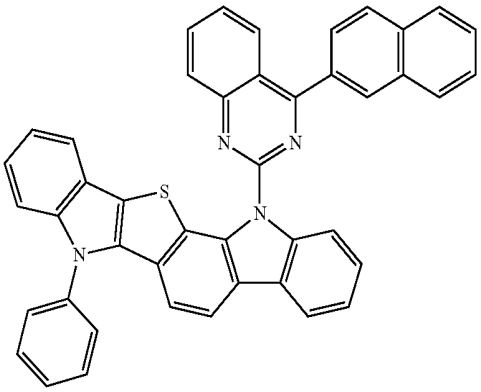

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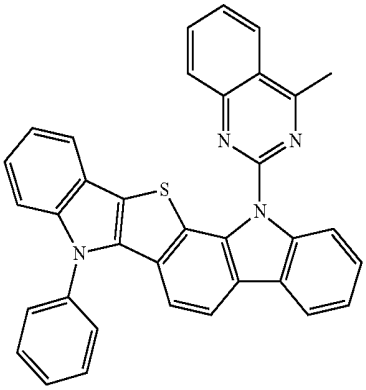

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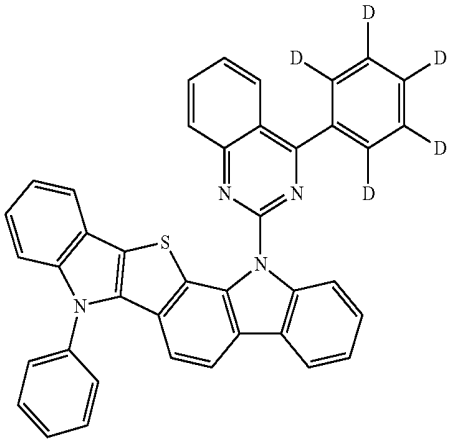

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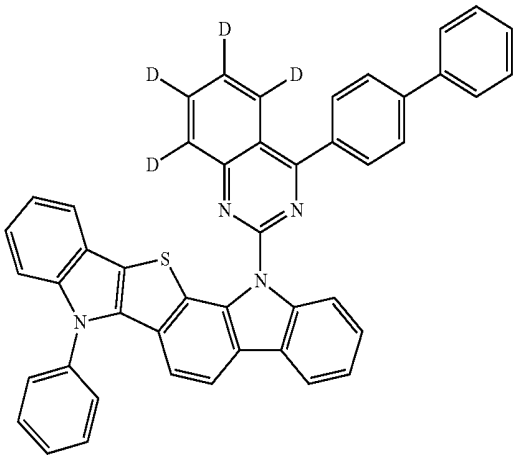

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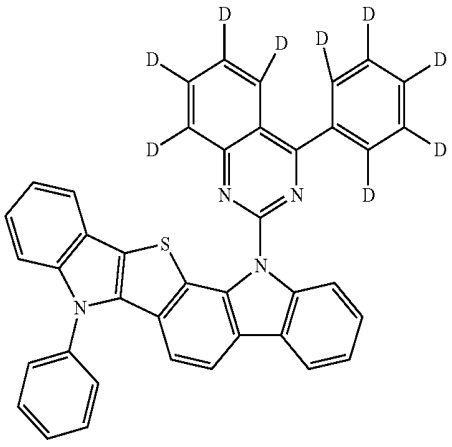

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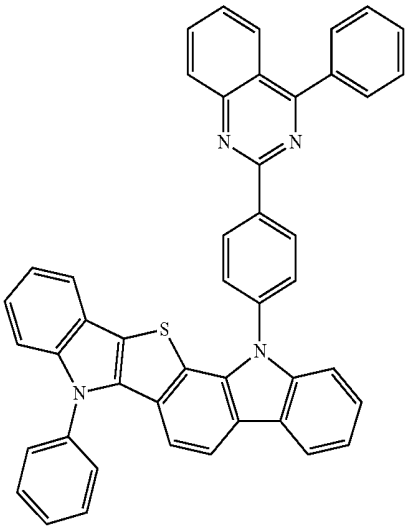

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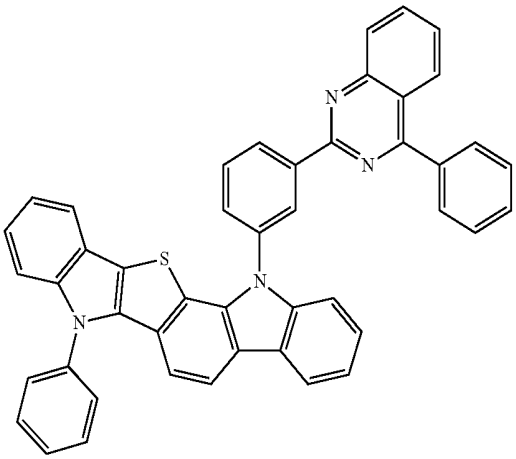

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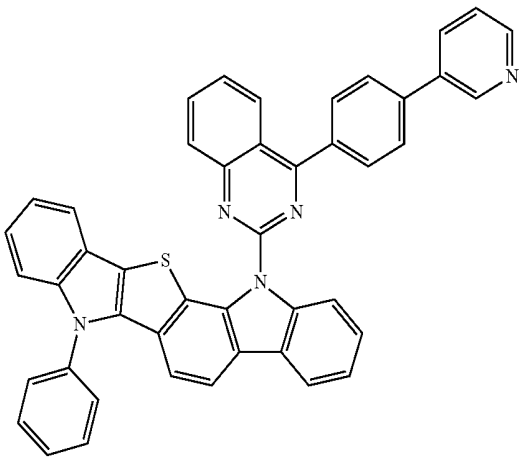

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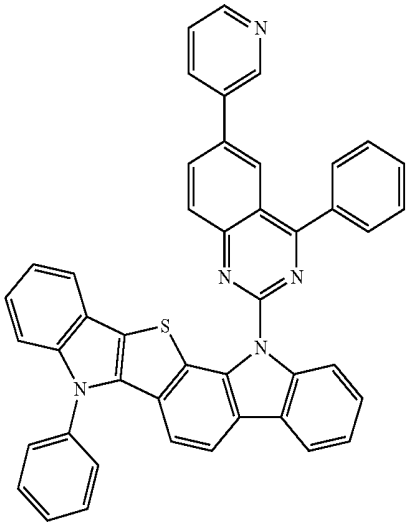

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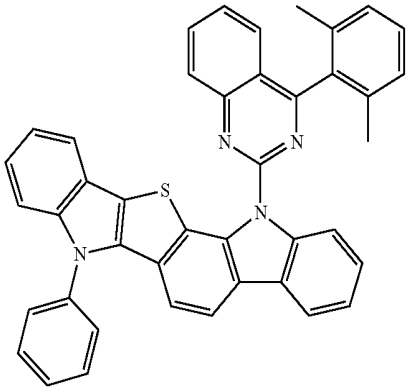

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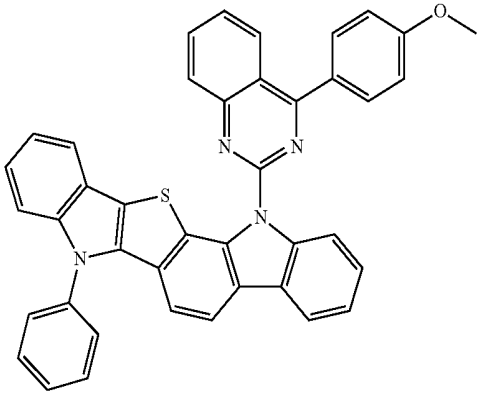

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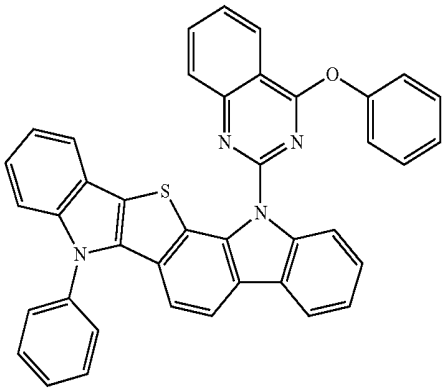

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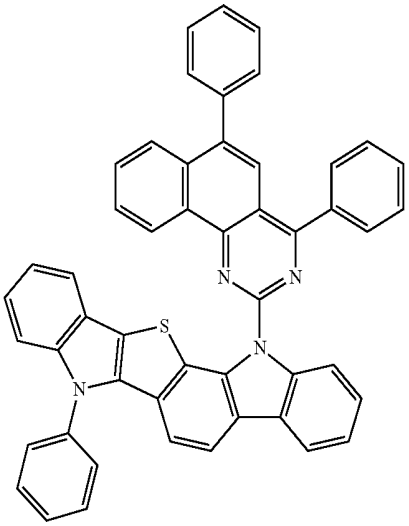

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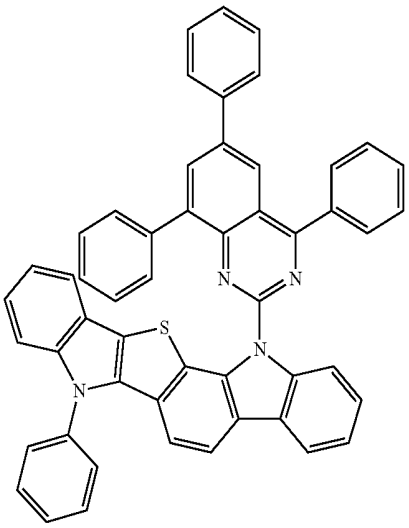

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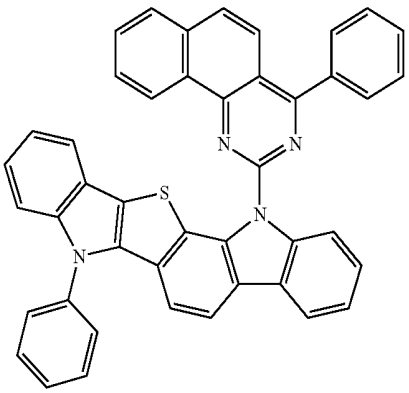

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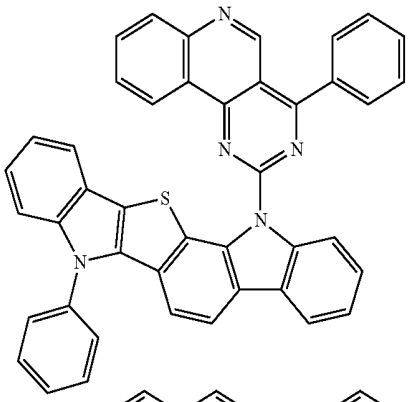

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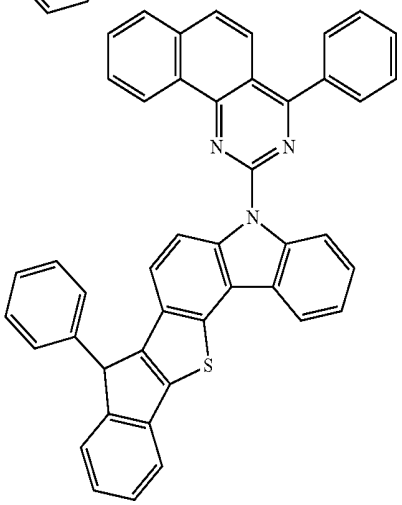

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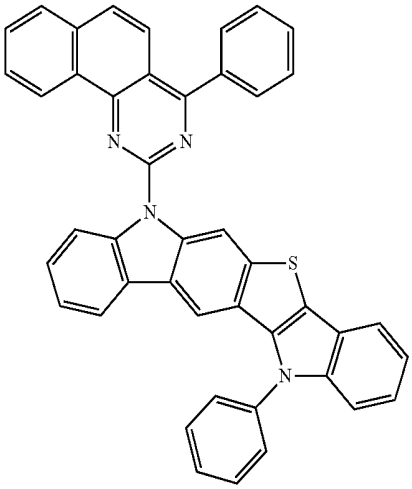

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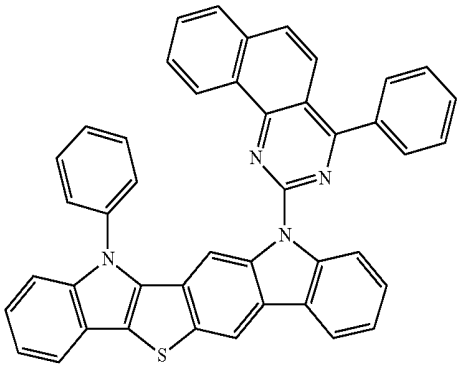

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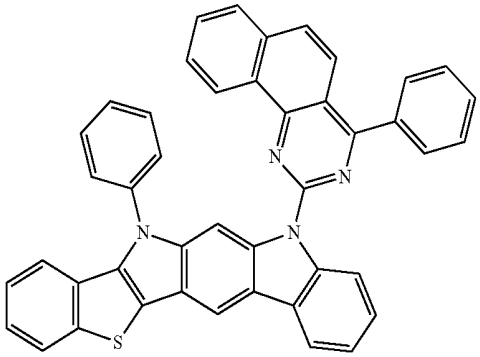

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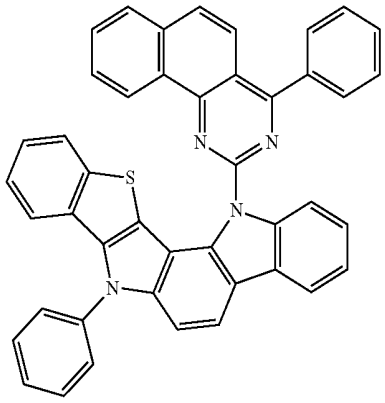

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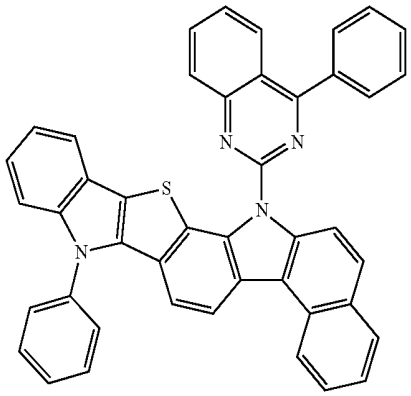

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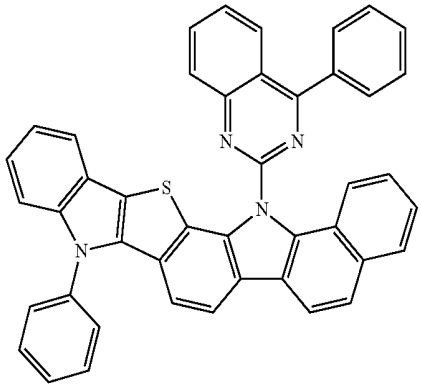

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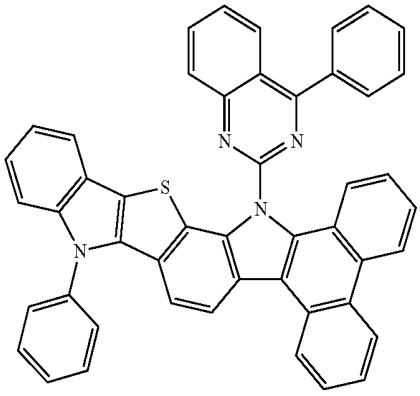

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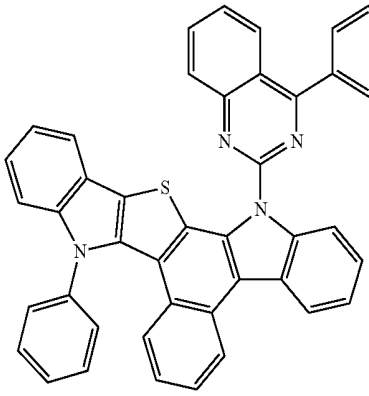

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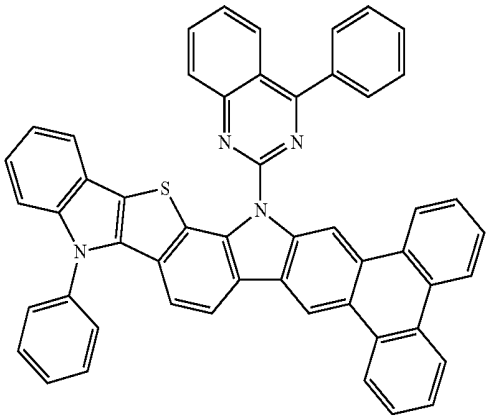

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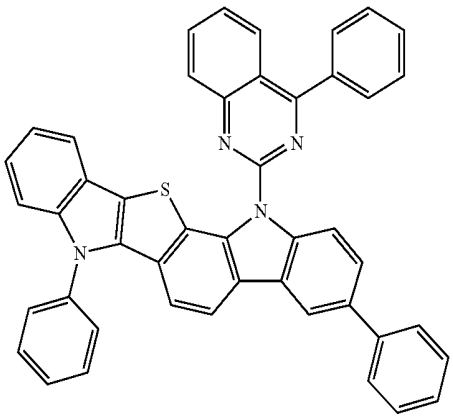

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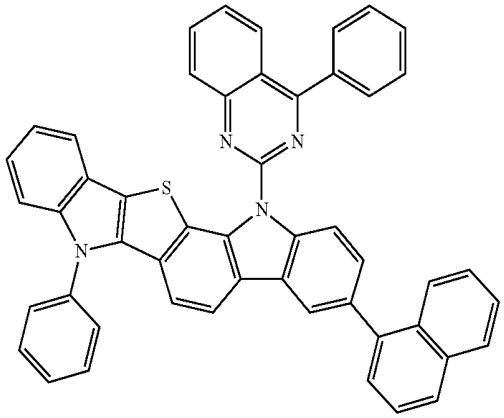

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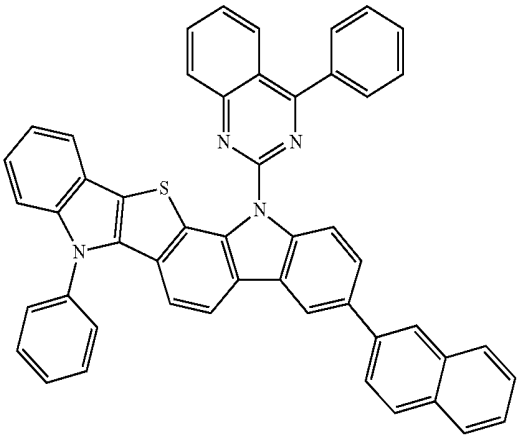

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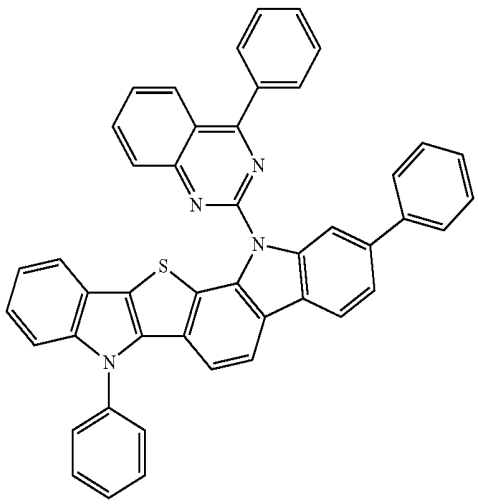

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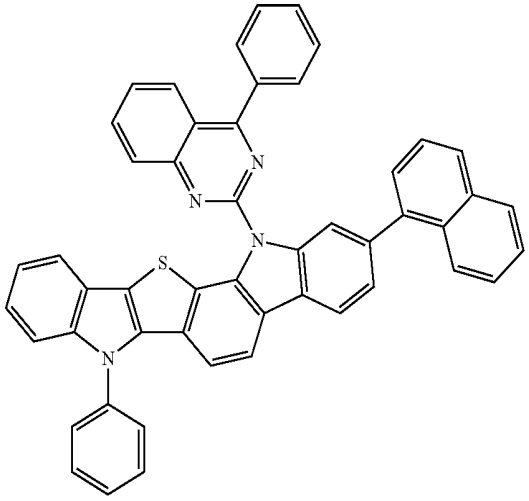

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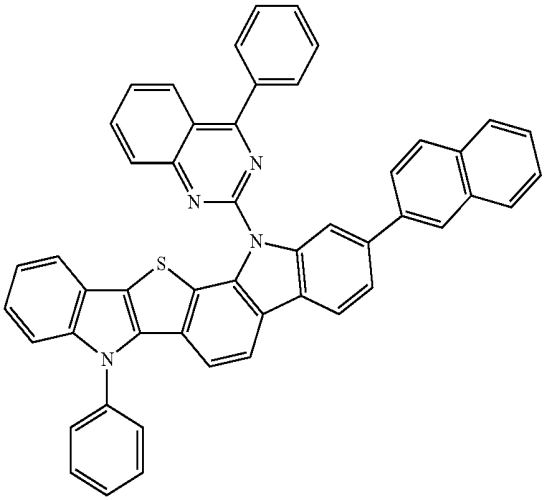

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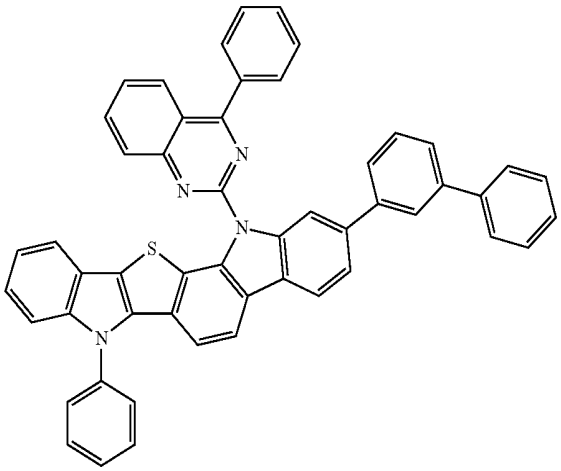

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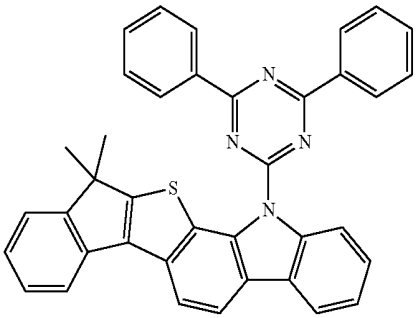

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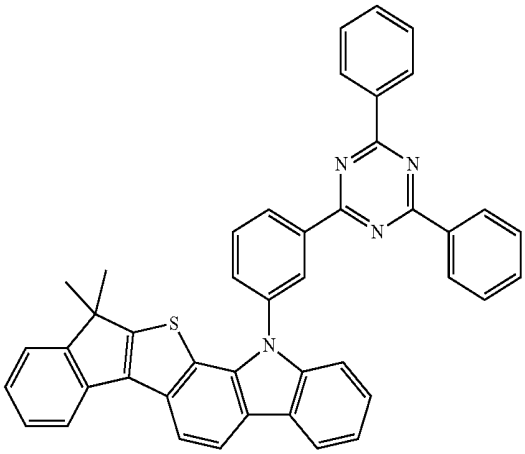

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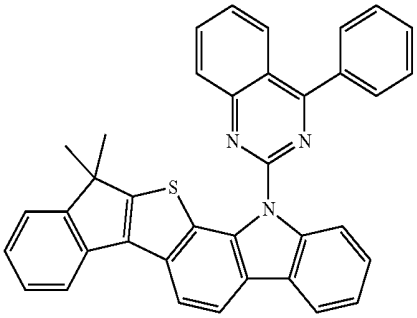

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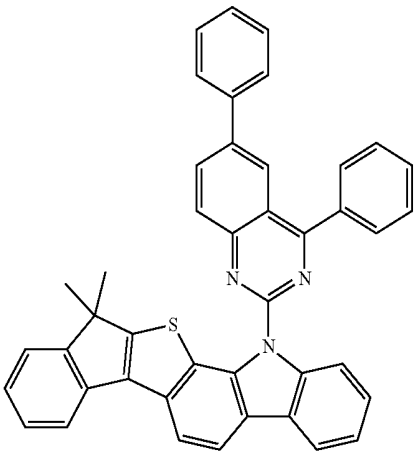

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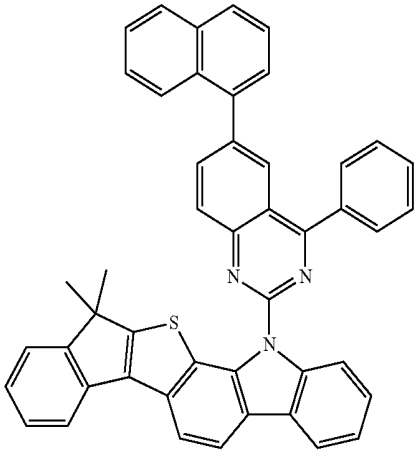

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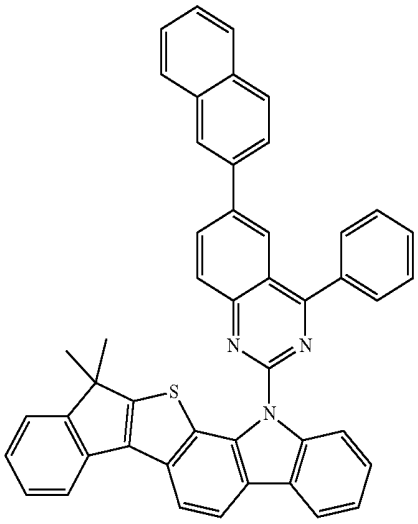

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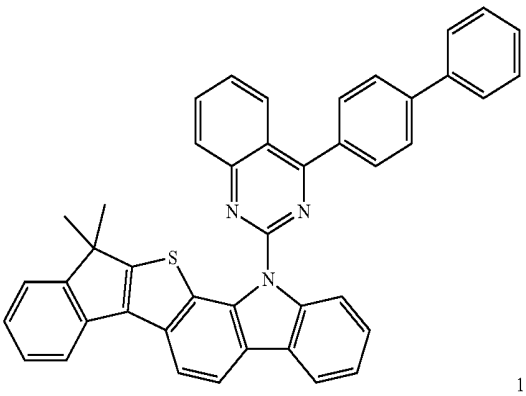

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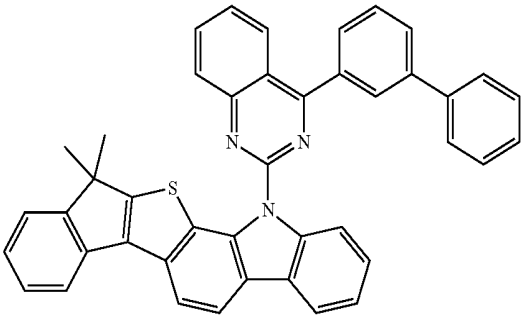

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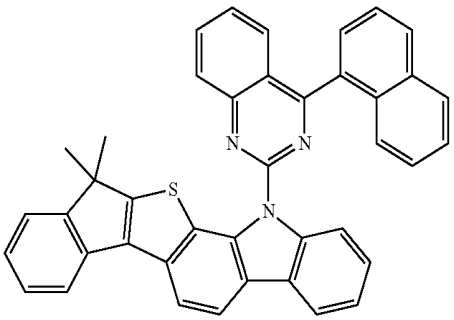

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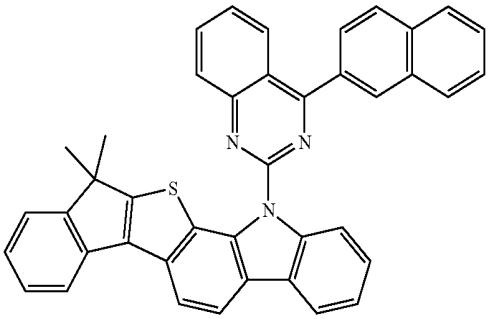

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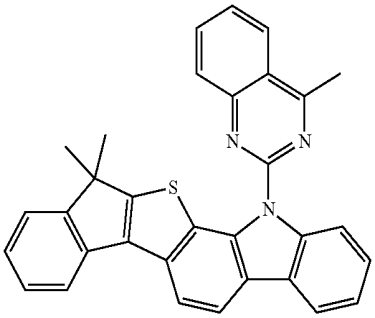

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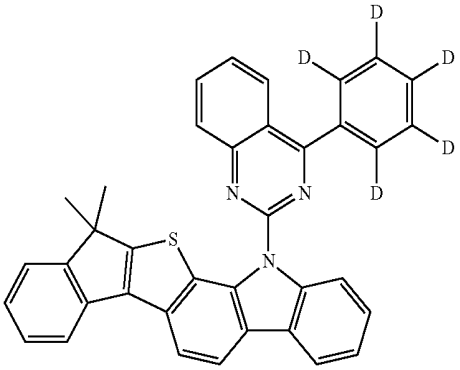

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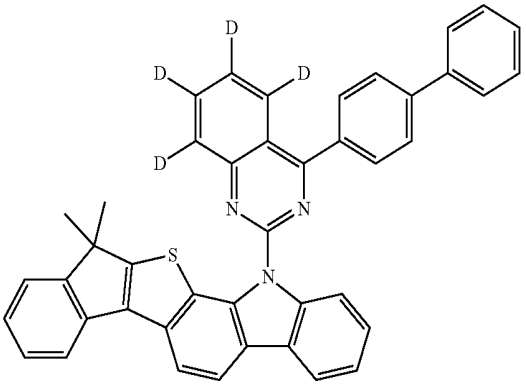

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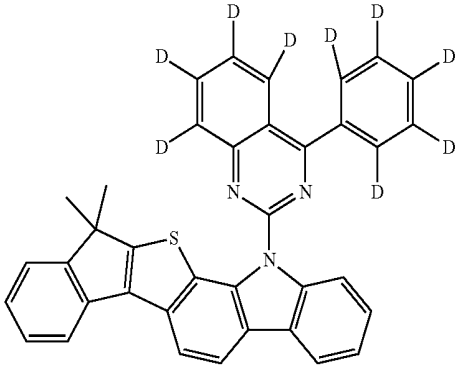

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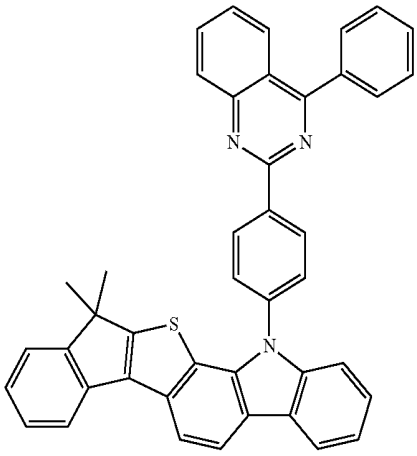

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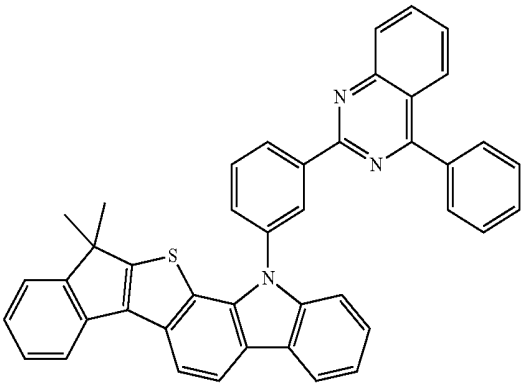

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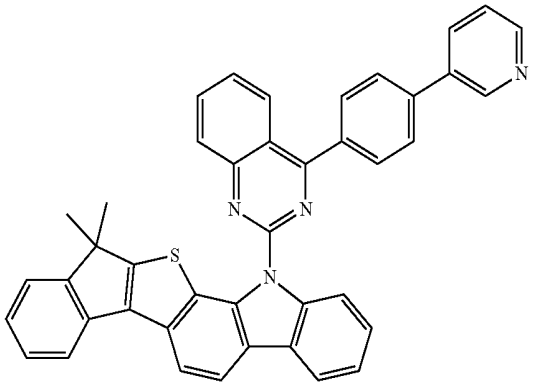

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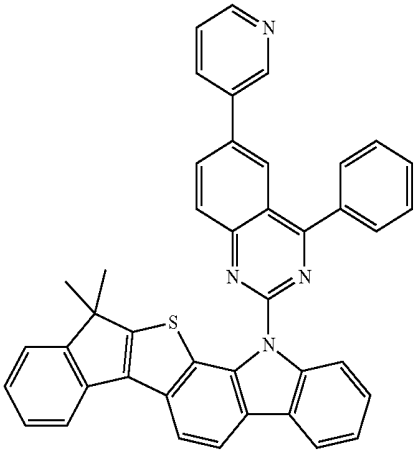

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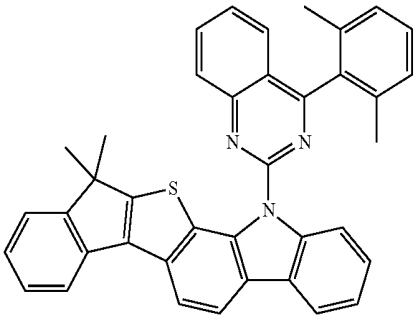

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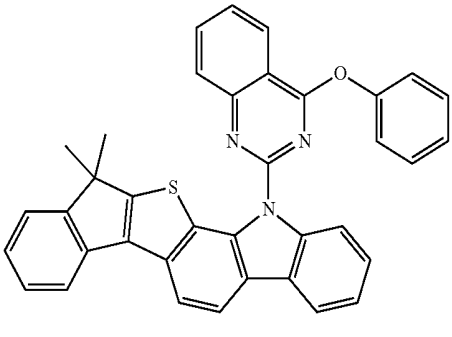

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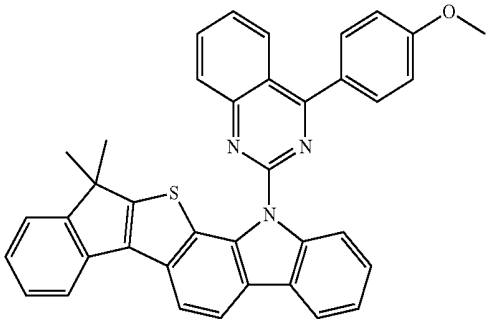

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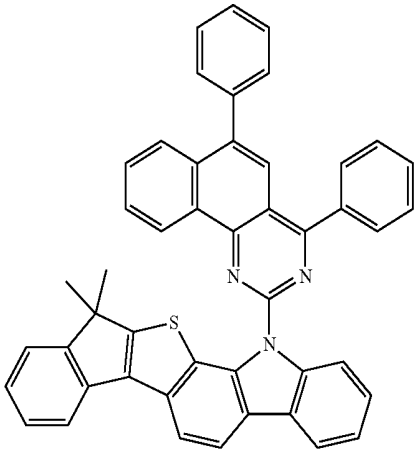

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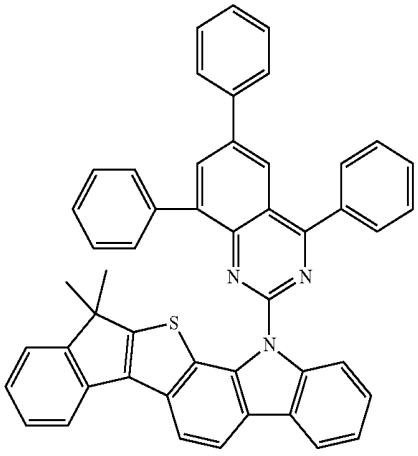

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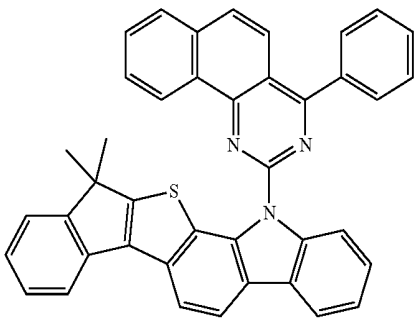

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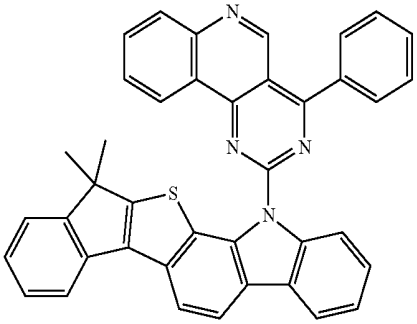

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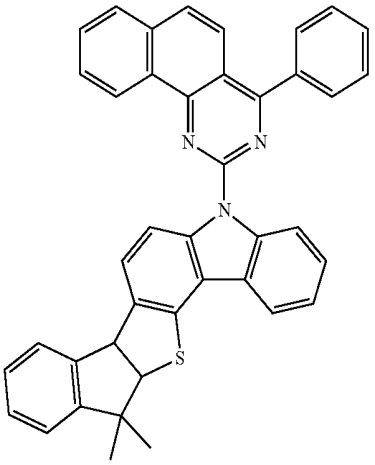

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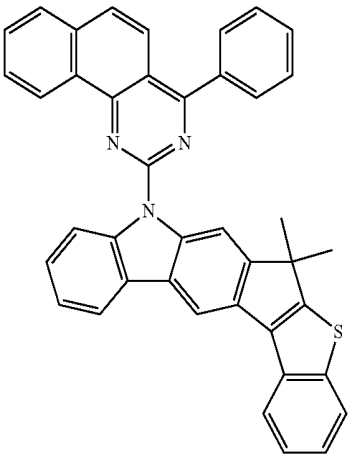

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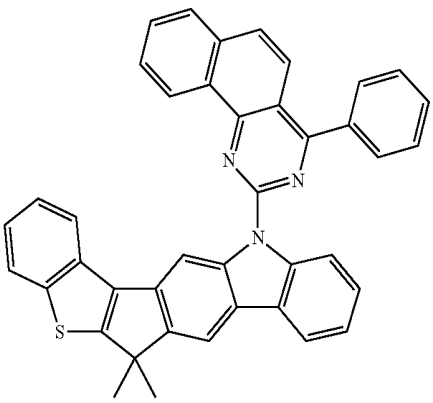

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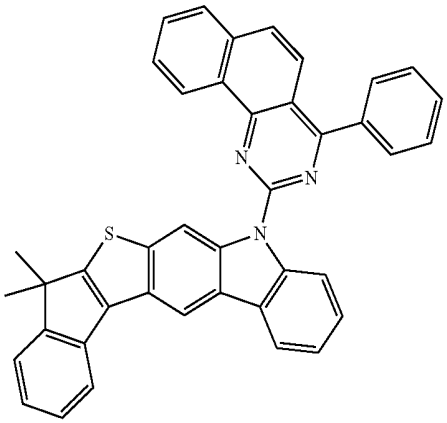

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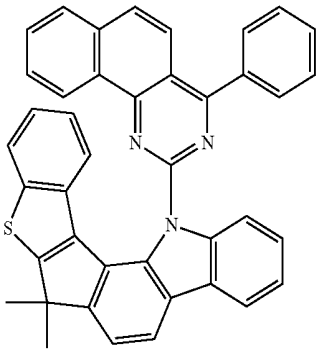

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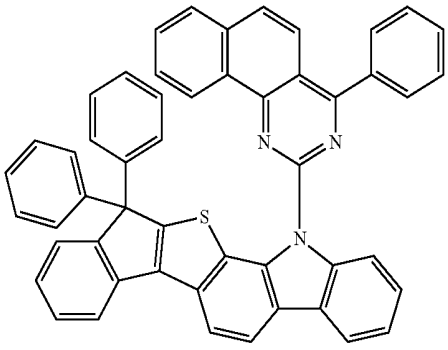

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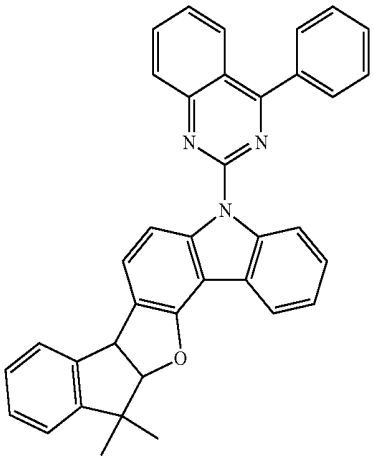

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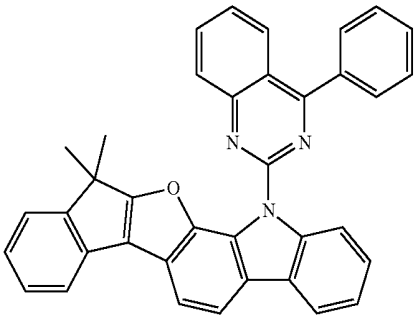

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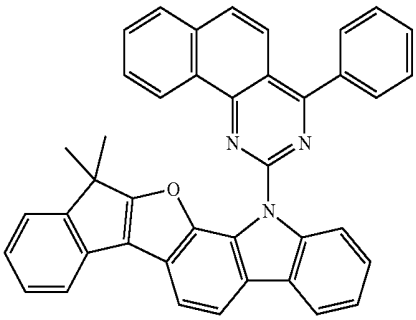

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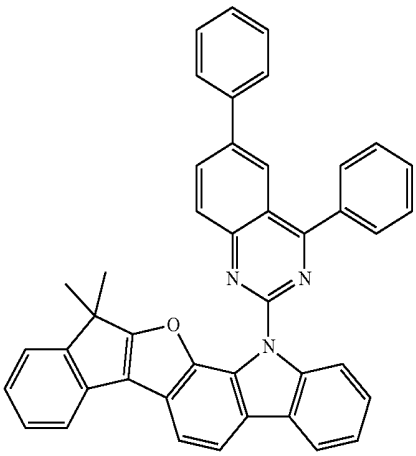

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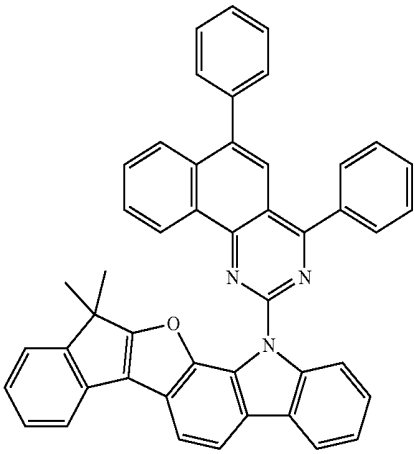

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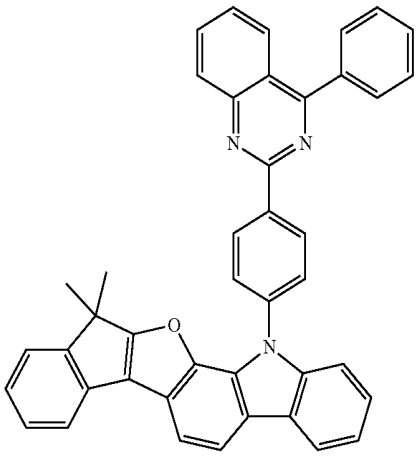

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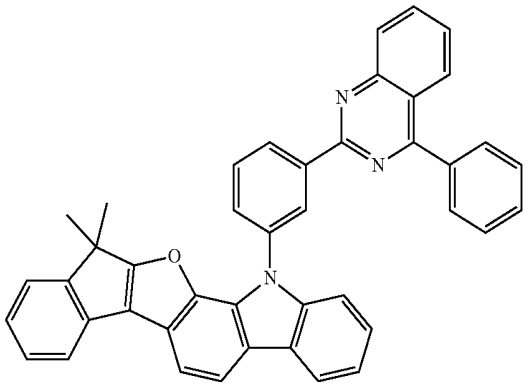

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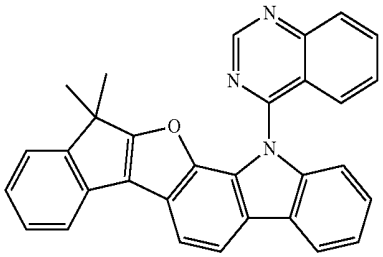

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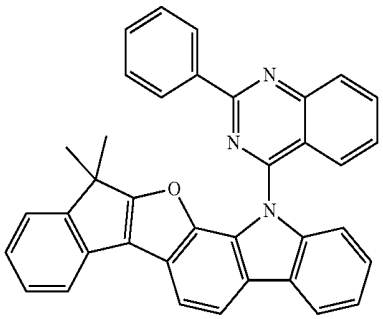

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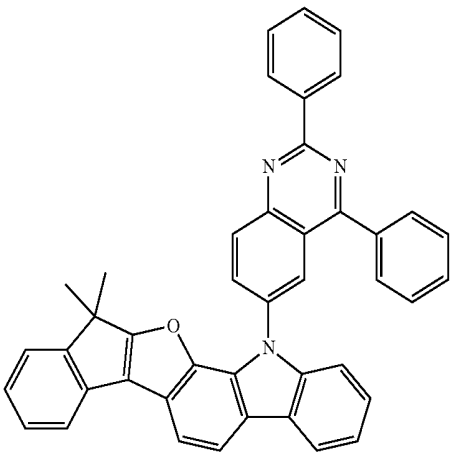

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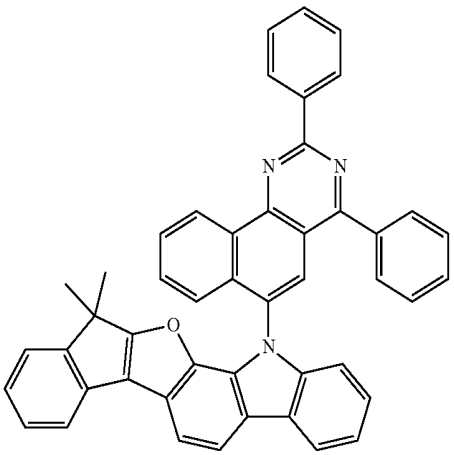

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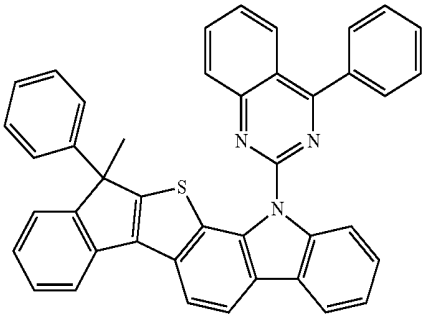

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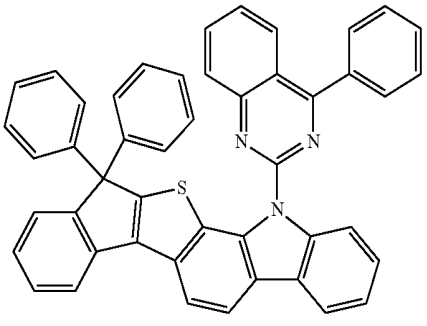

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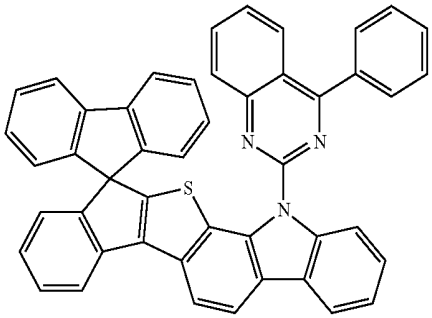

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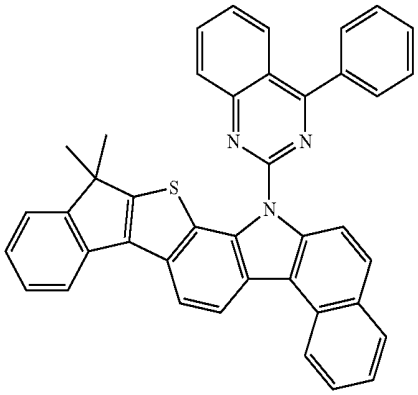

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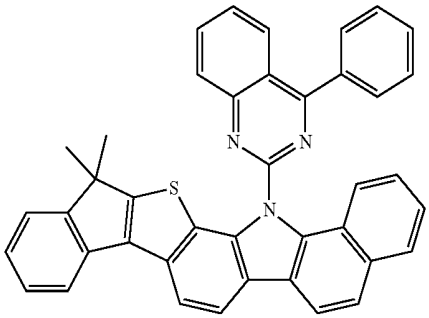

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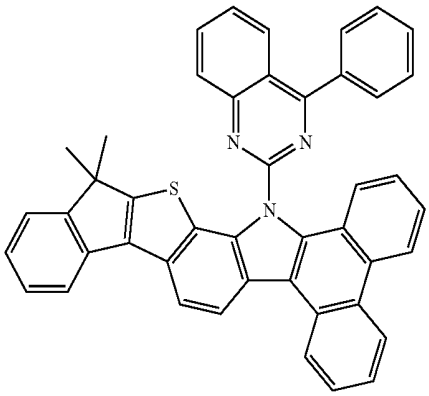

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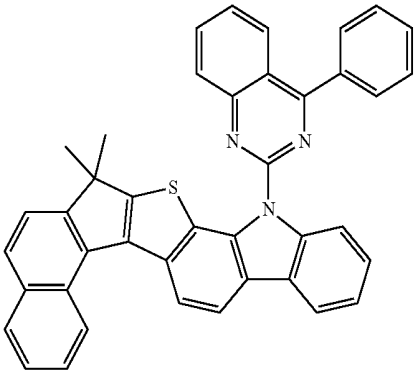

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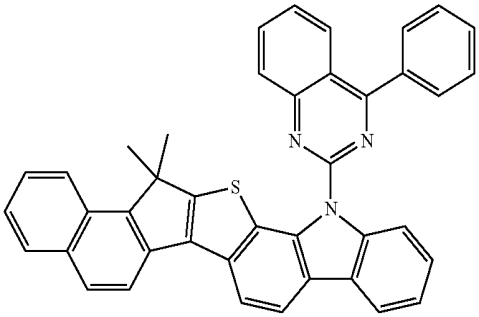

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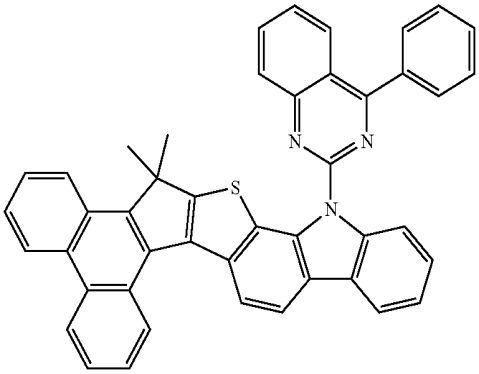

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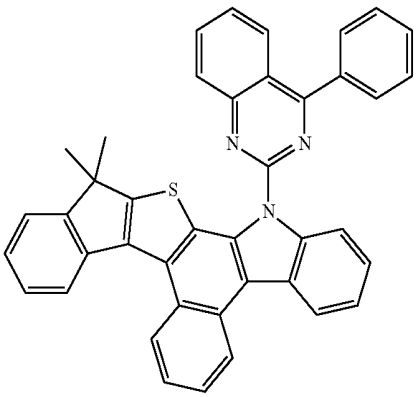

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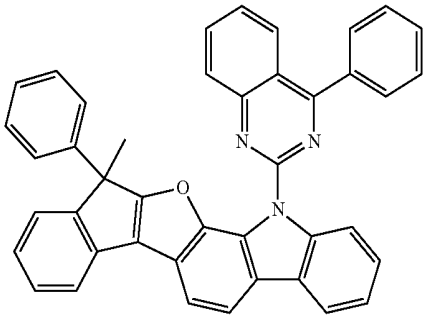

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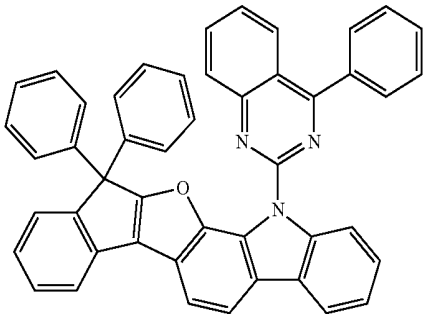

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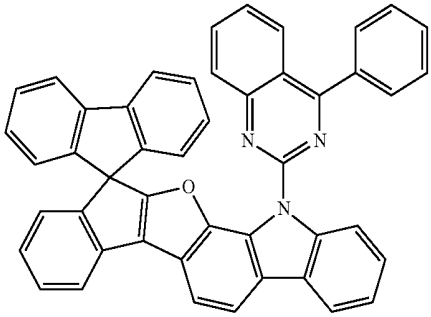

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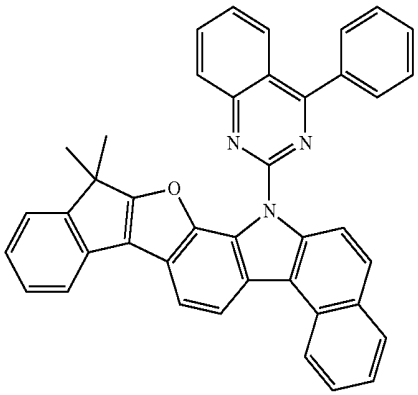

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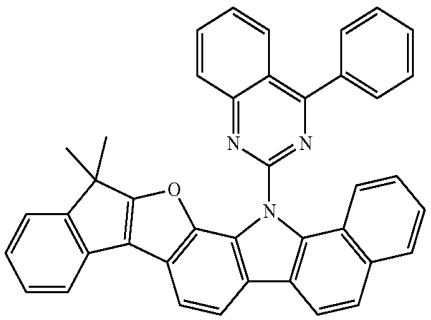

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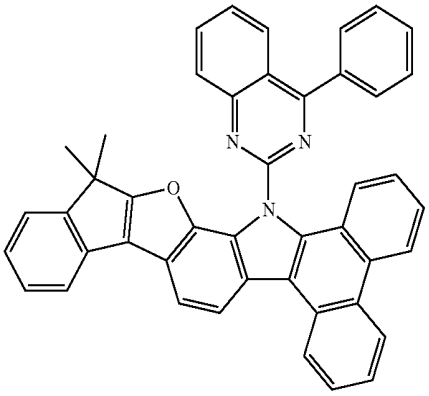

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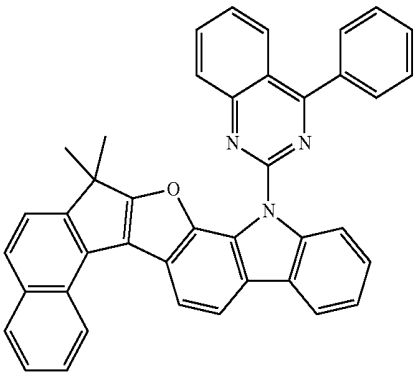

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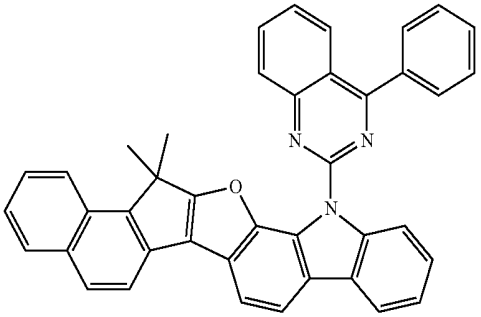

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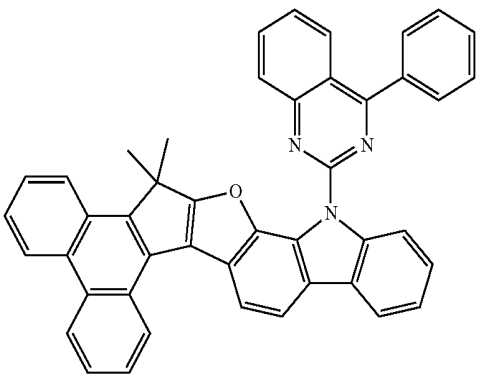

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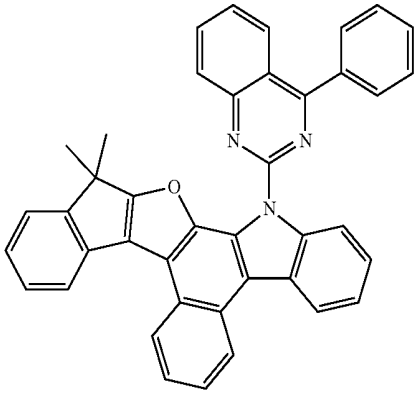

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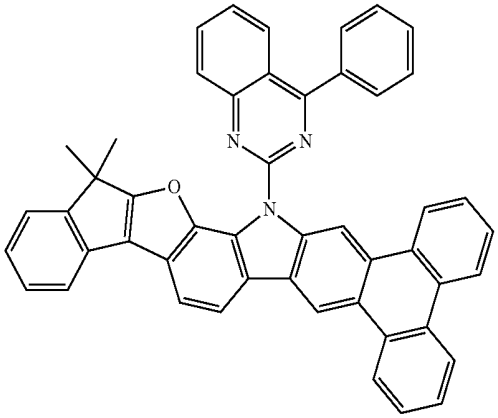

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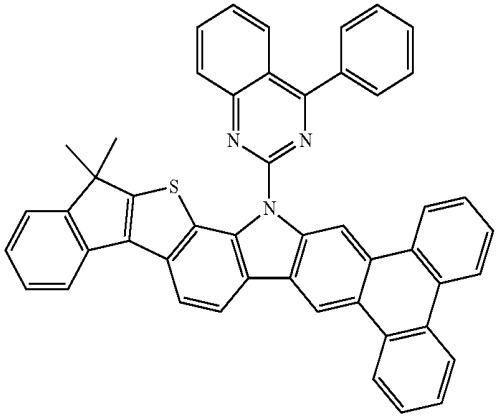

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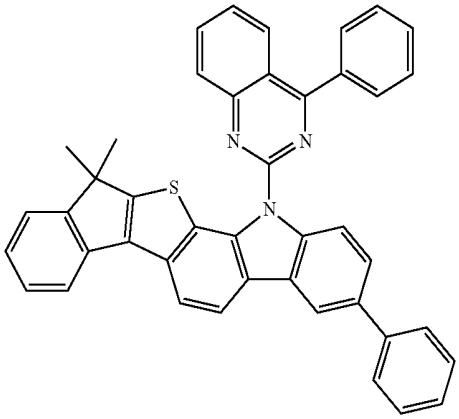

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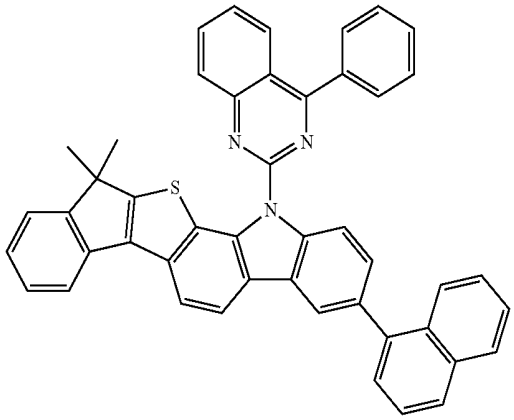

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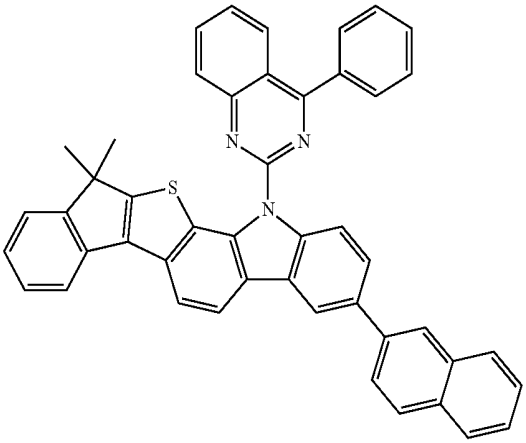

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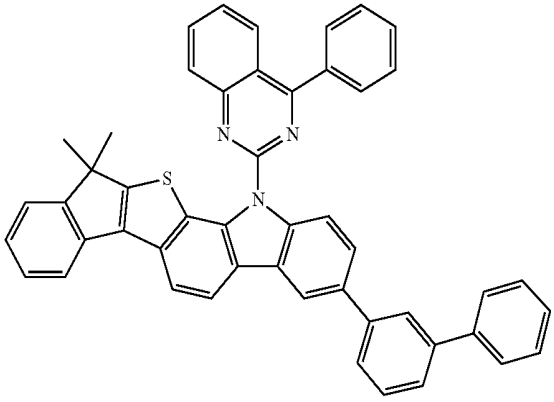

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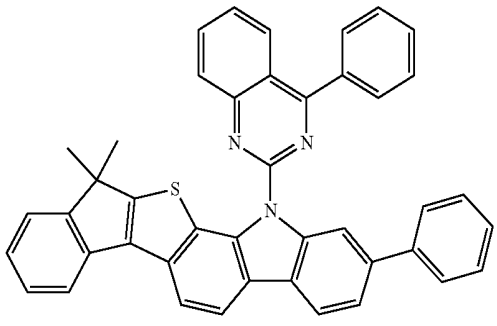

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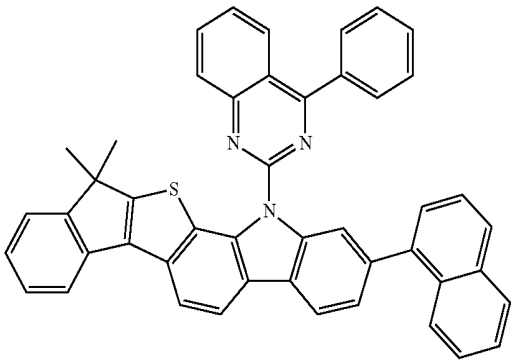

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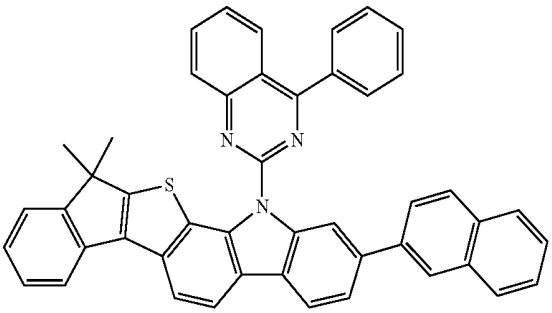

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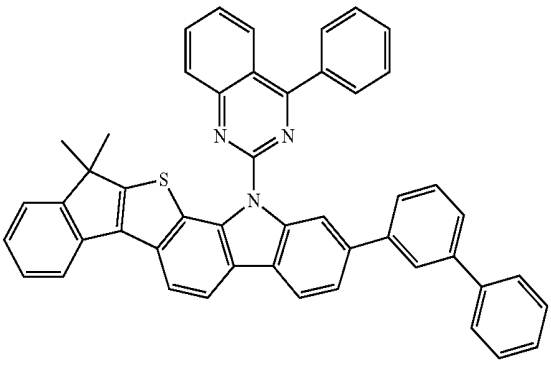

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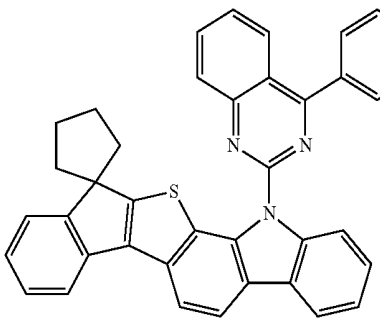

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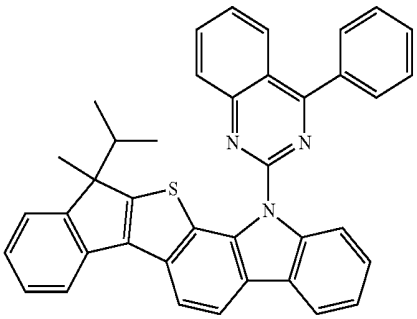

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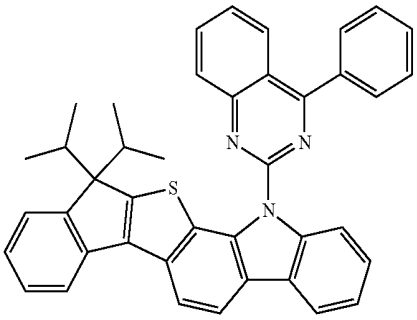

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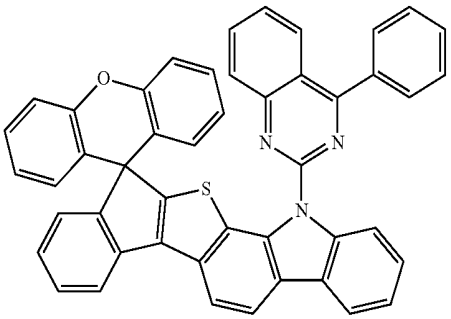

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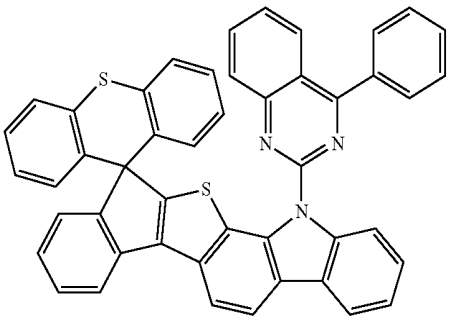

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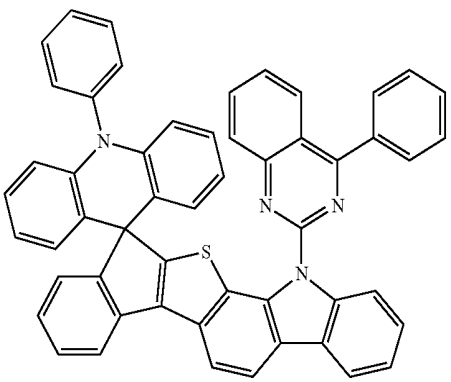

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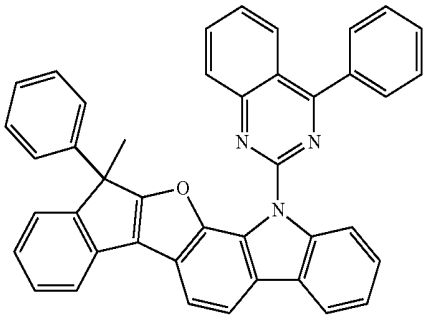

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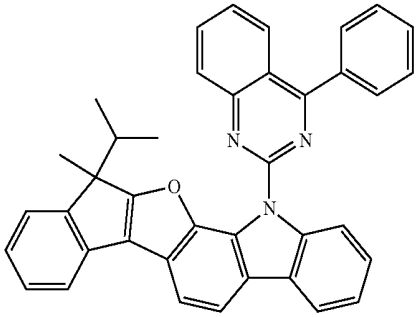

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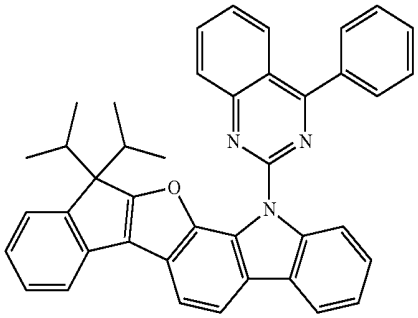

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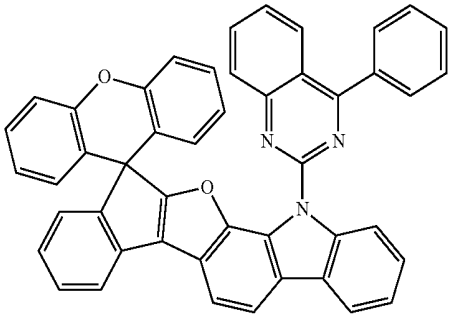

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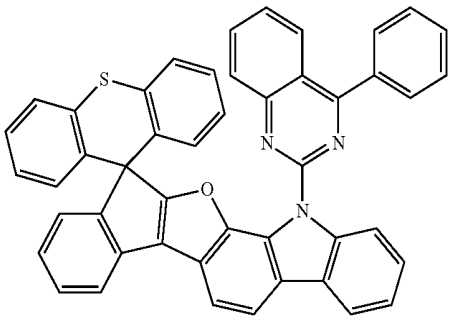

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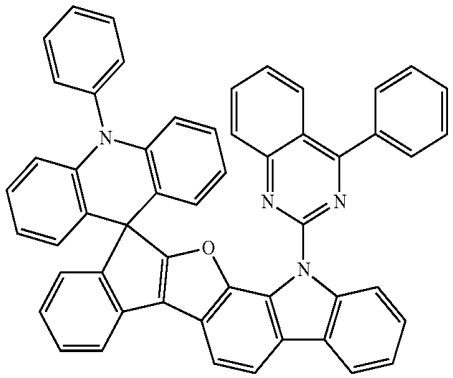

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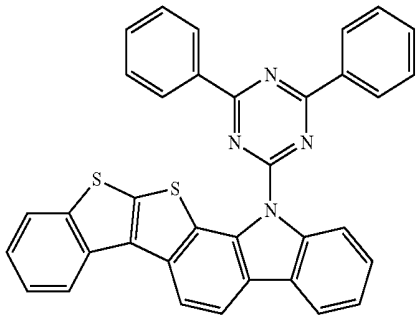

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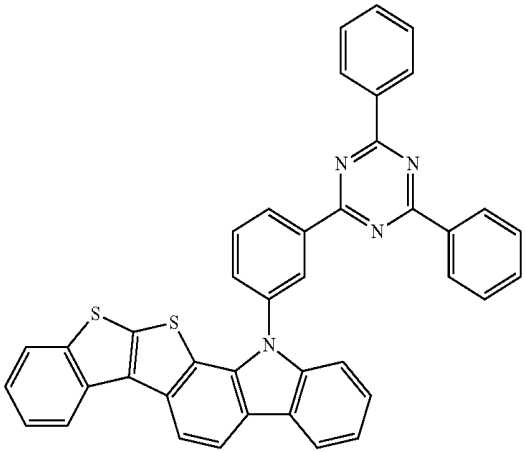

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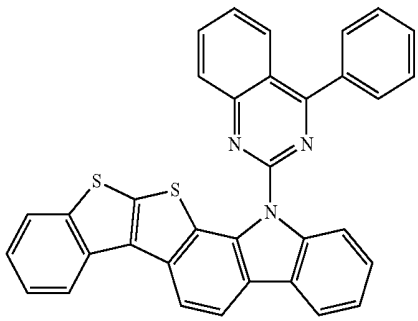

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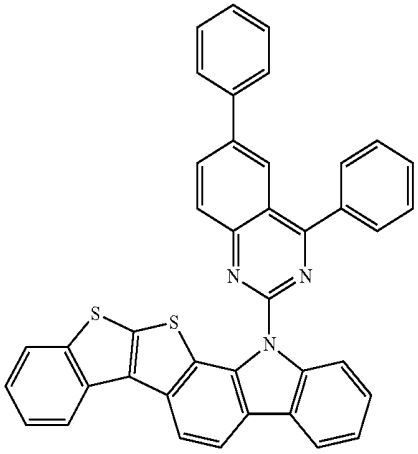

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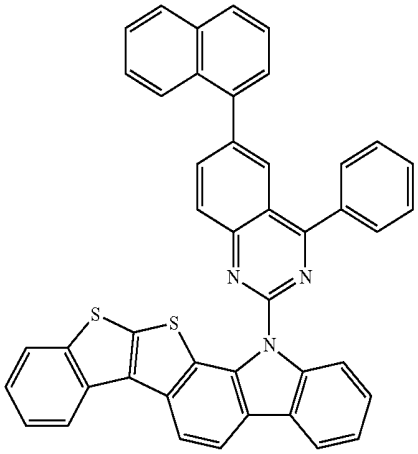

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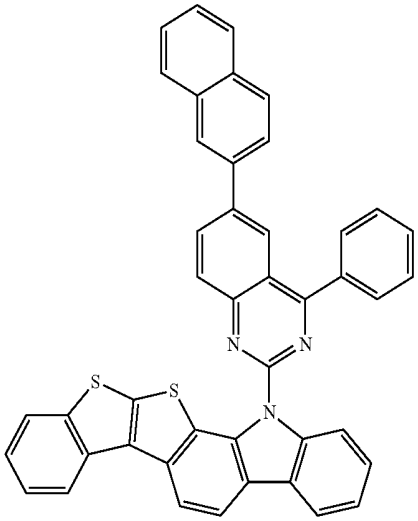

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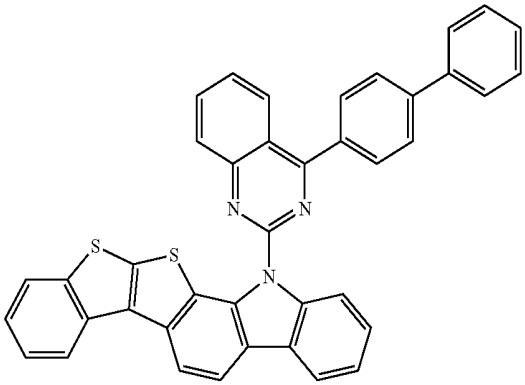

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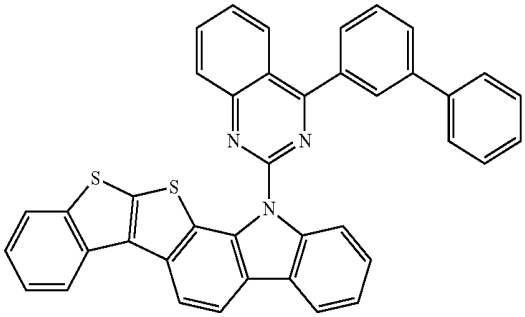

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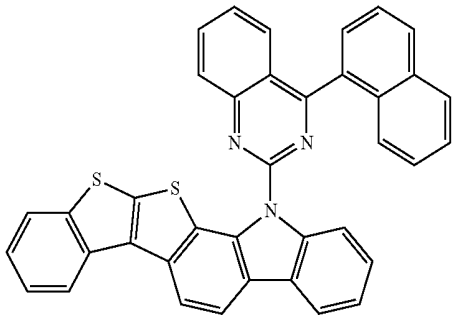

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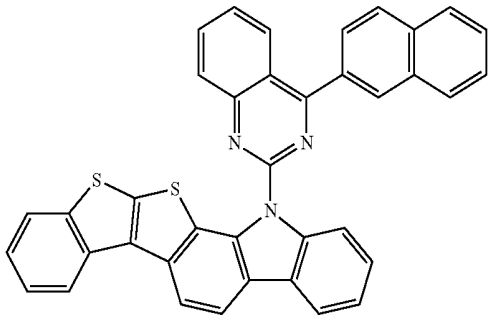

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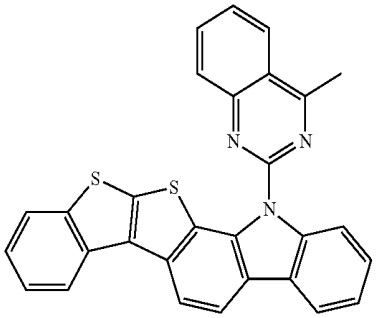

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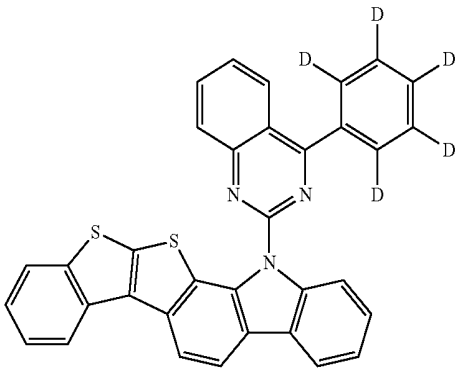

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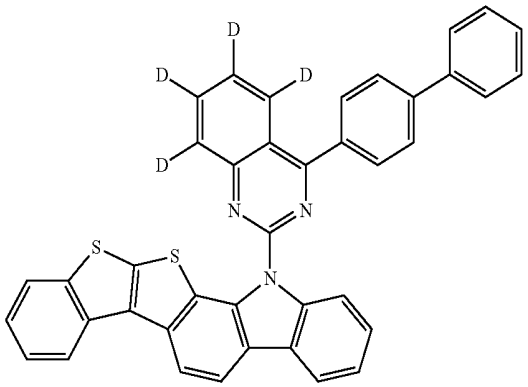

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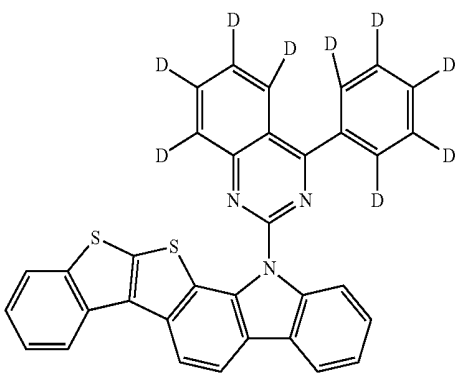

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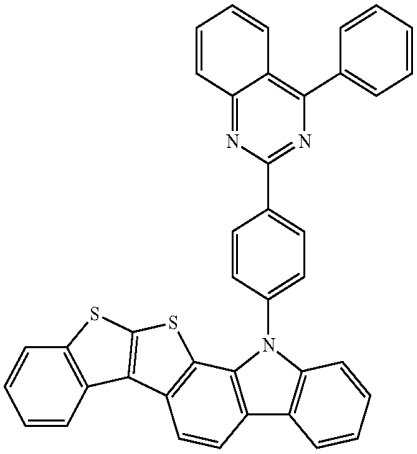

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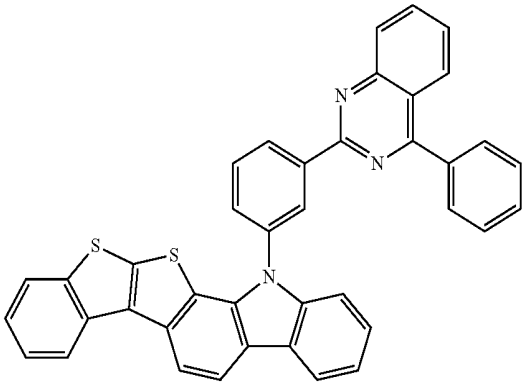

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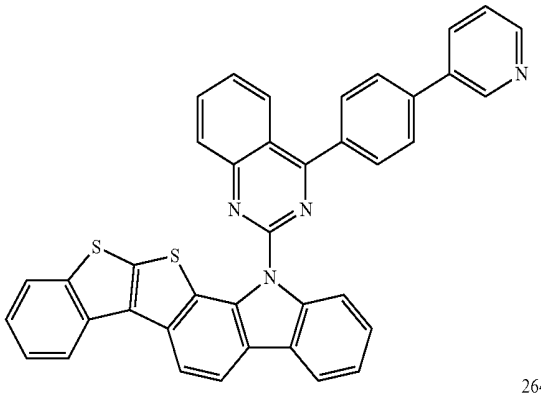

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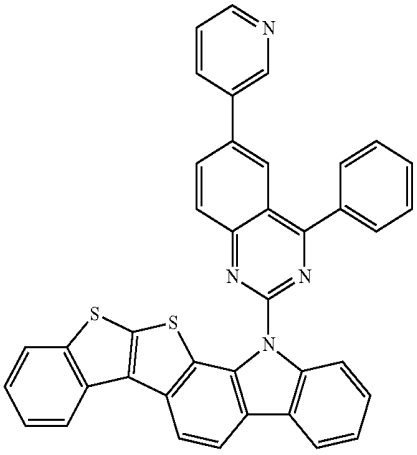

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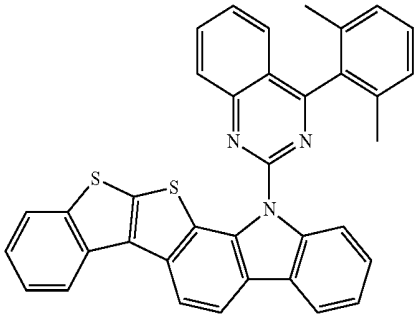

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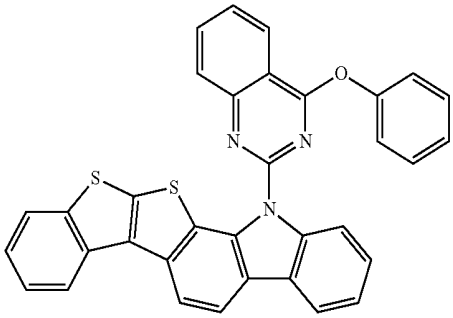

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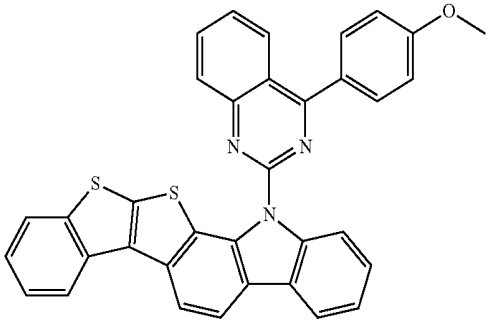

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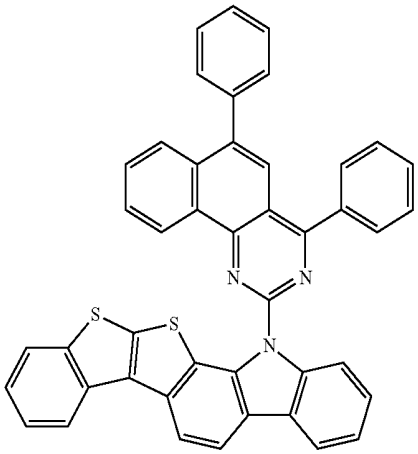

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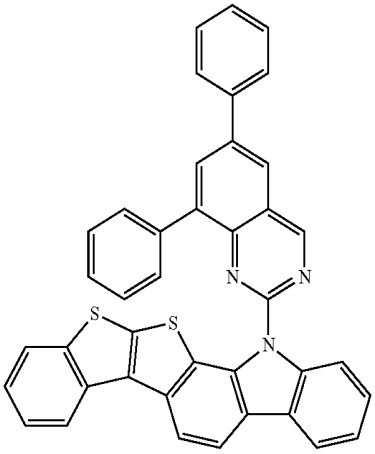

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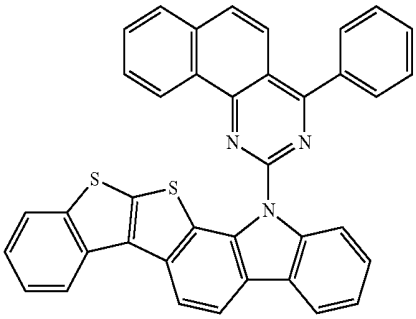

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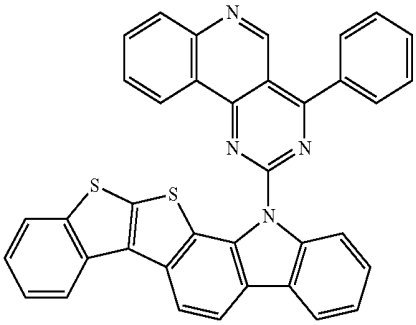

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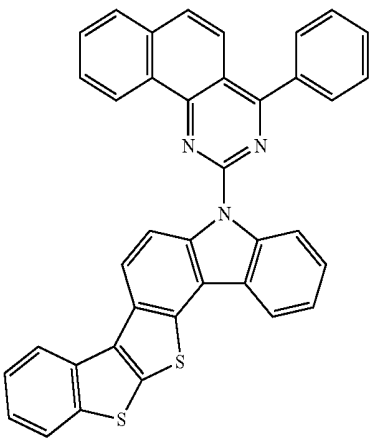

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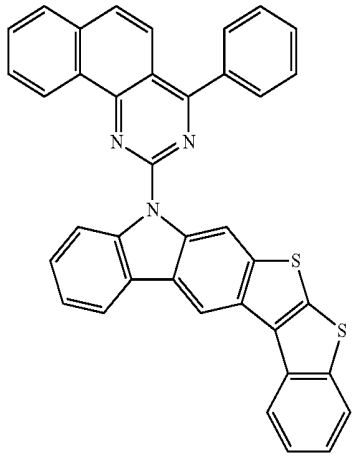

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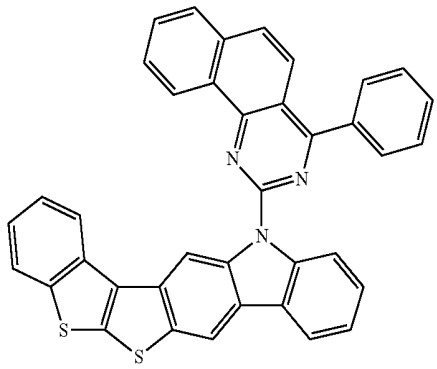

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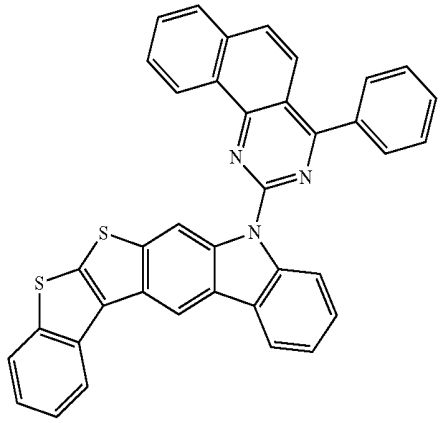

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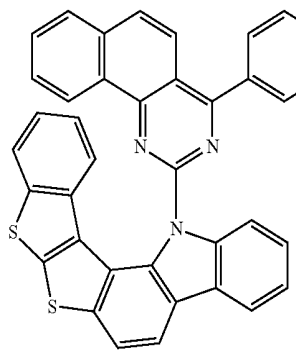

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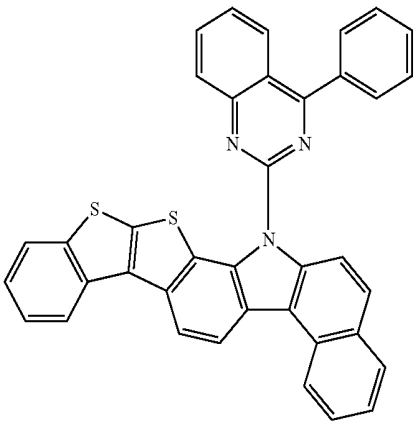

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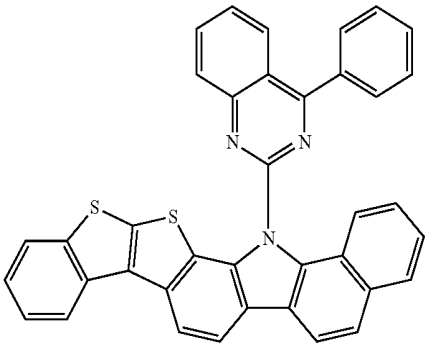

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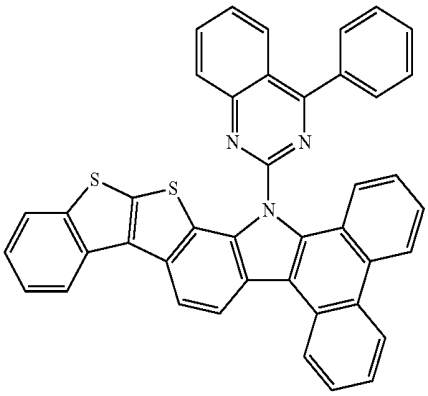

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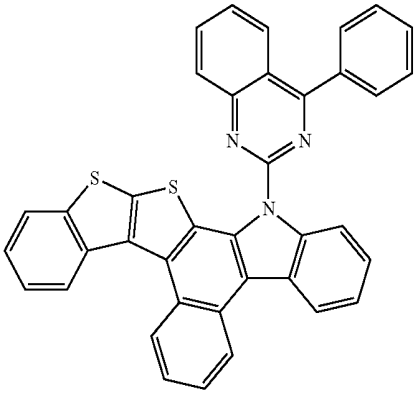

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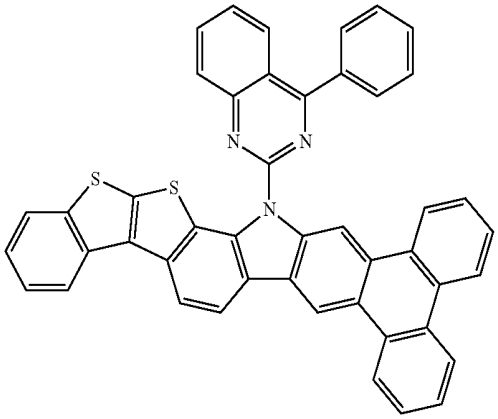

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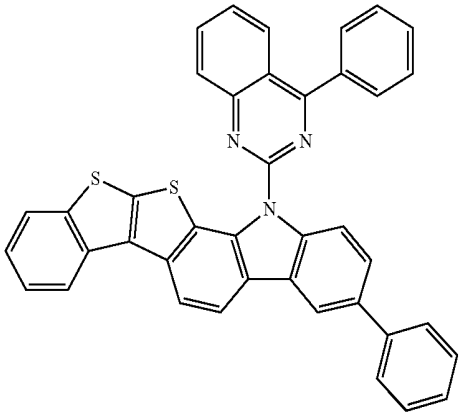

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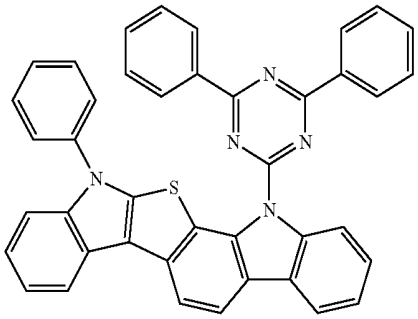

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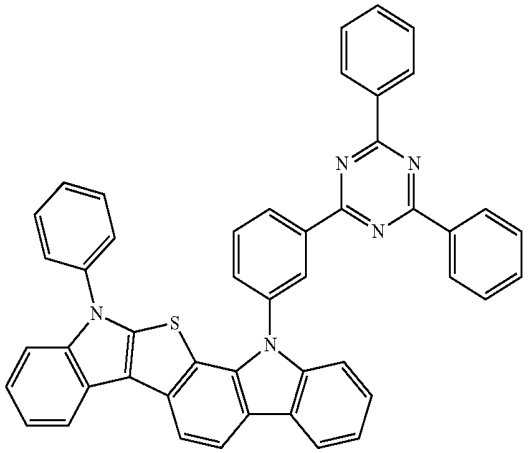

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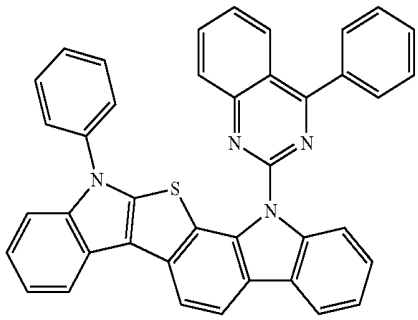

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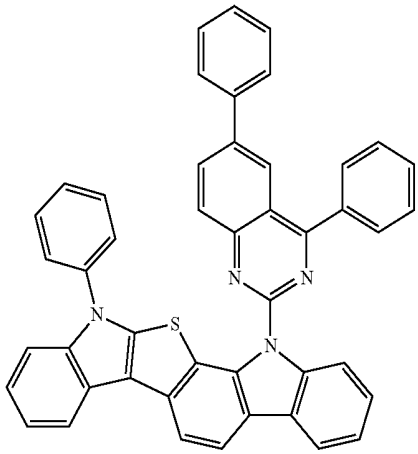

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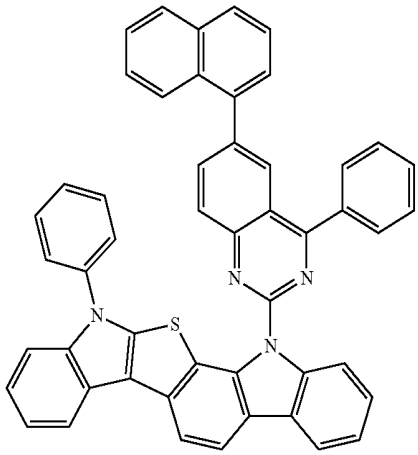

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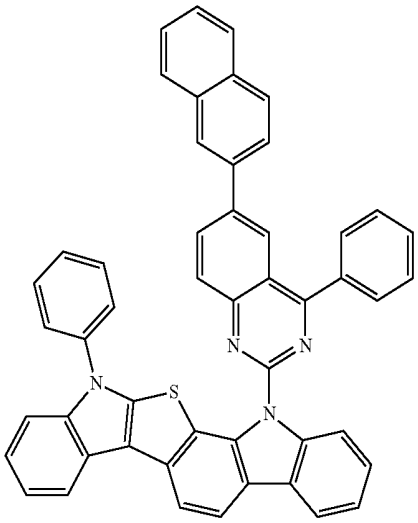

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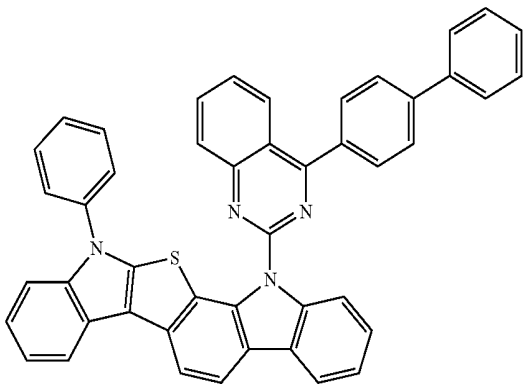

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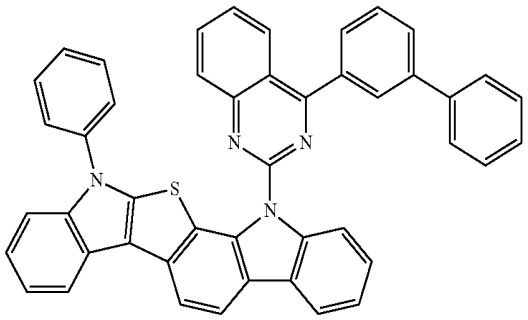

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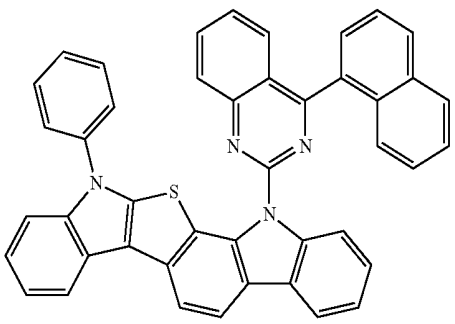

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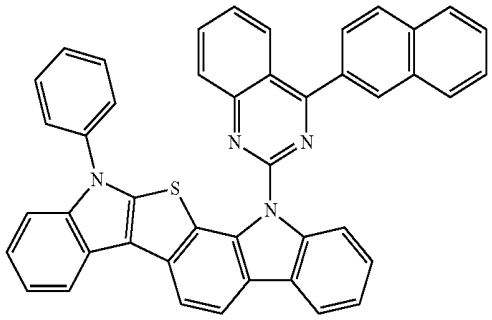

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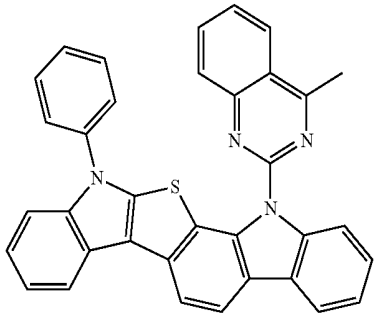

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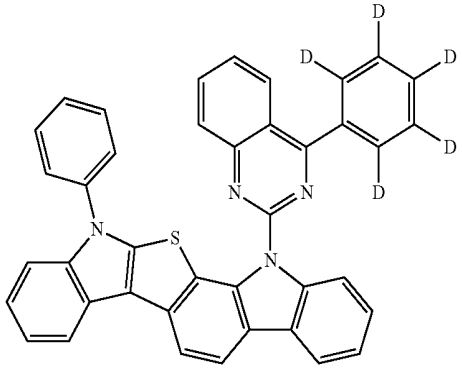

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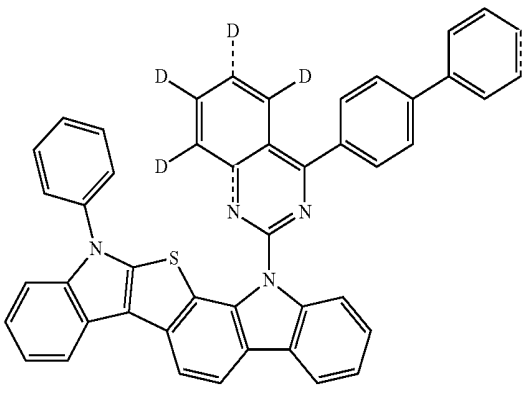

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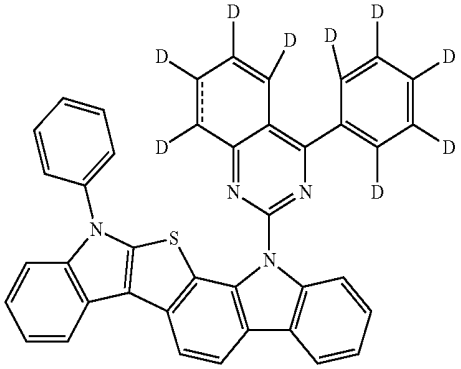

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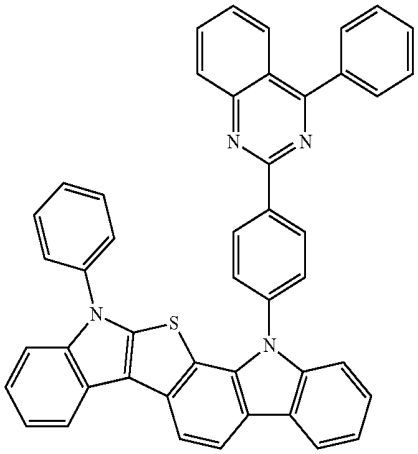

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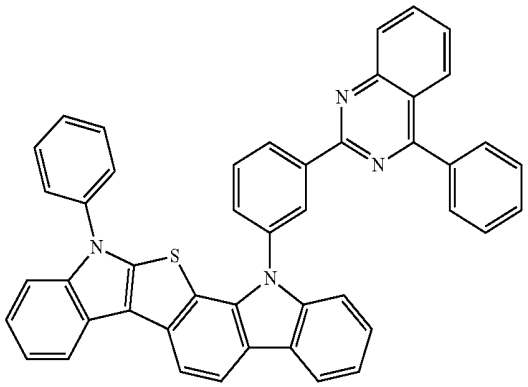

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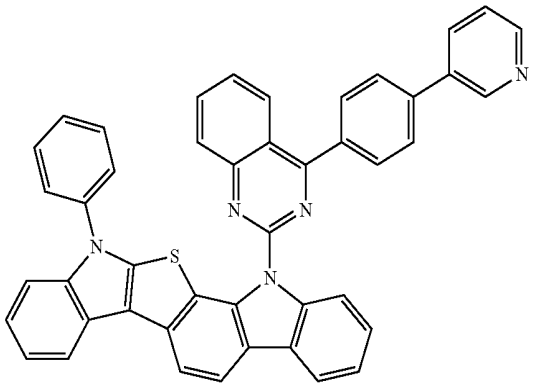

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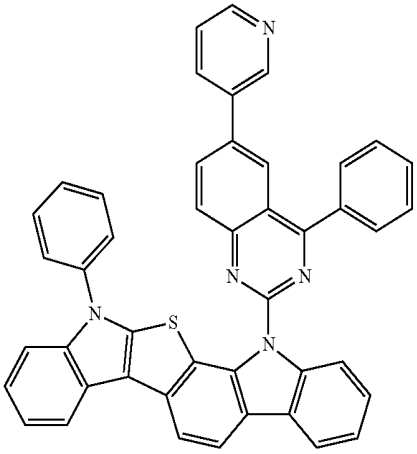

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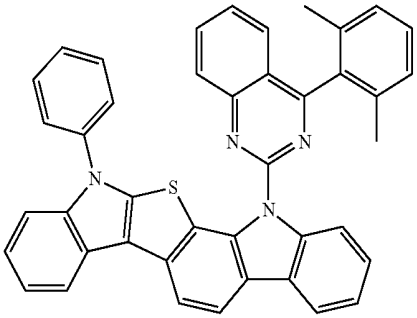

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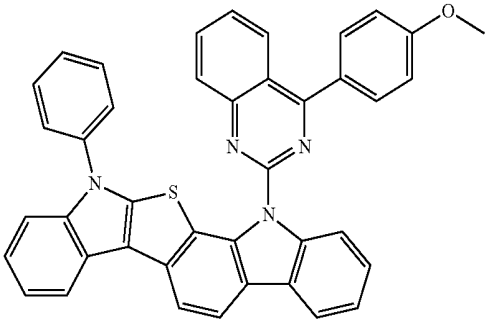

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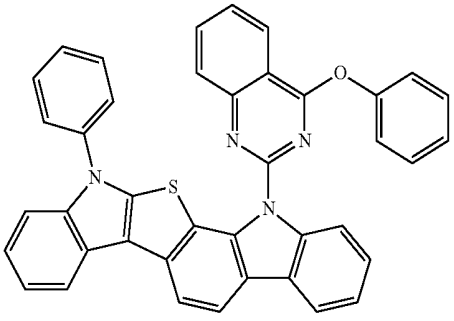

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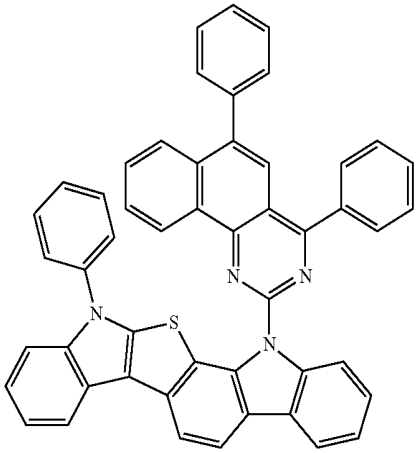

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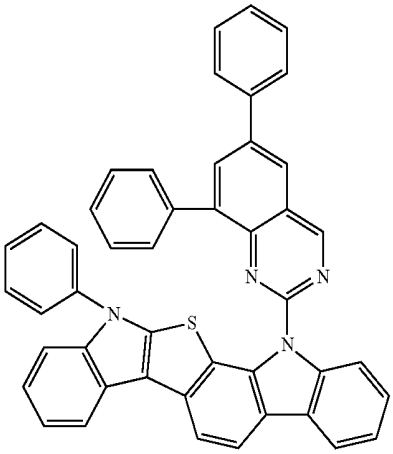

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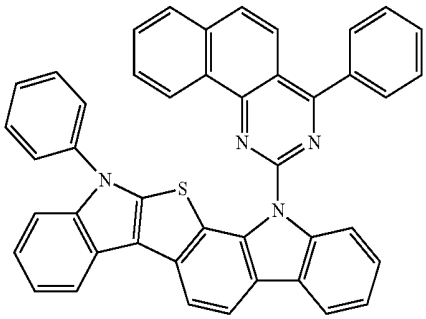

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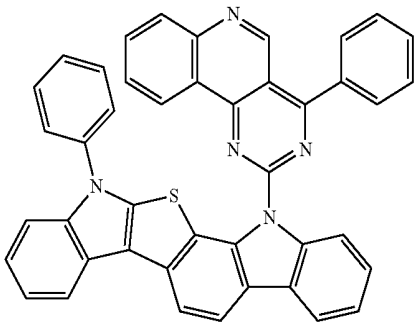

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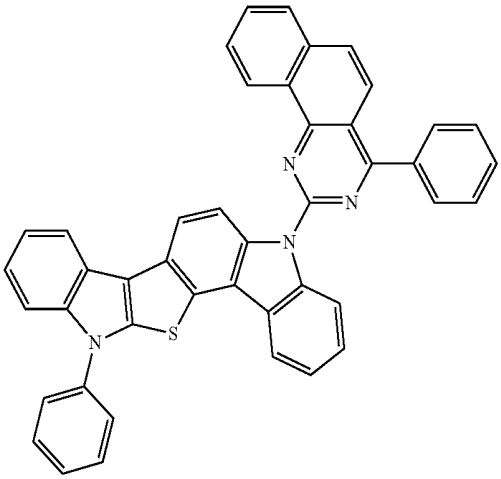

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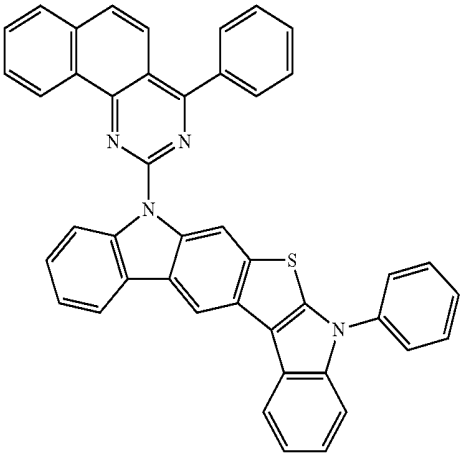

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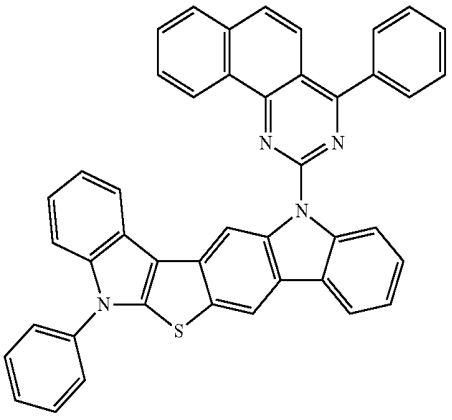

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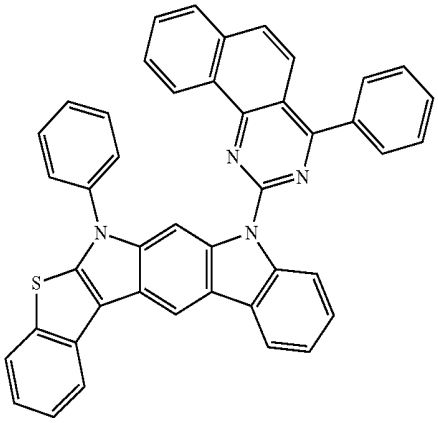

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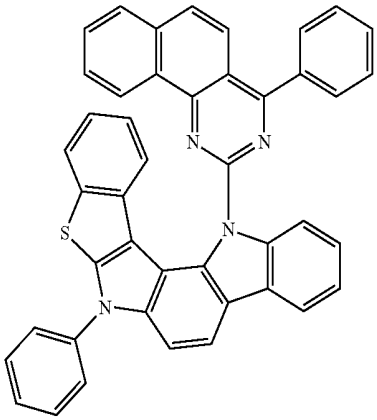

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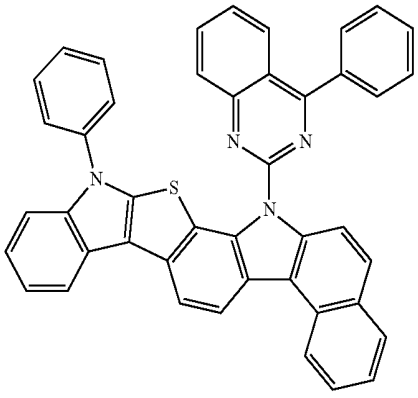

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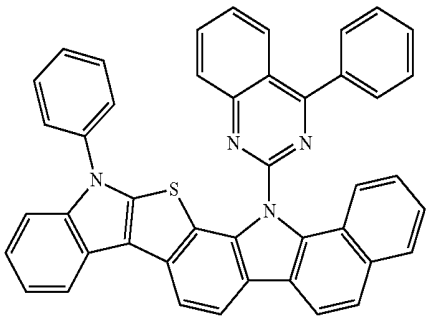

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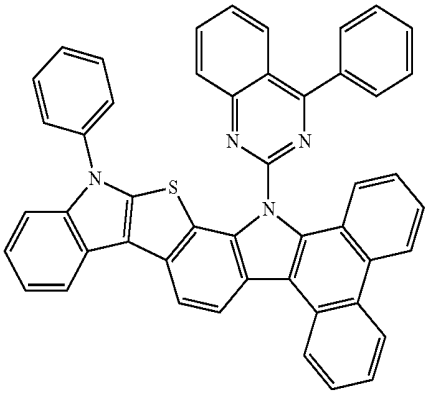

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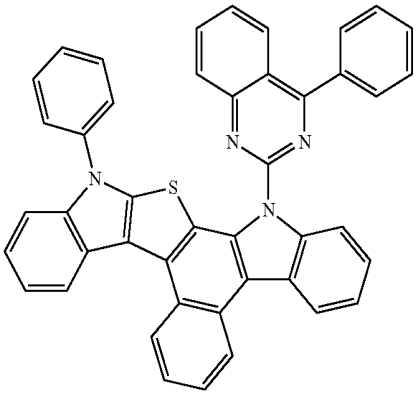

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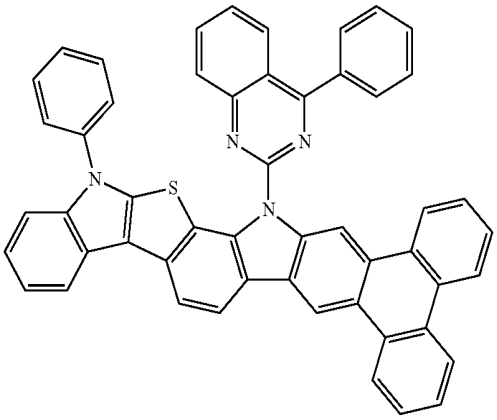

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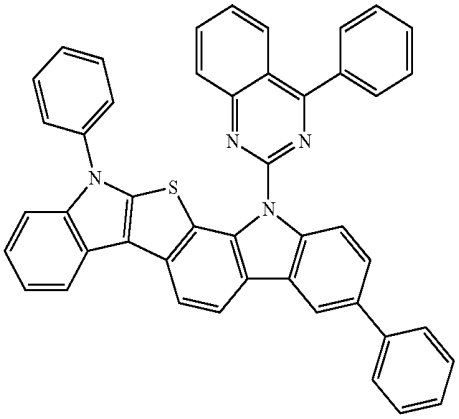

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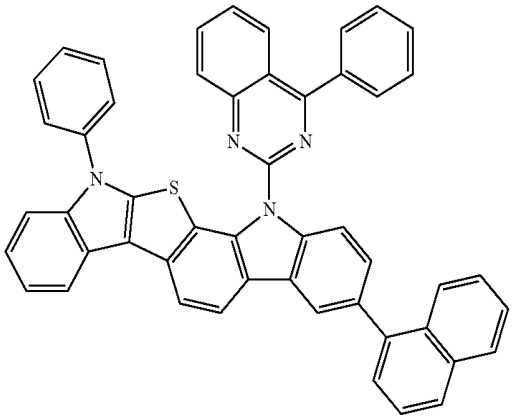

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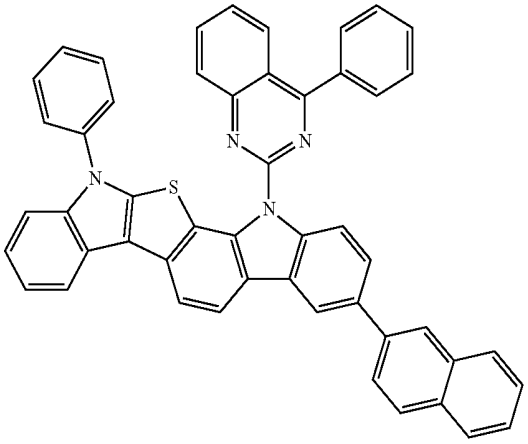

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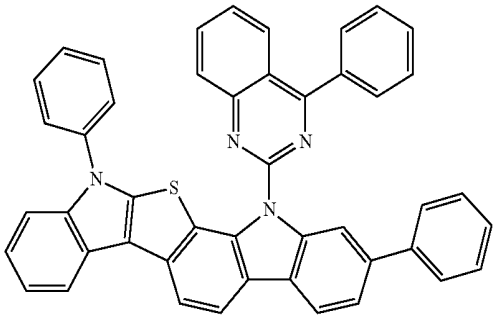

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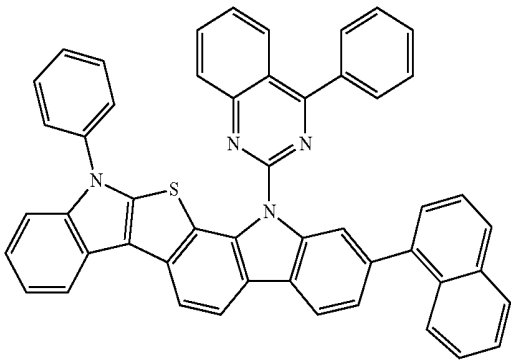

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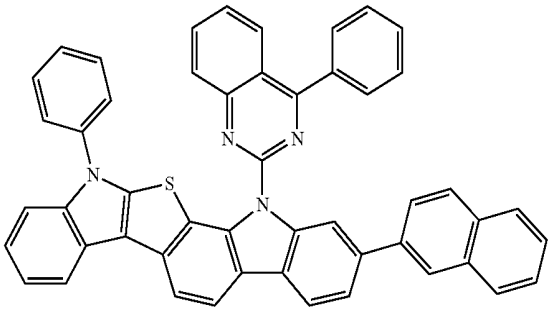

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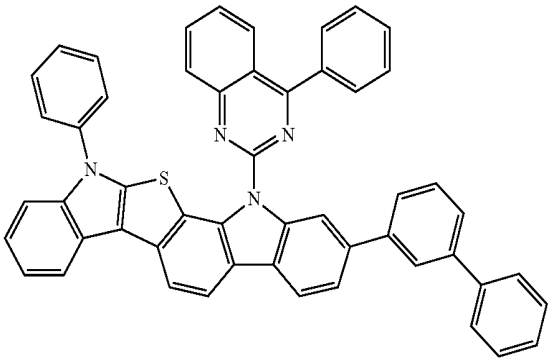

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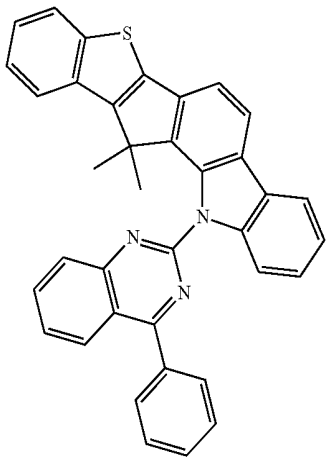

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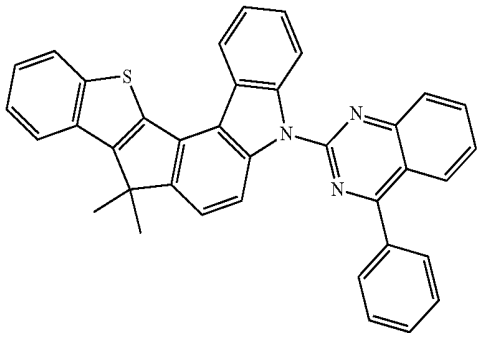

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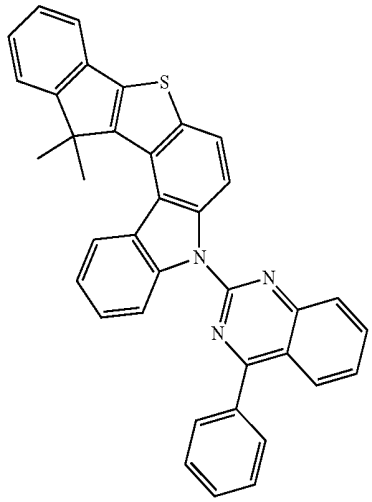

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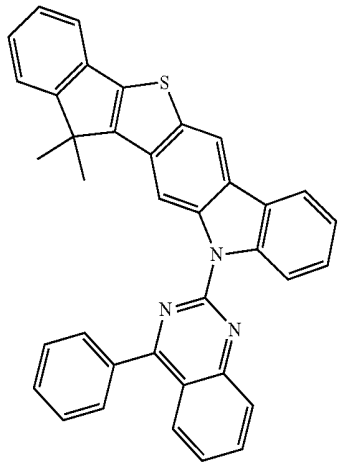

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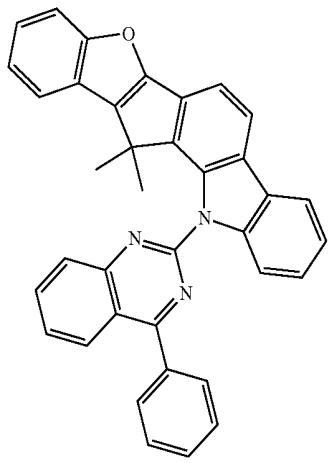

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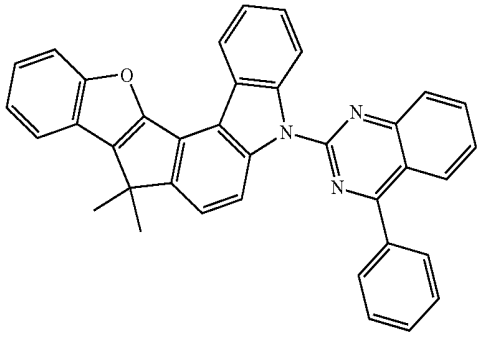

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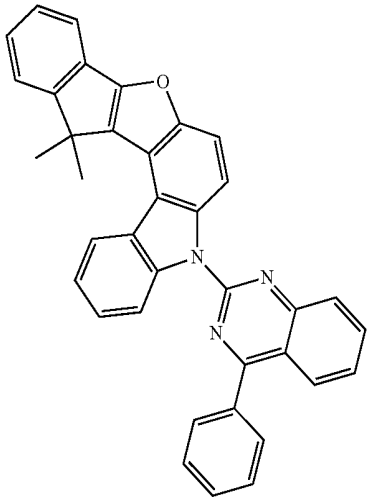

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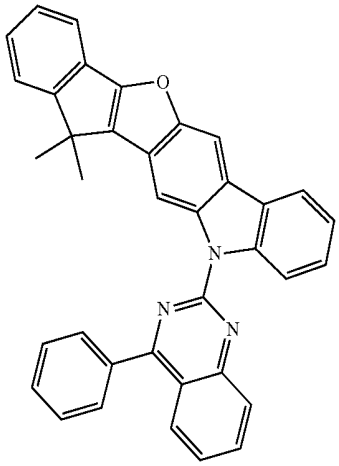

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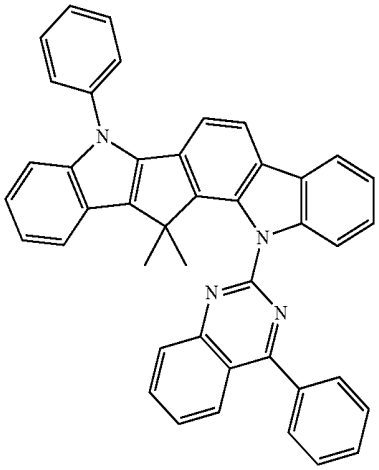

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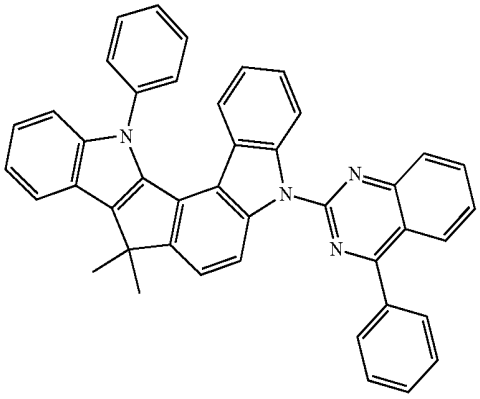

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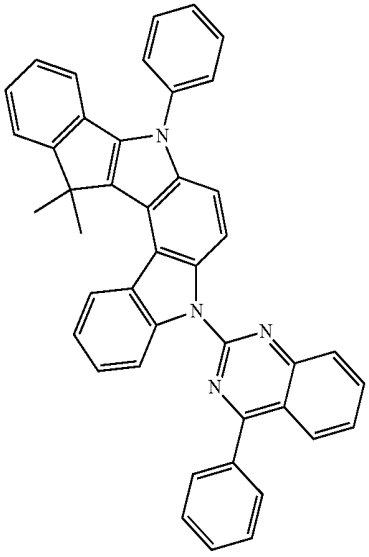

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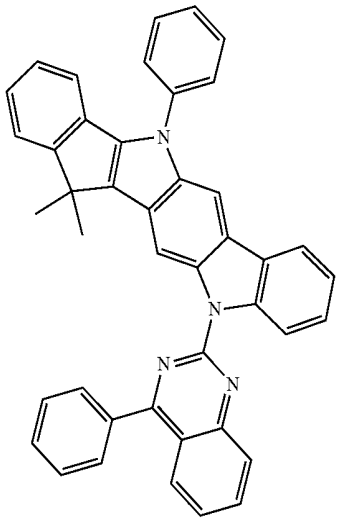

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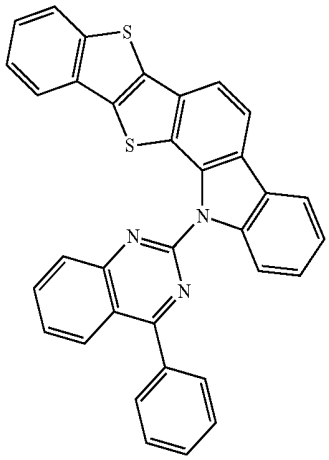

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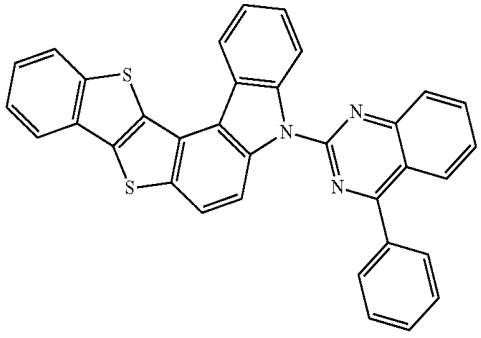

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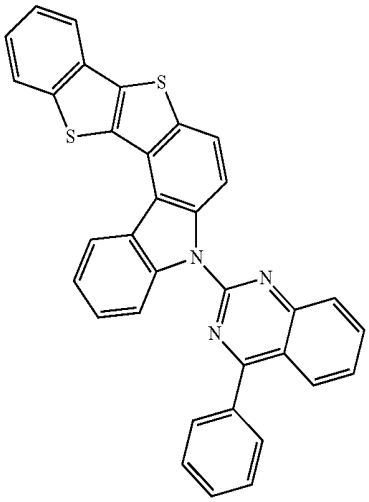

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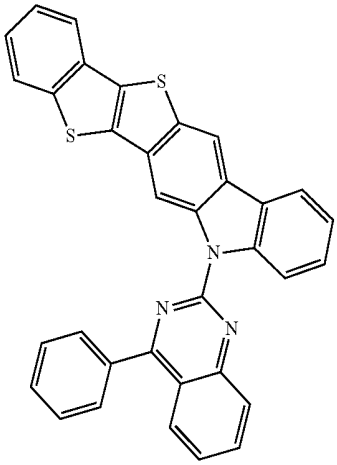

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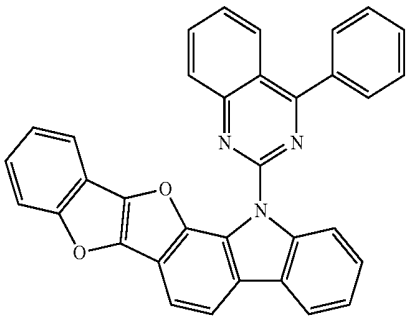

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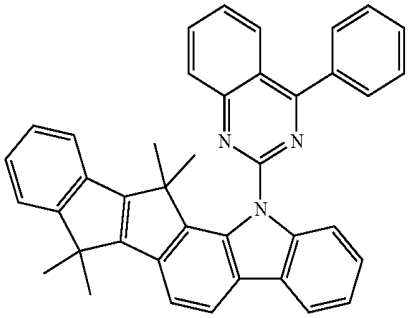

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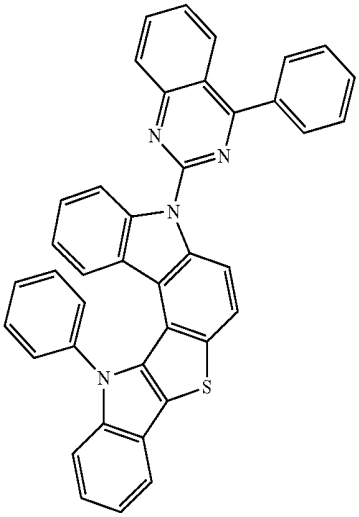

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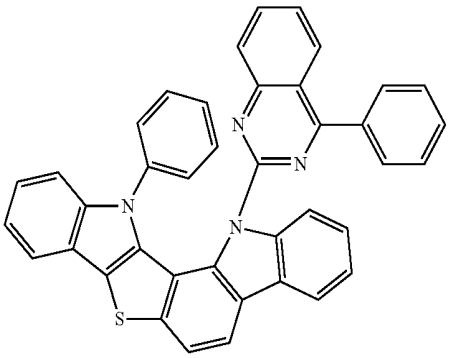

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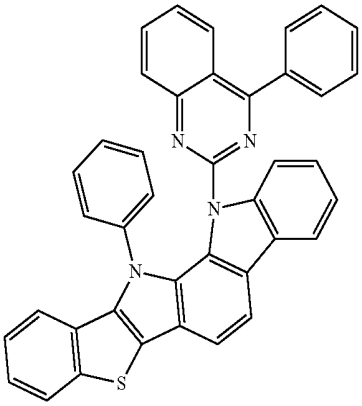

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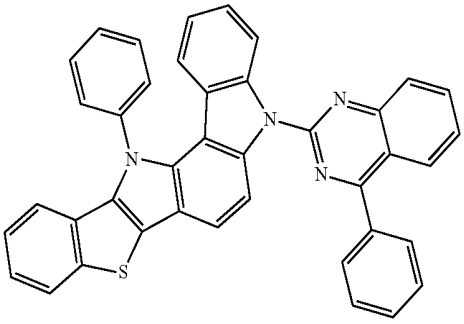

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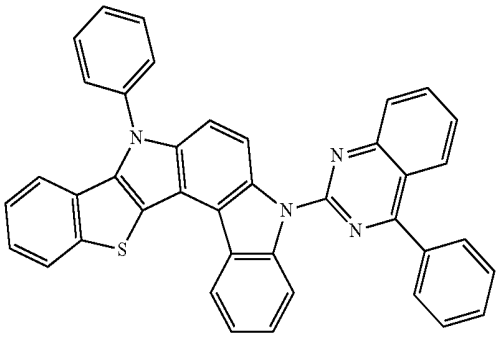

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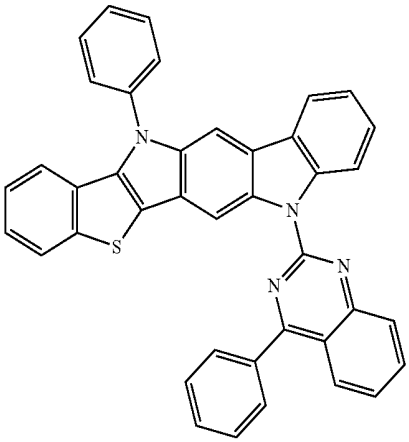

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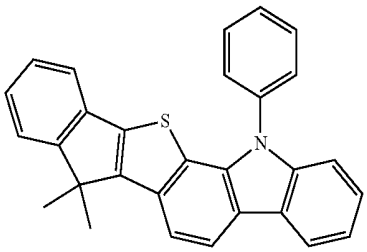

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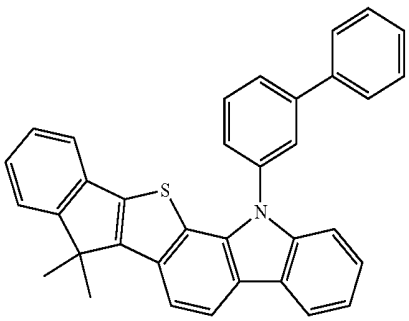

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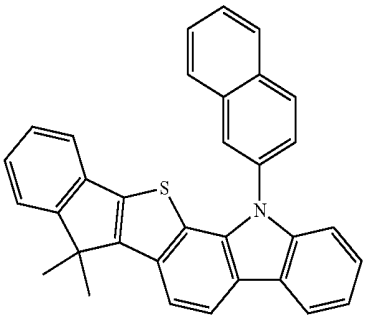

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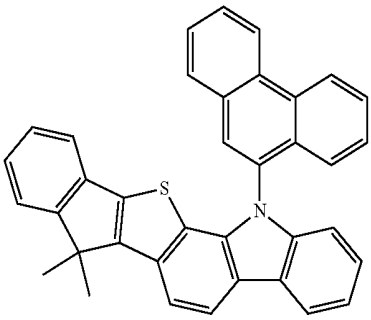

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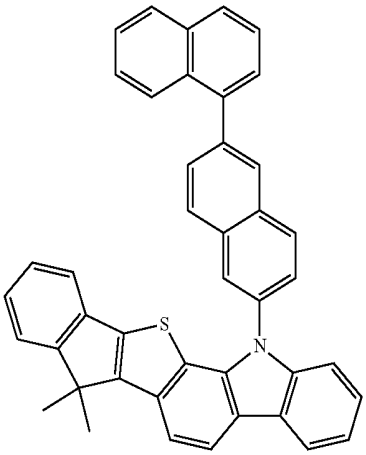

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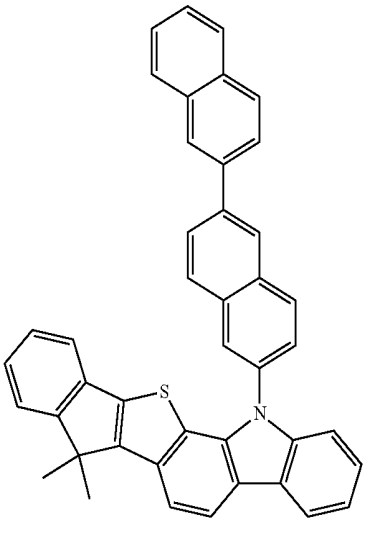

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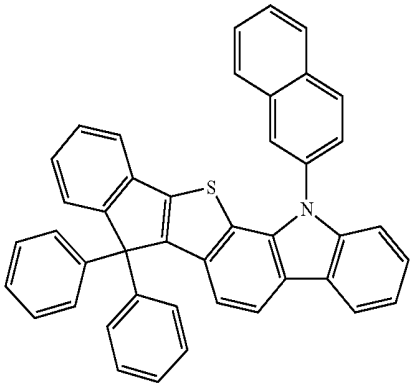

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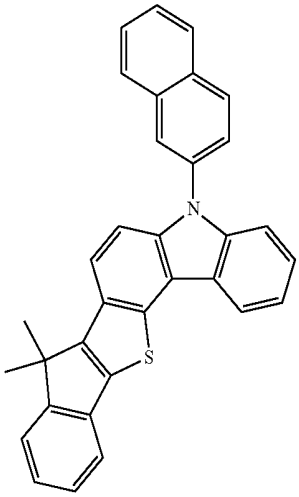

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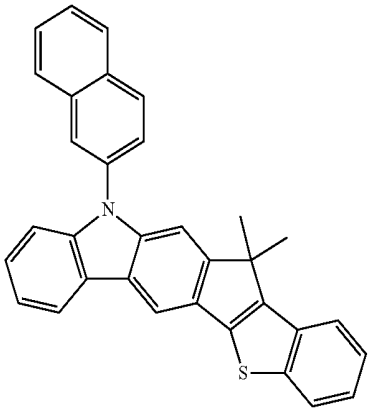

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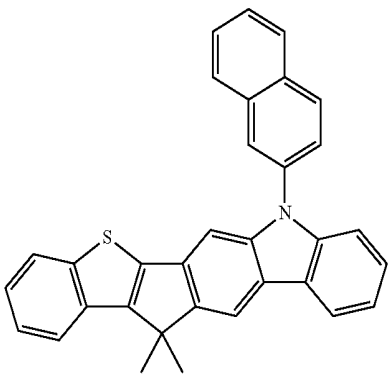

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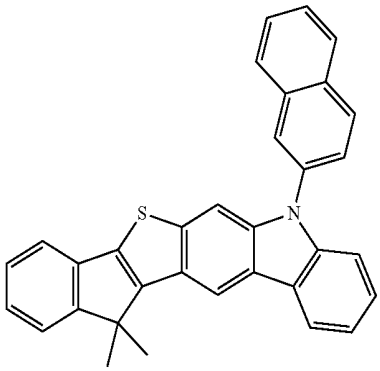

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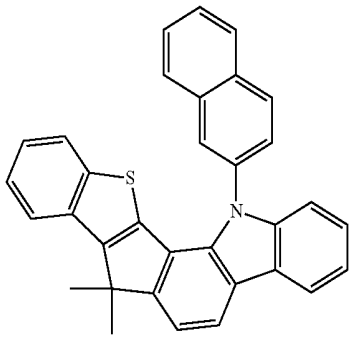

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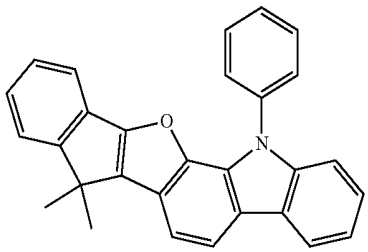

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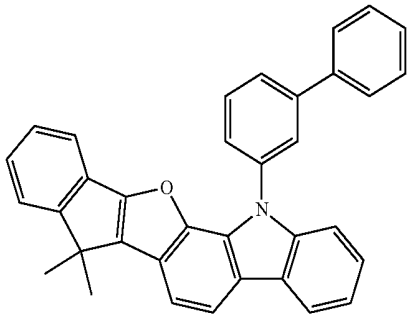

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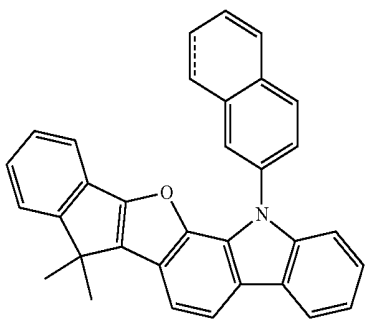

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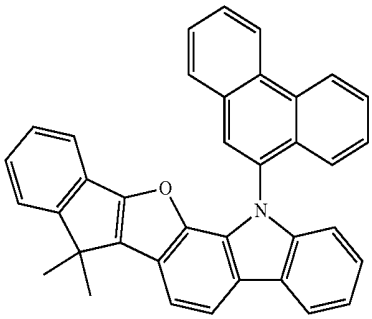

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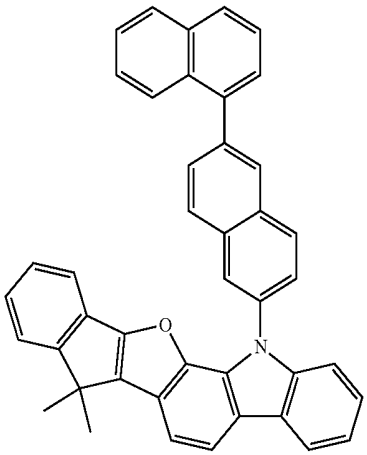

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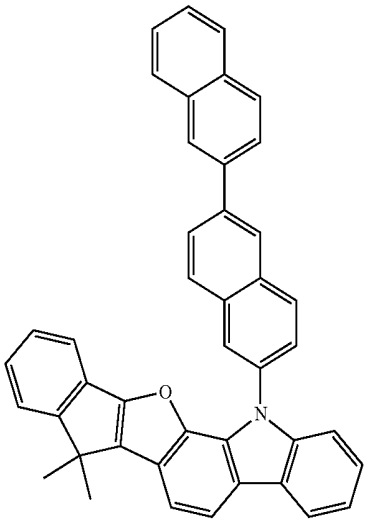

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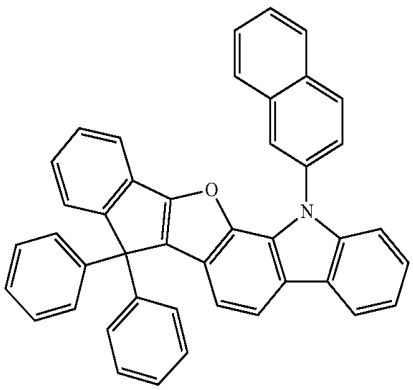

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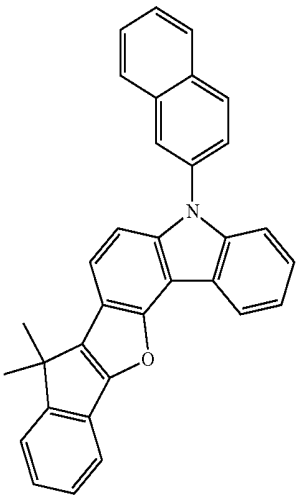

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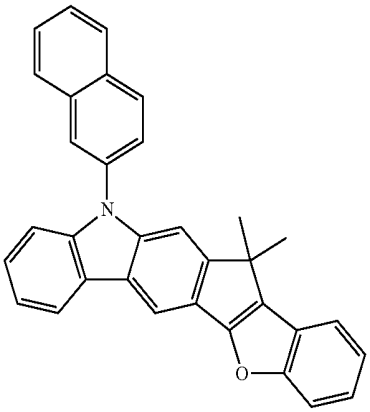

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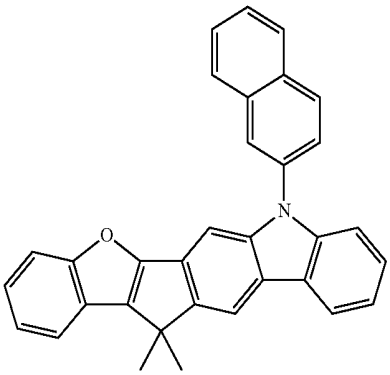

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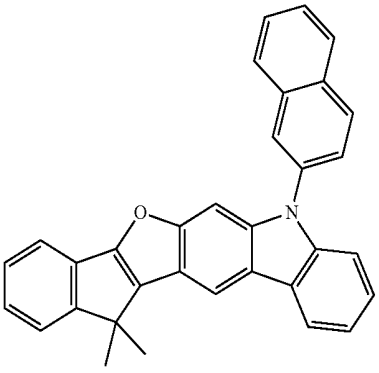

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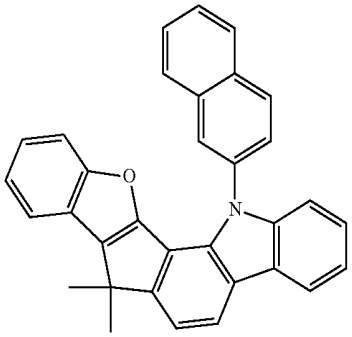

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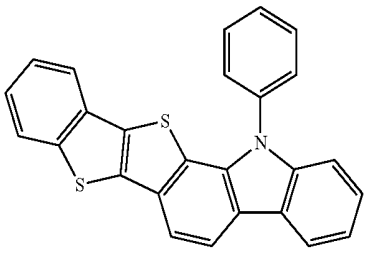

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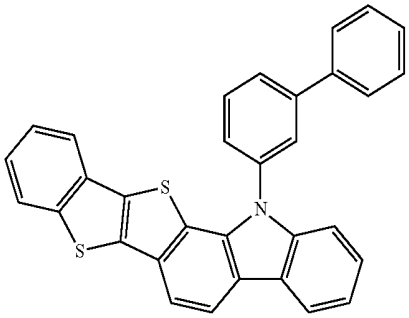

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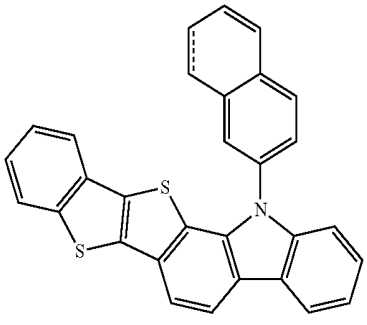

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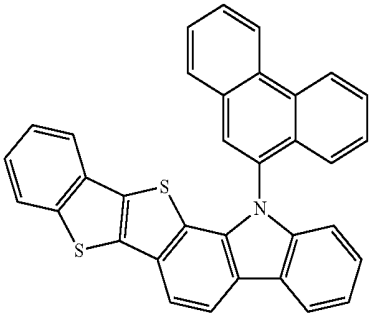

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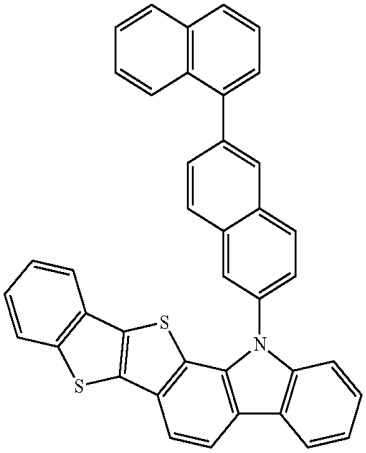

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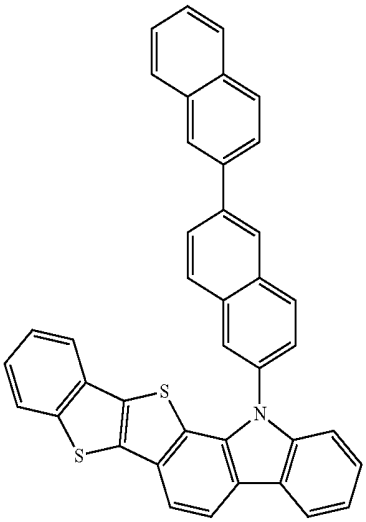

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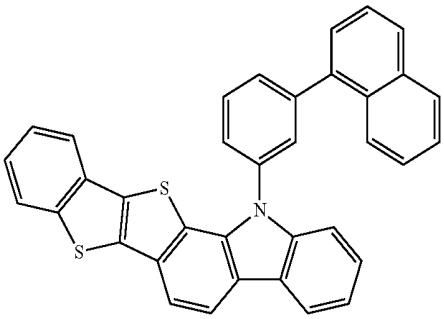

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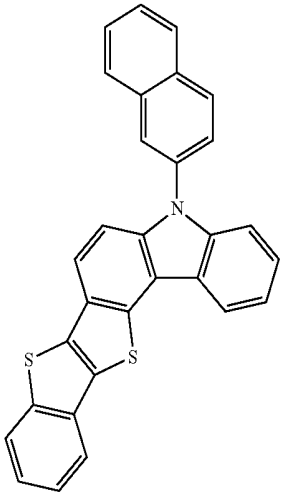

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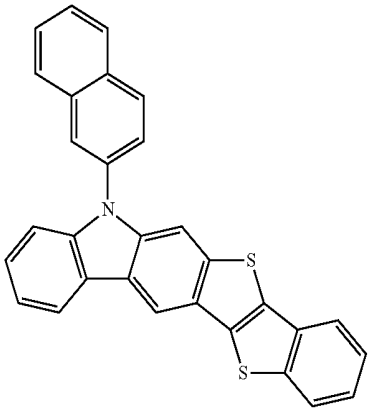

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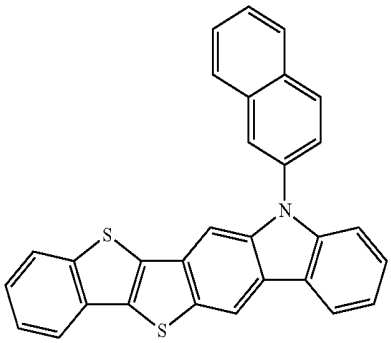

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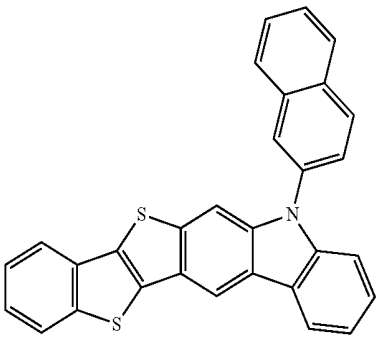

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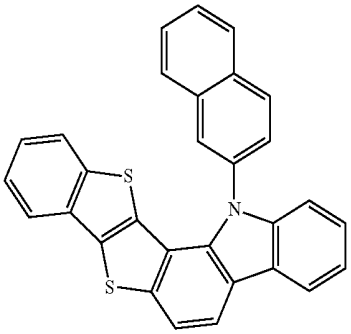

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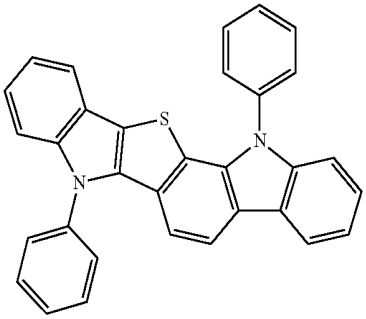

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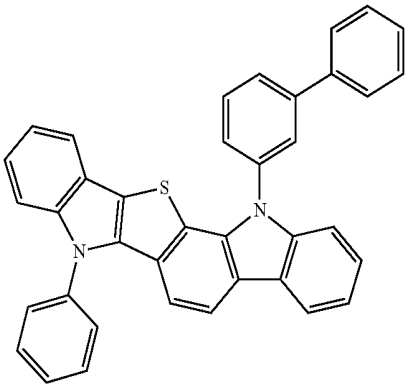

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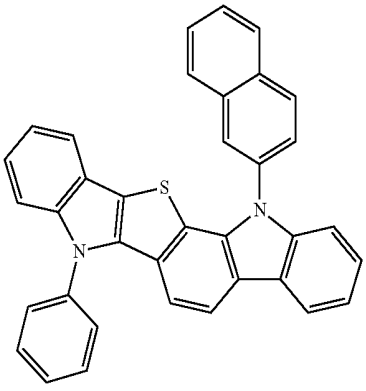

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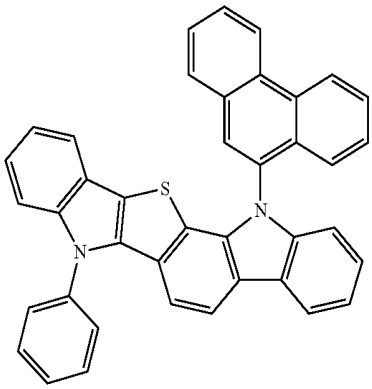

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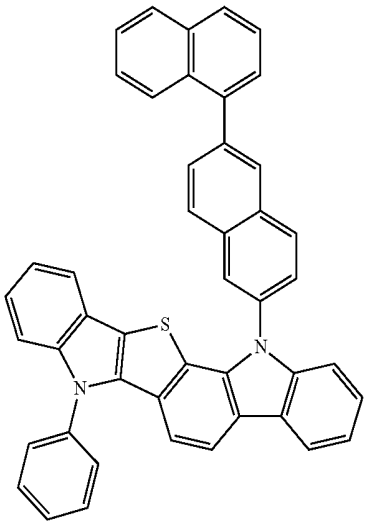

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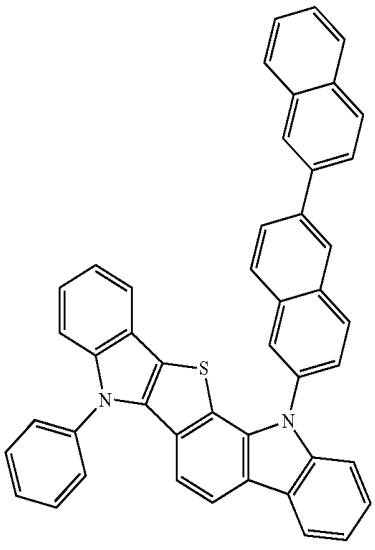

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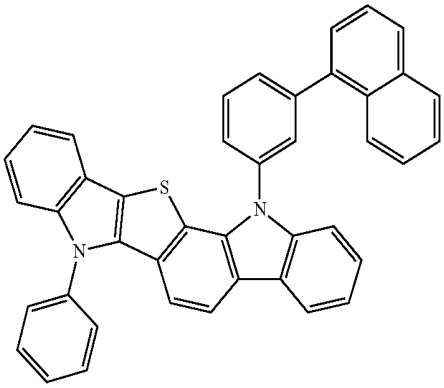

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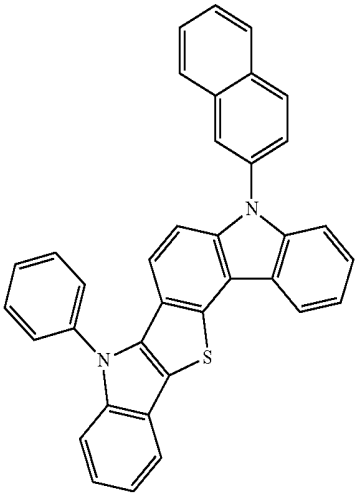

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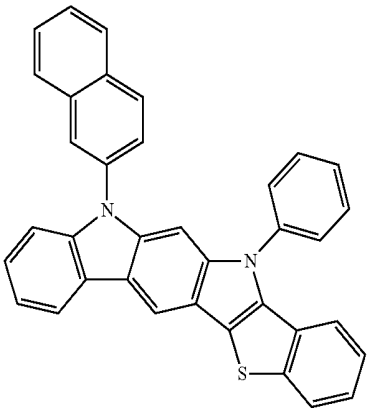

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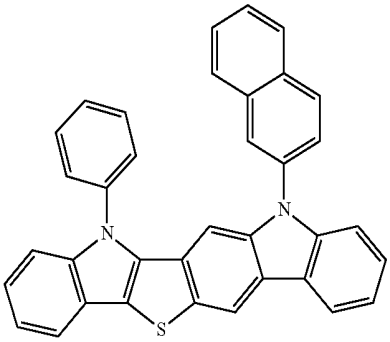

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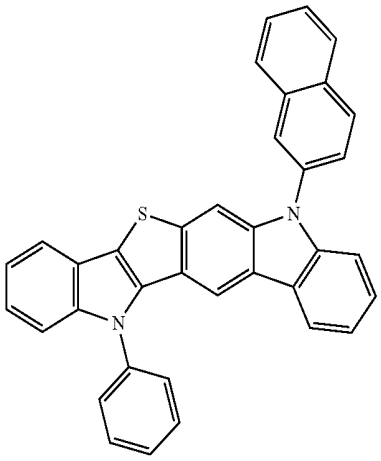

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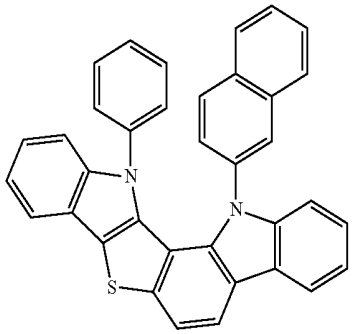

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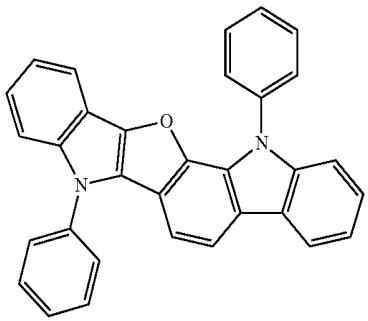

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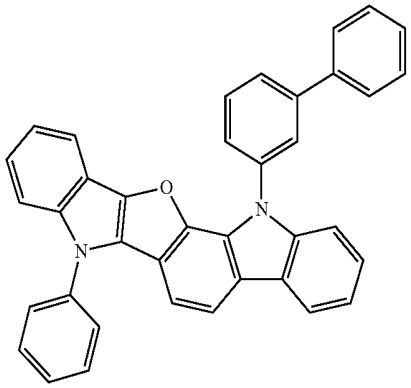

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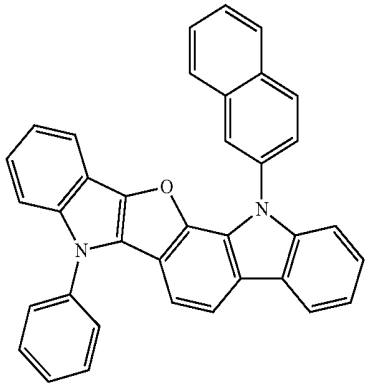

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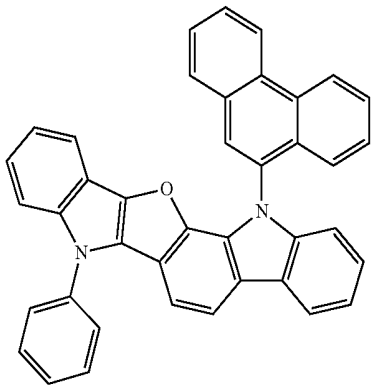

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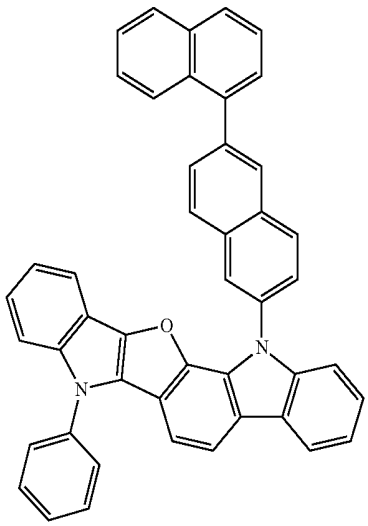

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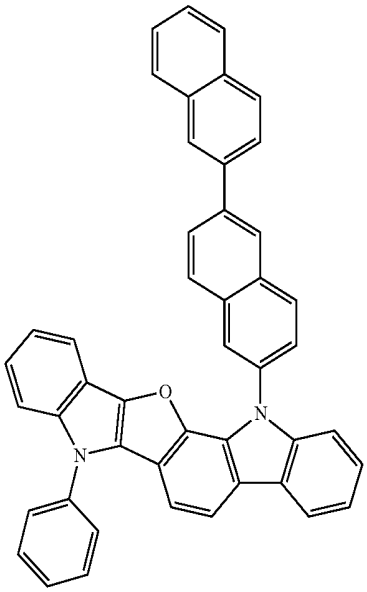

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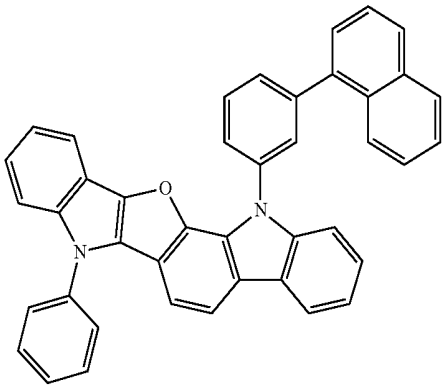

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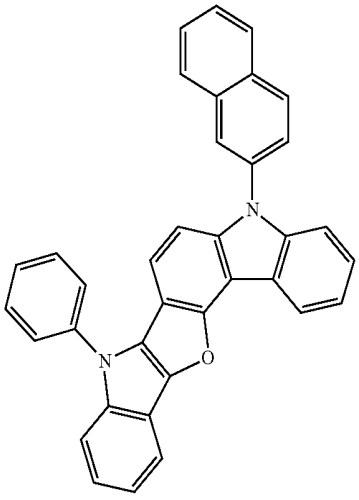

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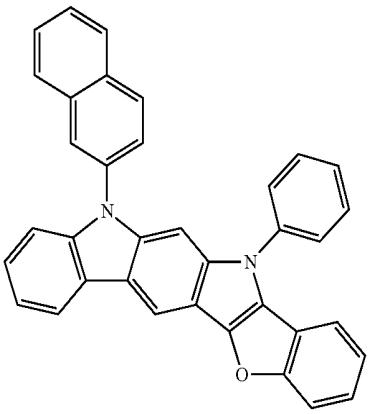

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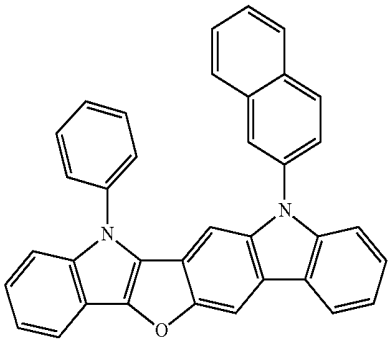

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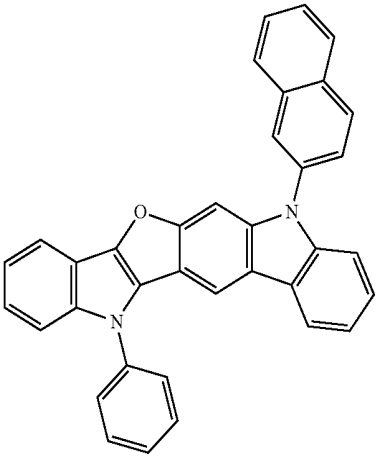

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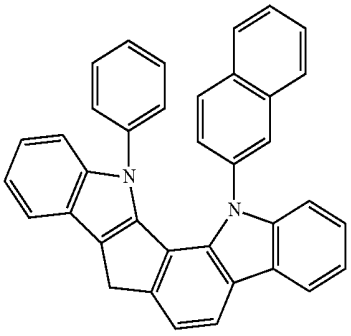

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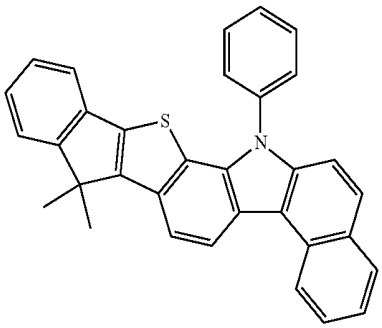

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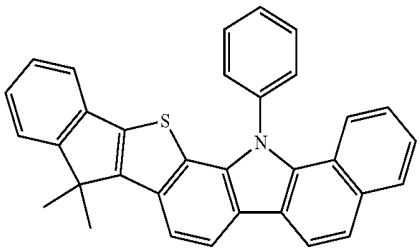

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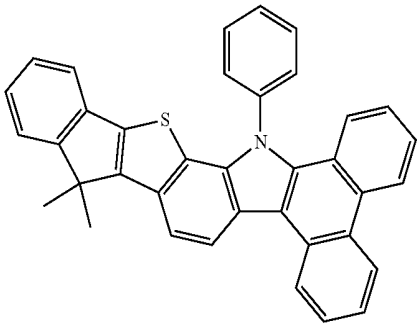

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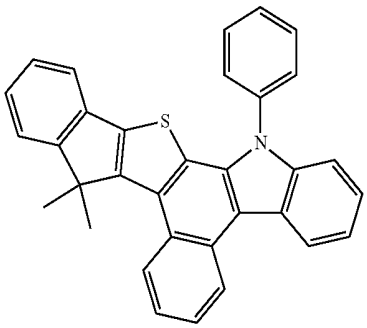

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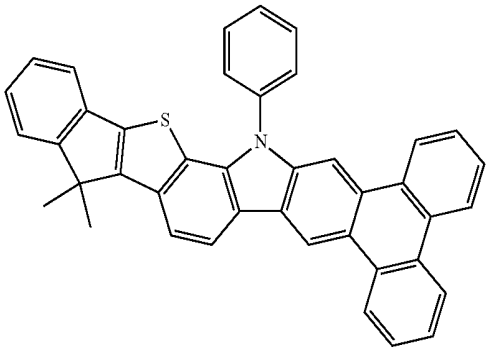

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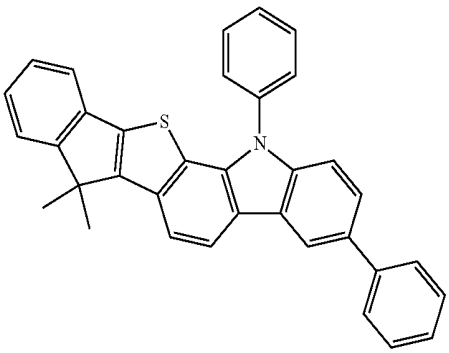

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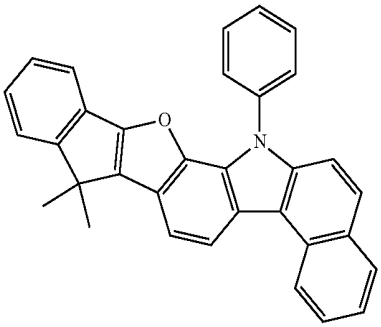

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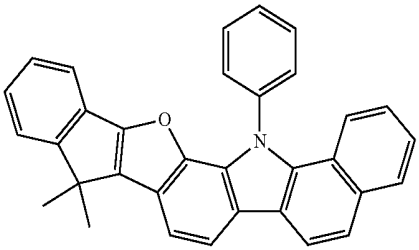

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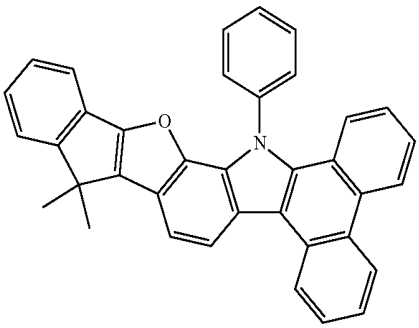

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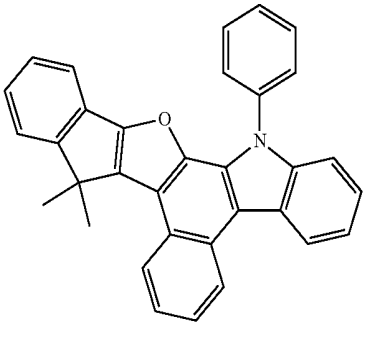

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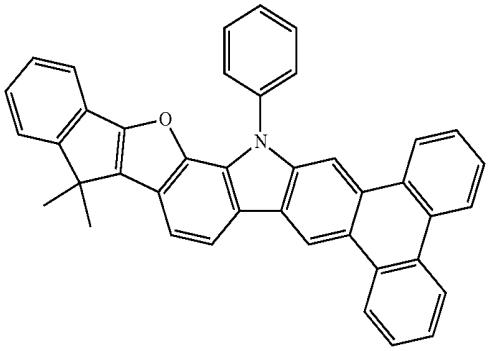

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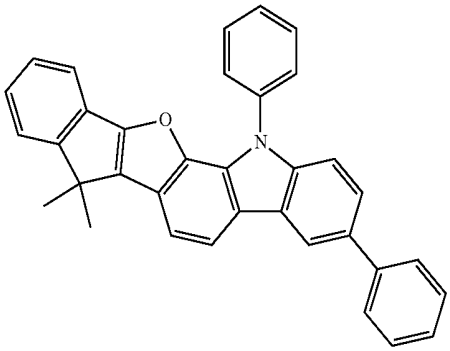

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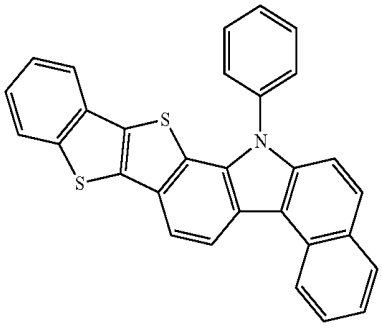

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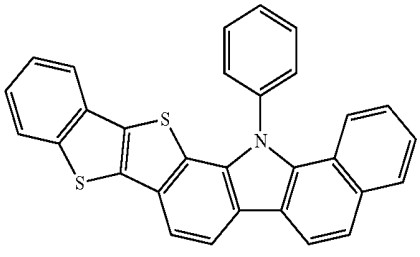

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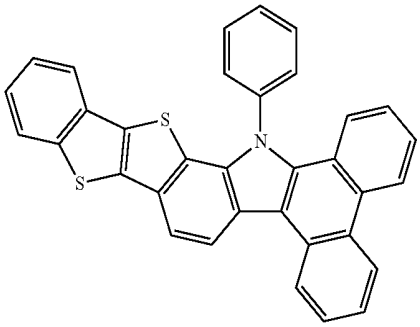

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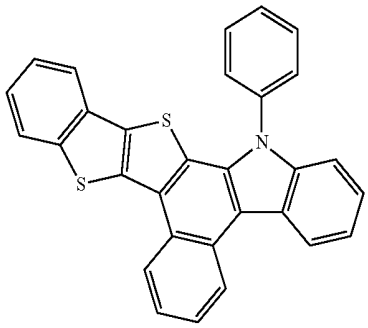

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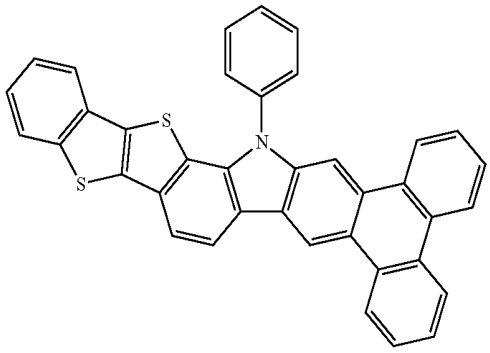

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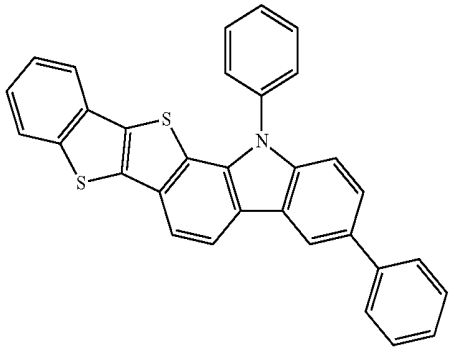

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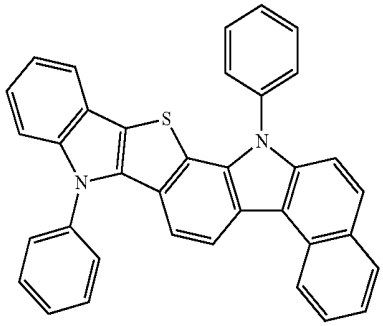

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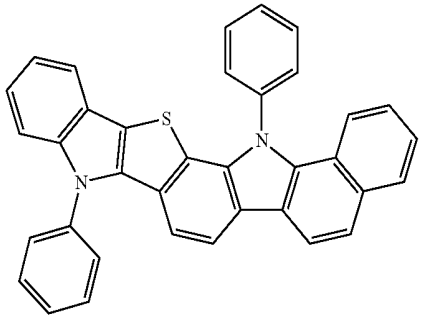

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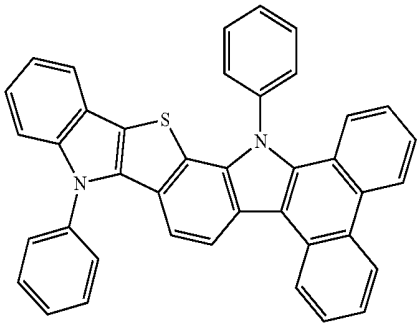

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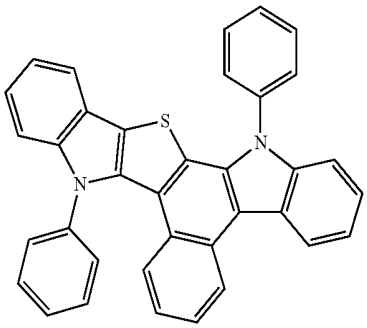

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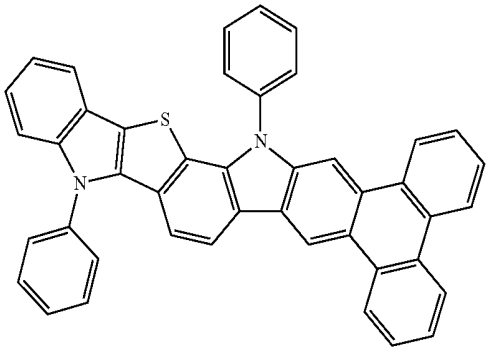

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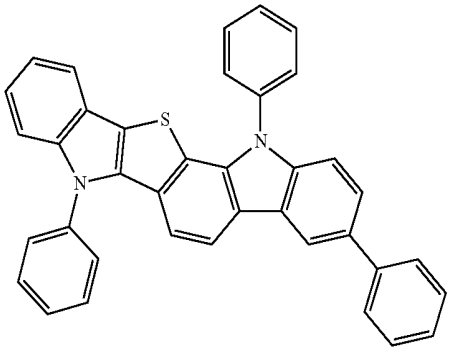

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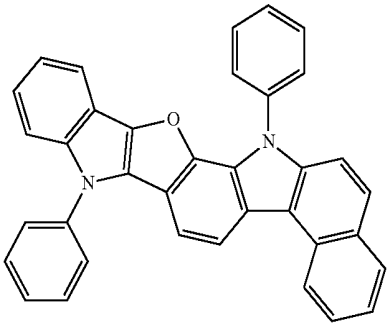

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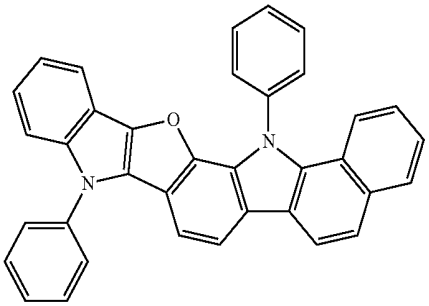

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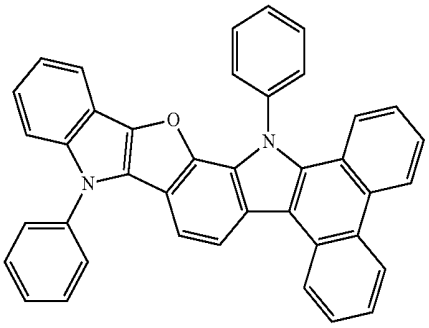

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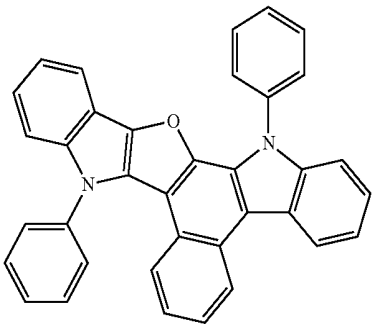

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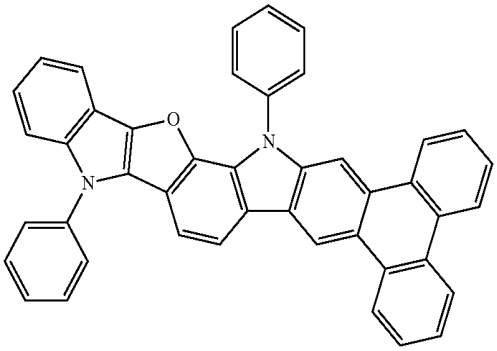

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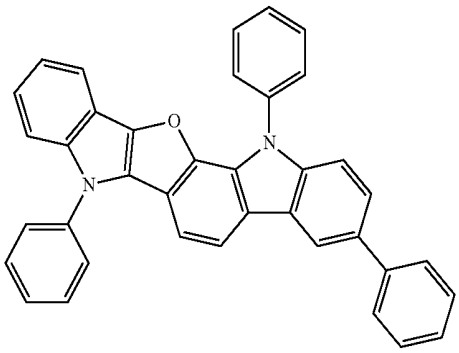

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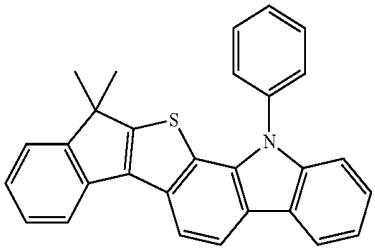

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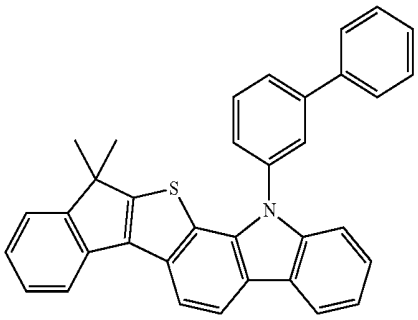

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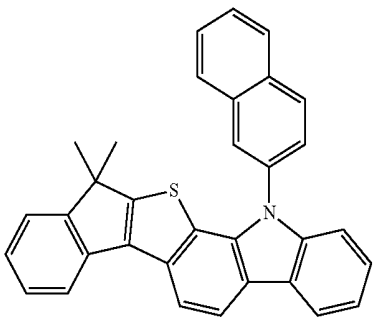

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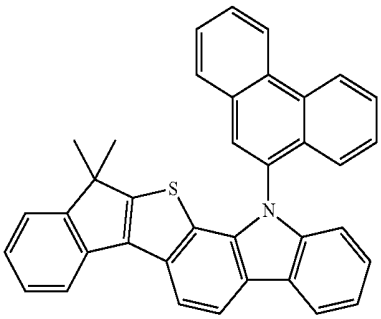

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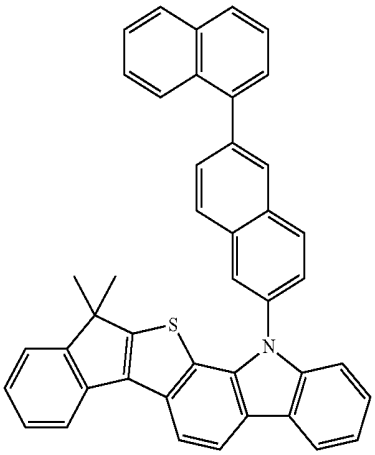

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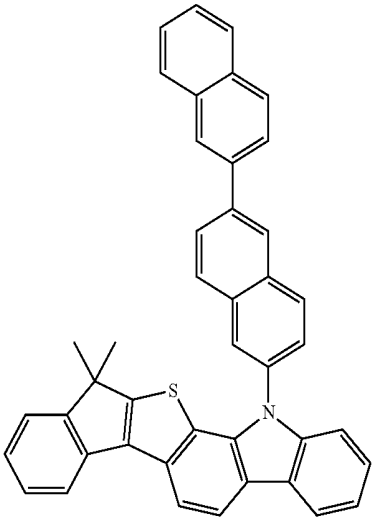

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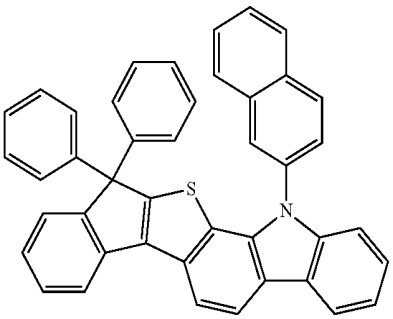

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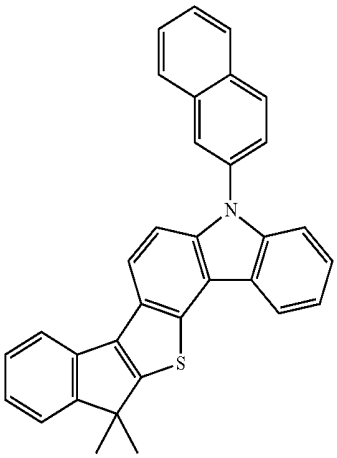

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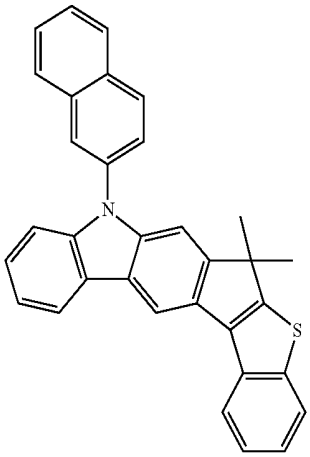

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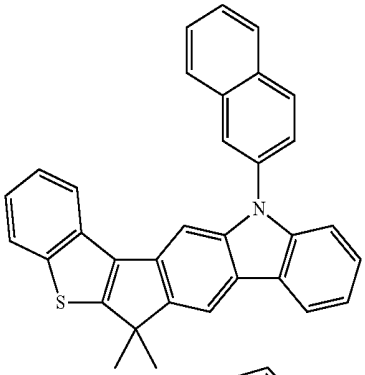

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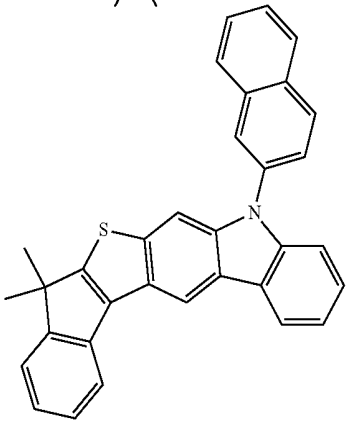

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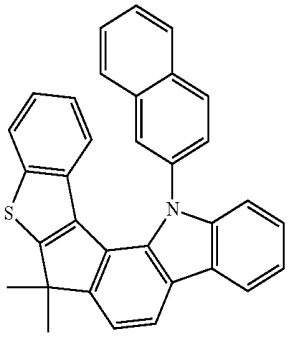

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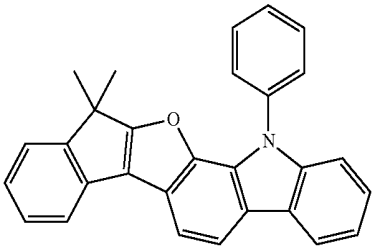

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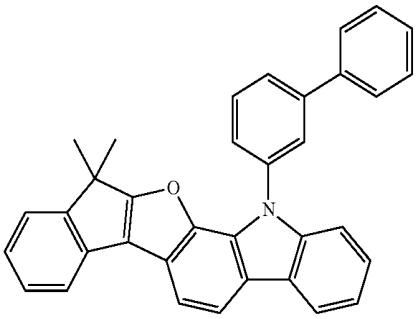

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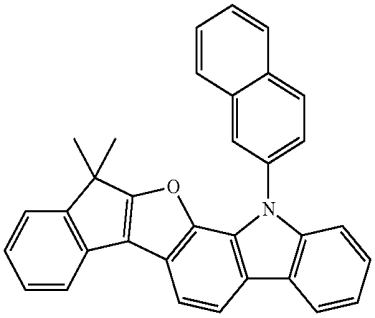

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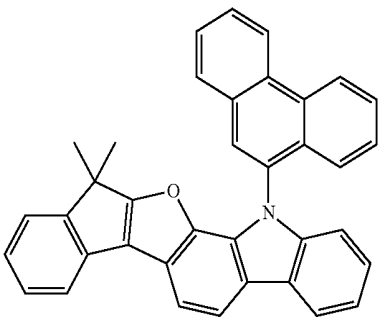

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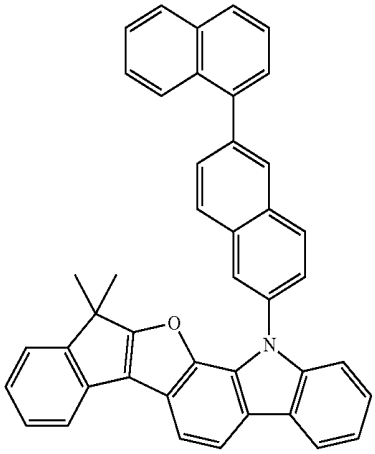

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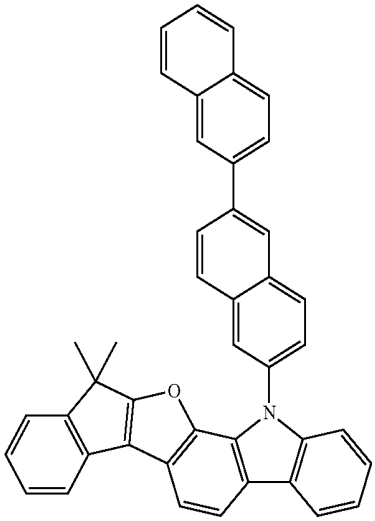

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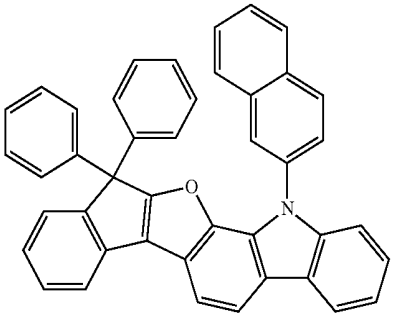

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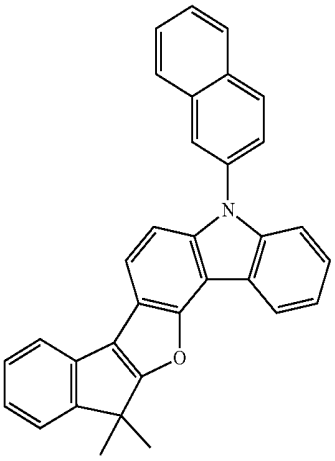

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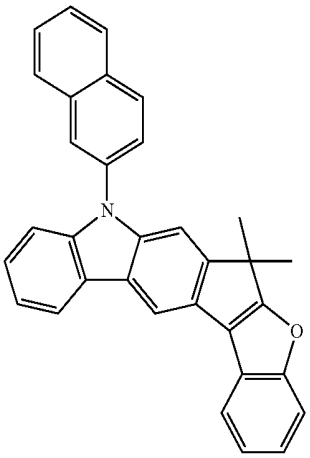

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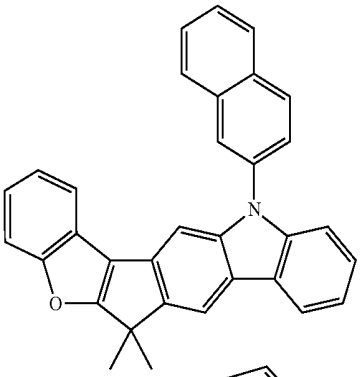

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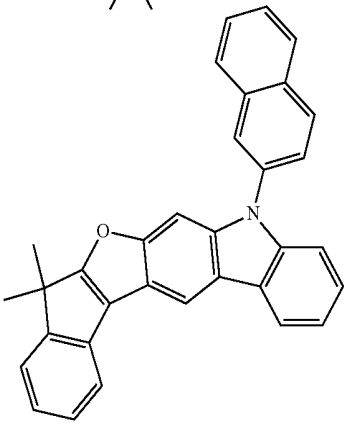

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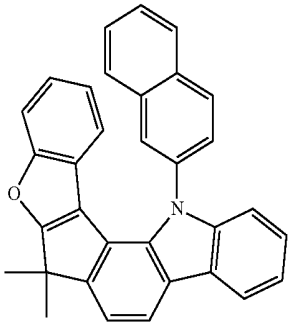

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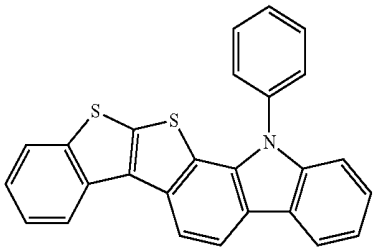

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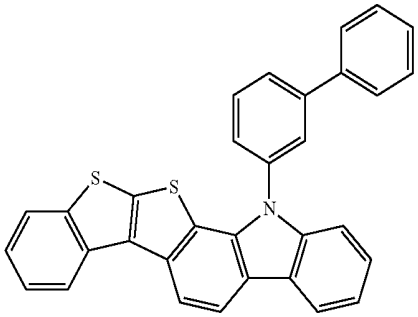

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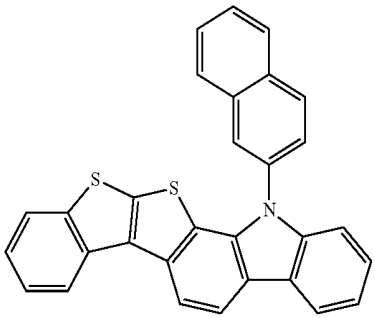

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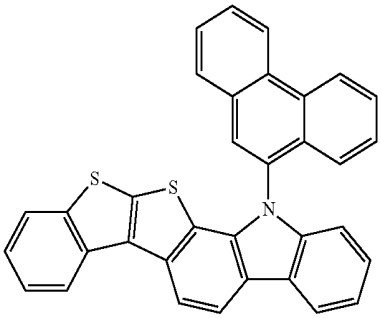

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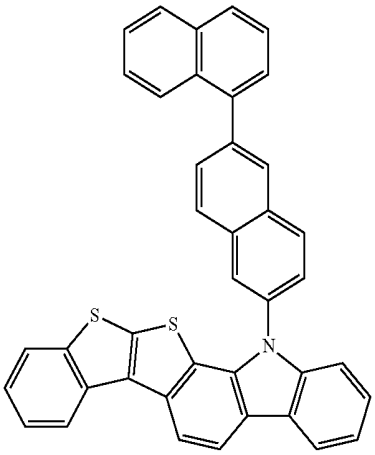

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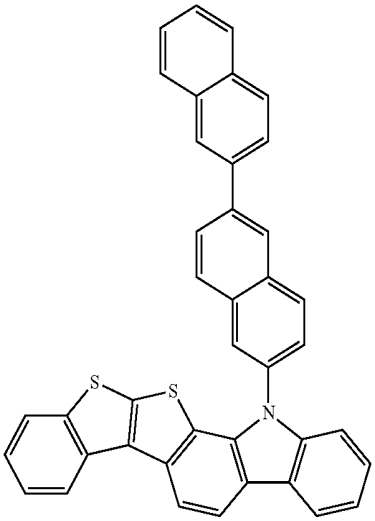

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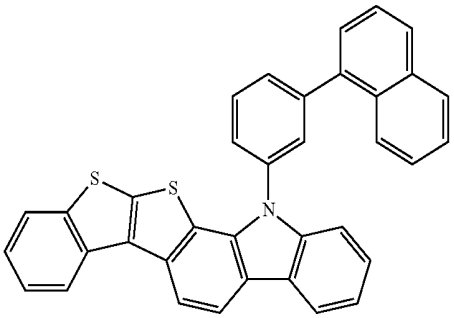

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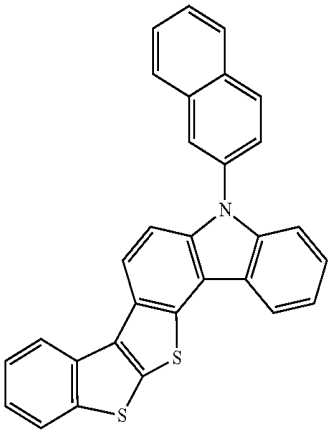

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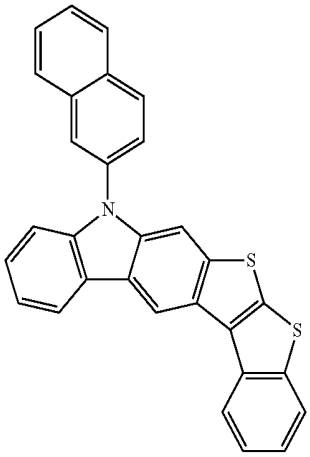

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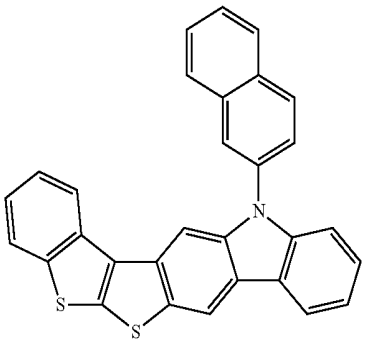

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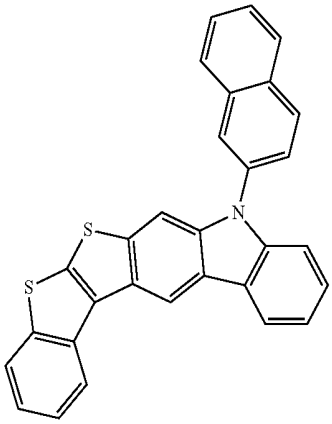

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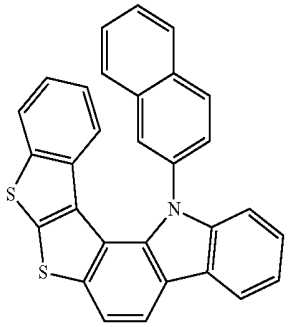

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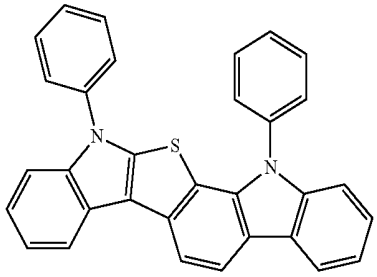

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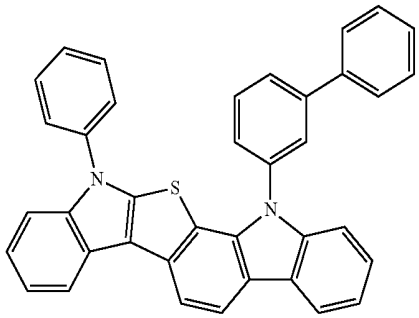

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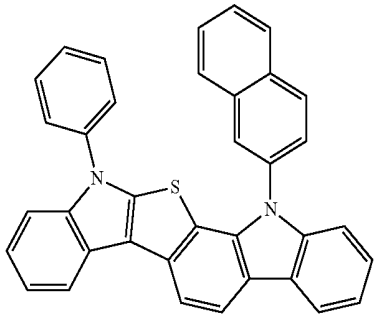

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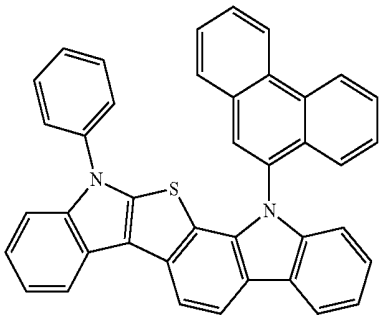

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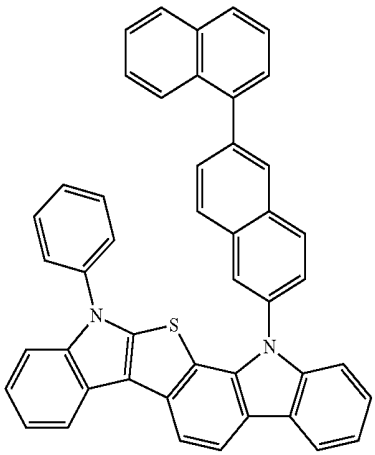

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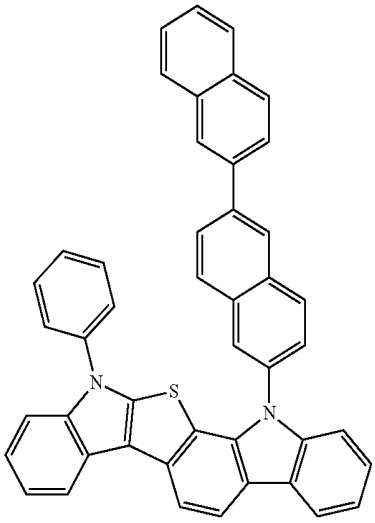

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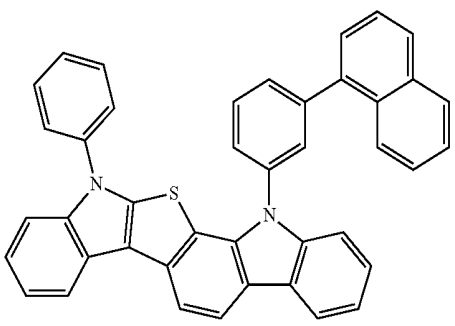

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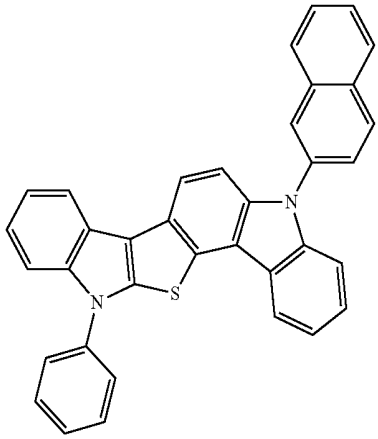

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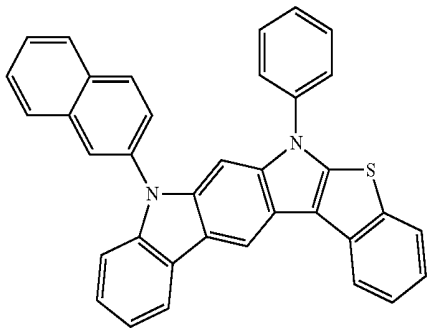

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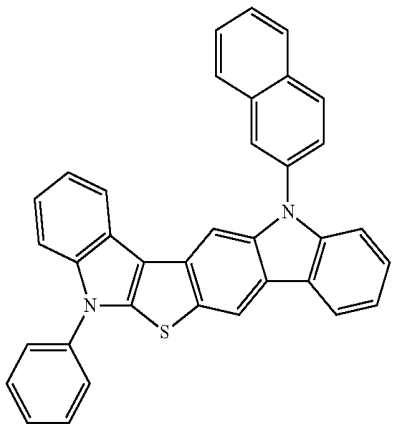

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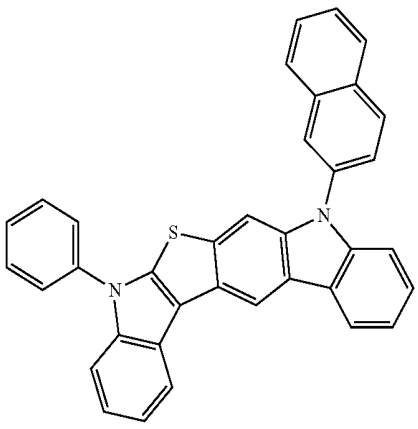

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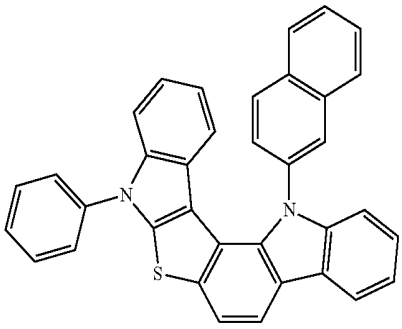

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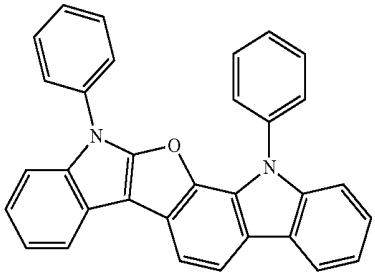

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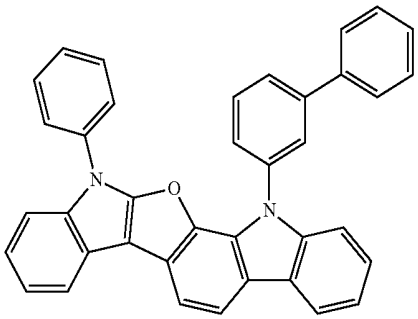

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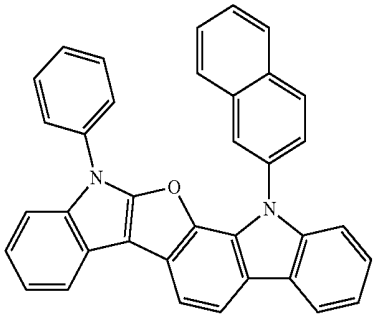

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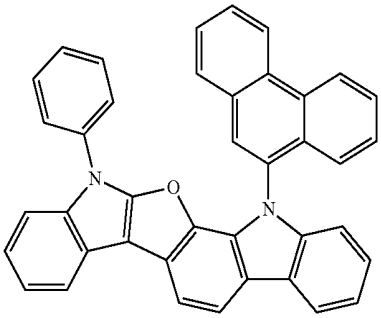

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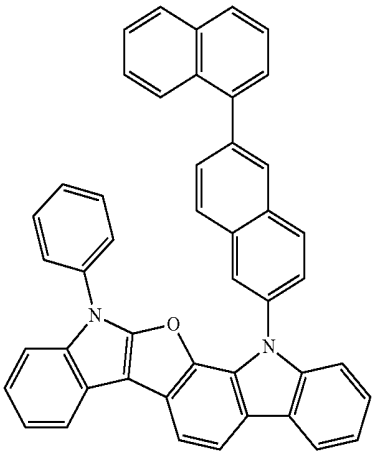

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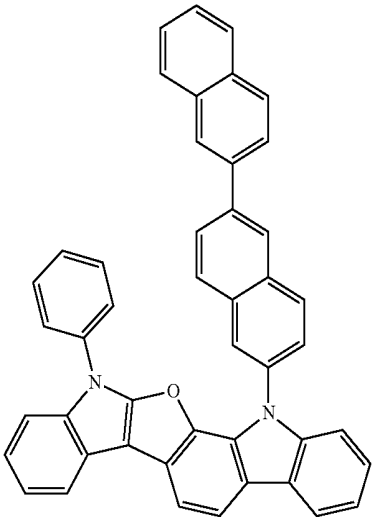

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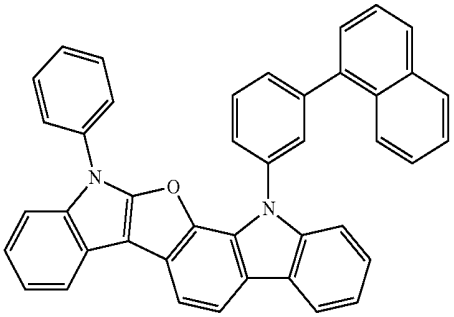

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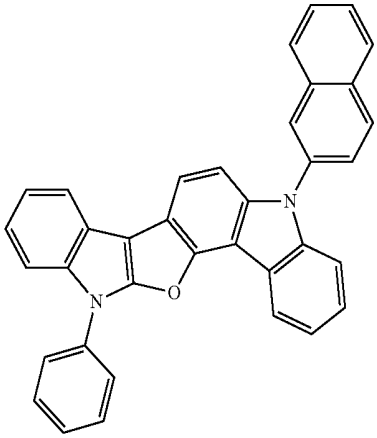

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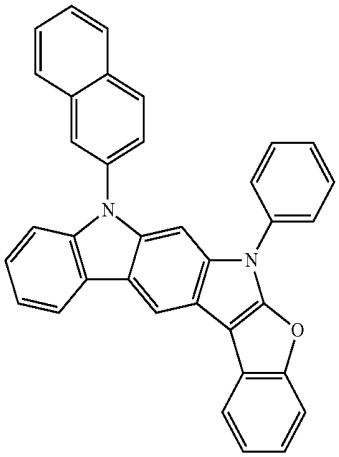

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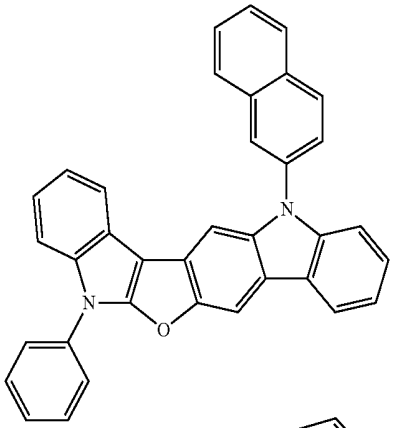

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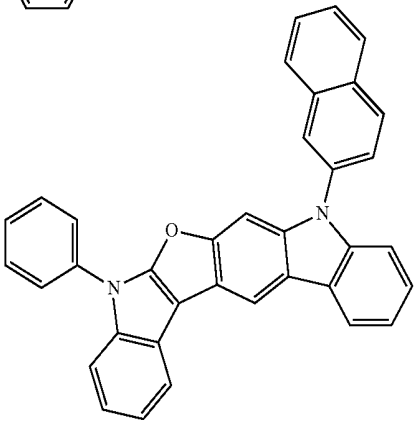

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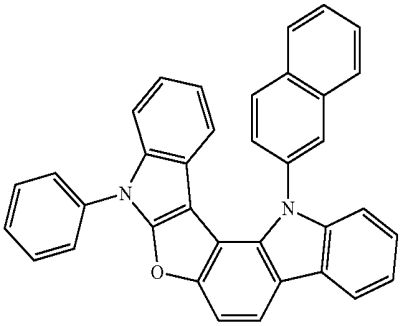

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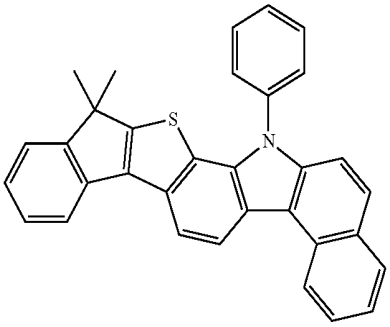

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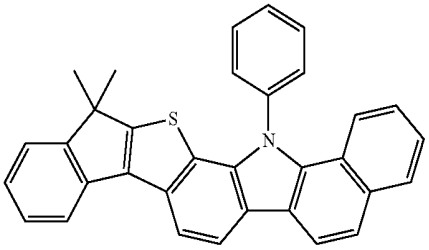

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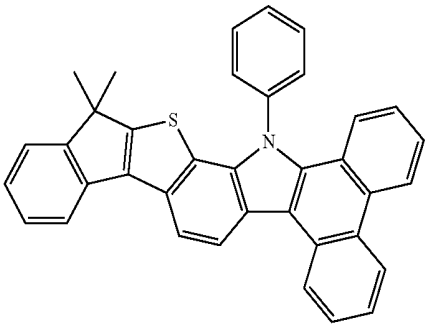

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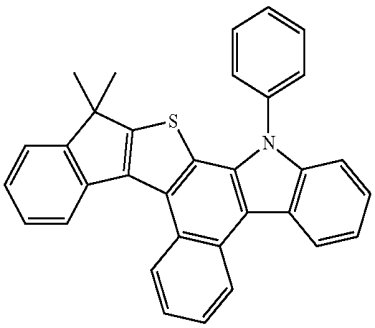

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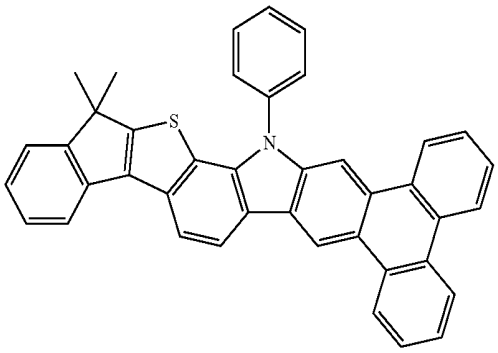

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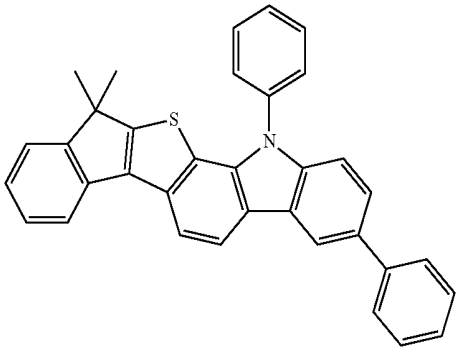

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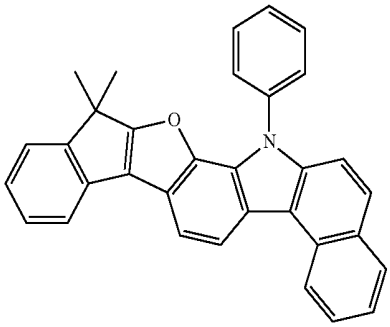

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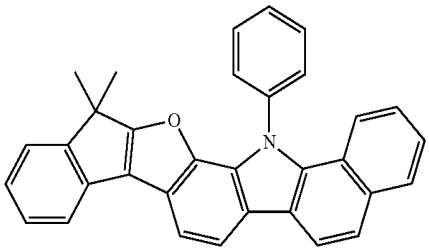

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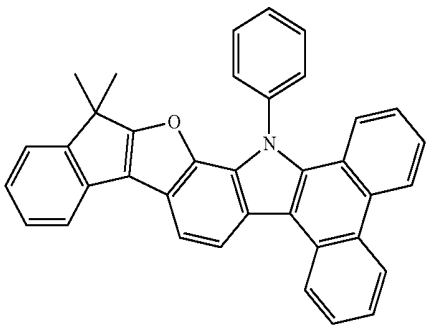

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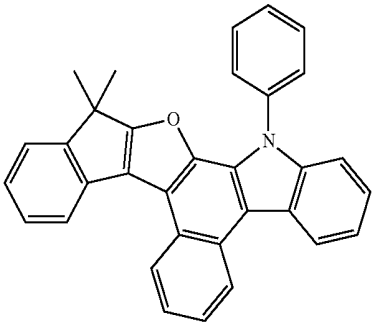

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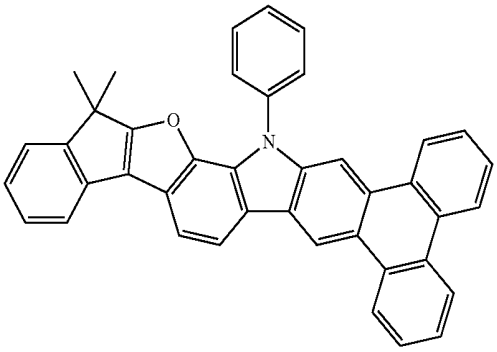

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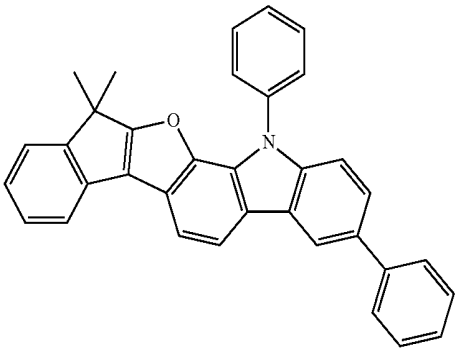

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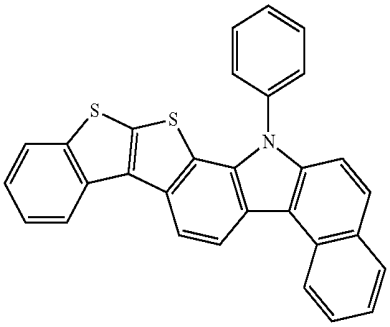

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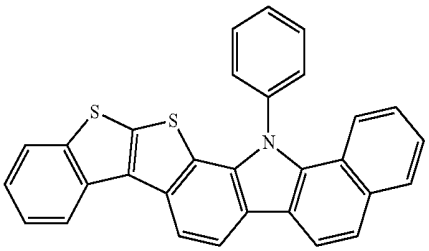

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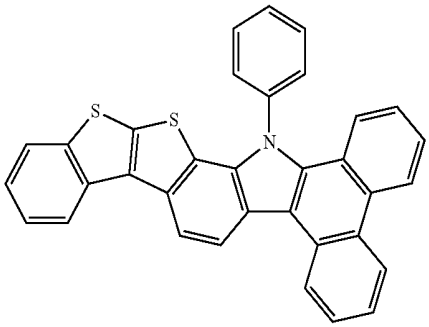

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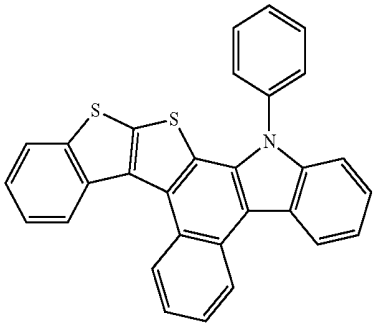

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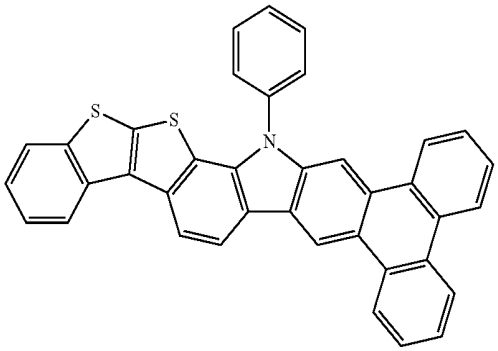

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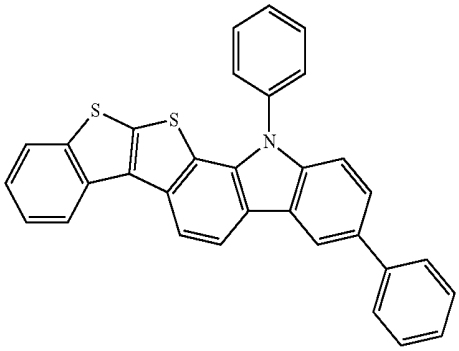

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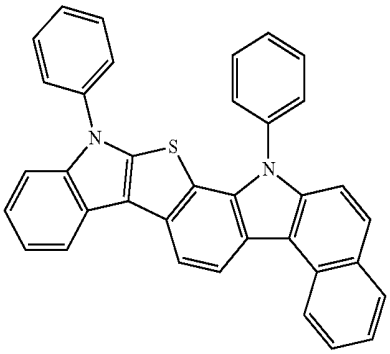

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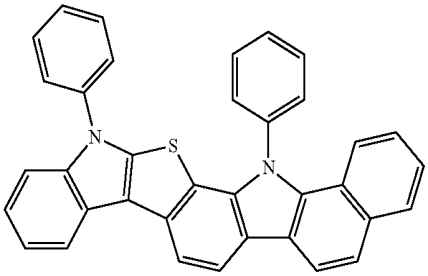

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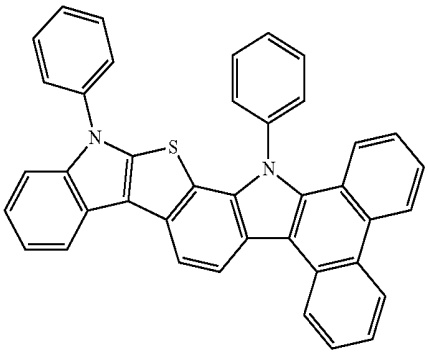

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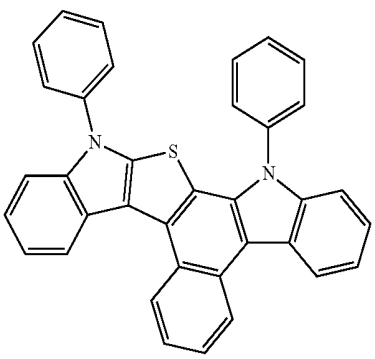

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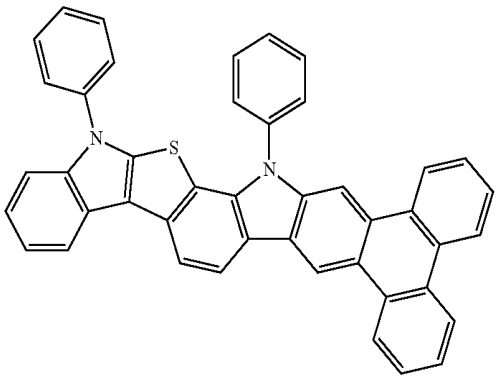

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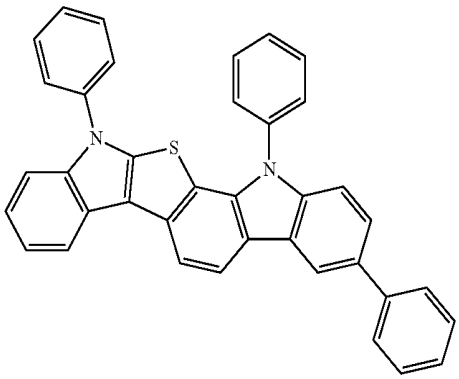

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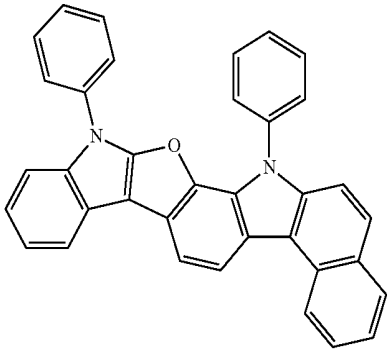

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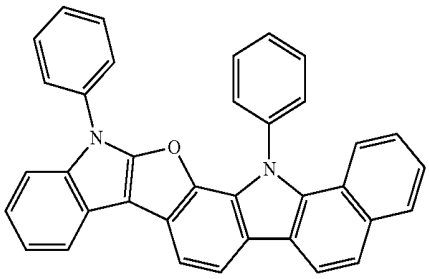

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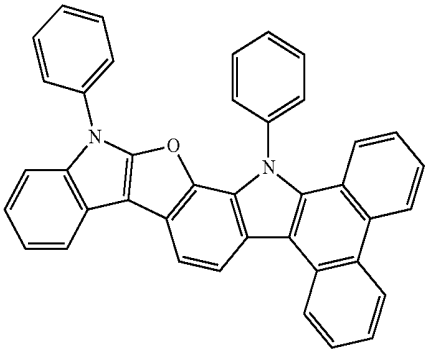

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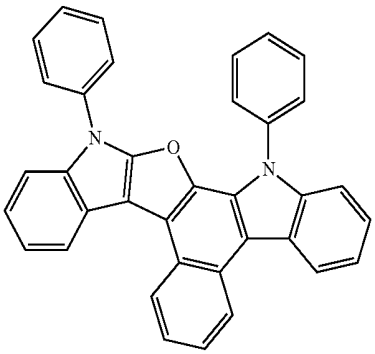

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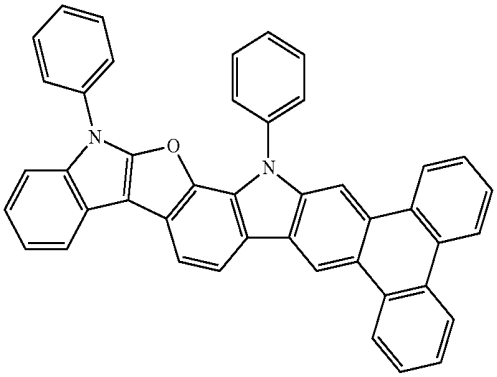

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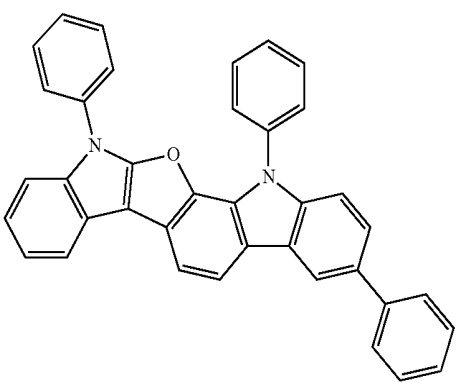

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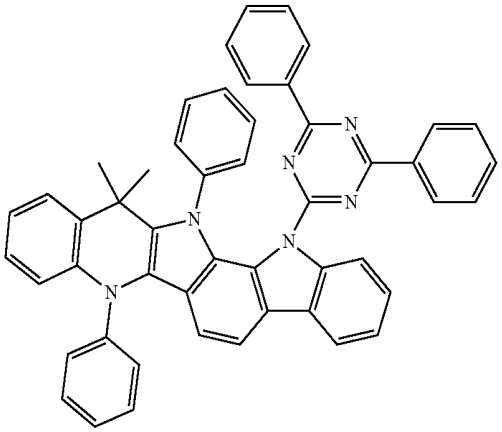

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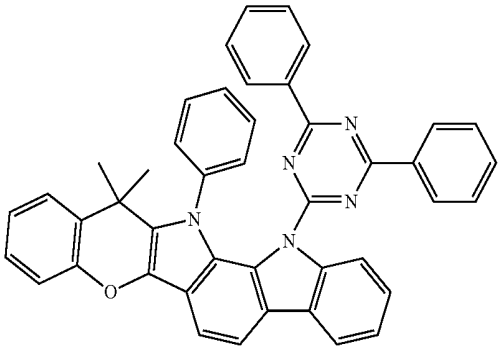

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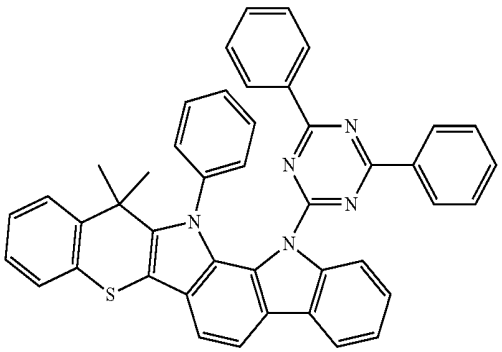

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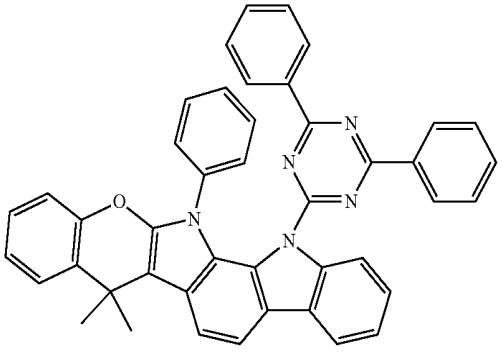

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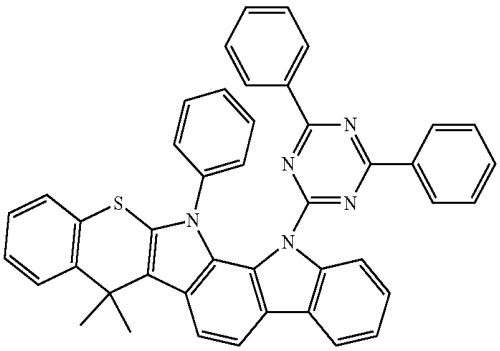

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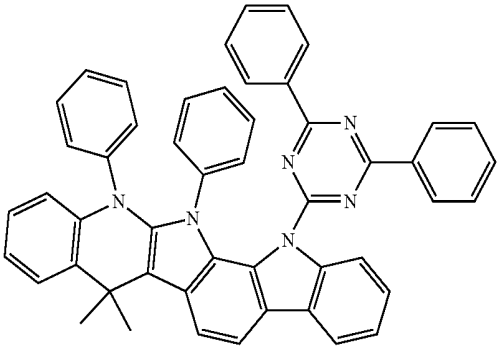

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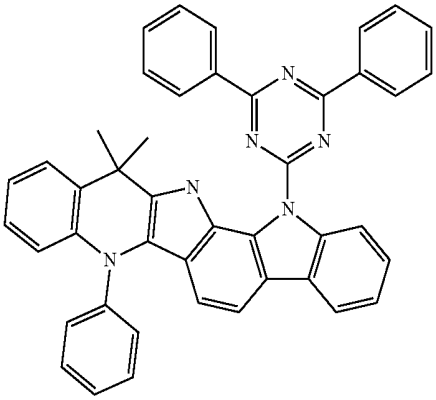

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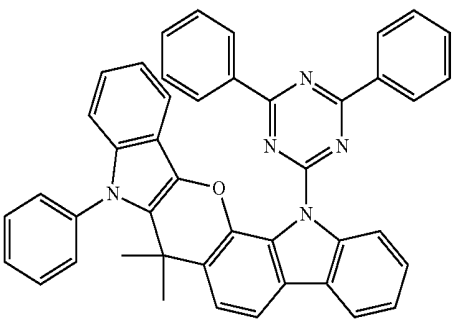

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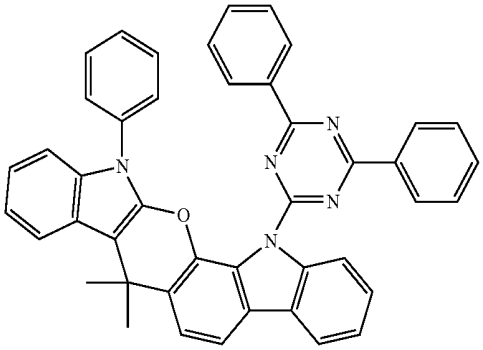

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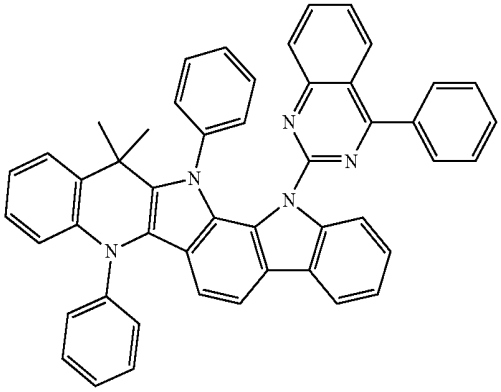

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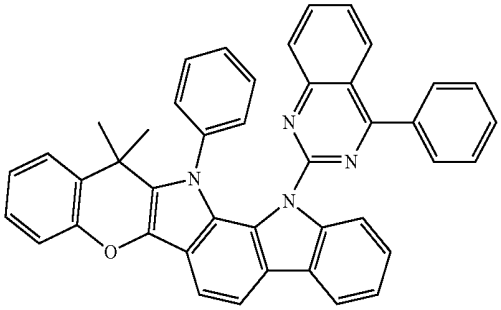

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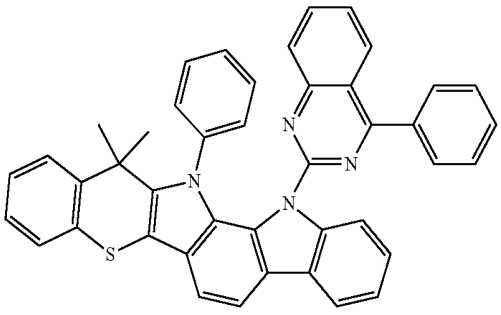

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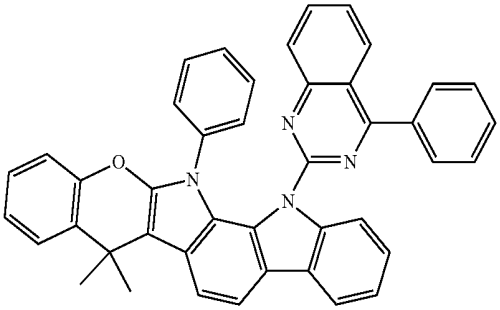

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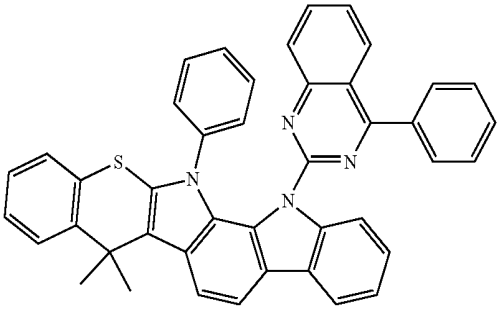

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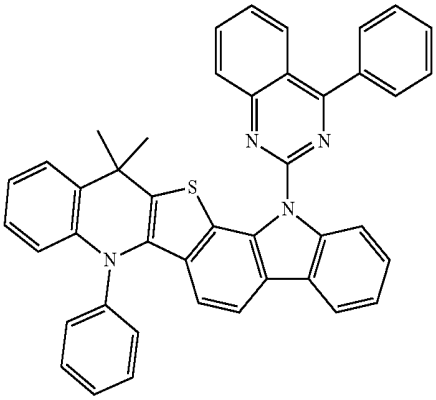

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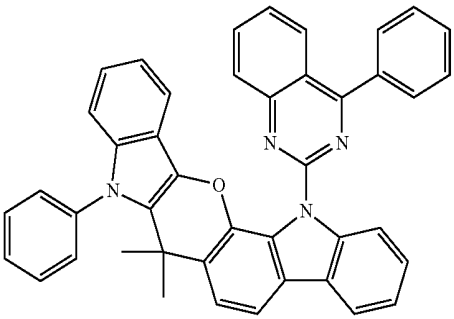

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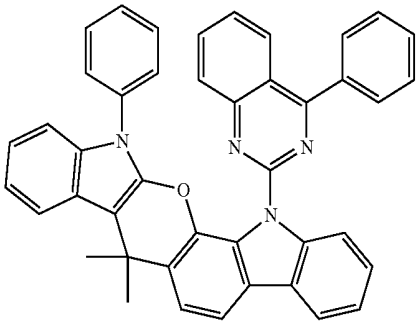

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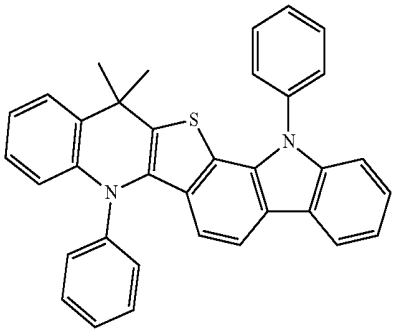

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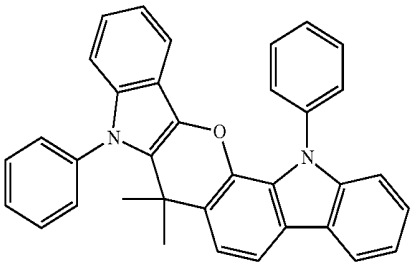

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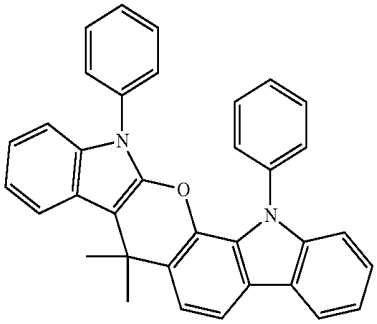

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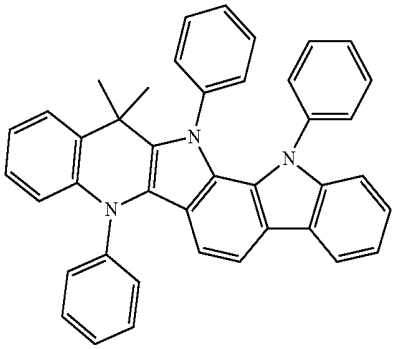

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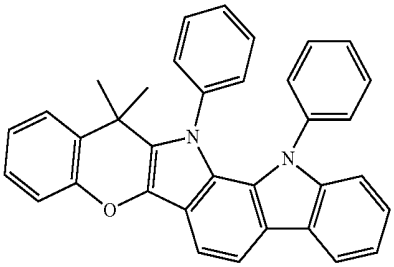

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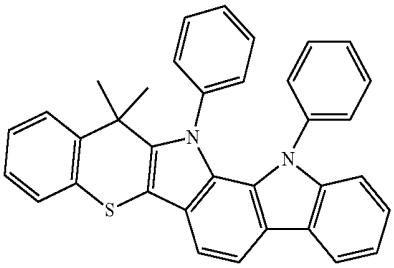

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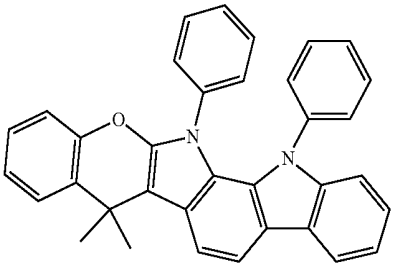

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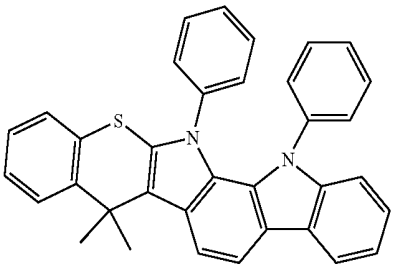

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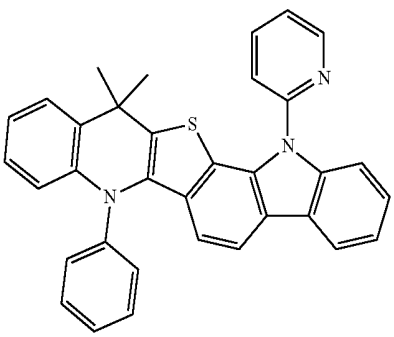

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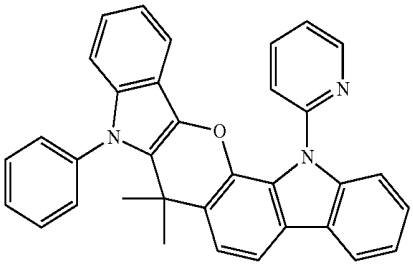

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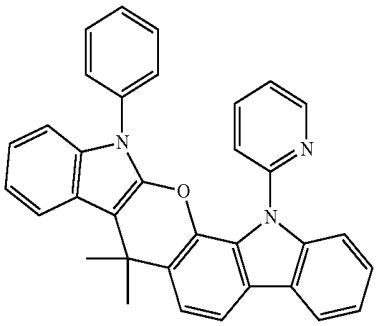

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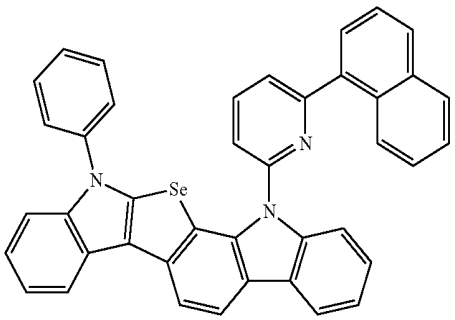

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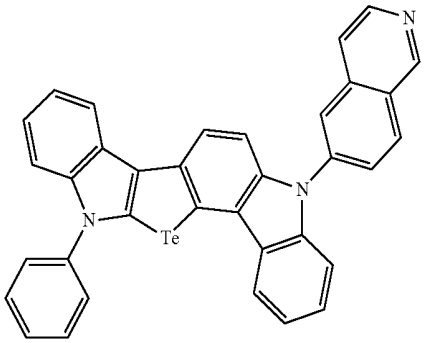

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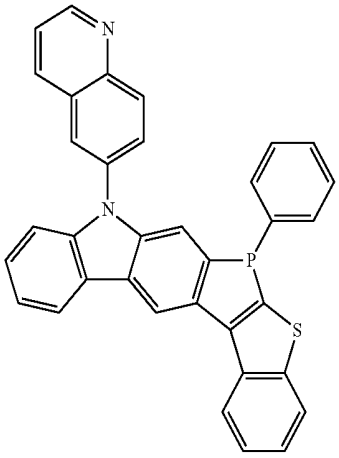

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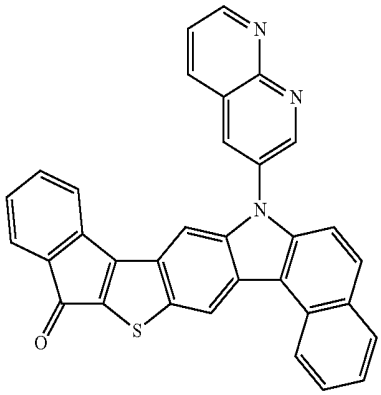

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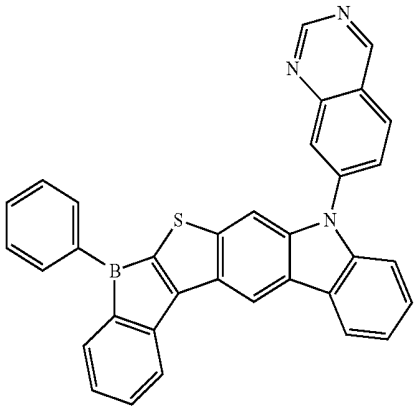

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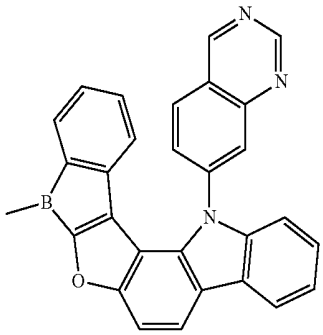

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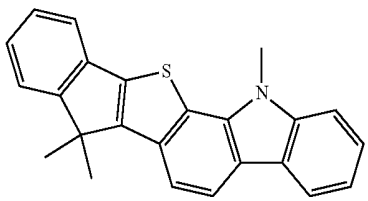

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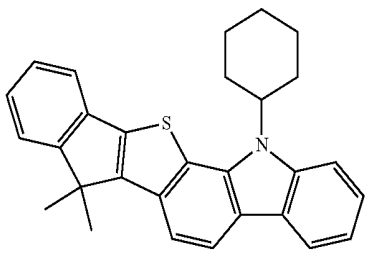

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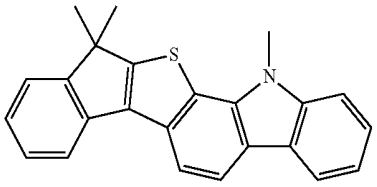

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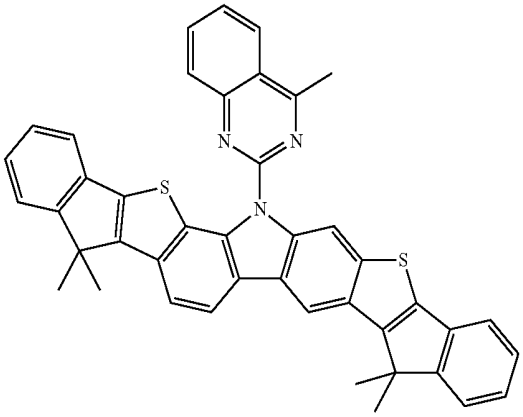

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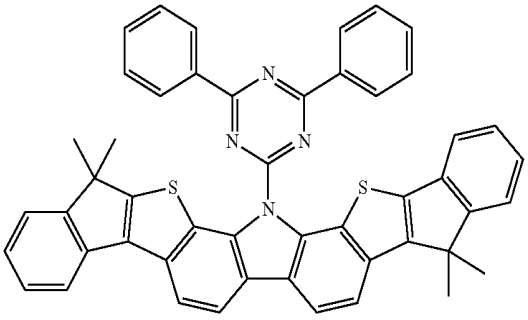

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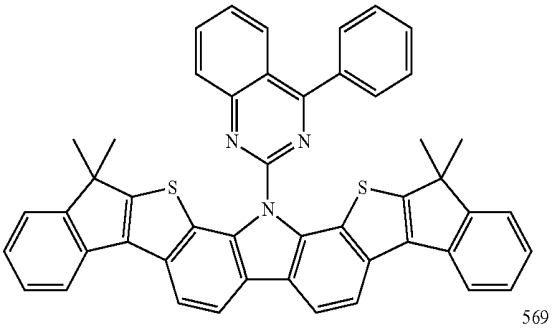

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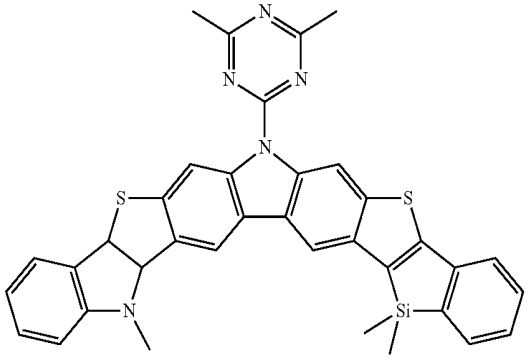

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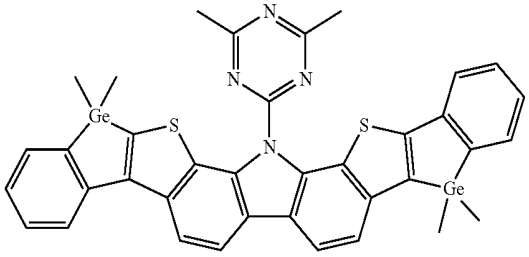

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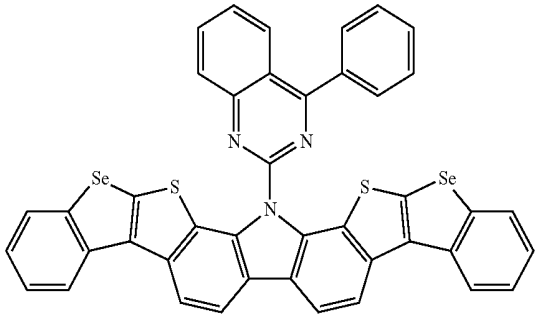

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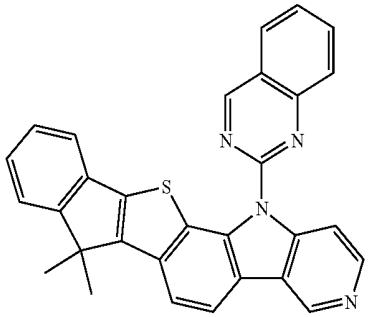

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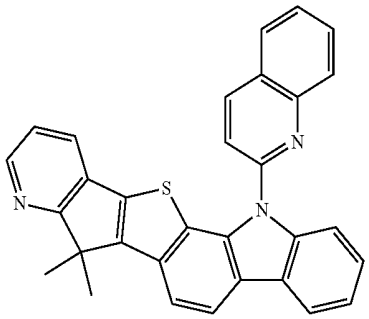

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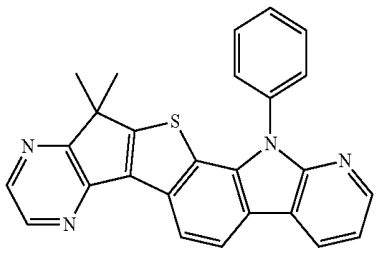

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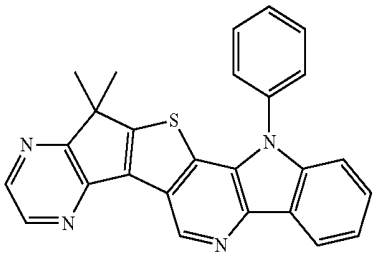

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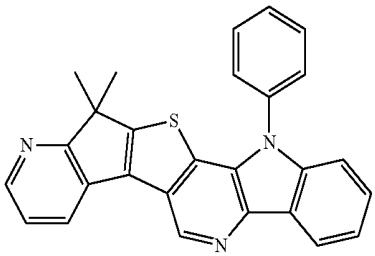

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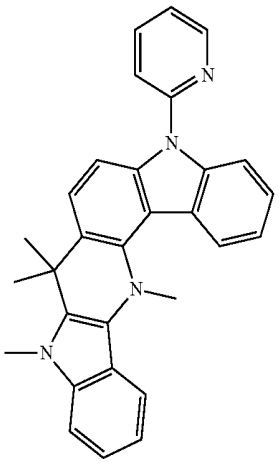

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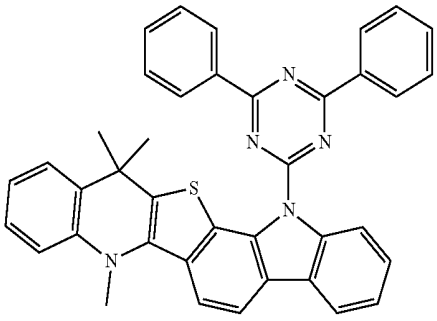

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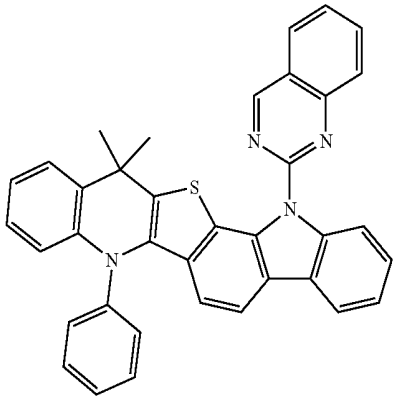

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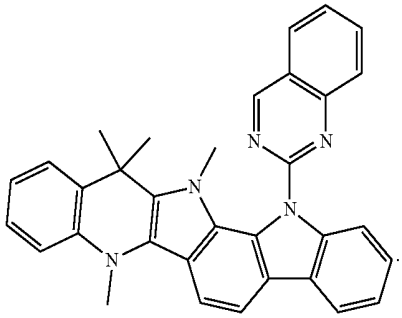

18. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

an organic layer between the first electrode and the second electrode and comprising an emission layer, wherein the organic layer comprises the heterocyclic compound of claim **1**.

19. The organic light-emitting device of claim **18**, wherein the emission layer further comprises a dopant and the heterocyclic compound is a host.

20. The organic light-emitting device of claim **19**, wherein the dopant is a phosphorescent dopant.

* * * * *

专利名称(译)	杂环化合物和包括其的有机发光装置		
公开(公告)号	US20150380663A1	公开(公告)日	2015-12-31
申请号	US14/747904	申请日	2015-06-23
[标]申请(专利权)人(译)	三星显示有限公司 SFC股份有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD. SFC CO.，LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD. SFC CO.，LTD.		
[标]发明人	KIM MI KYUNG PARK KYUNG HWA PARK BU BAE PARK JI HEE SHIN BONG KI KIM DONG HYUN KIM SE HUN CHO HWAN HEE		
发明人	KIM, MI-KYUNG PARK, KYUNG-HWA PARK, BU-BAE PARK, JI-HEE SHIN, BONG-KI KIM, DONG-HYUN KIM, SE-HUN CHO, HWAN-HEE		
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优先权	1020140079115 2014-06-26 KR 1020150035154 2015-03-13 KR		
外部链接	Espacenet USPTO		

摘要(译)

式1表示杂环化合物。在式1,1a和1b中，A 1 至A 8 中的两个相邻基团各自独立地连接至各自的*式1a或1b形成环，其中每个*是式1的碳原子。有机发光器件包括杂环化合物。