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LEE et al.(10) **Pub. No.: US 2019/0237679 A1**(43) **Pub. Date: Aug. 1, 2019**(54) **HETEROCYCLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME****Publication Classification**(51) **Int. Cl.****H01L 51/00** (2006.01)**C07D 409/14** (2006.01)**C09K 11/06** (2006.01)**C07D 403/14** (2006.01)**C07D 405/14** (2006.01)(52) **U.S. Cl.**CPC **H01L 51/0072** (2013.01); **C07D 409/14**(2013.01); **C09K 11/06** (2013.01); **H01L****51/0074** (2013.01); **H01L 51/5012** (2013.01);**H01L 51/0067** (2013.01); **C07D 405/14**(2013.01); **H01L 51/0073** (2013.01); **C07D****403/14** (2013.01)(71) Applicant: **Samsung Display Co., Ltd.**, Yongin-si
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Daeyup SHIN, Yongin-si (KR)(21) Appl. No.: **16/263,103**(22) Filed: **Jan. 31, 2019**(30) **Foreign Application Priority Data**

Feb. 1, 2018 (KR) 10-2018-0013082

(57)

ABSTRACTProvided are a heterocyclic compound and an organic light-
emitting device including the same.**40****220****190****150****110****210**

FIG. 1

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FIG. 2

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FIG. 3

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FIG. 4

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HETEROCYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of Korean Patent Application No. 10-2018-0013082, filed on Feb. 1, 2018, which is hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND

Field

[0002] Exemplary embodiments of the invention relate generally to a condensed heterocyclic compound and an organic light-emitting device including the same.

Discussion of the Background

[0003] Organic light-emitting devices are self-emission devices that produce full-color images. Organic light-emitting devices also have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of brightness, driving voltage, and response speed, compared to other display devices.

[0004] An example of such organic light-emitting devices 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, which are sequentially disposed on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as holes and electrons, recombine in the emission layer to produce excitons. These excitons transit from an excited state to a ground state, thereby generating light.

[0005] The above information disclosed in this Background section is only for understanding of the background of the inventive concepts, and, therefore, it may contain information that does not constitute prior art.

SUMMARY

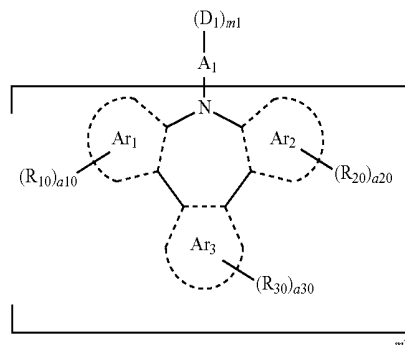
[0006] One or more exemplary embodiments include a novel heterocyclic compound and an organic light-emitting device including the same.

[0007] 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.

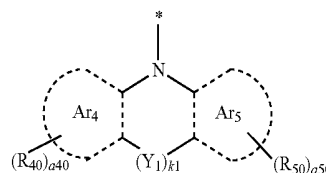
[0008] Additional features of the inventive concepts will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the inventive concepts.

[0009] An exemplary embodiment provides a heterocyclic compound represented by Formula 1:

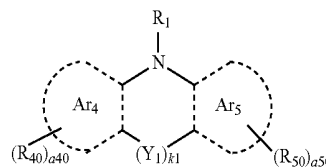
<Formula 1>



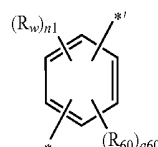
<Formula 2A>



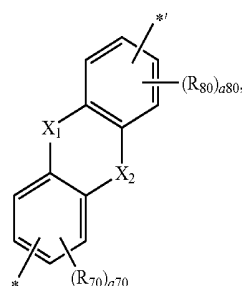
<Formula 2B>



<Formula 3A>



<Formula 3B>



[0010] wherein, in Formulae 1, 2A, and 2B,

[0011] Ar₁ to Ar₅ may each independently be a n electron-depleted nitrogen-free heterocyclic group,

[0012] D₁ may be a group represented by Formula 2A or 2B,

[0013] Y₁ may be selected from a single bond, *—N(R₂)—*, *—C(R₂)(R₃)—*, and *—C(R₂)=C(R₃)—*,

[0014] k₁ may be 1 or 2,

[0015] m₁ may be 0 or 1,

[0016] m₂ may be 1 or 2,

[0017] m₁ and m₂ may satisfy m₁+m₂=2,

[0018] A₁ may be a group represented by Formula 3A or 3B,

[0019] R_w may be a cyano group or a substituted or unsubstituted π electron-depleted nitrogen-containing heterocyclic group,

[0020] $n1$ may be an integer of 1 to 4,

[0021] X_1 may be $^*O^*$, $^*S^*$, or $^*S(=O)_2^*$, and X_2 may be a single bond or $^*C(R_4)(R_5)^*$, wherein X_1 is $^*S(=O)_2^*$ or X_2 is $^*C(R_4)(R_5)^*$,

[0022] R_1 to R_5 , R_{10} , R_{20} , R_{30} , R_{40} , R_{50} , R_{60} , R_{70} , and R_{80} may each independently be hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_1)(Q_2)(Q_3)$, $-N(Q_1)(Q_2)$, $-B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)(Q_1)$, or $-P(=O)(Q_1)(Q_2)$,

[0023] R_2 and R_3 ; or R_4 and R_5 may each optionally be linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

[0024] $a10$, $a20$, $a30$, $a40$, and $a50$ may each independently be an integer of 1 to 8,

[0025] $a60$ may be an integer of 0 to 3,

[0026] $a70$ and $a80$ may each independently be an integer of 1 to 3,

[0027] at least one substituent of the substituted C_5-C_{60} carbocyclic group, the substituted C_2-C_{60} heterocyclic 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:

[0028] deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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;

[0029] 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 selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, $-Si(Q_{11})(Q_{12})(Q_{13})$, $-N(Q_{11})(Q_{12})$, $-B(Q_{11})(Q_{12})$, $-C(=O)(Q_{11})$, $-S(=O)_2(Q_{11})$, and $-P(=O)(Q_{11})(Q_{12})$;

[0030] 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;

[0031] 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 selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, $-Si(Q_{21})(Q_{22})(Q_{23})$, $-N(Q_{21})(Q_{22})$, $-B(Q_{21})(Q_{22})$, $-C(=O)(Q_{21})$, $-S(=O)_2(Q_{21})$, and $-P(=O)(Q_{21})(Q_{22})$; and

[0032] $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$;

[0033] Q_1 to Q_3 , Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

[0034] $*$ and * each indicate a binding site to a neighboring atom.

[0035] Another exemplary embodiment provides an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, wherein the organic layer includes an emission layer and at least one of the heterocyclic compound.

[0036] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] The accompanying drawings, which are included to provide a further understanding of the invention and are

incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the invention, and together with the description serve to explain the inventive concepts.

[0038] FIG. 1, FIG. 2, FIG. 3, and FIG. 4 are each a schematic views of an organic light-emitting device according to an exemplary embodiment.

DETAILED DESCRIPTION

[0039] In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of various exemplary embodiments of the invention. As used herein “embodiments” are non-limiting examples of devices or methods employing one or more of the inventive concepts disclosed herein. It is apparent, however, that various exemplary embodiments may be practiced without these specific details or with one or more equivalent arrangements. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring various exemplary embodiments. Further, various exemplary embodiments may be different, but do not have to be exclusive. For example, specific shapes, configurations, and characteristics of an exemplary embodiment may be used or implemented in another exemplary embodiment without departing from the inventive concepts.

[0040] Unless otherwise specified, the illustrated exemplary embodiments are to be understood as providing exemplary features of varying detail of some ways in which the inventive concepts may be implemented in practice. Therefore, unless otherwise specified, the features, components, modules, layers, films, panels, regions, and/or aspects, etc. (hereinafter individually or collectively referred to as “elements”), of the various embodiments may be otherwise combined, separated, interchanged, and/or rearranged without departing from the inventive concepts.

[0041] In the accompanying drawings, the size and relative sizes of elements may be exaggerated for clarity and/or descriptive purposes. When an exemplary embodiment may be implemented differently, a specific process order may be performed differently from the described order. For example, two consecutively described processes may be performed substantially at the same time or performed in an order opposite to the described order. Also, like reference numerals denote like elements.

[0042] When an element, such as a layer, is referred to as being “on,” “connected to,” or “coupled to” another element or layer, it may be directly on, connected to, or coupled to the other element or layer or intervening elements or layers may be present. When, however, an element or layer is referred to as being “directly on,” “directly connected to,” or “directly coupled to” another element or layer, there are no intervening elements or layers present. To this end, the term “connected” may refer to physical, electrical, and/or fluid connection, with or without intervening elements. For the purposes of this disclosure, the phrases “at least one of” and “at least one” preceding a list of elements modifies the entire list of elements. Thus, the phrases “at least one of X, Y, and Z” and “at least one selected from the group consisting of X, Y, and Z” may be construed as X only, Y only, Z only, or any combination of two or more of X, Y, and Z, such as, for instance, XYZ, XYY, YZ, and ZZ. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0043] Although the terms “first,” “second,” etc. may be used herein to describe various types of elements, these elements should not be limited by these terms. These terms are used to distinguish one element from another element. Thus, a first element discussed below could be termed a second element without departing from the teachings of the disclosure.

[0044] Spatially relative terms, such as “beneath,” “below,” “under,” “lower,” “above,” “upper,” “over,” “higher,” “side” (e.g., as in “sidewall”), and the like, may be used herein for descriptive purposes, and, thereby, to describe one elements relationship to another element(s) as illustrated in the drawings. Spatially relative terms are intended to encompass different orientations of an apparatus in use, operation, and/or manufacture in addition to the orientation depicted in the drawings. For example, if the apparatus in the drawings is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. Furthermore, the apparatus may be otherwise oriented (e.g., rotated 90 degrees or at other orientations), and, as such, the spatially relative descriptors used herein interpreted accordingly.

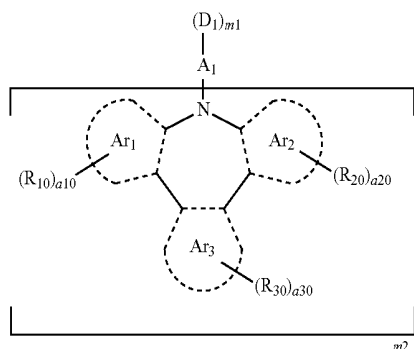
[0045] The terminology used herein is for the purpose of describing particular embodiments and is not intended to be limiting. As used herein, the singular forms, “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Moreover, the terms “comprises,” “comprising,” “includes,” and/or “including,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, components, and/or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It is also noted that, as used herein, the terms “substantially,” “about,” and other similar terms, are used as terms of approximation and not as terms of degree, and, as such, are utilized to account for inherent deviations in measured, calculated, and/or provided values that would be recognized by one of ordinary skill in the art.

[0046] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure is a part. Terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and should not be interpreted in an idealized or overly formal sense, unless expressly so defined herein.

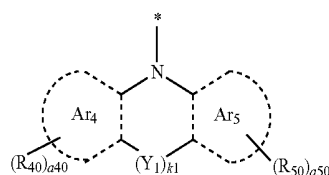
[0047] Reference will now be made in detail to exemplary embodiments illustrated in the accompanying drawings. In this regard, the present exemplary embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein or in the drawings. Accordingly, the exemplary embodiments are merely described below, by referring to the figures, to explain various exemplary embodiments of the invention.

[0048] A heterocyclic compound according to an exemplary embodiment is represented by Formula 1:

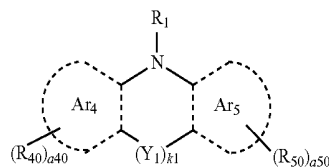
<Formula 1>



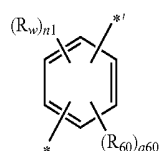
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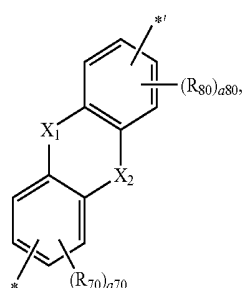
<Formula 2B>



<Formula 3A>



<Formula 3B>



[0049] In Formula 1, D₁ may refer to a group represented by Formula 2A or Formula 2B.

[0050] In Formulas 1, 2A, and 2B, Ar₁ to Ar₅ may each independently be a C₅-C₆₀ carbocyclic group or a π electron-depleted nitrogen-free C₁-C₆₀ heterocyclic group.

[0051] The “π electron-depleted nitrogen-free C₁-C₆₀ heterocyclic group” may refer to a C₁-C₆₀ heterocyclic group not having *—N=* moiety as a ring-forming moiety.

[0052] For example, the “π electron-depleted nitrogen-free ring” may be i) a 5-membered to 7-membered heteromonocyclic group not having *—N=* moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each not having

—N= moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one 5-membered to 7-membered heteromonocyclic group not having *—N=* moiety is condensed with at least one C₅-C₆₀ carbocyclic group.

[0053] Examples of the π electron-depleted nitrogen-free ring may include an azepine, dibenzazepine, a carbazole, an acridine, a 9,10-dihydroacridine, a dibenzofuran, a dibenzothiophene, a dibenzosilole, a tribenzazepine, a benzocarbazole, a benzoacridine, a 7,12-dihydrobenzo[a]acridine, a 5,12-dihydrobenzo[b]acridine, a 7,12-dihydrobenzo[c]acridine, a dibenzocarbazole, an indenocarbazole, a naphthobenzofuran, a naphthobenzothiophene, and a naphthobenzosilole, but embodiments of the present disclosure are not limited thereto.

[0054] In one exemplary embodiment, Ar₁ to Ar₅ in Formulas 1, 2A, and 2B may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, a dibenzothiophene group, and a dibenzosilole group.

[0055] In one or more exemplary embodiments, Ar_r to Ar₅ may each independently be a benzene group or a naphthalene group, but exemplary embodiments are not limited thereto.

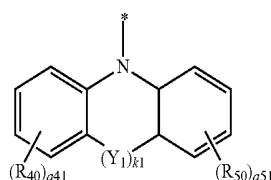
[0056] In one or more exemplary embodiments, Ar_r to Ar₅ may each independently be a benzene group, but exemplary embodiments are not limited thereto.

[0057] In Formulas 2A and 2B, Y₁ may be selected from a single bond, *—N(R₂)—*, *—C(R₂)(R₃)—*, and *—C(R₂)=C(R₃)—*, and k₁ may be 1 or 2.

[0058] In one exemplary embodiment, in Formula 1, D₁ may be selected from: an acridinyl group, a carbazolyl group, a phenazinyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an indenocarbazolyl group, a 11,12-dihydroindolocarbazolyl group, a dibenzazepine group, a 10,11-dihydrodibenzazepine group, and a tribenzazepine group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a biphenyl group, and a terphenyl group.

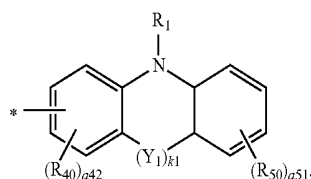
[0059] In one or more exemplary embodiments, in Formula 1, D₁ may be a group represented by Formula 2A-1 or 2B-1:

<Formula 2A-1>



-continued

<Formula 2B-1>



[0060] In Formulae 2A-1 and 2B-1, Y_1 and k_1 are respectively defined the same as those of Formula 2A and Formula 2B.

[0061] R_1 to R_3 , R_{40} , and R_{50} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a biphenyl group, and a terphenyl group,

[0062] a_{41} and a_{51} may each independently be an integer of 1 to 4,

[0063] a_{42} may be an integer of 1 to 3, and

[0064] $*$ and $*'$ each indicate a binding site to a neighboring atom.

[0065] In one or more exemplary embodiments, in Formula 1, D_1 may be selected from an acridinyl group, a phenazinyl group, a carbazolyl group, a dibenzazepine group, a dihydrodibenzazepine group, and a tribenzazepine group.

[0066] In Formula 1, m_1 may be 0 or 1, m_2 may be 1 or 2, and m_1 and m_2 may satisfy $m_1 + m_2 = 2$.

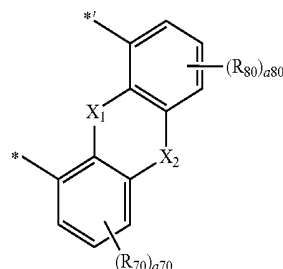
[0067] For example, in Formula 1, (i) m_1 may be 0, and m_2 may be 2; (ii) m_1 may be 1, and m_2 may be 1.

[0068] In Formula 1, A_1 may be a group represented by Formula 3A or Formula 3B.

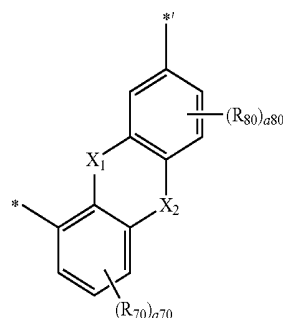
[0069] In one exemplary embodiment, A_1 of Formula 1 may be a group represented by one selected from Formulas 3A-1 to 3A-3 and 3B-1 to 3B-10:

-continued

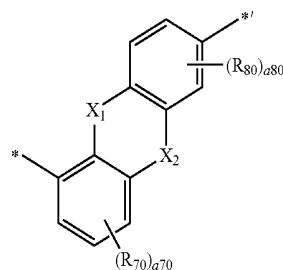
3B-1



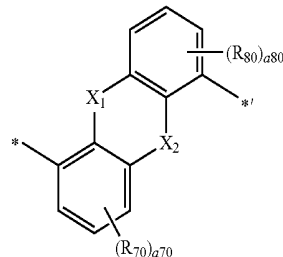
3B-2



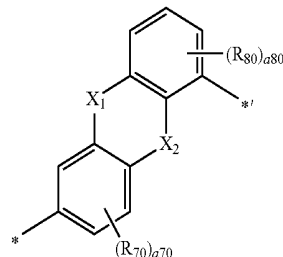
3B-3



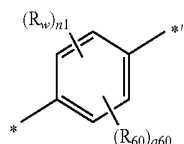
3B-4



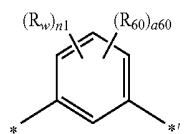
3B-5



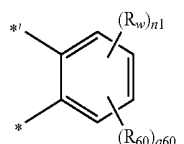
3A-1



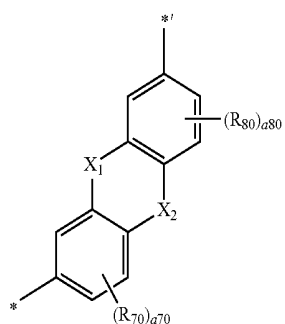
3A-2



3A-3



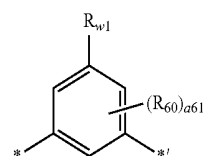
-continued



3B-6

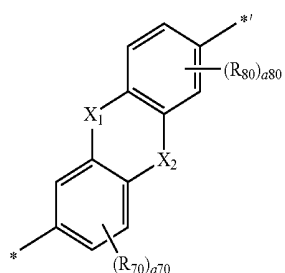
[0071] * and *' each indicate a binding site to a neighboring atom.

[0072] In one or more exemplary embodiments, A₁ may be a group represented by one selected from Formulae 3A-2-1 to 3A-2-4, and 3B-8-1 to 3B-8-4:

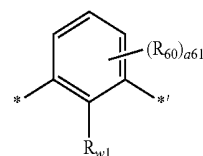


3A-2-1

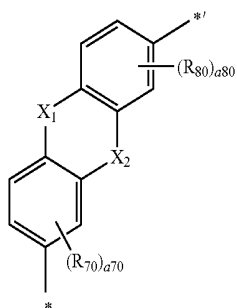
3B-7



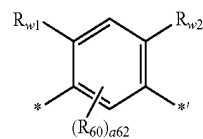
3A-2-2



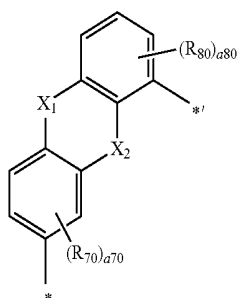
3B-8



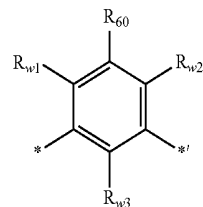
3A-2-3



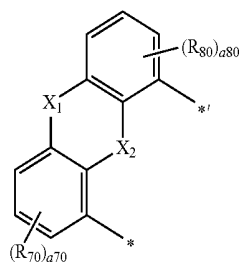
3B-9



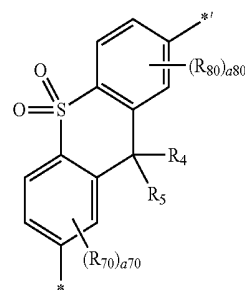
3A-2-4



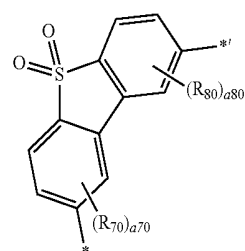
3B-8-1



3B-10



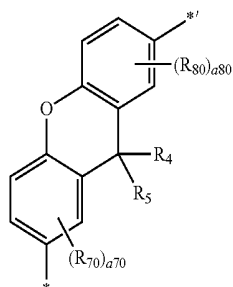
3B-8-2



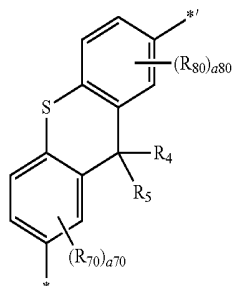
[0070] In Formulas 3A-1 to 3A-3 and 3B-1 to 3B-10, R_w, n1, X₁, X₂, R₆₀, R₇₀, R₈₀, a60, a70, and a80 are defined the same as described those in the rest of the present specification, and

-continued

3B-8-3



3B-8-4



[0073] In Formulas 3A-2-1 to 3A-2-4 and 3B-8-1 to 3B-8-4, R_4 , R_5 , R_{60} , R_{70} , R_{80} , a_{70} , and a_{80} are respectively defined the same as those described in the present specification.

[0074] R_{w1} , R_{w2} , and R_{w3} are defined the same as described in connection with R_w .

[0075] a_{61} may be an integer of 1 to 3,

[0076] a_{62} may be 1 or 2, and

[0077] * and *' each indicate a binding site to a neighboring atom.

[0078] In Formula 3A, R_w may be a cyano group or a substituted or unsubstituted 7E electron-depleted nitrogen-containing heterocyclic group.

[0079] The “ π electron-depleted nitrogen-containing ring” may refer to a C_1 - C_{60} heterocyclic group having at least one $*-N=*'$ moiety as a ring-forming moiety.

[0080] For example, the “ π electron-depleted nitrogen-containing ring” may refer to i) a 5-membered to 7-membered heteromonocyclic group at least one $*-N=*'$ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one $*-N=*'$ moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one 5-membered to 7 membered heteromonocyclic group having at least one $*-N=*'$ moiety is condensed with at least one C_5 - C_{60} carbocyclic group.

[0081] Examples of the π electron-depleted nitrogen-containing ring may include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but embodiments of the present disclosure are not limited thereto.

[0082] In one exemplary embodiment, R_w may be selected from:

[0083] a cyano group, a pyridinyl group, a pyrimidyl group, and a triazinyl group; and

[0084] a pyridinyl group, a pyrimidyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a biphenyl group, and a terphenyl group.

[0085] In Formula 3A, n_1 may be an integer of 1 to 4.

[0086] In one exemplary embodiment, n_1 may be 1, 2, or 3.

[0087] For example, (i) n_1 may be 1, and R_w may be a triazine group substituted with a phenyl group; (ii) n_1 may be 2, and two R_w (s) may each be a cyano group; (iii) n_1 may be 3, and two R_w (s) may each be a cyano group, and one R_w may be a triazine group substituted with a phenyl group, but embodiments of the present disclosure are not limited thereto.

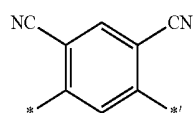
[0088] In Formula 3B,

[0089] X_1 may be $*-O-*'$, $*-S-*'$, or $*-S(=O)_2-*'$, and X_2 may be a single bond or $*-C(R_4)(R_5)-*'$, wherein X_1 may be $*-S(=O)_2-*'$, or X_2 may be $*-C(R_4)(R_5)-*'$.

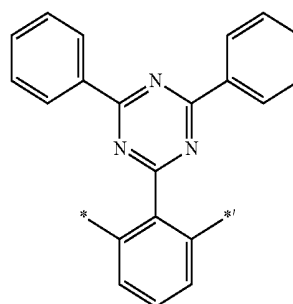
[0090] For example, (i) X_1 may be $*-O-*'$ or $*-S-*'$, and X_2 may be $*-C(R_4)(R_5)-*'$, or (ii) X_1 may be $*-S(=O)_2-*'$, and X_2 may be a single bond or $*-C(R_4)(R_5)-*'$.

[0091] In one or more exemplary embodiments, X_1 may be $*-S(=O)_2-*'$, but embodiments of the present disclosure are not limited thereto.

[0092] In one exemplary embodiment, A_1 may be a group represented by one selected to from Formulas 4-1 to 4-7:

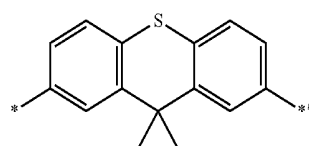
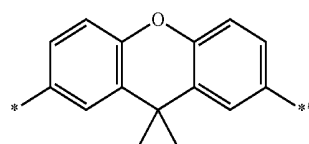
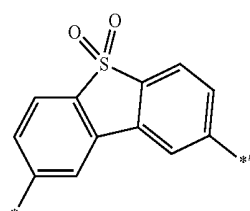
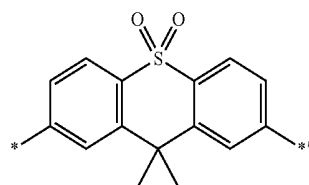
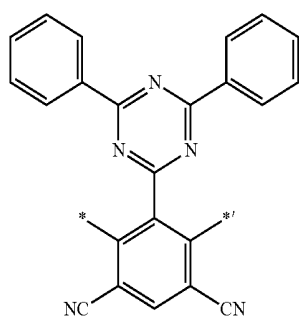


4-1



4-2

-continued



[0093] In Formulas 4-1 to 4-7,

[0094] * and *¹ each indicate a binding site to a neighboring atom.

[0095] In Formulas 1, 2A, 2B, 3A, and 3B, R₁ to R₅, R₁₀, R₂₀, R₃₀, R₄₀, R₅₀, R₆₀, R₇₀ and R₈₀ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₁-C₆₀ arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed het-

eropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)(Q₁), and —P(=O)(Q₁)(Q₂),

[0096] R₂ and R₃; or R₄ and R₅ may optionally be linked to form a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₂-C₆₀ heterocyclic group,

[0097] a₁₀, a₂₀, a₃₀, a₄₀, and a₅₀ may each independently be an integer of 1 to 8,

[0098] a₆₀ may be an integer of 0 to 3, and

[0099] a₇₀ and a₈₀ may each independently be an integer of 1 to 3.

[0100] In one exemplary embodiment, R₁ to R₅ may each independently be selected from:

[0101] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, and a phenyl group; and

[0102] a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, and a phenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, and a ter-butyl group.

[0103] In one exemplary embodiment, R₂ and R₃; or R₄ and R₅ may optionally be linked to form a cyclopentane group, a cyclohexane group, a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, or a fluorene group.

[0104] For example, R₂ and R₃ may be linked to form a benzene group, but exemplary embodiments of the present disclosure are not limited thereto.

[0105] In one exemplary embodiment, R₁₀, R₂₀, R₃₀, R₄₀, and R₅₀ may each independently be selected from:

[0106] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group; and

[0107] a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinoxalinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group.

[0108] In one exemplary embodiment, R_{60} , R_{70} , and R_{80} may each independently be selected from:

[0109] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group; and

[0110] a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group.

[0111] In one or more embodiments, R_{60} , R_{70} , and R_{80} may each independently be selected from:

[0112] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a biphenyl group, and a terphenyl group; and

[0113] a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a biphenyl group, and a terphenyl group.

[0114] At least one substituent of the substituted C_5 - C_{60} carbocyclic group, the substituted C_2 - C_{60} heterocyclic 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:

[0115] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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;

[0116] 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 selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, —Si(Q_{11})(Q_{12})(Q_{13}), —N(Q_{11})(Q_{12}), —B(Q_{11})(Q_{12}), —C(=O)(Q_1), —S(=O)₂(Q_{11}), and —P(=O)(Q_{11})(Q_{12});

[0117] 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;

[0118] 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 selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, —Si(Q_{21})(Q_{22})(Q_{23}), —N(Q_{21})(Q_{22}), —B(Q_{21})(Q_{22}), —C(=O)(Q_{21}), —S(=O)₂(Q_{21}), and —P(=O)(Q_{21})(Q_{22}); and

[0119] —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32});

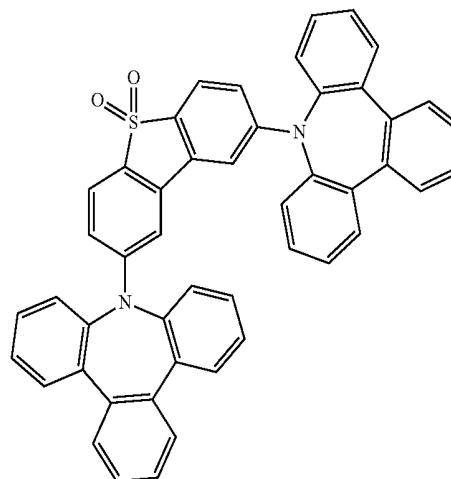
[0120] Q_1 to Q_3 , Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{60} alkyl group, a C_2 - C_{60} 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, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

[0121] * and *' each indicate a binding site to a neighboring atom.

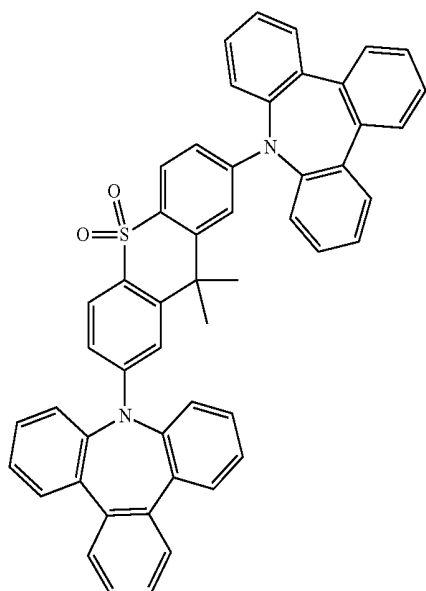
[0122] In one exemplary embodiment, the heterocyclic compound may be selected from Compounds T-1 to T-17, but embodiments of the present disclosure are not limited thereto:

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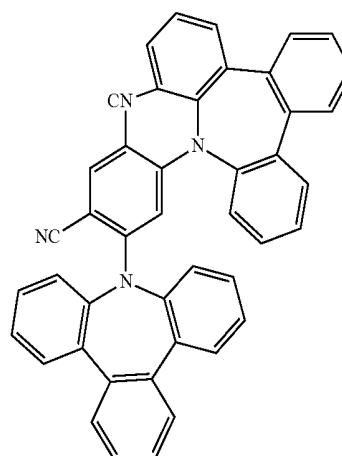
T-3



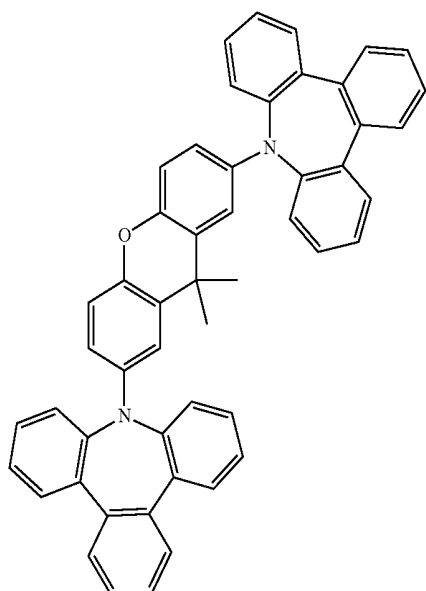
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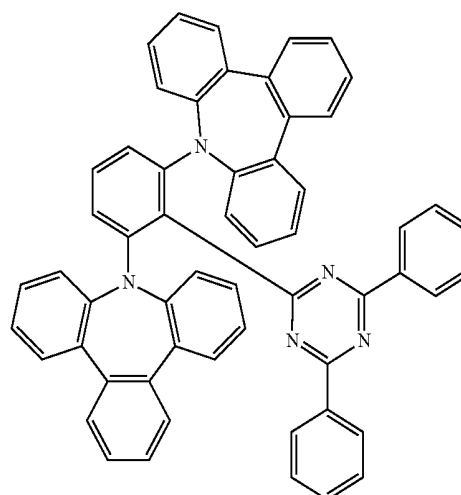
T-4



T-2

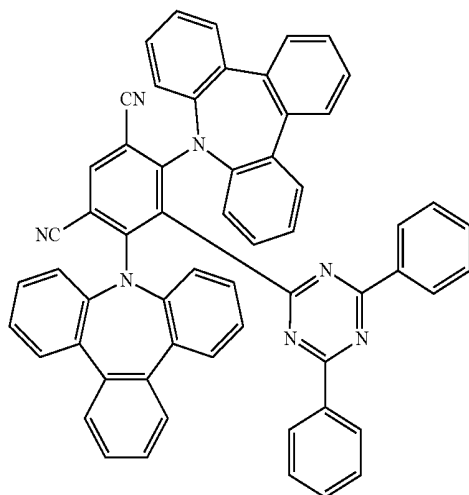


T-5



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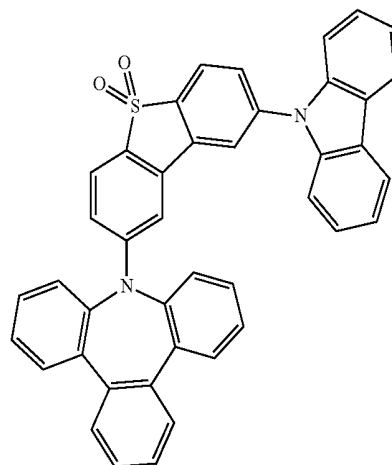
T-6



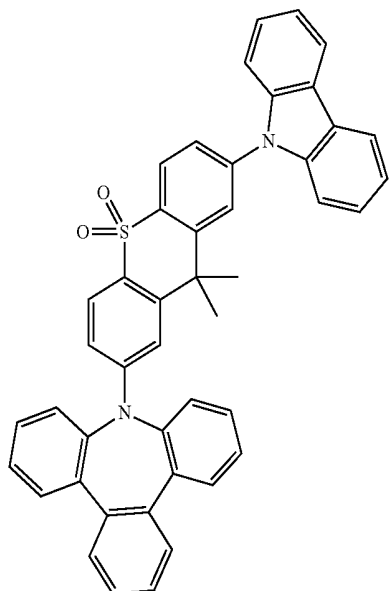
T-7

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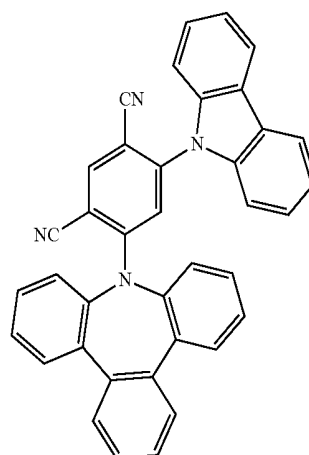
T-9



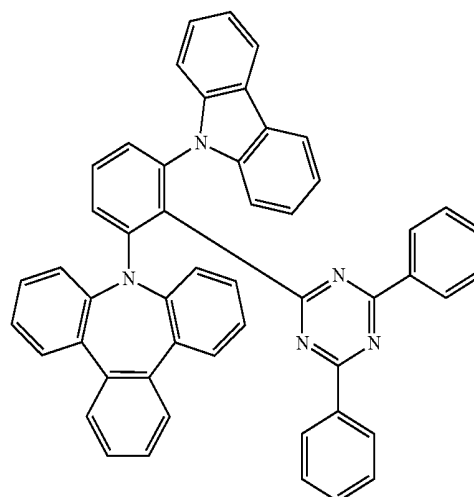
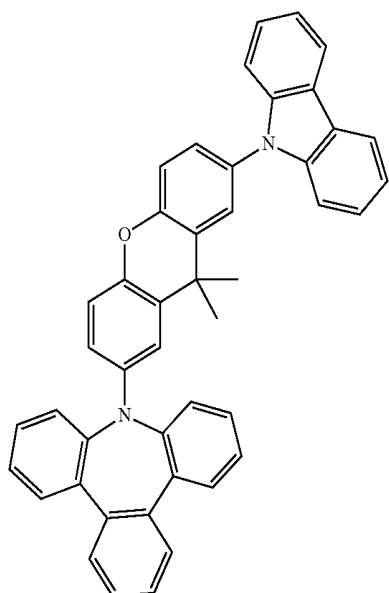
T-10



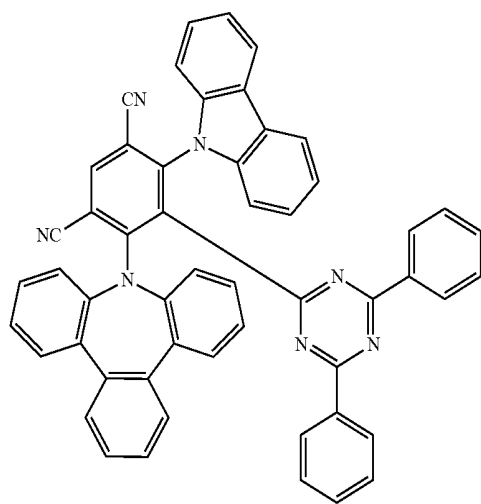
T-8



T-11

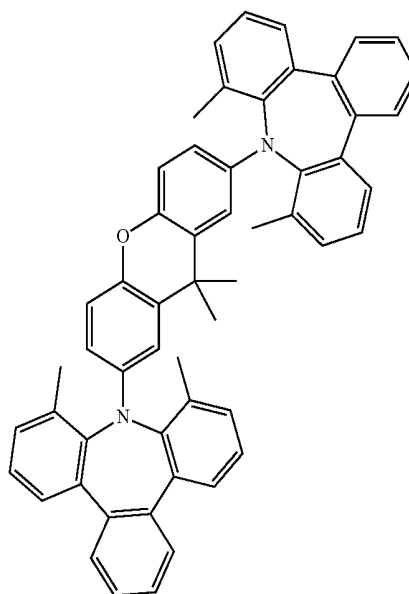


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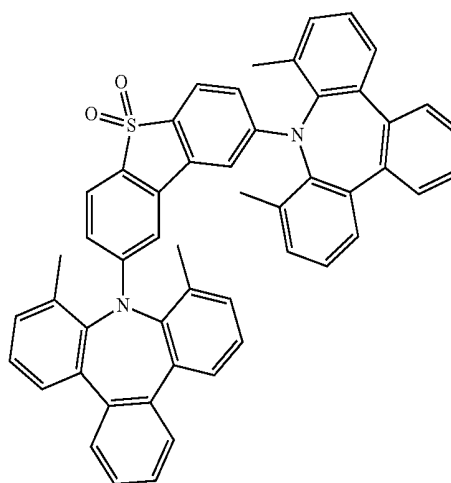


T-12

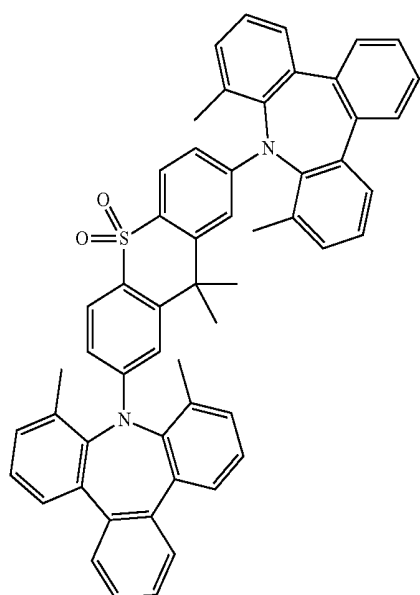
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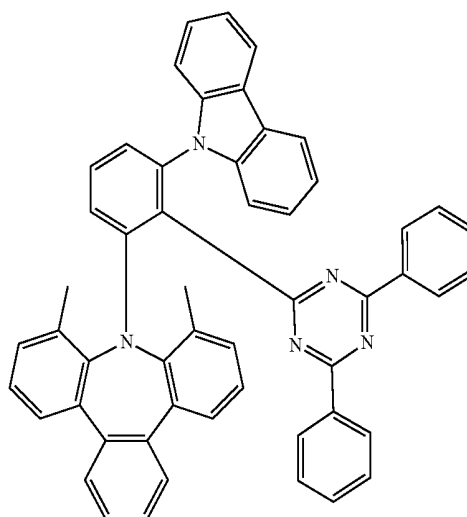
T-14



T-15



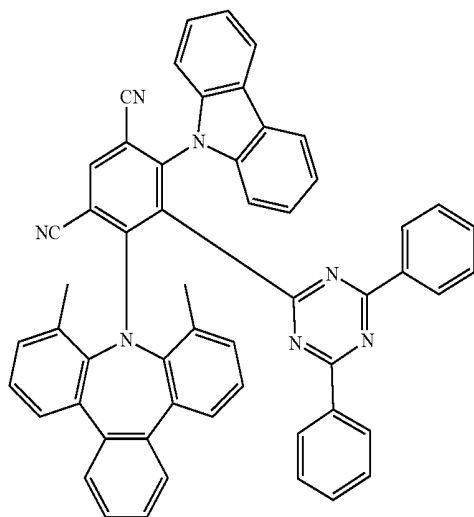
T-13



T-16

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T-17

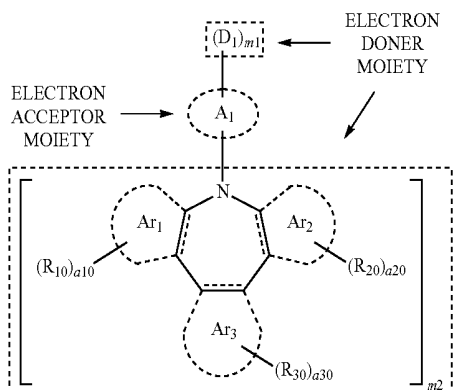


[0123] The heterocyclic compound may include a substituent having a property of an electron withdrawing group (EWG) and a substituent having a property of an electron donating group (EDG) at the same time, and by introducing these substituents at appropriate positions, the energy difference between single and triplet states of the overall compound may be appropriately controlled, thereby exhibiting thermally activated delayed fluorescence (TADF).

[0124] The following equation may be satisfied between the singlet energy and the triplet energy of the heterocyclic compound:

$$E_{st}=S1-T1<0.3\text{ eV.}$$

[0125] The heterocyclic compound may have a structure of Formula 1. In particular, the heterocyclic compound may include two electron donor moieties and one electron acceptor moiety as shown below, so that electrons may be easily moved within a molecule, thereby improving the emission efficiency. In addition, a dipole may be formed from the electron donor moiety to the electron acceptor moiety, resulting in the increased dipole moment within the molecule. Accordingly, the emission efficiency may be further improved:



[0126] In addition, in the heterocyclic compound, the electron donor moiety and the electron acceptor moiety may

be separated from each other to effectively block the orbital overlap in the molecule and prevent the single and triplet from overlapping, resulting in a very low ΔE_{st} . As a result, the reverse intersystem crossing (RISC) may be enabled from a triplet excited state to a singlet excited state even at room temperature through heat activation, and in this regard, delayed fluorescence may be exhibited. Accordingly, the triplet exciton may be used for light emission, thereby improving the emission efficiency.

[0127] Furthermore, the heterocyclic compound may have a relatively high charge (e.g., holes or electrons) transport ability. Thus, in an organic light-emitting device including the heterocyclic compound represented by Formula 1, the exciton formation ratio in an emission layer may be improved. In this regard, such an organic light-emitting device may have a low driving voltage, a high efficiency, a long lifespan, and a high maximum quantum efficiency.

[0128] A synthesis method for the heterocyclic compound represented by Formula 1 would be apparent to those of ordinary skill in the art by referring to the following examples.

[0129] At least one of 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 may be included in at least one layer selected from a hole transport region, an electron transport region, and an emission layer. In one or more embodiments, the heterocyclic compound of Formula 1 may be used as a material for a capping layer located outside a pair of electrodes of an organic light-emitting device.

[0130] Accordingly, provided is an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes at least one condensed cyclic compound.

[0131] The expression “(an organic layer) includes at least one heterocyclic compound” used herein may include a case in which “(an organic layer) includes identical compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more different heterocyclic compounds represented by Formula 1.”

[0132] For example, the organic layer may include, as the heterocyclic compound, only Compound 1. In this regard, Compound 1 may exist in an emission layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the heterocyclic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may exist in an identical layer (for example, Compound 1 and Compound 2 may all exist in an emission layer), or different layers (for example, Compound 1 may exist in an emission layer and Compound 2 may exist in an electron transport layer).

[0133] In one exemplary embodiment, the first electrode of the organic light-emitting device may be an anode, the second electrode of the organic light-emitting device may be a cathode, the organic layer of the organic light-emitting device may further include a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, the hole transport region may include a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and the electron transport region may include a hole

blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0134] In one or more exemplary embodiments, the emission layer of the organic light-emitting device may include the heterocyclic compound.

[0135] In one or more exemplary embodiments, the heterocyclic compound included in the emission layer of the organic light-emitting device may serve as a TADF emitter, and thus, the emission layer may emit delayed fluorescence.

[0136] In one or more exemplary embodiments, the emission layer of the organic light-emitting device may consist of the heterocyclic compound; or the emission layer of the organic light-emitting device may further include a host, wherein an amount of the heterocyclic compound per 100 parts by weight of the emission layer may be in a range of about 0.1 parts to about 50 parts by weight.

[0137] The host included in the emission layer may include at least one selected from an anthracene-based compound, a pyrene-based compound and a spiro-bifluorene-based compound, but exemplary embodiments are not limited thereto.

[0138] In one exemplary embodiment, the hole transport region of the organic light-emitting device may include a p-dopant having a lowest unoccupied molecular orbital (LUMO) energy level of less than -3.5 eV.

[0139] In one exemplary embodiment, the electron transport region of the organic light-emitting device may further include: a triazole-containing compound or a benzotriazole-containing compound, or

[0140] an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth metal complex, a rare earth metal complex, or any combination thereof.

[0141] The term “organic layer” used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the “organic layer” is not limited to an organic material.

[0142] (Description of FIG. 1)

[0143] FIG. 1 is a schematic view of an organic light-emitting device 10 according to an exemplary embodiment. The organic light-emitting device 10 includes a first electrode 110, an organic layer 150, and a second electrode 190.

[0144] Hereinafter, the structure of the organic light-emitting device 10 according to an embodiment and a method of manufacturing the organic light-emitting device 10 will be described in connection with FIG. 1.

[0145] (First Electrode 110)

[0146] In FIG. 1, a substrate may be additionally disposed under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

[0147] 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 a first electrode may be selected from materials with a high work function to facilitate hole injection.

[0148] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, a material for forming a first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combinations thereof, but exemplary embodiments are not limited thereto. In one or more exemplary embodiments, when the first electrode 110 is a semi-transmissive electrode or a reflectable electrode, a material for forming a first electrode may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any combinations thereof, but exemplary embodiments are not limited thereto.

[0149] The first electrode 110 may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode 110 may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode 110 is not limited thereto.

[0150] (Organic Layer 150)

[0151] The organic layer 150 is disposed on the first electrode 110. The organic layer 150 may include an emission layer.

[0152] The organic layer 150 may further include a hole transport region between the first electrode 110 and the emission layer, and an electron transport region between the emission layer and the second electrode 190.

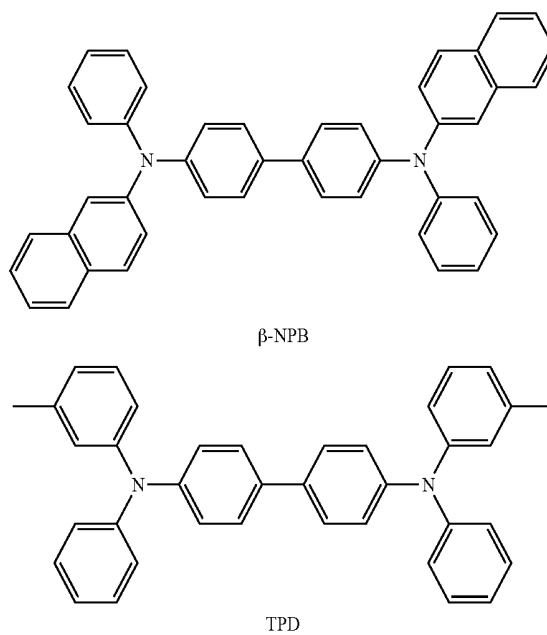
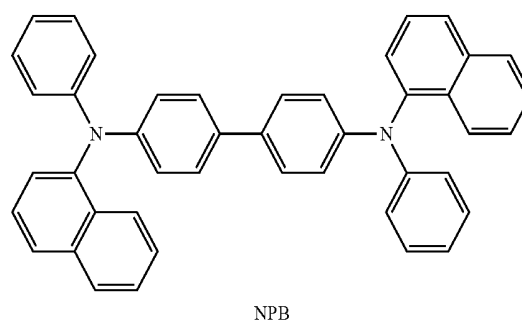
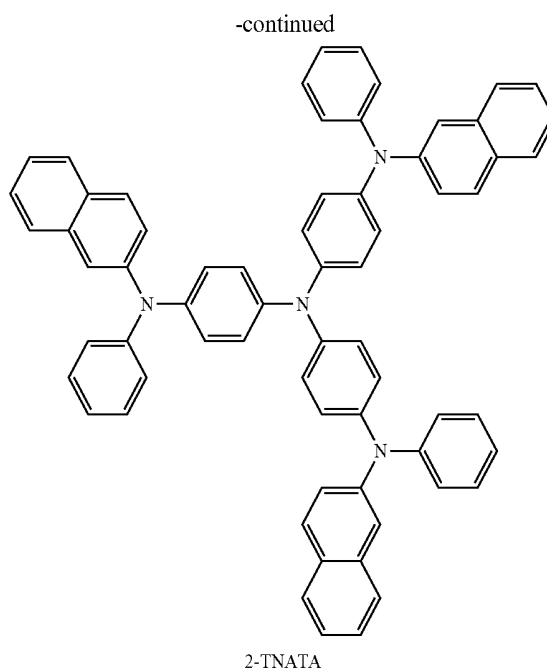
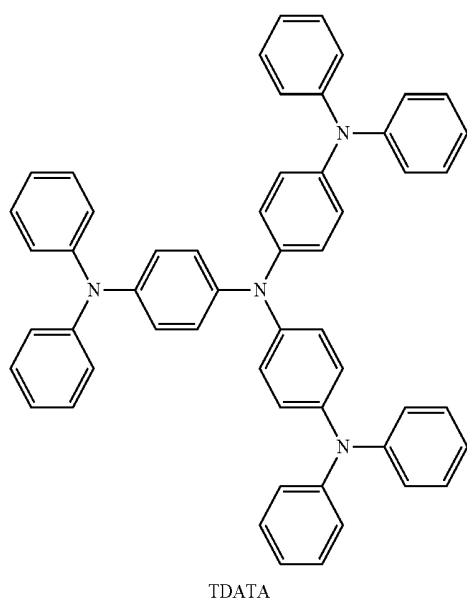
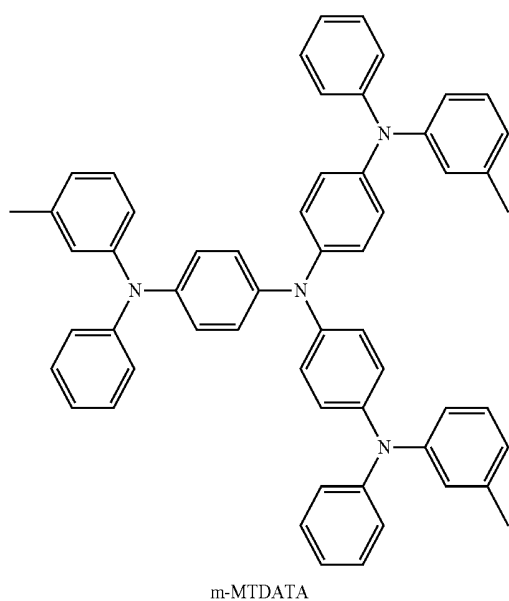
[0153] (Hole Transport Region in Organic Layer 150)

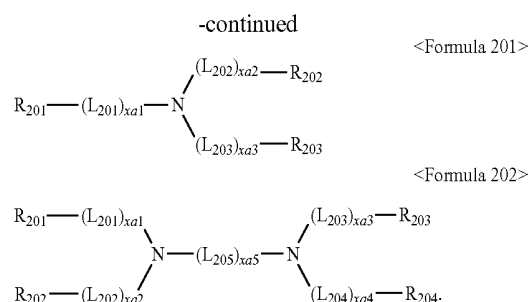
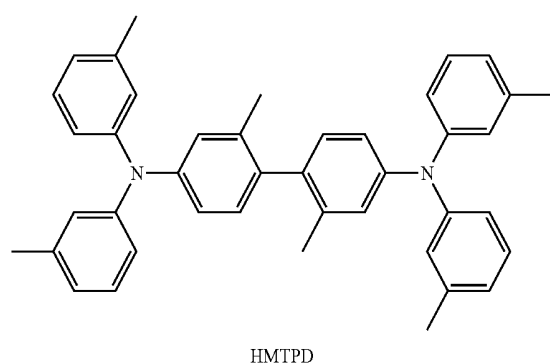
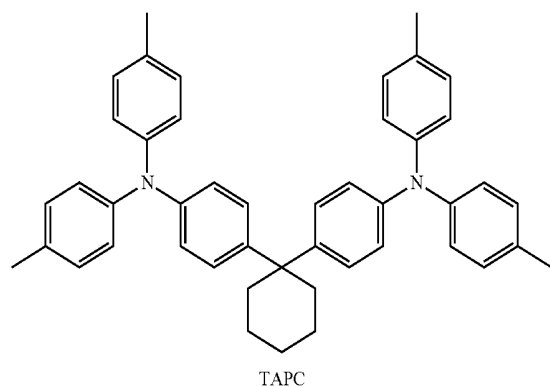
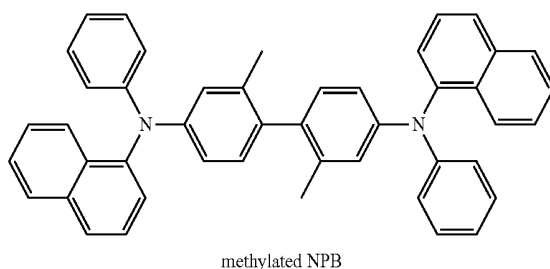
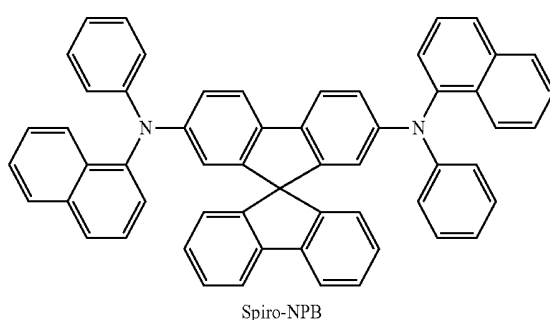
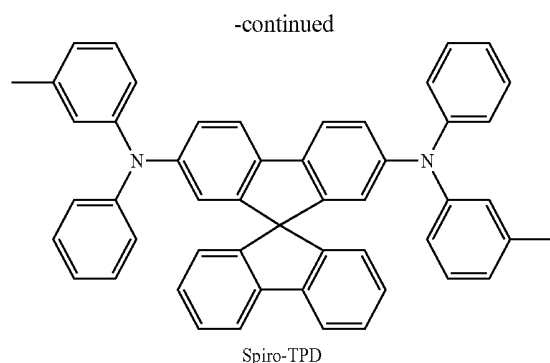
[0154] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0155] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

[0156] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode 110 in this stated order, but the structure of the hole transport region is not limited thereto.

[0157] The hole transport region may include at least one selected from, m-MTDATA, TDATA, 2-TNATA, NPB (NPD), β -NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 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:





[0158] In Formulas 201 and 202,

[0159] L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0160] L_{205} may be selected from $^*\text{—O—}^*$, $^*\text{—S—}^*$, $^*\text{—N(Q}_{201}\text{)—}^*$, a substituted or unsubstituted C_1 - C_{20} alkylene group, a substituted or unsubstituted C_2 - C_{20} alkenylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0161] $\text{xa}1$ to $\text{xa}4$ may each independently be an integer of 0 to 3,

[0162] $\text{xa}5$ may be an integer of 1 to 10, and

[0163] R_{201} to R_{204} and Q_{201} may each independently be selected from 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.

[0164] For example, in Formula 202, R_{201} and R_{202} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R_{203} and R_{204} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0165] In one or more exemplary embodiments, in Formulas 201 and 202,

[0166] L_{201} to L_{205} may each independently be selected from:

[0167] 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-bifluorenylene 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 thiophenylene group, a furanylene group, a carbazolylene group, an indolyene group, an isoindolyene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group; and

[0168] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene 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 thiophenylene group, a furanylene group, a carbazolylene group, an indolyene group, an isoindolyene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, 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-bifluorenyl 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 thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), and —N(Q₃₁)(Q₃₂).

[0169] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0170] In one or more exemplary embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0171] In one or more exemplary embodiments, xa5 may be 1, 2, 3, or 4.

[0172] In one or more exemplary embodiments, R₂₀₁ to R₂₀₄ and Q₂₀₁ may each independently be selected from:

[0173] a phenyl group, a biphenyl group, a terphenyl 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-bifluorenyl 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 thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0174] a phenyl group, a biphenyl group, a terphenyl 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-bifluorenyl 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 thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, 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-bifluorenyl 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 thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), and —N(Q₃₁)(Q₃₂), and

[0175] Q₃₁ to Q₃₃ are defined the same as described above.

[0176] In one or more exemplary embodiments, in Formula 201, at least one selected from R₂₀₁ to R₂₀₃ may each independently be selected from:

[0177] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0178] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group. However, exemplary embodiments are not limited thereto.

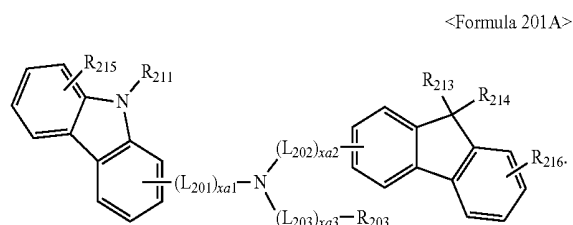
[0179] In one or more exemplary embodiments, in Formula 202, i) R_{201} and R_{202} may be linked via a single bond, and/or ii) R_{203} and R_{204} may be linked via a single bond.

[0180] In one or more exemplary embodiments, in Formula 202, at least one selected from R_{201} to R_{204} may be selected from:

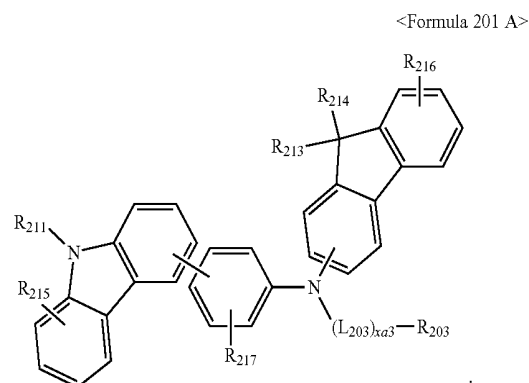
[0181] a carbazolyl group; and

[0182] a carbazolyl group substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group. However, exemplary embodiments are not limited thereto.

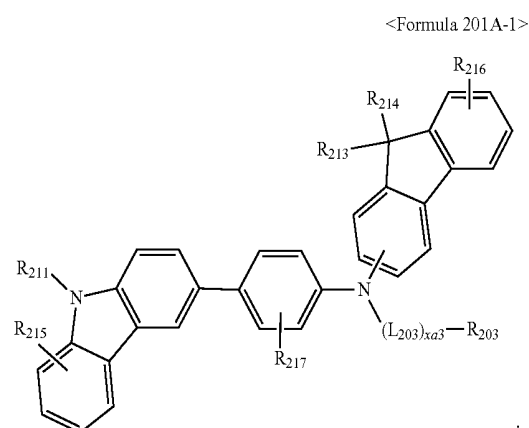
[0183] The compound represented by Formula 201 may be represented by Formula 201A:



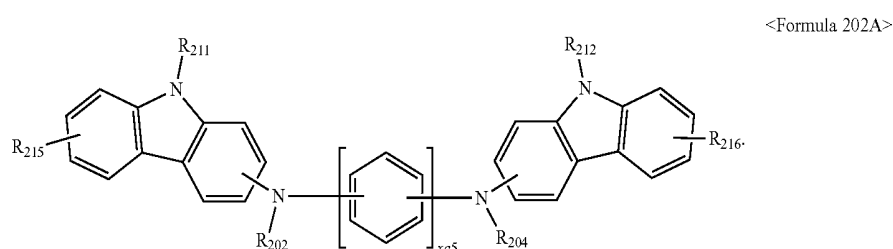
[0184] In one exemplary embodiment, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but exemplary embodiments are not limited thereto:



[0185] In one exemplary embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but exemplary embodiments are not limited thereto:

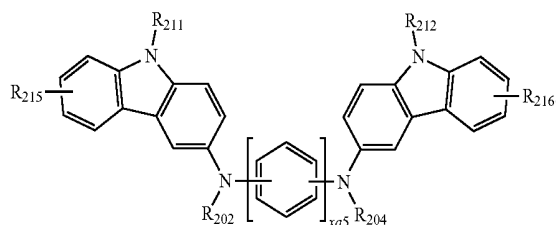


[0186] In one exemplary embodiment, the compound represented by Formula 202 may be represented by Formula 202A:



[0187] In one exemplary embodiment, the compound represented by Formula 202 may be represented by Formula 202A-1:

<Formula 202A-1>



[0188] In Formulas 201A, 201A(1), 201A-1, 202A, and 202A-1,

[0189] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} are each defined the same as described above,

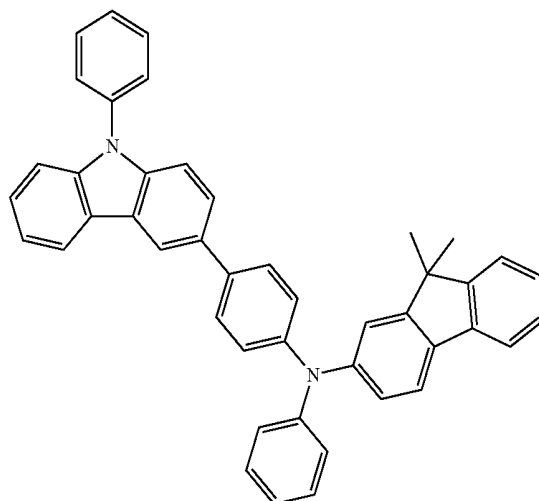
[0190] R_{211} and R_{212} may each independently be defined the same as described in connection with R_{203} , and

[0191] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a

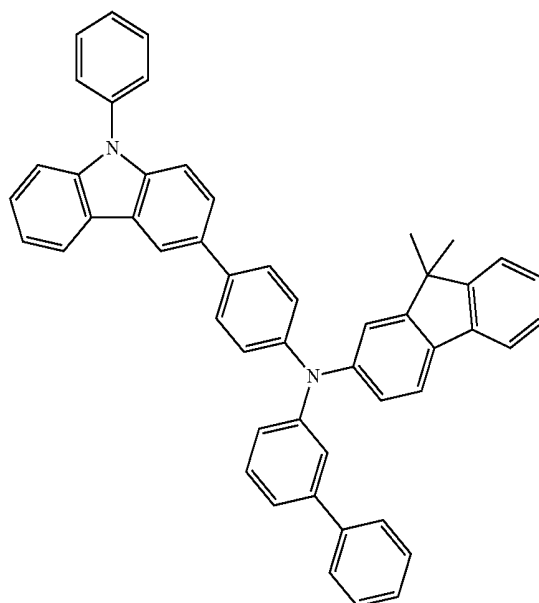
hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with $-F$, 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-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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 thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0192] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but exemplary embodiments are not limited thereto:

HT1

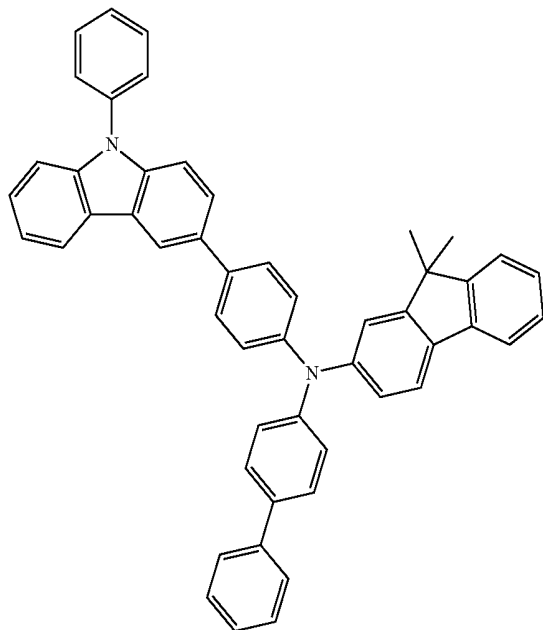


HT2

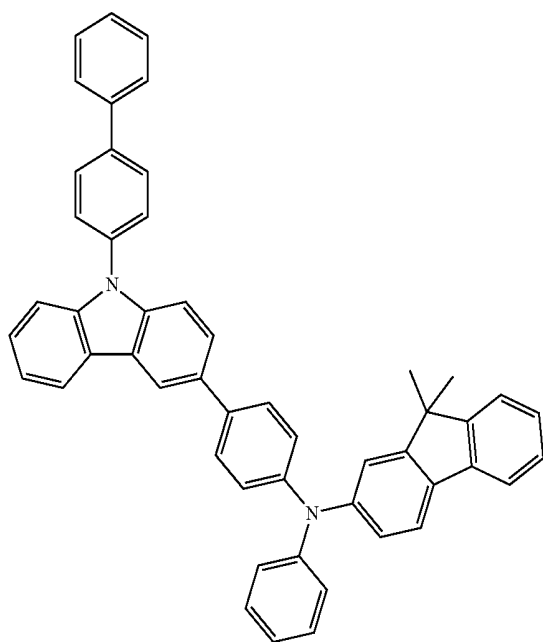


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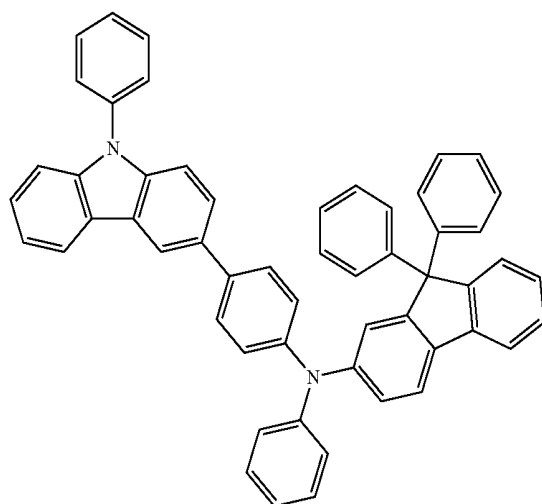
HT3



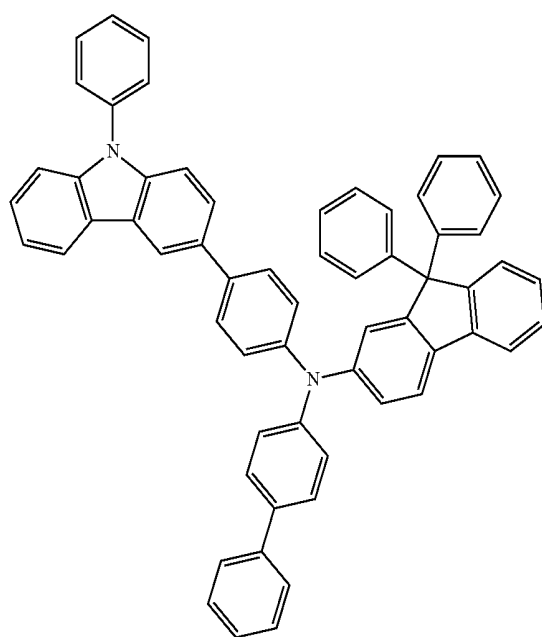
HT4



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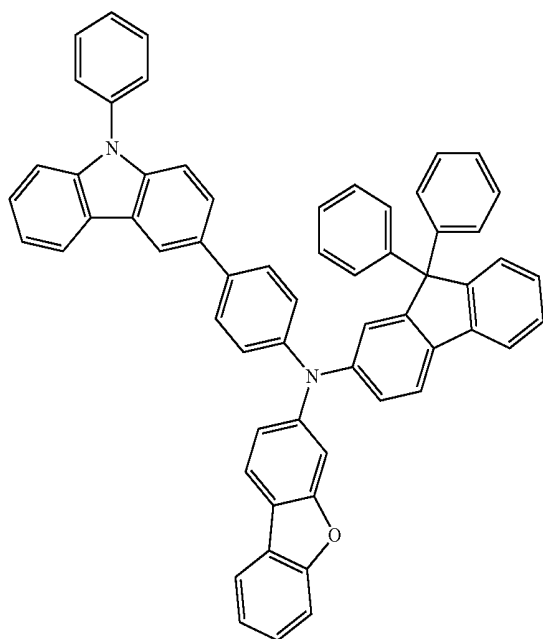
HT5



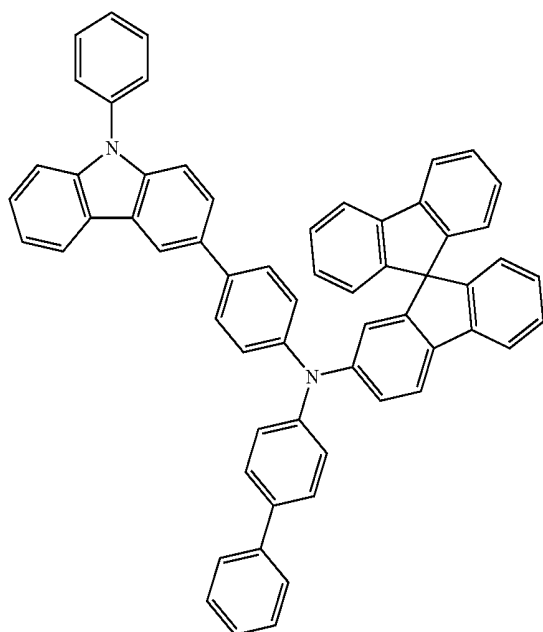
HT6

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HT7

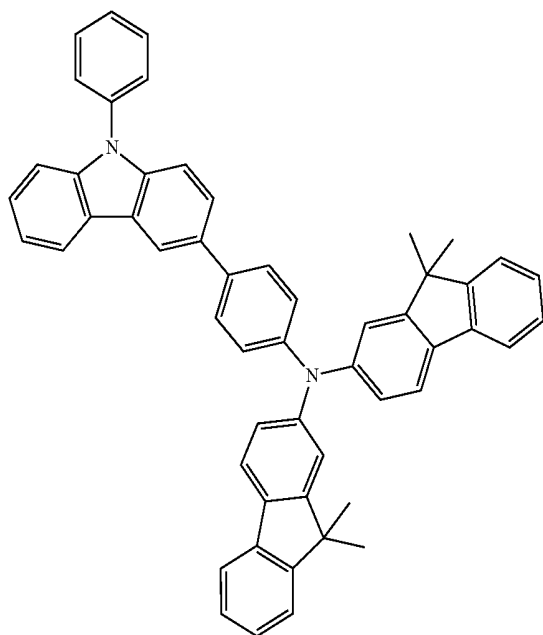


HT8

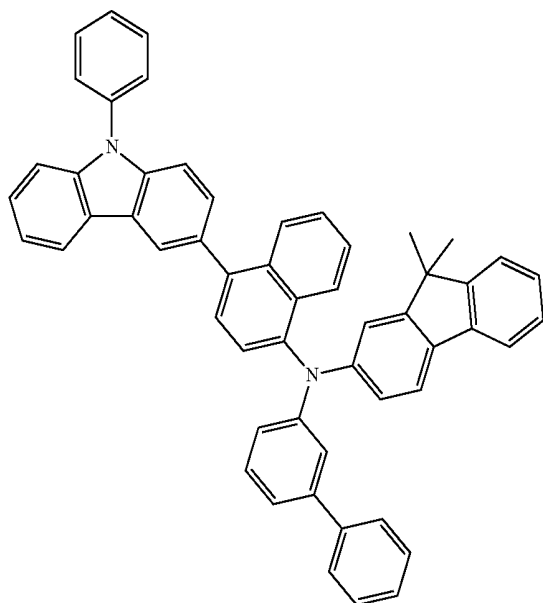


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HT9

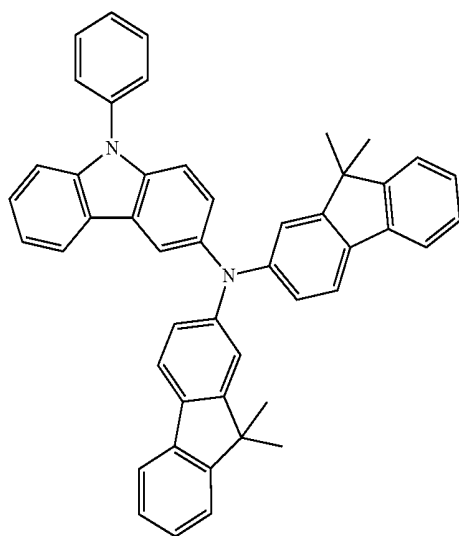


HT10

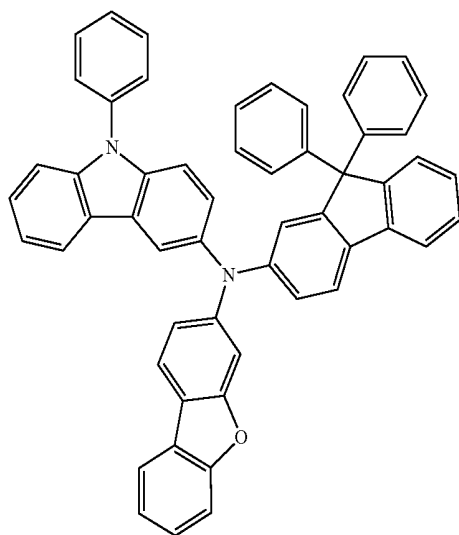


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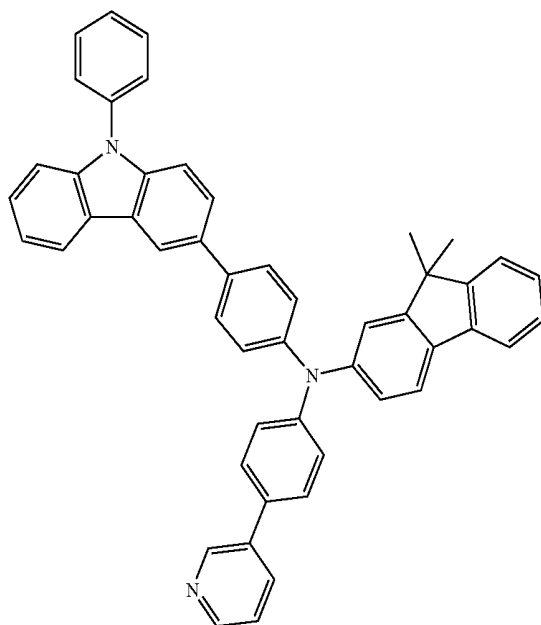
HT11



HT12

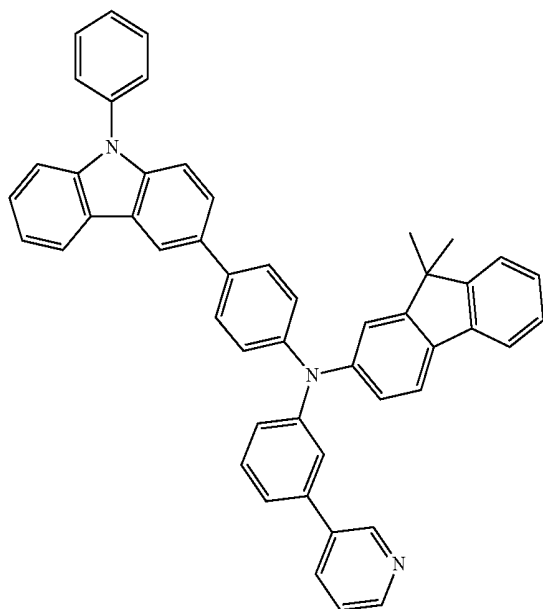


HT13

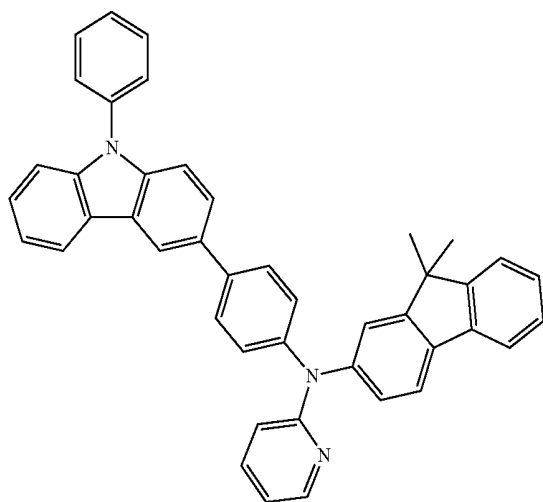


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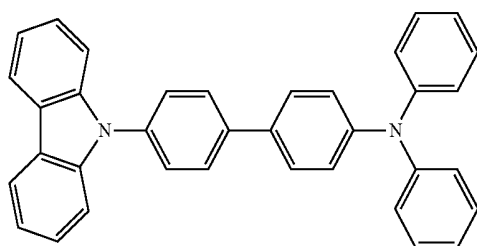
HT14



HT15

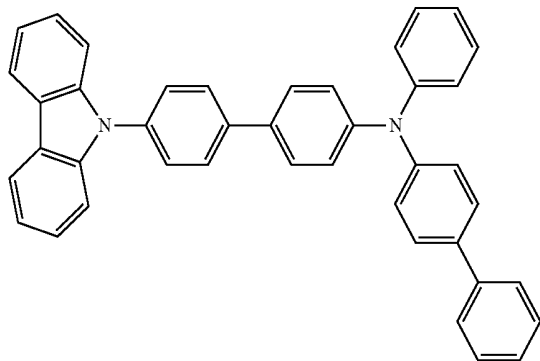


HT16

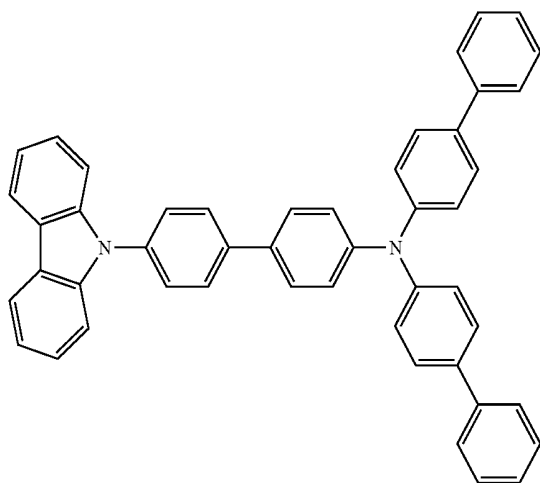


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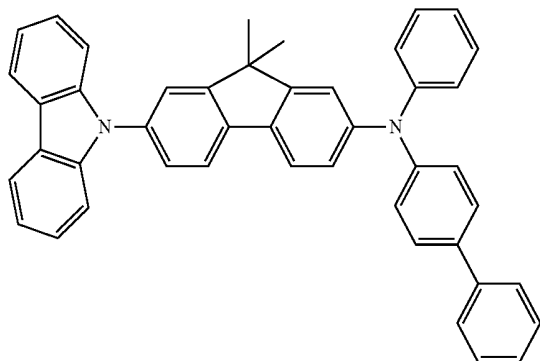
HT17



HT18

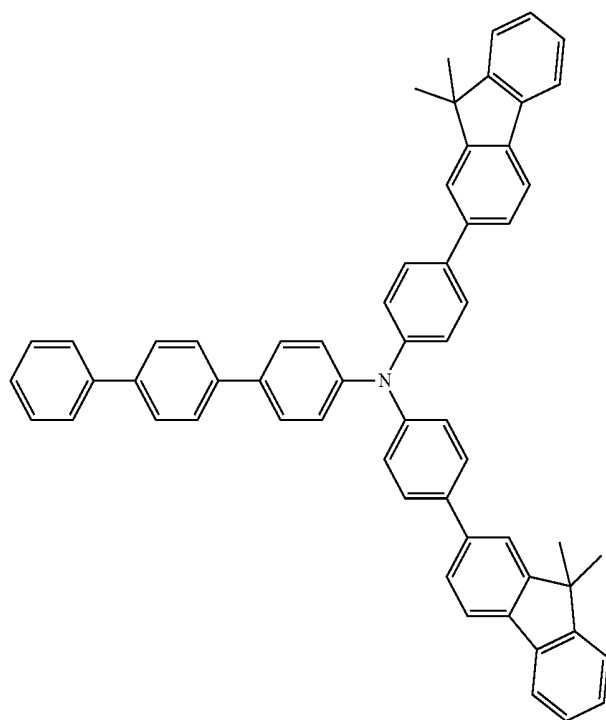


HT19

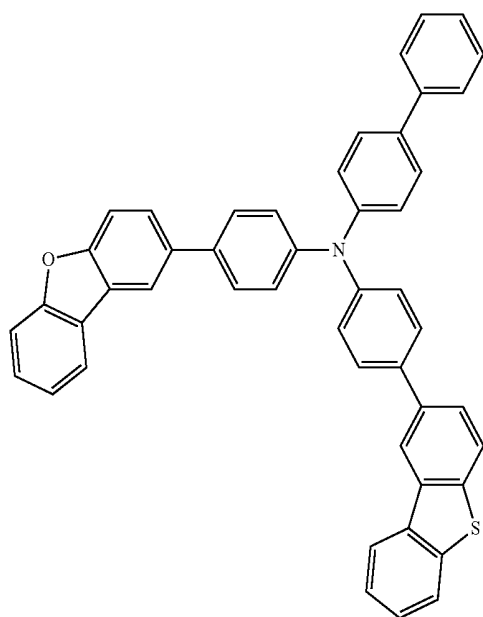


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HT20

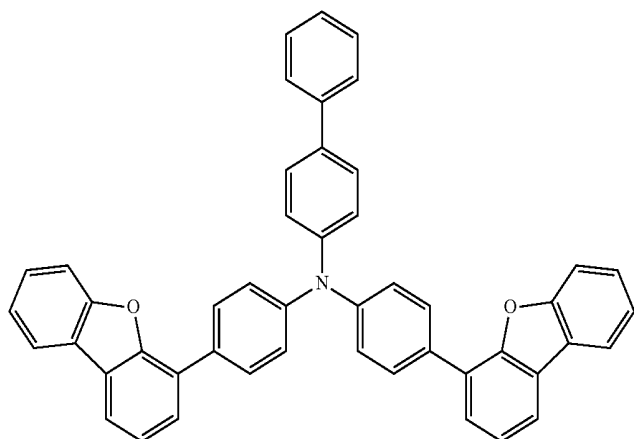


HT21

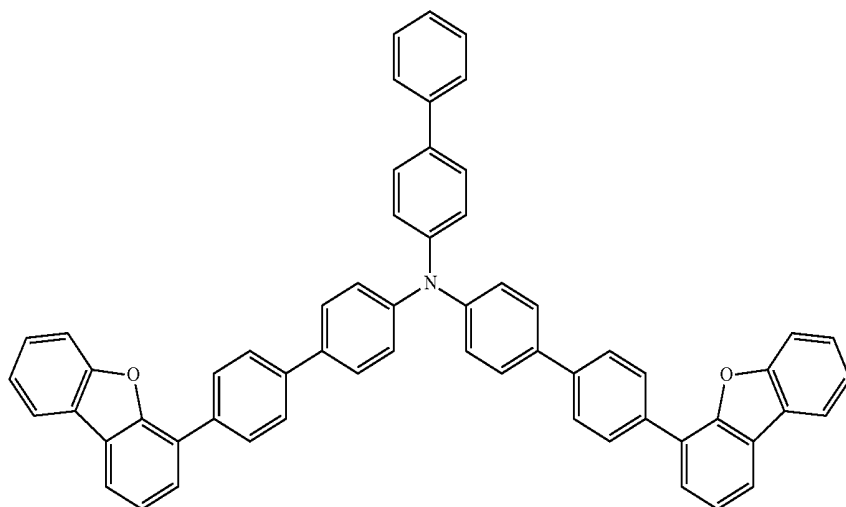


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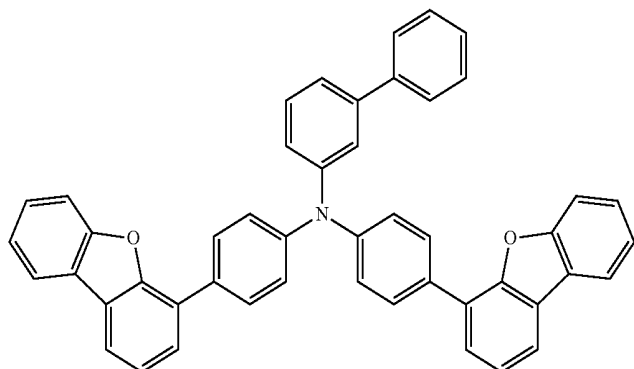
HT22



HT23

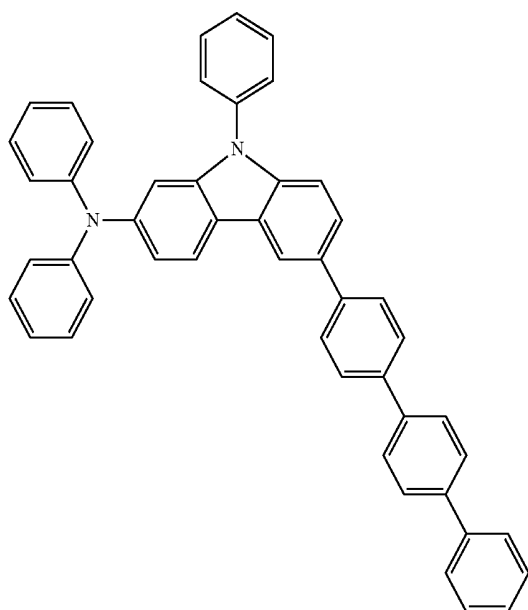


HT24

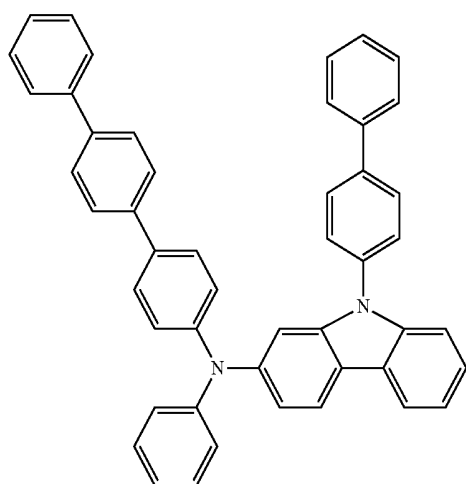


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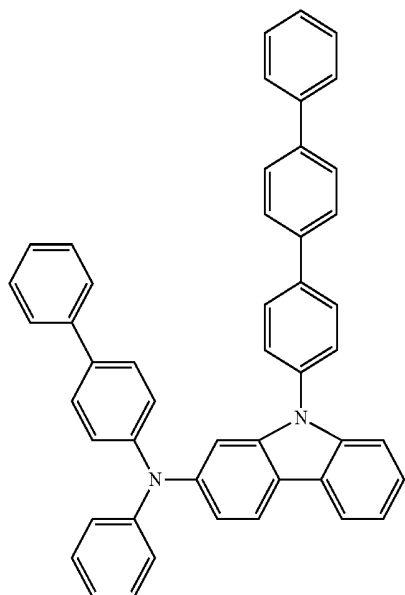
HT25



HT26

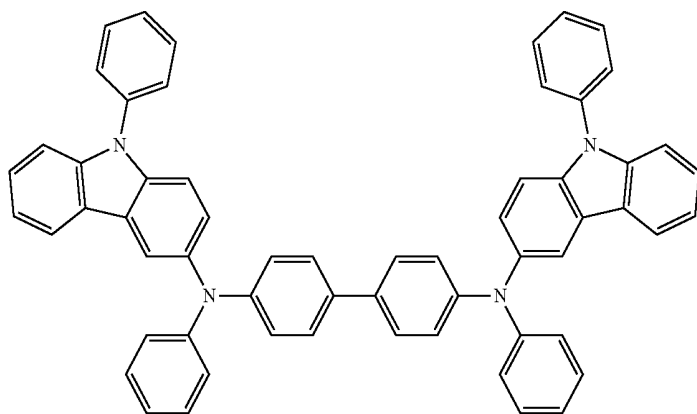


HT27

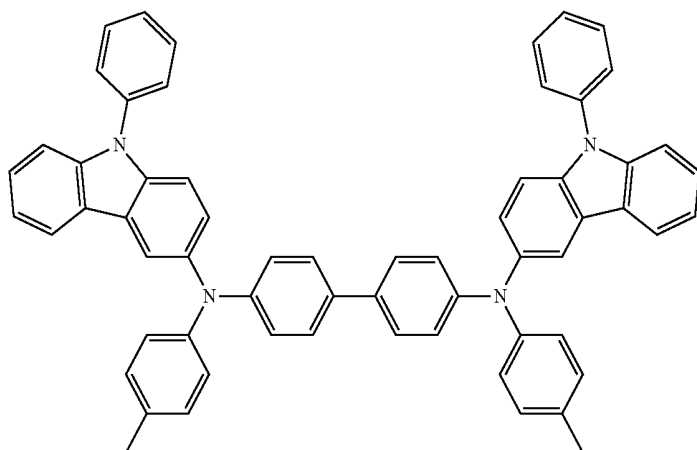


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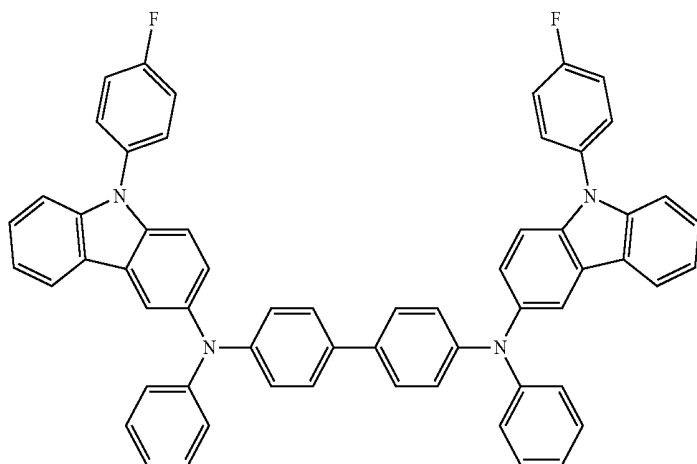
HT28



HT29

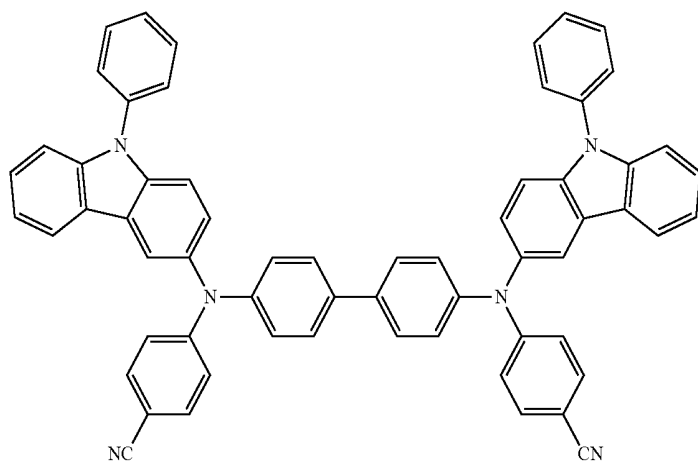


HT30

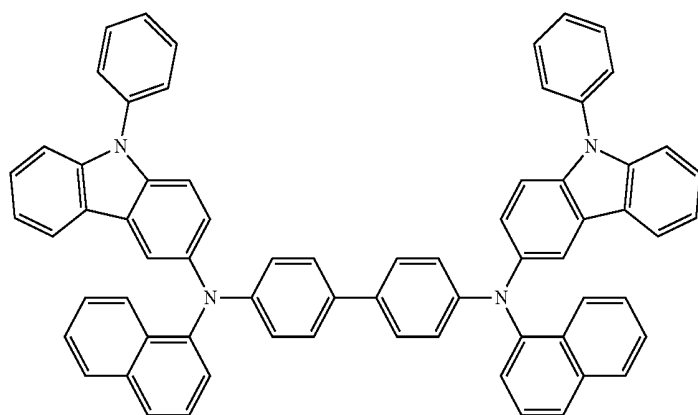


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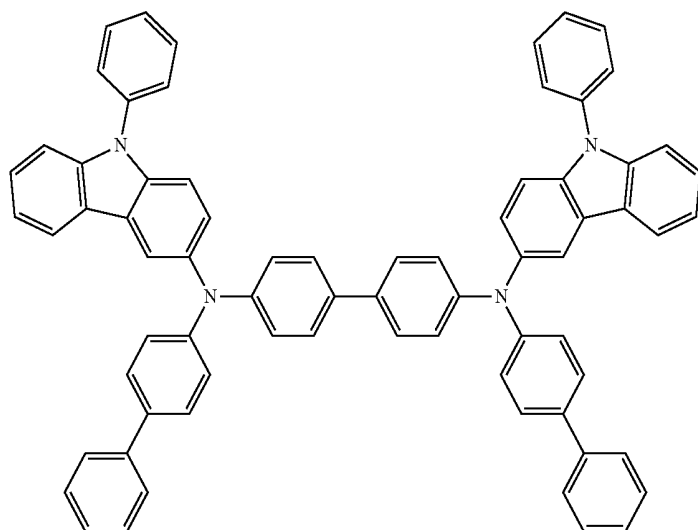
HT31



HT32

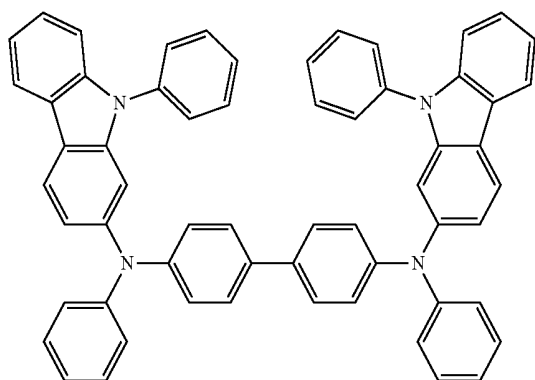


HT33

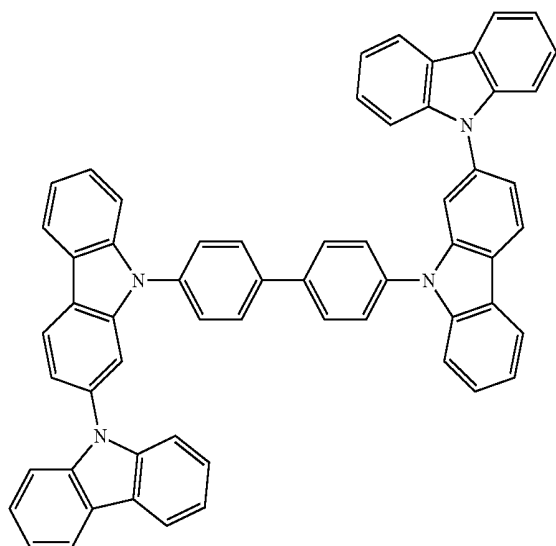


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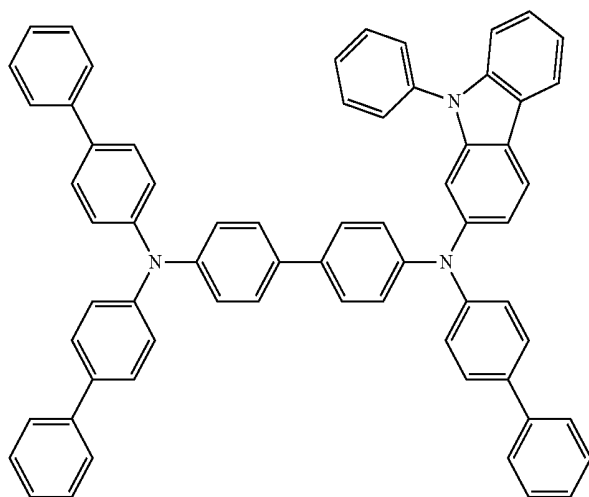
HT34



HT35

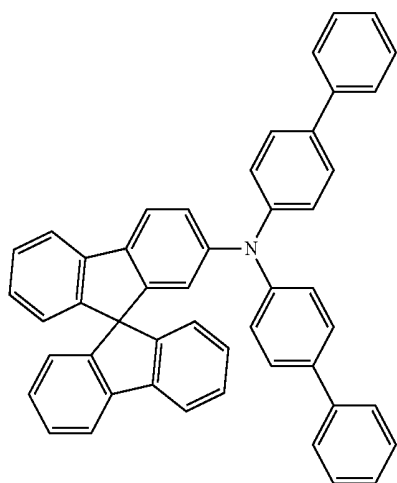


HT36

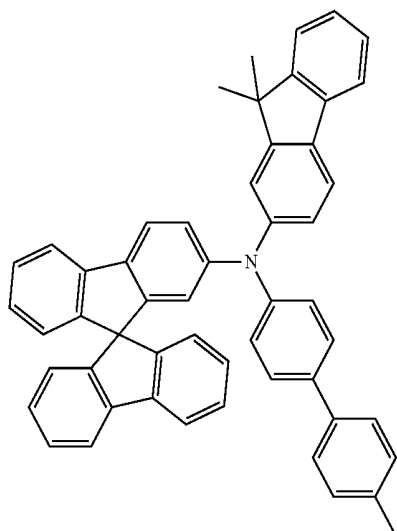


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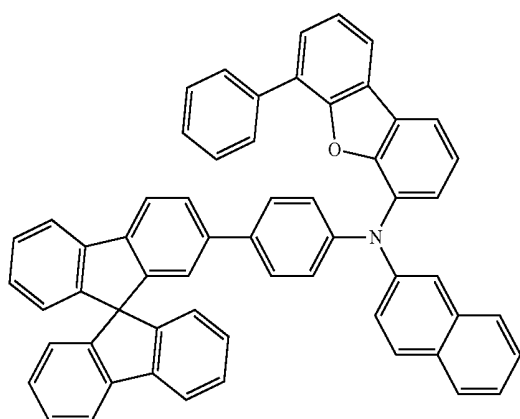
HT37



HT38



HT39



[0193] 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 at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to

about 2,000 Å, for example about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0194] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted

by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

[0195] (p-dopant)

[0196] The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

[0197] The charge-generation material may be, for example, a p-dopant.

[0198] In one exemplary embodiment, the p-dopant may have a LUMO level of -3.5 eV or less.

[0199] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but exemplary embodiments are not limited thereto.

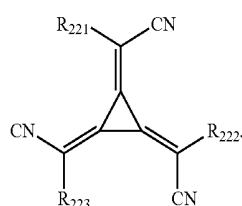
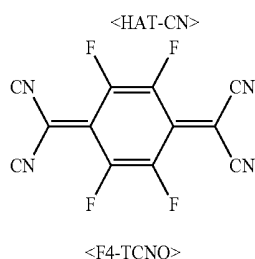
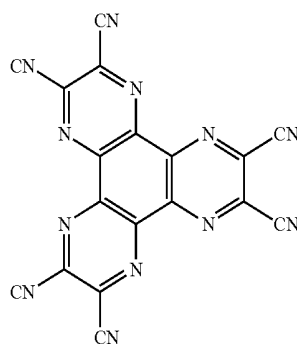
[0200] For example, the p-dopant may include, without limitation, at least one selected from:

[0201] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0202] a metal oxide, such as tungsten oxide or molybdenum oxide;

[0203] 1,4,5,8,9,12-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0204] a compound represented by Formula 221 below:



<Formula 221>

[0205] In Formula 221,

[0206] R_{221} to R_{223} may each independently be selected from 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_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, wherein at least one selected from R_{221} to R_{223} may have at least one substituent selected from a cyano group, $-F$, $-Cl$, $-Br$, $-I$, a C_1 - C_{20} alkyl group substituted with $-F$, a C_1 - C_{20} alkyl group substituted with $-Cl$, a C_1 - C_{20} alkyl group substituted with $-Br$, and a C_1 - C_{20} alkyl group substituted with $-I$.

[0207] (Emission Layer in Organic Layer 150)

[0208] 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, or a blue emission layer, according to a sub-pixel. In one or more exemplary embodiments, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In one or more exemplary embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

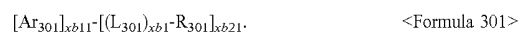
[0209] The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0210] In the emission layer, an amount of the dopant may be in a range of about 0.01 parts to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0211] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0212] (Host in Emission Layer)

[0213] In one or more exemplary embodiments, the host may include a compound represented by Formula 301 below.



[0214] In Formula 301,

[0215] Ar_{301} may be a substituted or unsubstituted C_5 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0216] $xb11$ may be 1, 2, or 3,

[0217] L_{301} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0218] $xb1$ may be an integer from 0 to 5,

[0219] R_{301} may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_{301})(Q_{302})(Q_{303}), —N(Q_{301})(Q_{302}), —B(Q_{301})(Q_{302}), —C(=O)(Q_{301}), —S(=O)₂(Q_{301}), and —P(=O)(Q_{301})(Q_{302}),

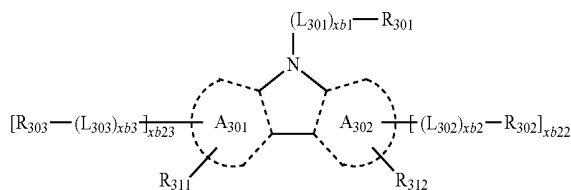
indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}), and

[0225] Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group. However, exemplary embodiments are not limited thereto.

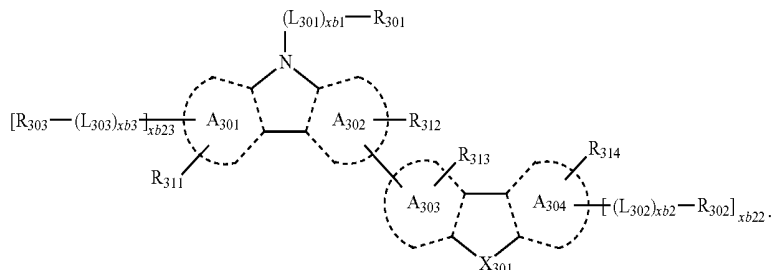
[0226] When $xb11$ in Formula 301 is two or more, two or more $Ar_{301}(s)$ may be linked via a single bond.

[0227] In one or more exemplary embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

<Formula 301-1>



<Formula 301-2>



[0220] $xb21$ may be an integer from 1 to 5, and

[0221] Q_{301} to Q_{303} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0222] In one exemplary embodiment, Ar_{301} in Formula 301 may be selected from:

[0223] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group; and

[0224] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an

[0228] In Formulas 301-1 and 301-2,

[0229] A_{301} to A_{304} may each independently be selected from a benzene, a naphthalene, a phenanthrene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a pyridine, a pyrimidine, an indene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, an indole, a carbazole, a benzocarbazole, a dibenzocarbazole, a furan, a benzofuran, a dibenzofuran, a naphthofuran, a benzonaphthofuran, a dinaphthofuran, a thiophene, a benzothiophene, a dibenzothiophene, a naphthothiophene, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0230] X_{301} may be O, S, or N-[(L_{304})_{xb4}- R_{304}],

[0231] R_{311} to R_{314} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}),

[0232] $xb22$ and $xb23$ may each independently be 0, 1, or 2,

[0233] L_{301} , $xb1$, R_{301} , and Q_{31} to Q_{33} are defined the same as described above,

[0234] L_{302} to L_{304} may each independently be defined the same as described in connection with L_{301} ,

[0235] $xb2$ to $xb4$ may each independently be defined the same as described in connection with $xb1$, and

[0236] R_{302} to R_{304} may each independently be defined the same as described in connection with R_{301} .

[0237] For example, in Formulas 301, 301-1, and 301-2, L_{301} to L_{304} may each independently be selected from:

[0238] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysénylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyrimidinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

[0239] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysénylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyrimidinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

nylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysényl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolylyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyrimidinyl group, an imidazopyrimidinyl group, an azacarbazolylyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}), and

[0240] Q_{31} to Q_{33} are defined the same as described above.

[0241] In one exemplary embodiment, in Formula 301, 301-1, and 301-2, R_{301} to R_{304} may each independently be selected from:

[0242] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysényl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolylyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyrimidinyl group, an imidazopyrimidinyl group, and an azacarbazolylyl group; and

[0243] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl

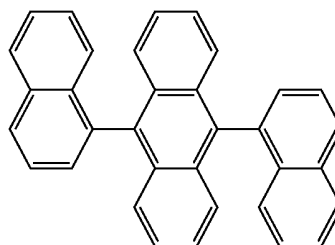
group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl 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 phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl 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 phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$, and

[0244] Q_{31} to Q_{33} are defined the same as described above.

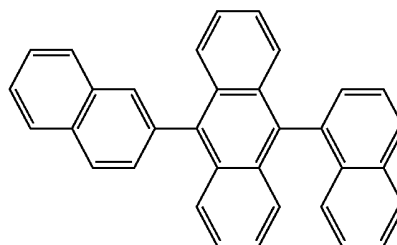
[0245] In one or more exemplary embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0246] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene

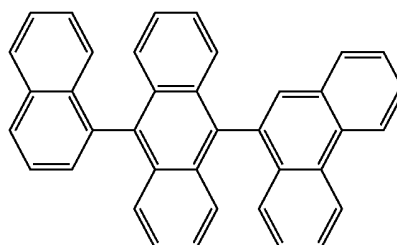
(mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but exemplary embodiments are not limited thereto:



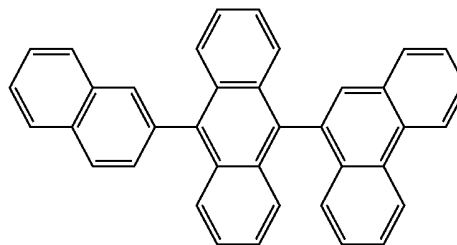
H1



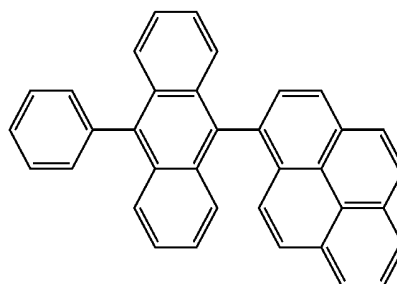
H2



H3

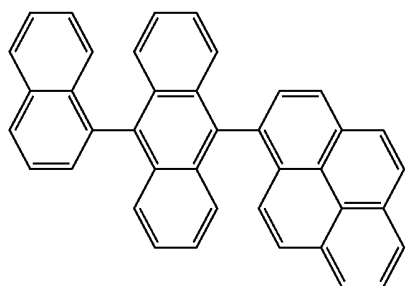


H4



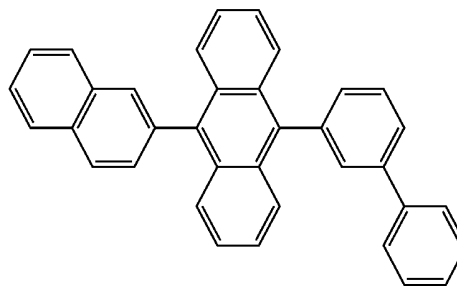
H5

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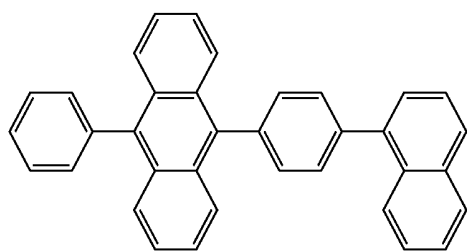


H6

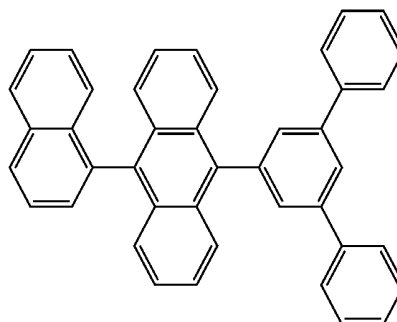
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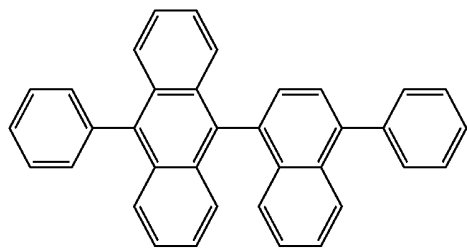
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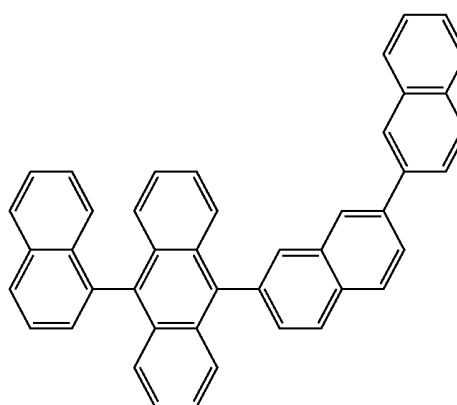
H7



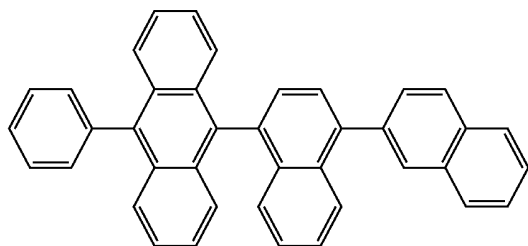
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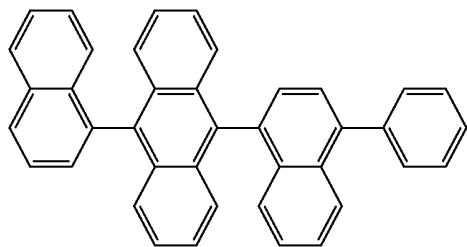
H8



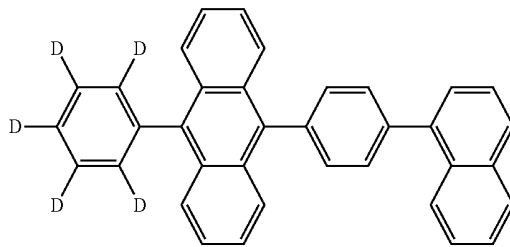
H14



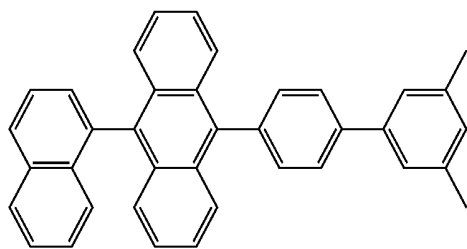
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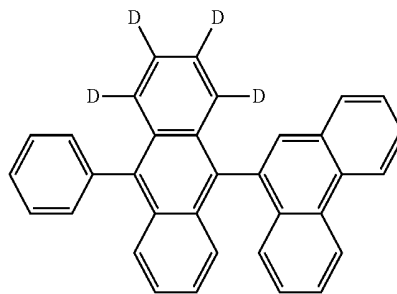
H10



H15



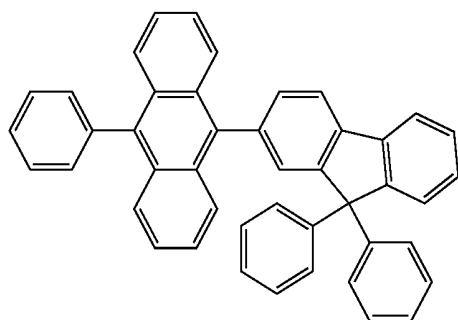
H11



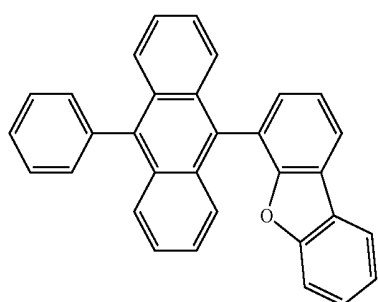
H16

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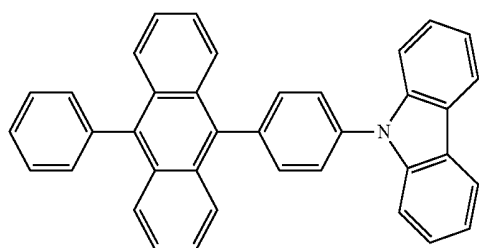
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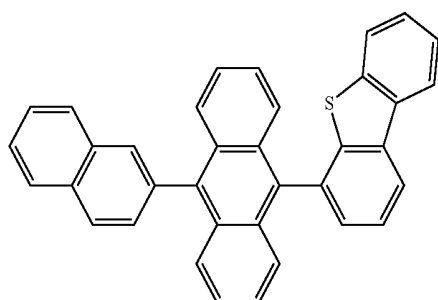
H18



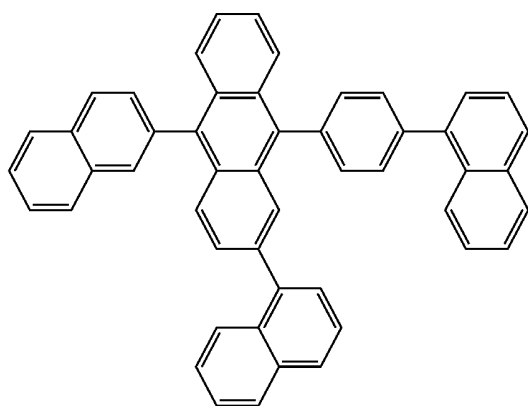
H19



H20

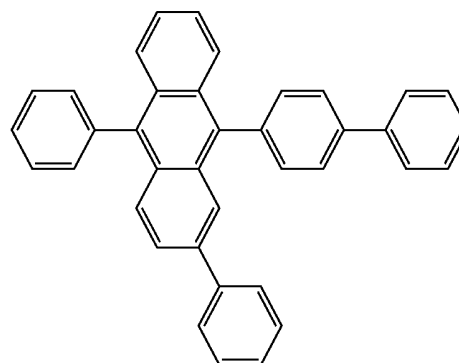


H21

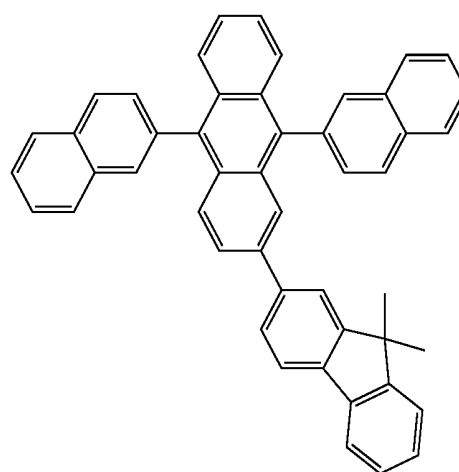


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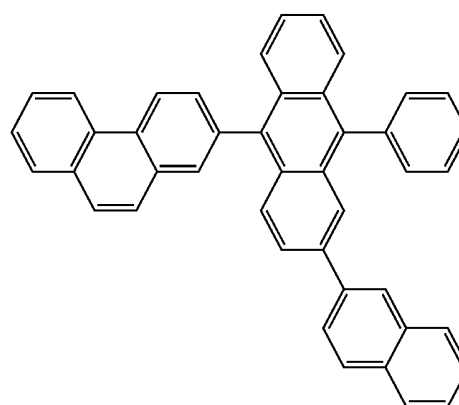
H22



H23



H24

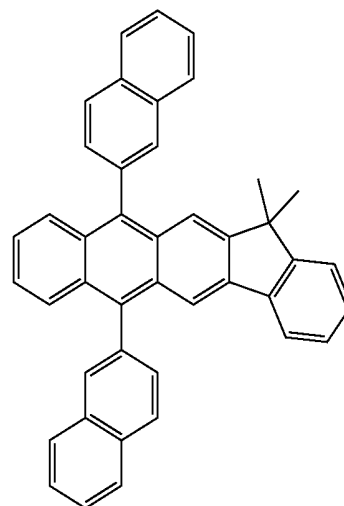
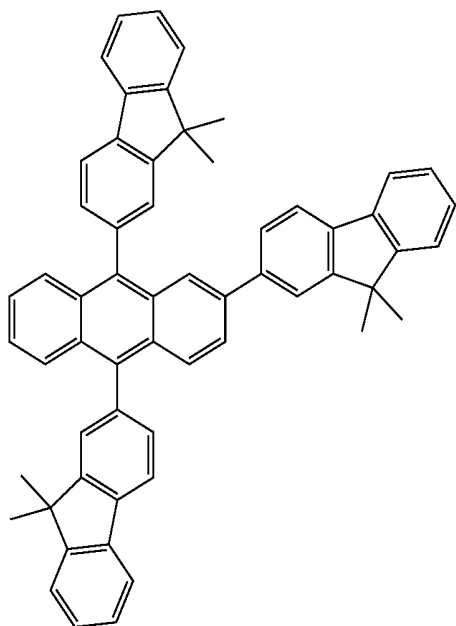


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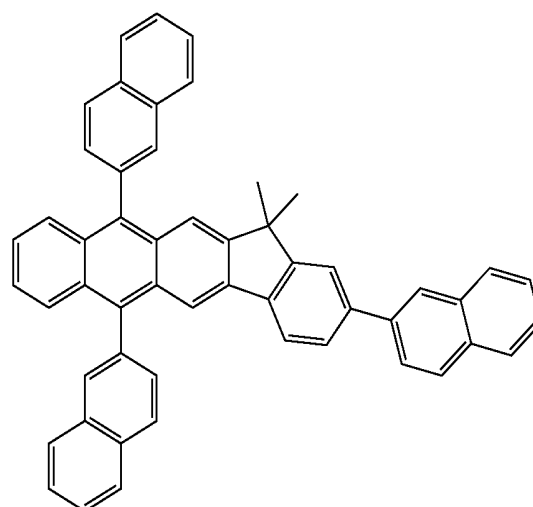
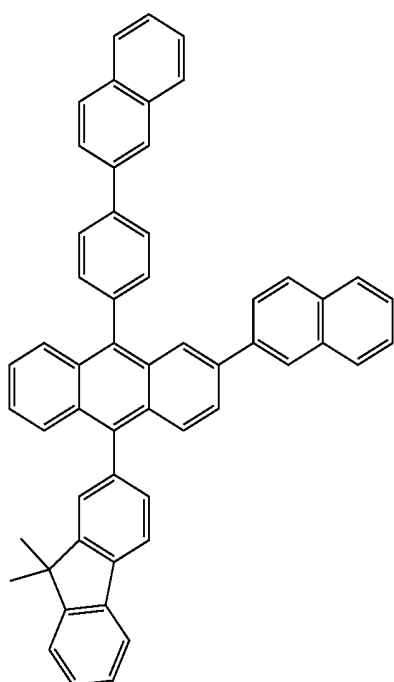
H27

H25

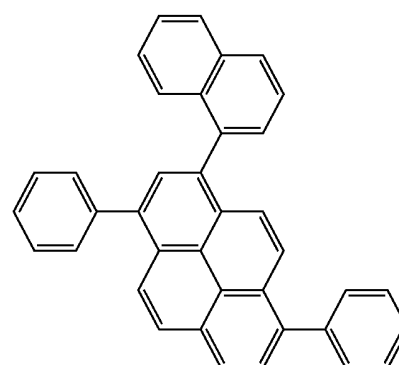


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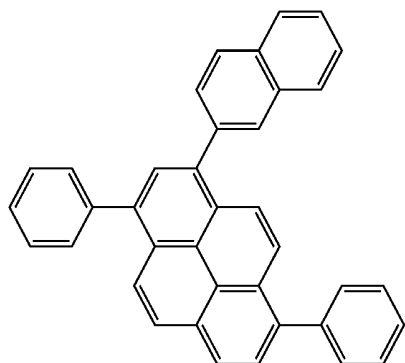
H26



H29

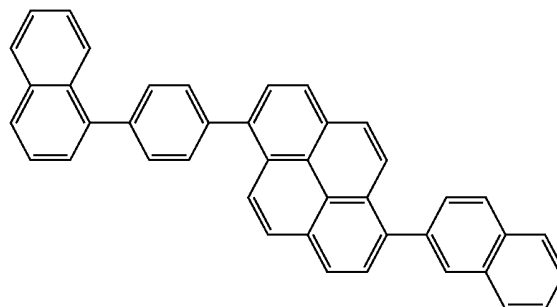


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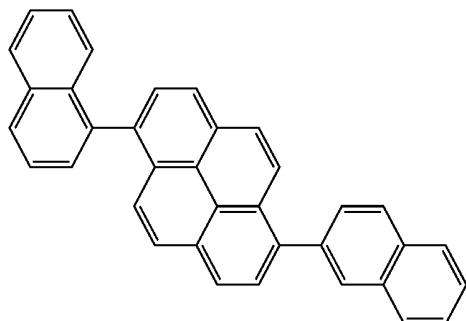
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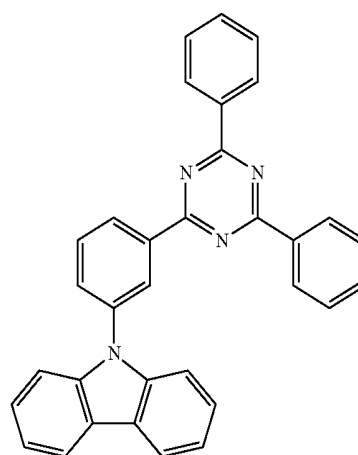


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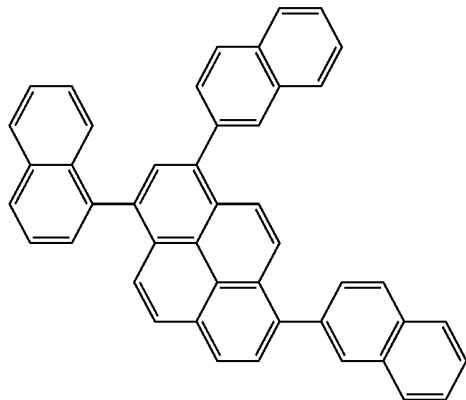
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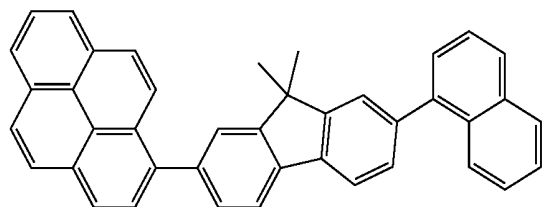
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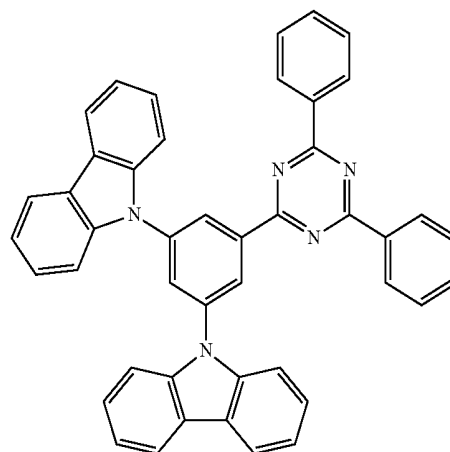
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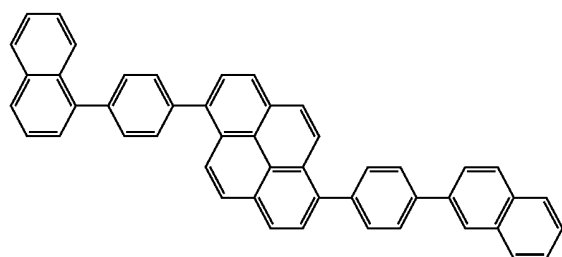
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H34

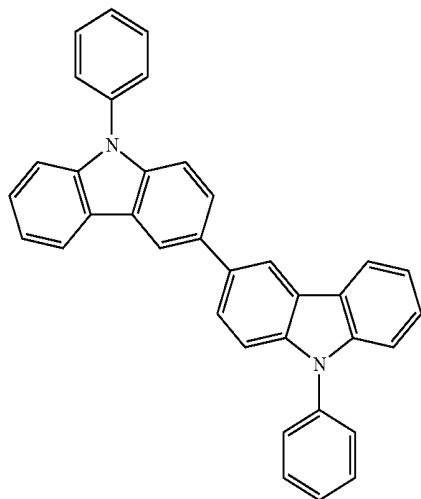


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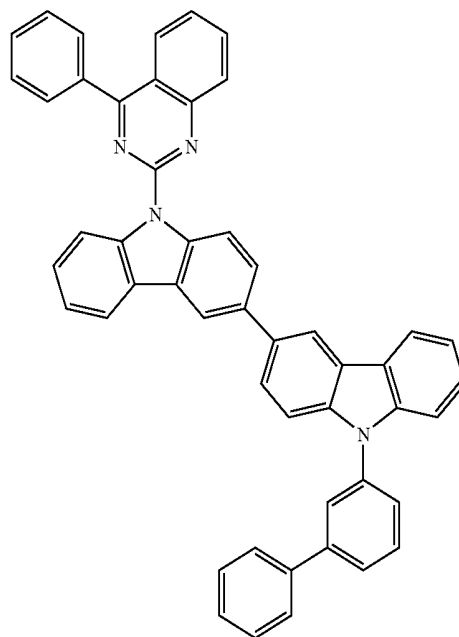
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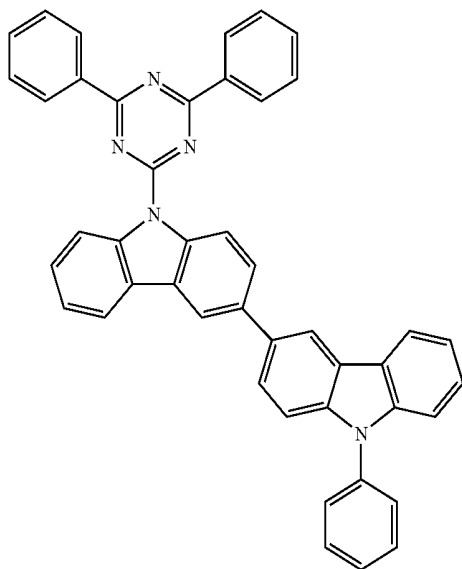


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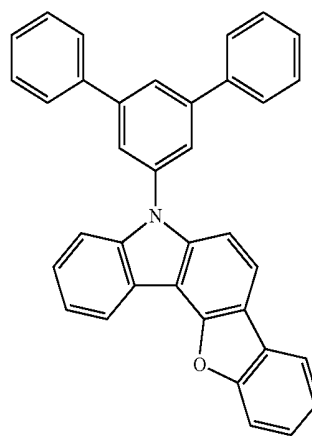
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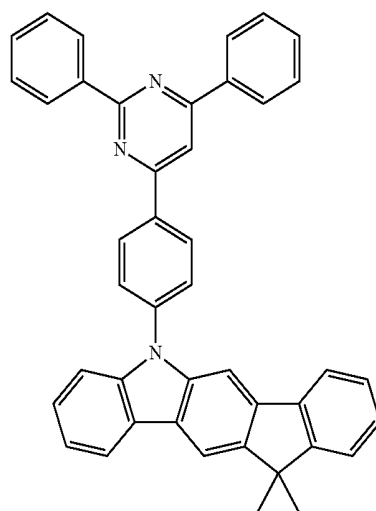
H41



H40

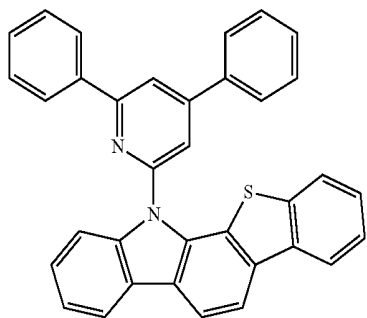


H42



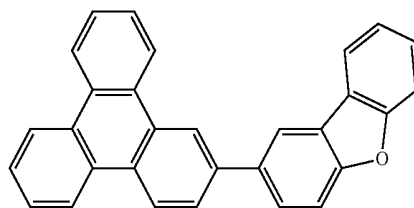
H43

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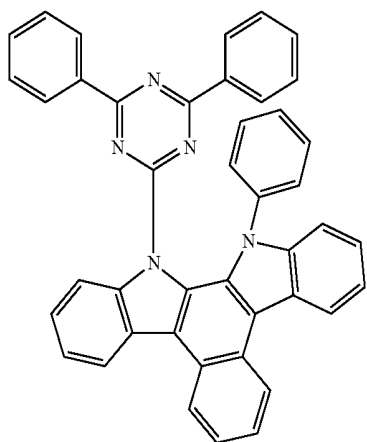


H44

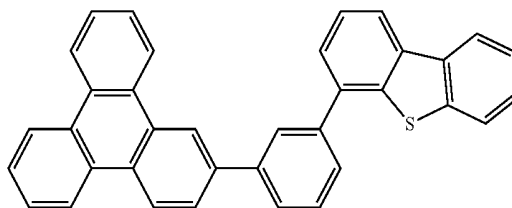
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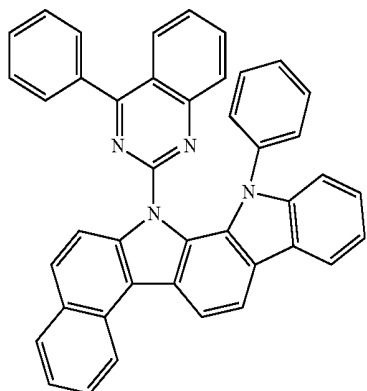
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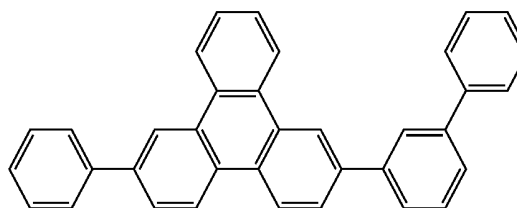
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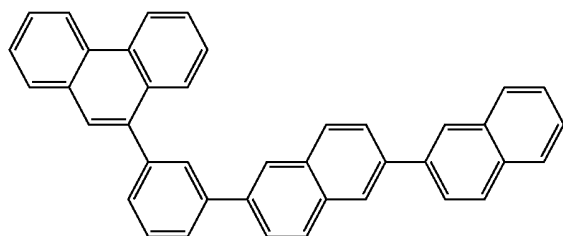
H50



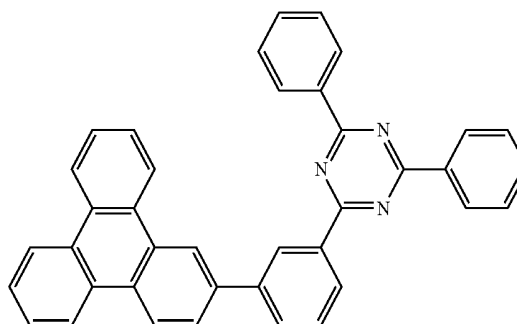
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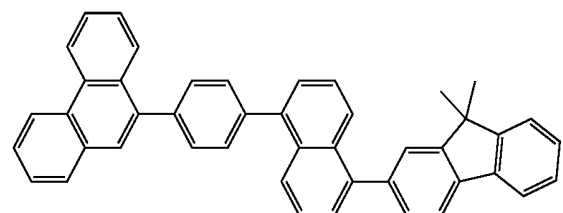
H51



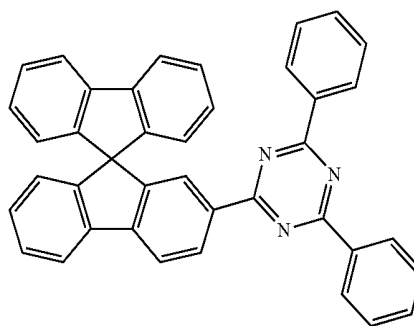
H47



H52

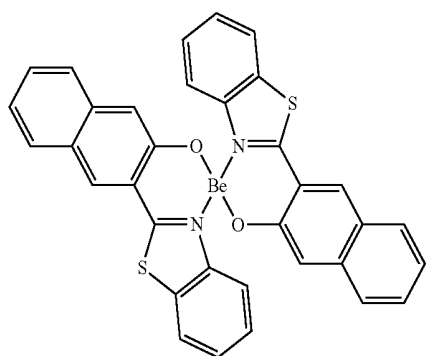
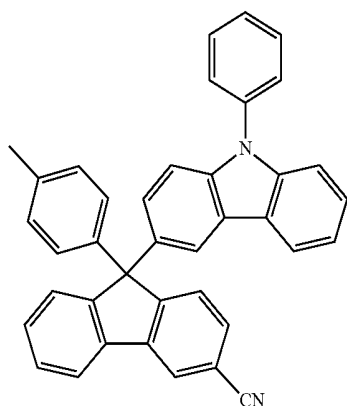


H48

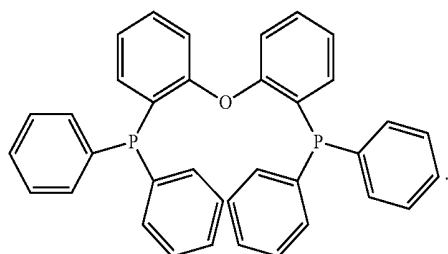


H53

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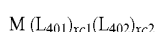


[0247] In one exemplary embodiment, the host may be a compound including a phosphorous atom, and an example thereof is Compound BH-1. However, exemplary embodiments are not limited thereto:



[0248] (Phosphorescent Dopant Included in Emission Layer in Organic Layer 150)

[0249] The phosphorescent dopant may include an organometallic complex represented by Formula 401:

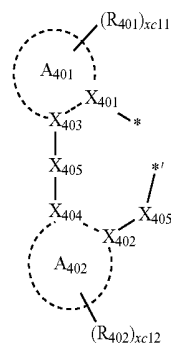


<Formula 401>

-continued

<Formula 402>

H54



H55

[0250] In Formulas 401 and 402,

[0251] M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm),

[0252] L_{401} may be selected from ligands represented by Formula 402, and xc1 may be 1, 2, or 3, wherein, when xc1 is two or more, two or more L_{401} (s) may be identical to or different from each other,

[0253] L_{402} may be an organic ligand, and xc2 may be an integer from 0 to 4, wherein, when xc2 is two or more, two or more L_{402} (s) may be identical to or different from each other,

[0254] X_{401} to X_{404} may each independently be nitrogen or carbon,

[0255] X_{401} and X_{403} may be linked via a single bond or a double bond, and X_{402} and X_{404} may be linked via a single bond or a double bond,

[0256] A_{401} and A_{402} may each independently be selected from a C_5 - C_{60} carbocyclic group or a C_1 - C_{60} heterocyclic group,

[0257] X_{405} may be a single bond, $^*O^*$, $^*S^*$, $^*C(=O)^*$, $^*N(Q_{411})^*$, $^*C(Q_{411})(Q_{412})^*$, $^*C(Q_{411})=C(Q_{412})^*$, $^*C(Q_{411})^*$, or $^*C=^*$, wherein Q_{411} and Q_{412} are each independently hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group,

[0258] X_{406} may be a single bond, O, or S,

[0259] R_{401} and R_{402} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{60} 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, $-Si(Q_{401})(Q_{402})(Q_{403})$, $-N(Q_{401})(Q_{402})$, $-B(Q_{401})(Q_{402})$, $-C(=O)(Q_{401})$, $-S(=O)_2(Q_{401})$, and $-P(=O)(Q_{401})(Q_{402})$, wherein Q_{401} to Q_{403}

may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a C₆-C₂₀ aryl group, and a C₁-C₂₀ heteroaryl group,

[0260] xc11 and xc12 may each independently be an integer from 0 to 10, and

[0261] in Formula 402, * and *' each indicate a binding site to M of Formula 401.

[0262] In one exemplary embodiment, in Formula 402, A₄₀₁ and A₄₀₂ may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothiophene group, an isobenzothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiophene group.

[0263] In one or more exemplary embodiments, in Formula 402, i) X₄₀₁ may be nitrogen, and X₄₀₂ may be carbon, or ii) X₄₀₁ and X₄₀₂ may each be nitrogen at the same time.

[0264] In one or more exemplary embodiments, in Formula 402, R₄₀₁ and R₄₀₂ may each independently be selected from:

[0265] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[0266] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, and a norbornenyl group;

[0267] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0268] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl

group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0269] —Si(Q₄₀₁)(Q₄₀₂)(Q₄₀₃), —N(Q₄₀₁)(Q₄₀₂), —B(Q₄₀₁)(Q₄₀₂), —C(=O)(Q₄₀₁), —S(=O)₂(Q₄₀₁), and —P(=O)(Q₄₀₁)(Q₄₀₂), and

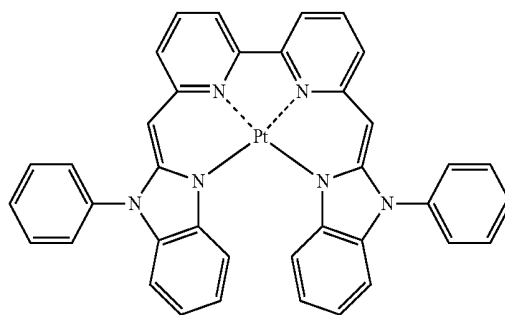
[0270] Q₄₀₁ to Q₄₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, but exemplary embodiments are not limited thereto.

[0271] In one or more exemplary embodiments, in Formula 401, when xc1 is two or more, two A₄₀₁(s) selected from two or more of L₄₀₁(s) may optionally be linked via X₄₀₇, which is a linking group; or when xc2 is two or more, two A₄₀₂(s) selected from two or more of L₄₀₂(s) may optionally be linked via X₄₀₈, which is a linking group (see Compounds PD1 to PD4 and PD7, wherein X₄₀₇ and X₄₀₈ may each independently be a single bond, *—O—*, *—S—*, *—C(=O)—*, *—N(Q₄₁₃)*, *—C(Q₄₁₃)(Q₄₁₄)*, or *—C(Q₄₁₃)=C(Q₄₁₄)* (wherein Q₄₁₃ and Q₄₁₄ may each independently be hydrogen, deuterium, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group), but exemplary embodiments are not limited thereto.

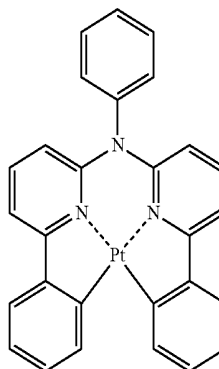
[0272] L₄₀₂ in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L₄₀₂ may be selected from halogen, diketone (for example, acetylacetonate), carboxylic acid (for example, picolinate), —C(=O), isonitrile, —CN, and phosphorus (for example, phosphine, or phosphite), but exemplary embodiments are not limited thereto.

[0273] In one or more exemplary embodiments, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25, but exemplary embodiments of the present disclosure are not limited thereto:

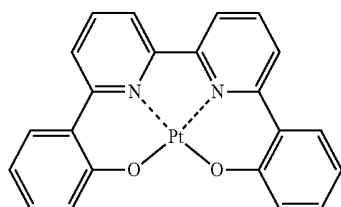
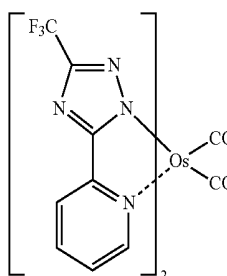
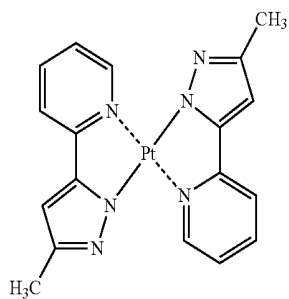
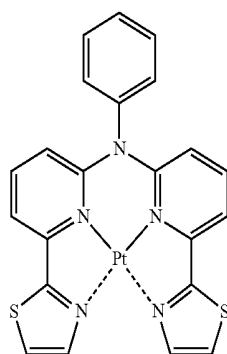
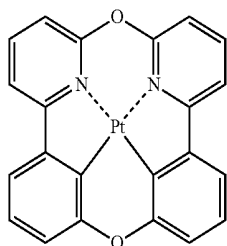
PD1



PD2

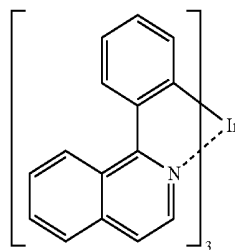


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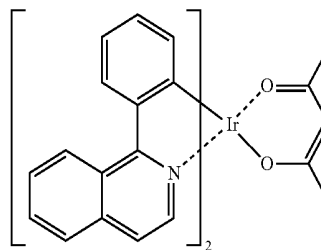
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PD3



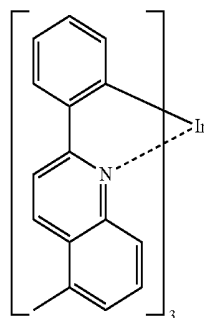
PD8

PD4



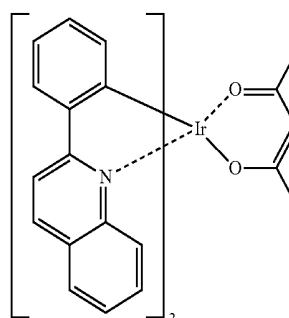
PD9

PD5



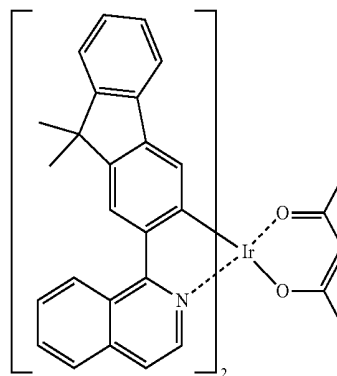
PD10

PD6



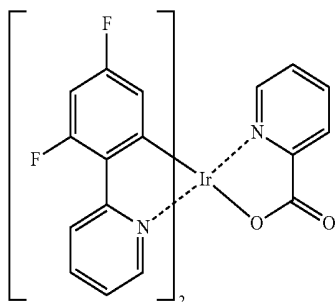
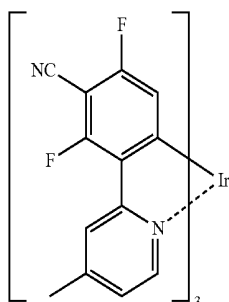
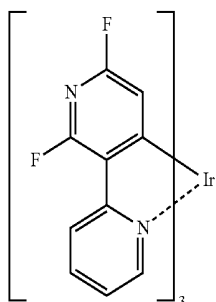
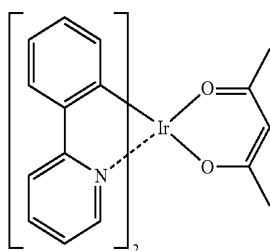
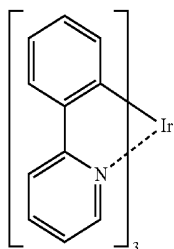
PD11

PD7



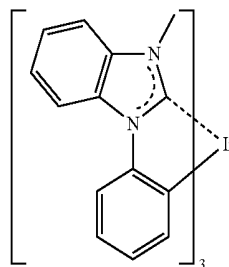
PD12

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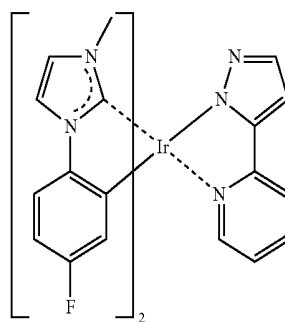
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PD13



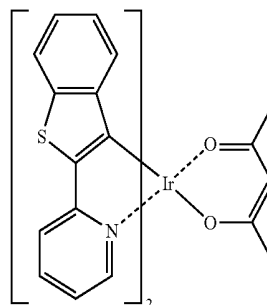
PD18

PD14



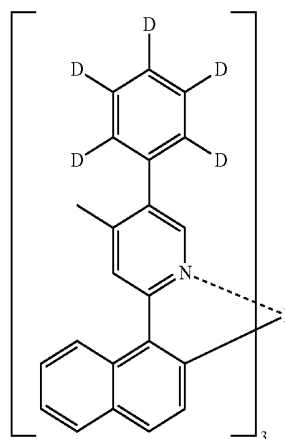
PD19

PD15



PD20

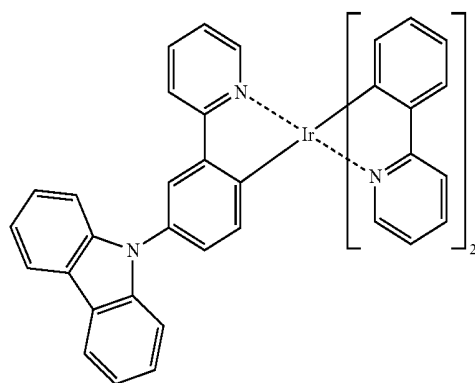
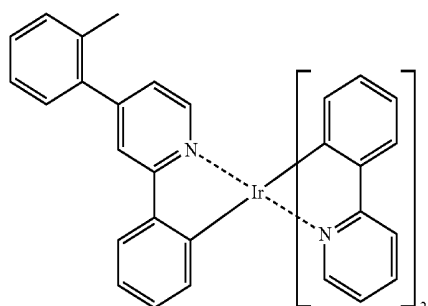
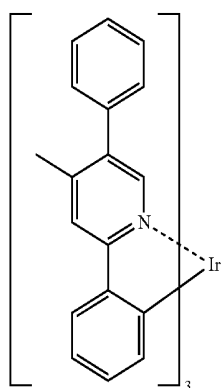
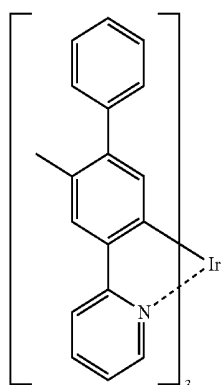
PD16



PD21

PD17

-continued



[0274] (Fluorescent Dopant in Emission Layer)

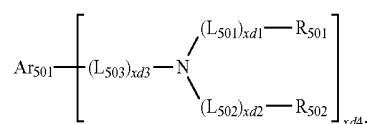
[0275] The fluorescent dopant may include a compound represented by Formula 1.

[0276] In one exemplary embodiment, the fluorescent dopant may include an arylamine compound or a styrylamine compound.

PD22

[0277] The fluorescent dopant may include a compound represented by Formula 501:

[0278] <Formula 501>



<Formula 501>

PD23

[0279] In Formula 501,

[0280] Ar_{501} may be a substituted or unsubstituted C_5 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,[0281] L_{501} to L_{503} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,[0282] x_{d1} to x_{d3} may each independently be an integer of 0 to 3,

PD24

[0283] R_{501} and R_{502} may each independently be selected from 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[0284] x_{d4} may be an integer of 1 to 6.

PD25

[0285] In one exemplary embodiment, Ar_{501} in Formula 501 may be selected from:

[0286] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group; and

[0287] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0288] In one or more exemplary embodiments, L_{501} to L_{503} in Formula 501 may each independently be selected from:

[0289] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylene group, a pentacenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group; and

[0290] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylene group, a pentacenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0291] In one or more exemplary embodiments, in Formula 501, R_{501} and R_{502} may each independently be selected from:

[0292] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

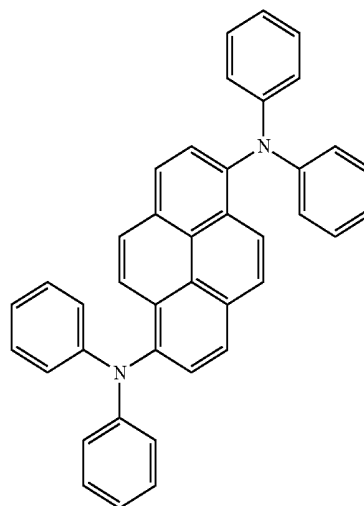
[0293] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group and —Si(Q_{31})(Q_{32})(Q_{33}), and

[0294] Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

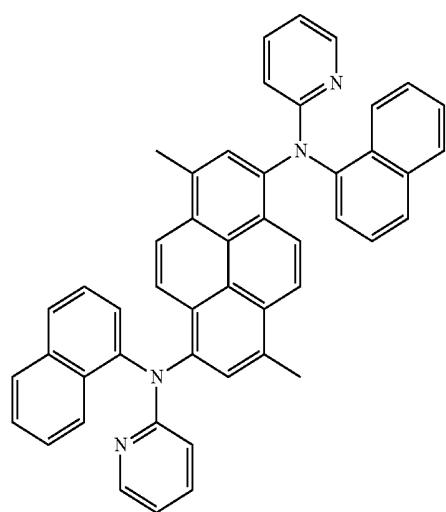
[0295] In one or more exemplary embodiments, $xd4$ in Formula 501 may be 2, but exemplary embodiments are not limited thereto.

[0296] For example, the fluorescent dopant may be selected from Compounds FD 1 to FD22:

FD1

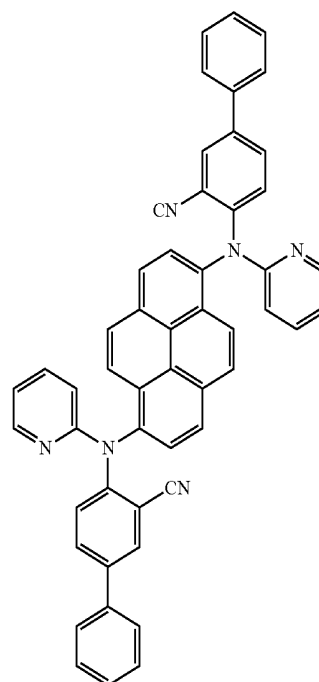


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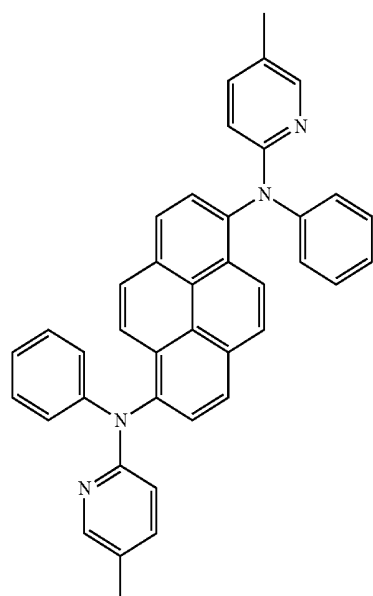


FD2

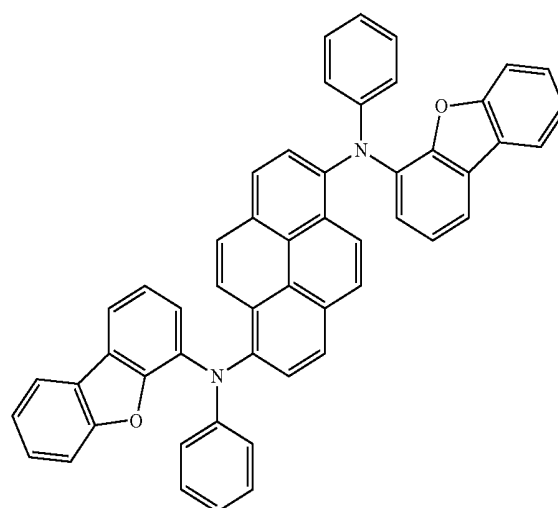
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FD4



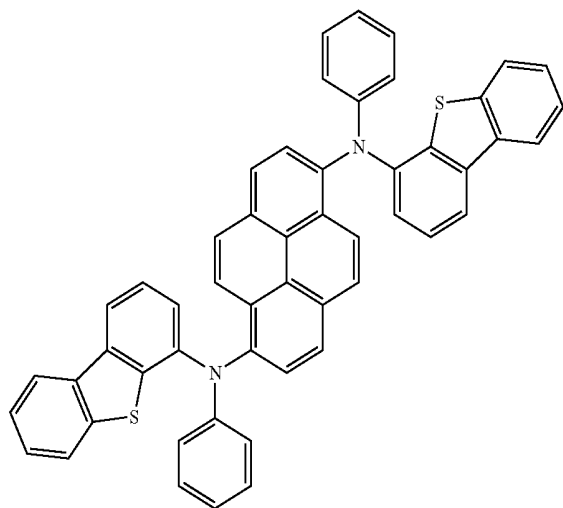
FD3



FD5

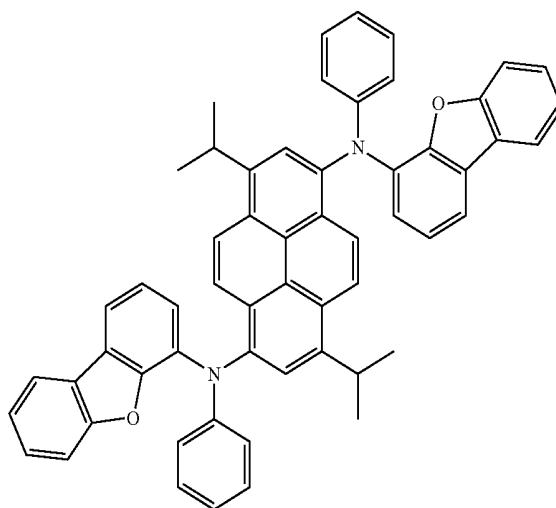
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FD6

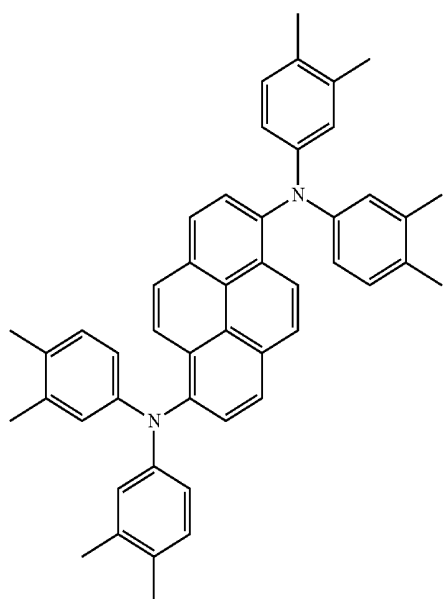


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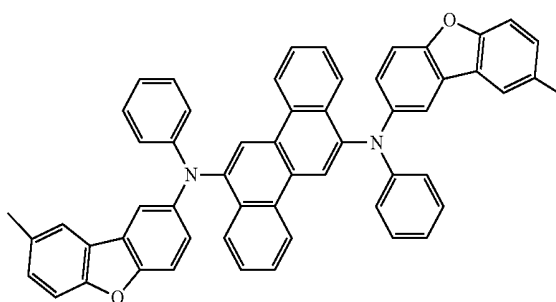
FD9



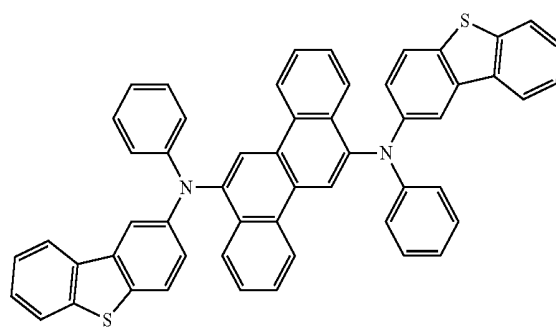
FD7



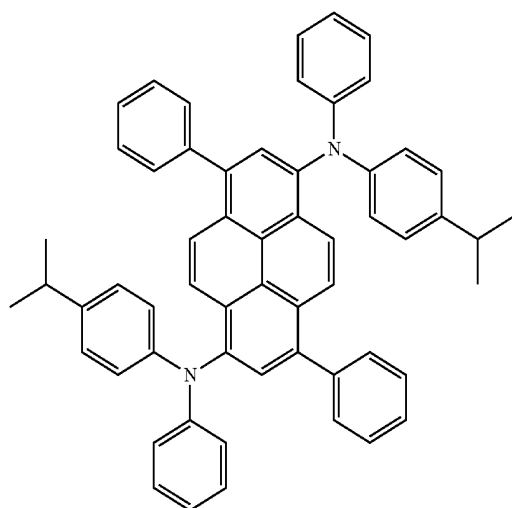
FD10



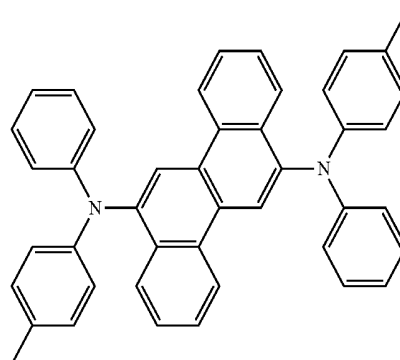
FD11



FD8

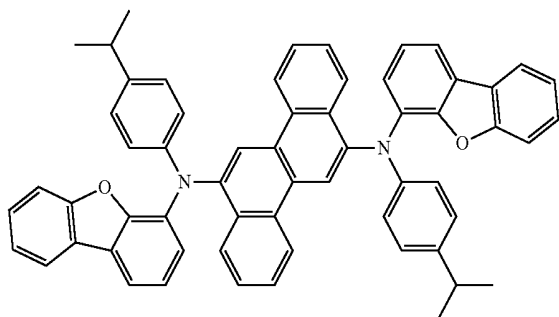


FD12



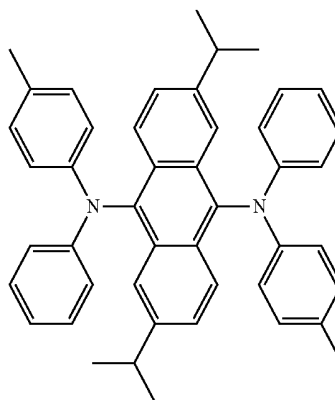
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FD13



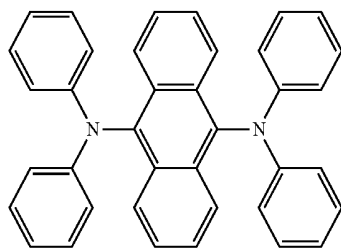
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FD18

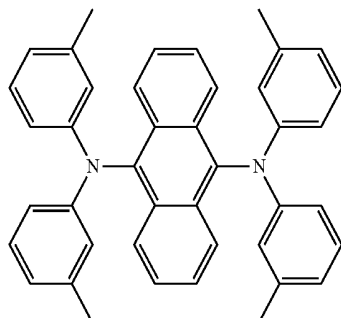
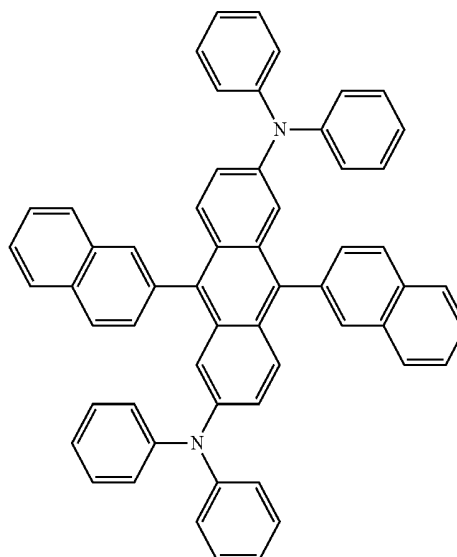


FD14

FD19

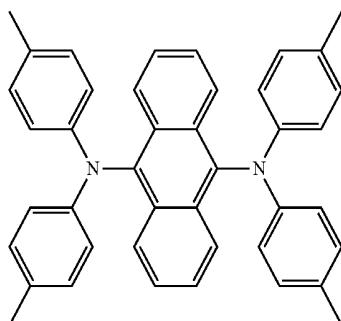


FD15



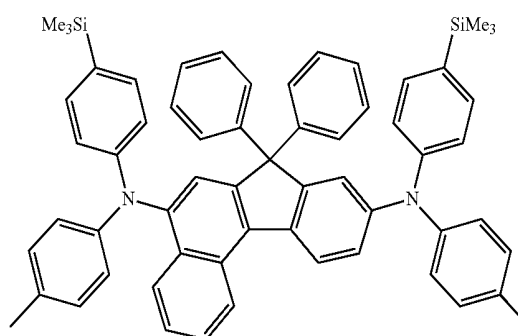
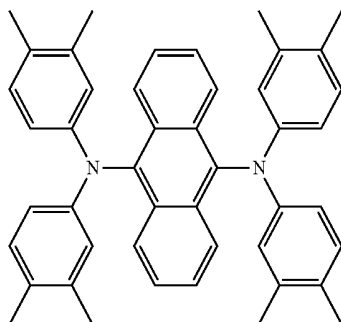
FD16

FD20



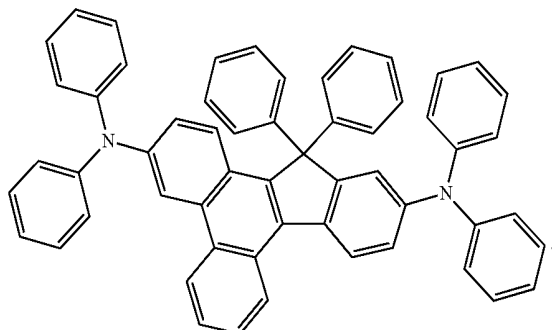
FD17

FD21

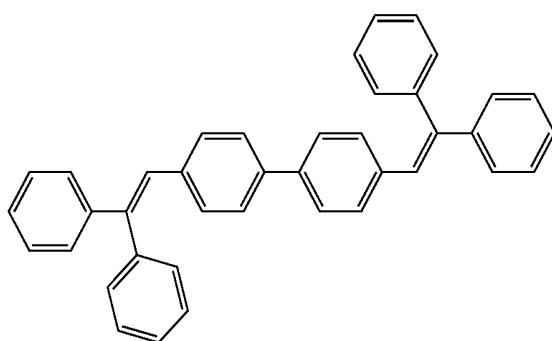


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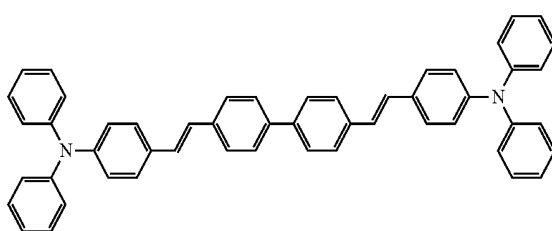
FD22



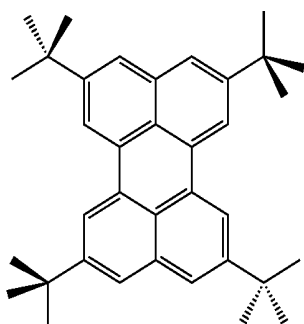
[0297] In one or more exemplary embodiments, the fluorescent dopant may be selected from the following compounds, but exemplary embodiments are not limited thereto:



DPVBi

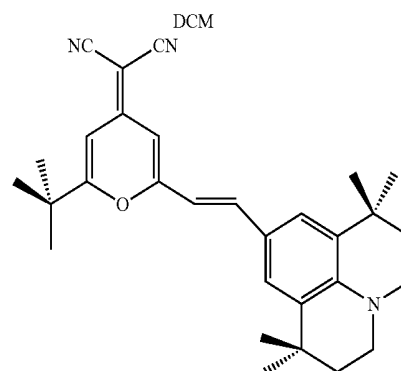
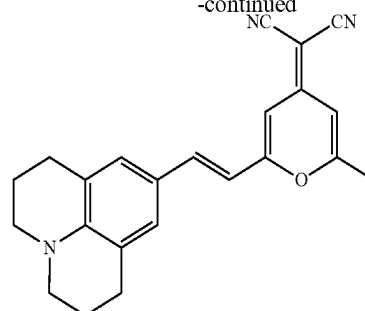


DPAVB

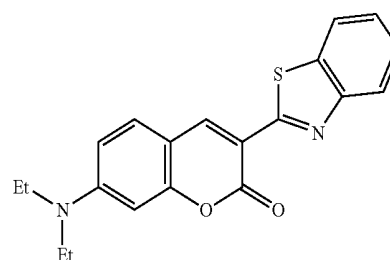


TBPe

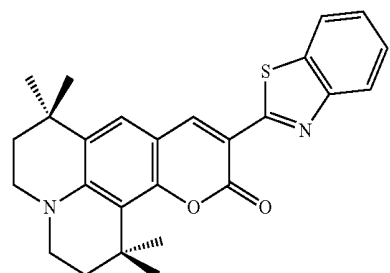
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DCJTb



Coumarin 6



C545T

[0298] (Electron Transport Region in Organic Layer 150)

[0299] The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0300] The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

[0301] For example, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from an emission layer. However, exemplary embodiments of the structure of the electron transport region are not limited thereto.

[0302] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, or an electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0303] The “ n electron-depleted nitrogen-containing ring” indicates a C_1 - C_{60} heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.

[0304] For example, the “ π electron-depleted nitrogen-containing ring” may be i) a 5-membered to 7-membered heteromonocyclic group having at least one $*-N=*$ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one $*-N=*$ moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one $*-N=*$ moiety, is condensed with at least one C_5 - C_{60} carbocyclic group.

[0305] Examples of the π electron-depleted nitrogen-containing ring include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazol, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but are not limited thereto.

[0306] For example, the electron transport region may include a compound represented by Formula 601:



[0307] In Formula 601,

[0308] Ar_{601} may be a substituted or unsubstituted C_5 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0309] $xe11$ may be 1, 2, or 3,

[0310] L_{601} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0311] $xe1$ may be an integer from 0 to 5,

[0312] R_{601} may be selected from 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 substi-

tuted 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, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{601})(Q_{602})(Q_{603})$, $-C(=O)(Q_{601})$, $-S(=O)_2(Q_{601})$, and $-P(=O)(Q_{601})(Q_{602})$,

[0313] Q_{601} to Q_{603} may each independently be a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and **[0314]** $xe21$ may be an integer from 1 to 5.

[0315] In one exemplary embodiment, at least one of $Ar_{601}(s)$ in the number of $xe11$ and $R_{601}(s)$ in the number of $xe21$ may include the π electron-depleted nitrogen-containing ring.

[0316] In one exemplary embodiment, ring Ar_{601} in Formula 601 may be selected from:

[0317] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0318] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a

hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

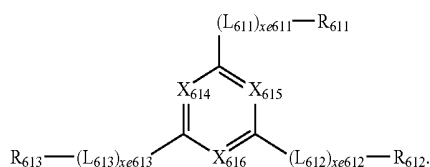
[0319] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0320] When xe11 in Formula 601 is two or more, two or more Ar₆₀₁(s) may be linked via a single bond.

[0321] In one or more exemplary embodiments, Ar₆₀₁ in Formula 601 may be an anthracene group.

[0322] In one or more exemplary embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

<Formula 601-1>



[0323] In Formula 601-1,

[0324] X₆₁₄ may be N or C(R₆₁₄), X₆₁₅ may be N or C(R₆₁₅), X₆₁₆ may be N or C(R₆₁₆), and at least one selected from X₆₁₄ to X₆₁₆ may be N,

[0325] L₆₁₁ to L₆₁₃ may each independently be defined the same as described in connection with L₆₀₁,

[0326] xe611 to xe613 may each independently be defined the same as described in connection with xe1,

[0327] R₆₁₁ to R₆₁₃ may each independently be defined the same as described in connection with R₆₀₁, and

[0328] R₆₁₄ to R₆₁₆ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0329] In one exemplary embodiment, L₆₀₁ and L₆₁₁ to L₆₁₃ in Formulas 601 and 601-1 may each independently be selected from:

[0330] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylylene group, a pyrenylene group, a chrysenylene group, a perylylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a benzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group; and

a group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group; and

[0331] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylylylene group, a pyrenylene group, a chrysenylene group, a perylylylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylyl group, a pyrenyl group, a chrysenyl group, a perylyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolylyl group, an indolylyl group, an isoindolylyl group, a benzofuranylyl group, a benzothiophenyl group, a dibenzofuranylyl group, a dibenzothiophenyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, a pyridinylyl group, an imidazolylyl group, a pyrazolylyl group, a thiazolylyl group, an isothiazolylyl group, an oxazolylyl group, an isoxazolylyl group, a thiadiazolylyl group, an oxadiazolylyl group, a pyrazinylyl group, a pyrimidinylyl group, a pyridazinylyl group, a triazinylyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinylyl group, a naphthyridinylyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinylyl group, an acridinylyl group, a phenanthrolinylyl group, a phenazinylyl group, a benzimidazolylyl group, an isobenzothiazolylyl group, a benzoxazolylyl group, an isobenzoxazolylyl group, a triazolylyl group, a tetrazolylyl group, an imidazopyridinylyl group, an imidazopyrimidinylyl group, and an azacarbazolylylyl group; and

idiny1 group, and an azacarbazoly1 group. However, exemplary embodiments are not limited thereto.

[0332] In one or more exemplary embodiments, xe1 and xe611 to xe613 in Formulas 601 and 601-1 may each independently be 0, 1, or 2.

[0333] In one or more exemplary embodiments, in Formulae 601 and 601-1, R₆₀₁ and R₆₁₁ to R₆₁₃ may each independently be selected from:

[0334] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazoly1 group, an indoly1 group, an isoindoly1 group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoly1 group, a dibenzocarbazoly1 group, a dibenzosiloly1 group, a pyridiny1 group, an imidazoly1 group, a pyrazoly1 group, a thiazoly1 group, an isothiazoly1 group, an oxazoly1 group, an isoxazoly1 group, a thiadiazoly1 group, an oxadiazoly1 group, a pyraziny1 group, a pyrimidinyl group, a pyridaziny1 group, a triaziny1 group, a quinoliny1 group, an isoquinoliny1 group, a benzoquinoliny1 group, a phthalaziny1 group, a naphthyridiny1 group, a quinoxaliny1 group, a quinazoliny1 group, a cinnoliny1 group, a phenanthridiny1 group, an acridiny1 group, a phenanthroliny1 group, a phenaziny1 group, a benzimidazoly1 group, an isobenzothiazoly1 group, a benzoxazoly1 group, an isobenzoxazoly1 group, a triazoly1 group, a tetrazoly1 group, an imidazopyridiny1 group, an imidazopyrimidinyl group, and an azacarbazoly1 group;

[0335] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazoly1 group, an indoly1 group, an isoindoly1 group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoly1 group, a dibenzocarbazoly1 group, a dibenzosiloly1 group, a pyridiny1 group, an imidazoly1 group, a pyrazoly1 group, a thiazoly1 group, an isothiazoly1 group, an oxazoly1 group, an isoxazoly1 group, a thiadiazoly1 group, an oxadiazoly1 group, a pyraziny1 group, a pyrimidinyl group, a pyridaziny1 group, a triaziny1 group, a quinoliny1 group, an isoquinoliny1 group, a benzoquinoliny1 group, a phthalaziny1 group, a naphthyridiny1 group, a quinoxaliny1 group, a quinazoliny1 group, a cinnoliny1 group, a phenanthridiny1 group, an acridiny1 group, a phenanthroliny1 group, a phenaziny1 group, a benzimidazoly1 group, an isobenzothiazoly1 group, a benzoxazoly1 group, an isobenzoxazoly1 group, a triazoly1 group, a tetra-

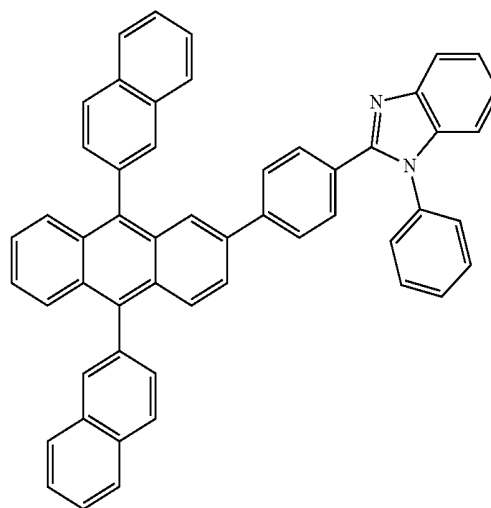
zoly1 group, an imidazopyridiny1 group, an imidazopyrimidinyl group, and an azacarbazoly1 group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazoly1 group, an indoly1 group, an isoindoly1 group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoly1 group, a dibenzocarbazoly1 group, a dibenzosiloly1 group, a pyridiny1 group, an imidazoly1 group, a pyrazoly1 group, a thiazoly1 group, an isothiazoly1 group, an oxazoly1 group, an isoxazoly1 group, a thiadiazoly1 group, an oxadiazoly1 group, a pyraziny1 group, a pyrimidinyl group, a pyridaziny1 group, a triaziny1 group, a quinoliny1 group, an isoquinoliny1 group, a benzoquinoliny1 group, a phthalaziny1 group, a naphthyridiny1 group, a quinoxaliny1 group, a quinazoliny1 group, a cinnoliny1 group, a phenanthridiny1 group, an acridiny1 group, a phenanthroliny1 group, a phenaziny1 group, a benzimidazoly1 group, an isobenzothiazoly1 group, a benzoxazoly1 group, an isobenzoxazoly1 group, a triazoly1 group, a tetrazoly1 group, an imidazopyridiny1 group, an imidazopyrimidinyl group, and an azacarbazoly1 group; and

[0336] —S(=O)₂(Q₆₀₁), and —P(=O)(Q₆₀₁)(Q₆₀₂), and

[0337] Q₆₀₁ and Q₆₀₂ are defined the same as described above.

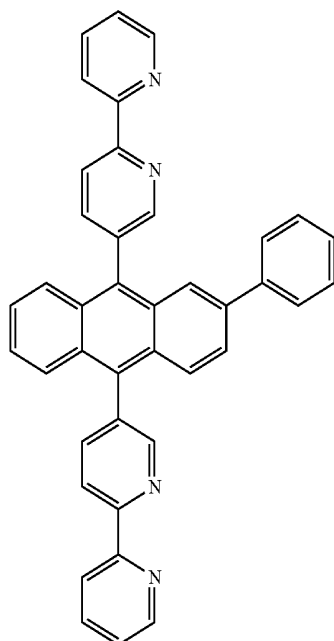
[0338] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but exemplary embodiments are not limited thereto:

ET1



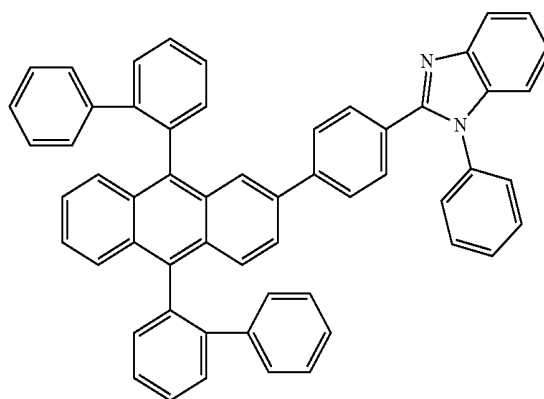
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ET2

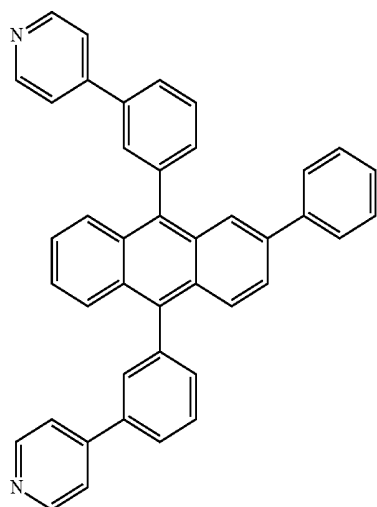


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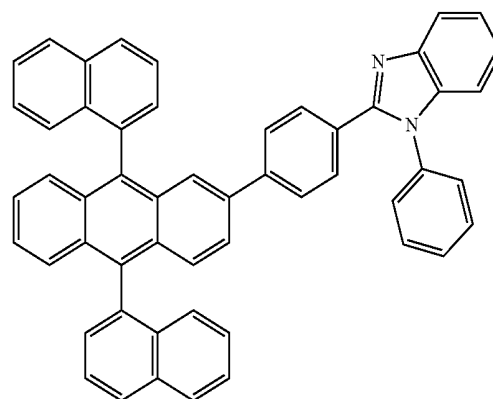
ET5



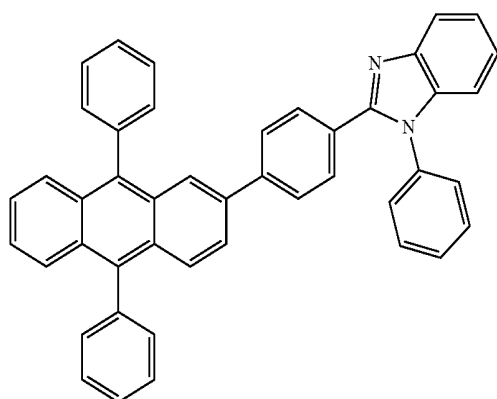
ET3



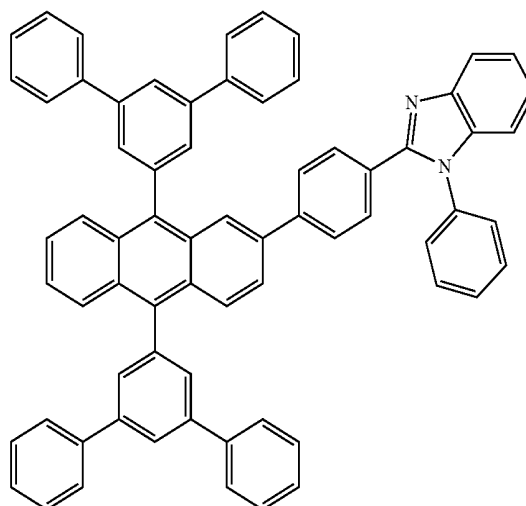
ET6



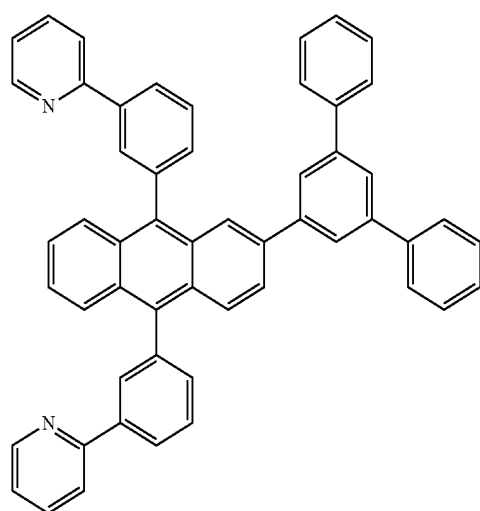
ET4



ET7

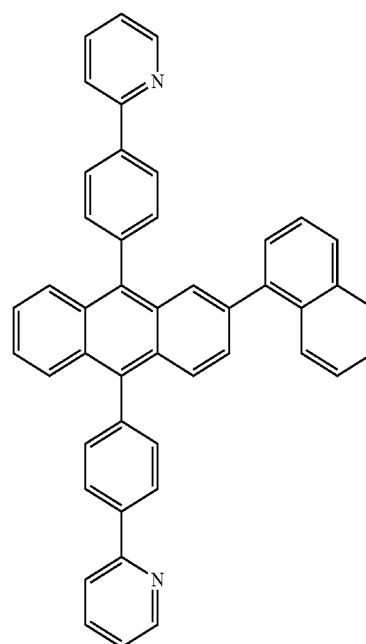


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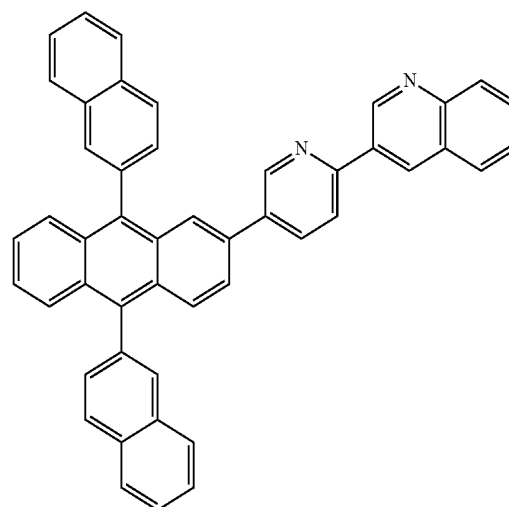
ET8

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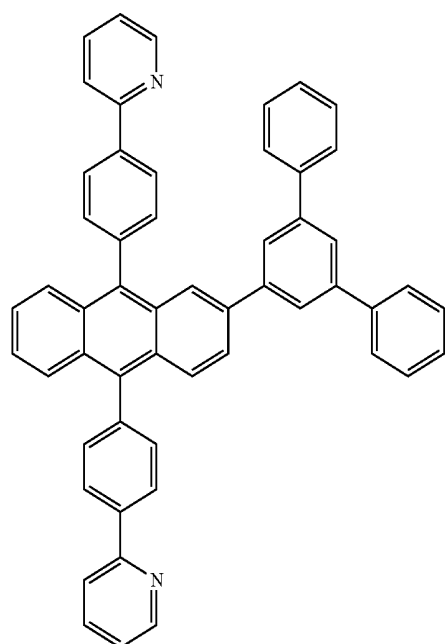


ET10

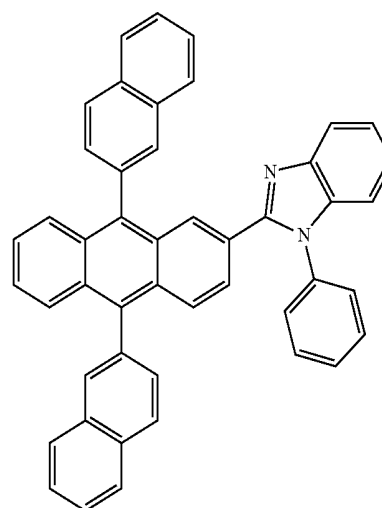
ET11



ET9

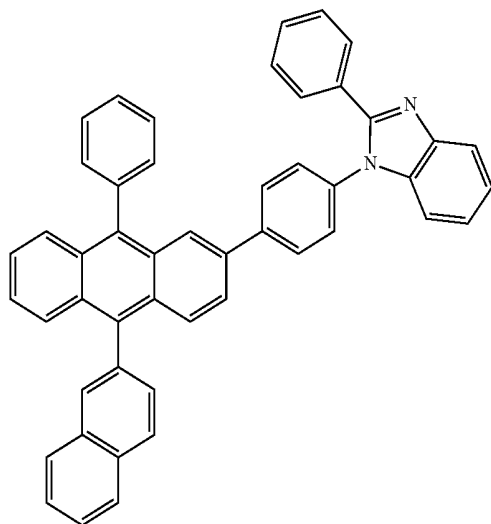


ET12



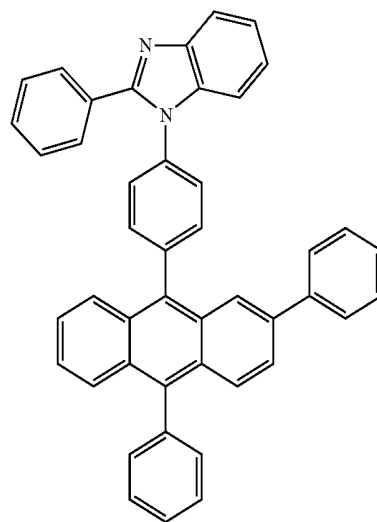
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ET13

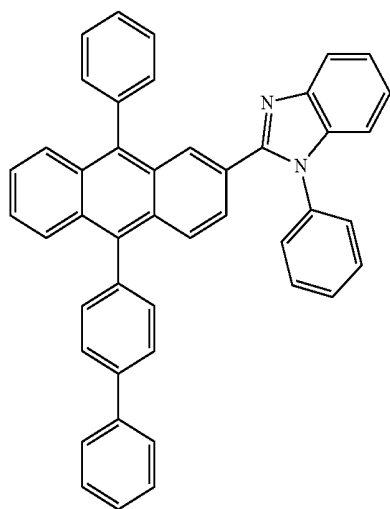


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ET16

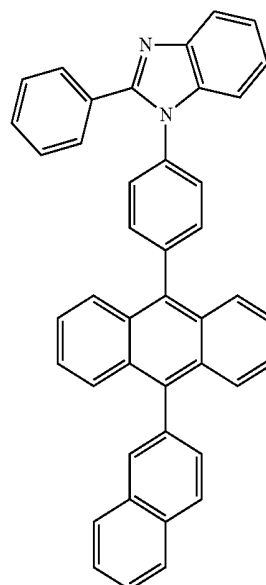
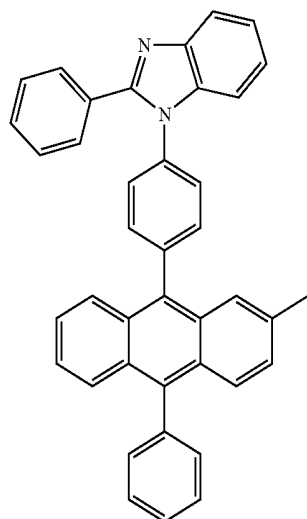


ET14

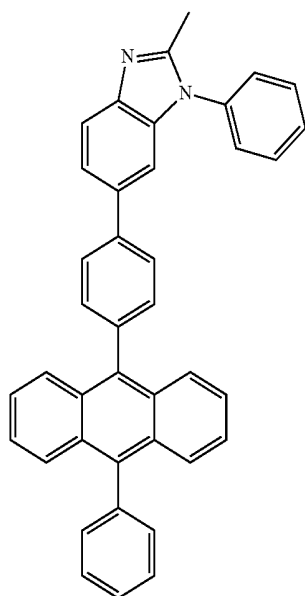


ET17

ET15

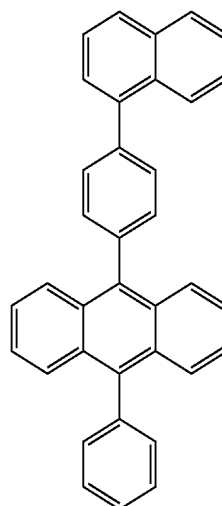


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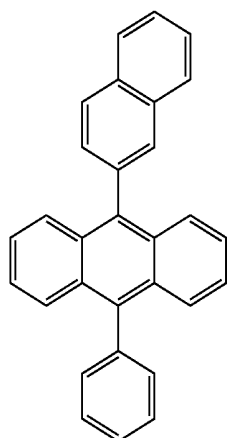
ET18

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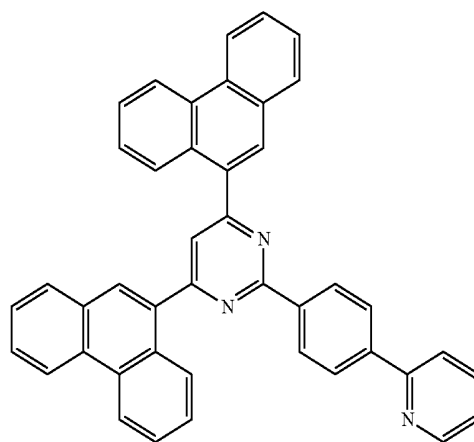


ET21

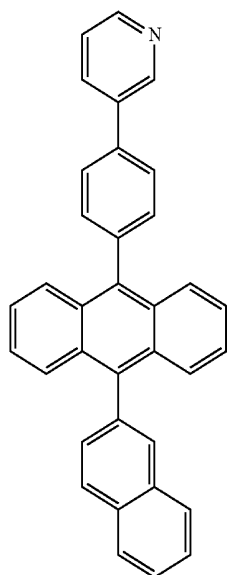
ET19



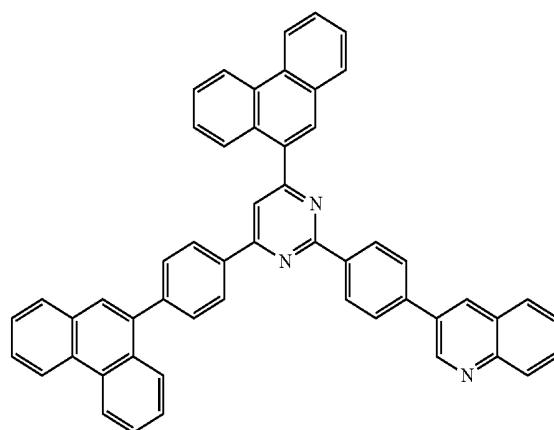
ET22



ET20



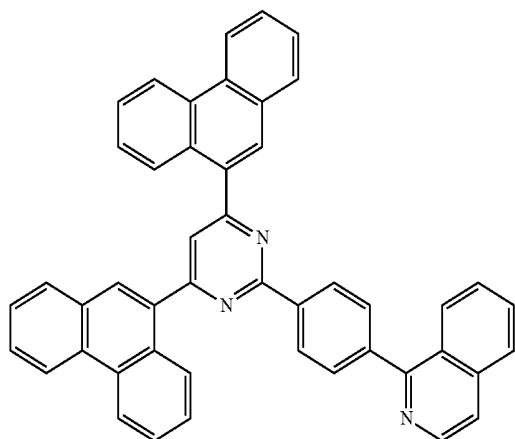
ET23



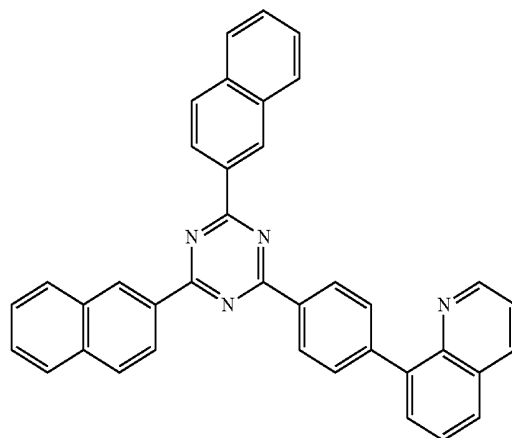
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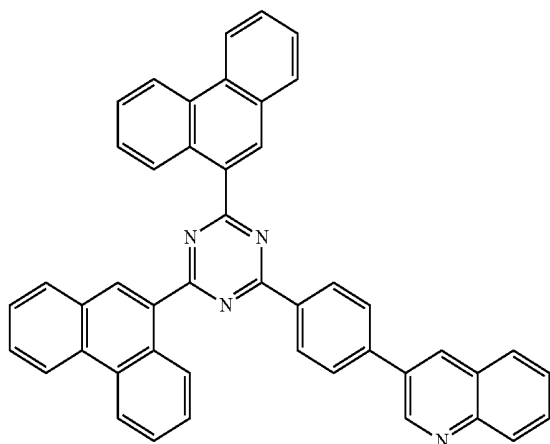
ET24



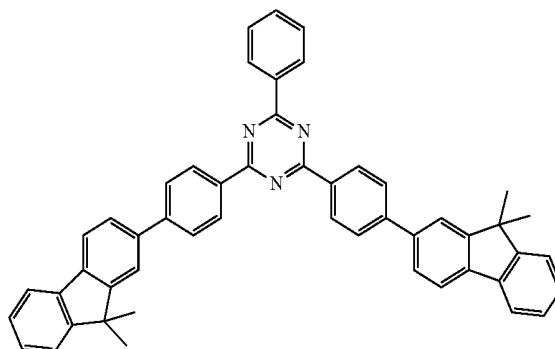
ET27



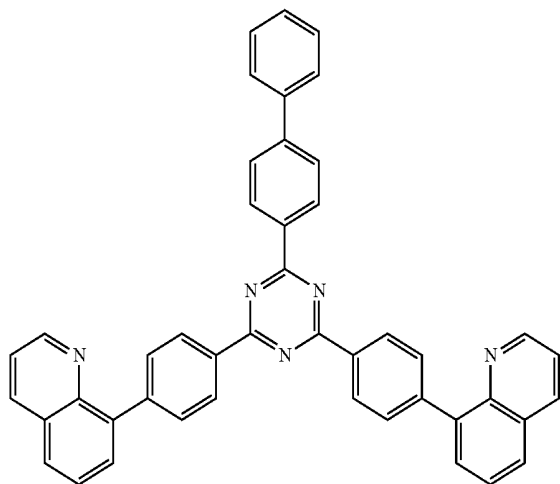
ET25



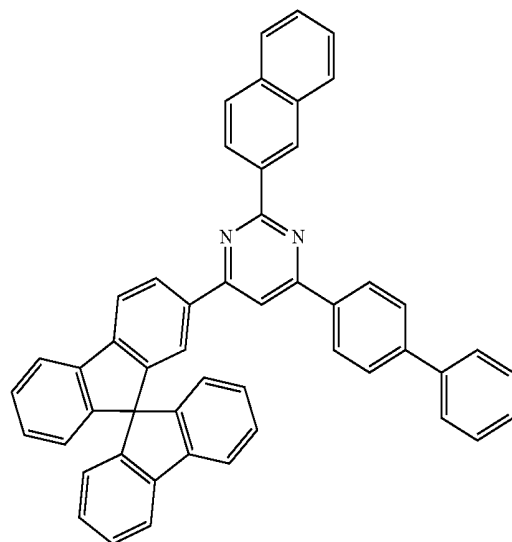
ET28



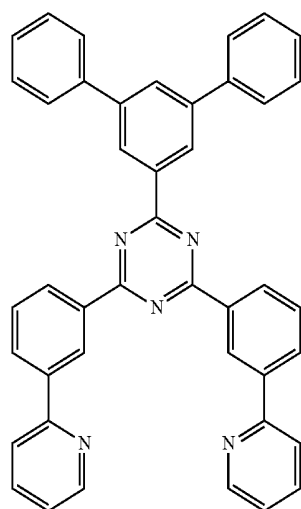
ET26



ET29

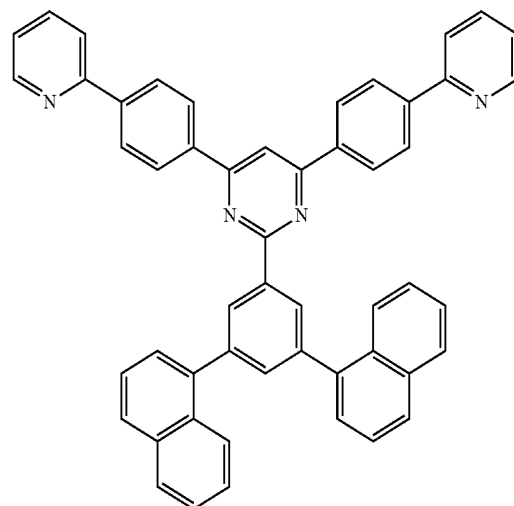


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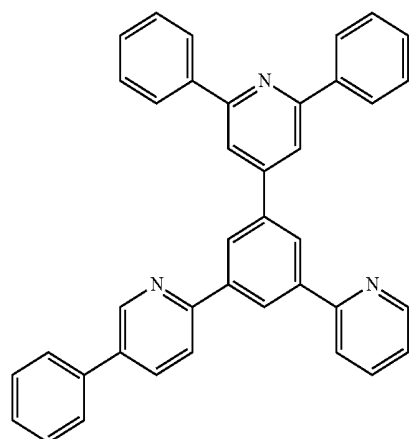


ET30

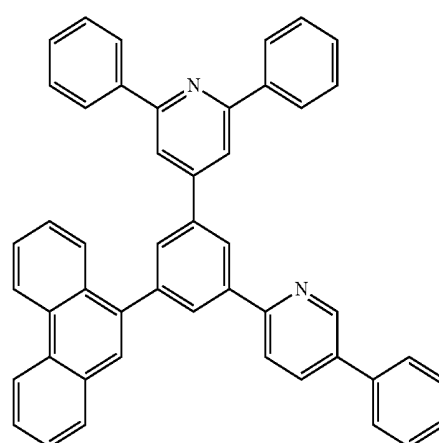
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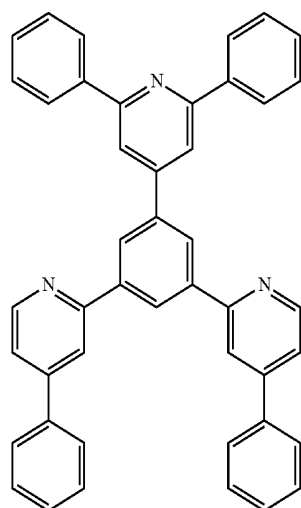
ET33



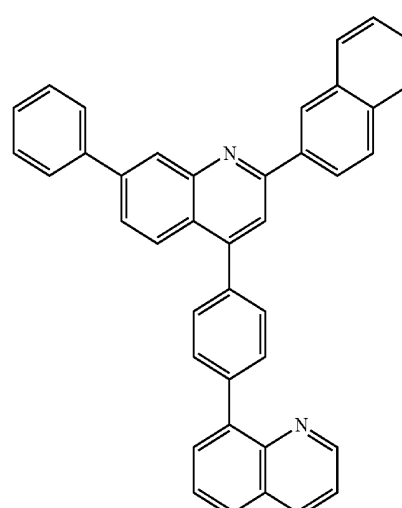
ET31



ET34



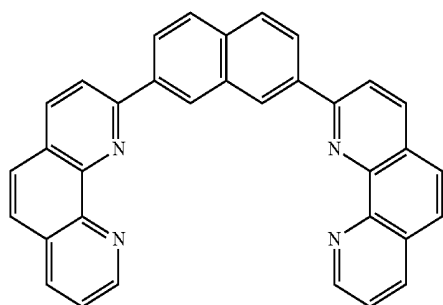
ET32



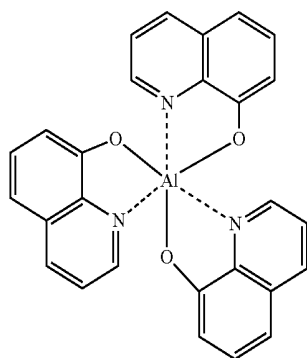
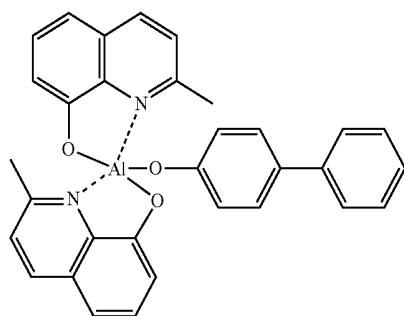
ET35

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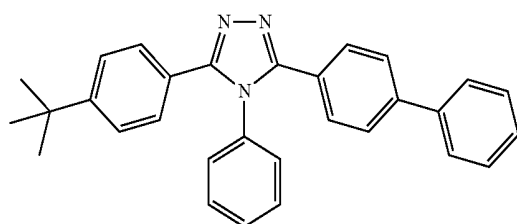
ET36



[0339] In one or more exemplary embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq₃, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:

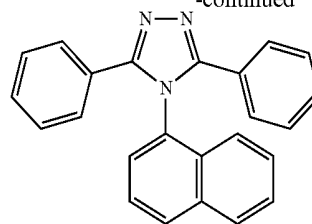
Alq₃

BAlq



TAZ

-continued



NTAZ

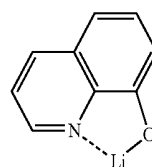
[0340] A thickness of the buffer layer, the hole blocking layer, or the electron control layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

[0341] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0342] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0343] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy diphenyloxadiazoole, a hydroxy diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene. However, exemplary embodiments are not limited thereto.

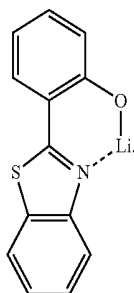
[0344] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2:



ET-D1

-continued

ET-D2



[0345] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0346] The electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0347] The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof.

[0348] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one embodiment, the alkali metal may be Li, Na, or Cs. In one or more exemplary embodiments, the alkali metal may be Li or Cs, but exemplary embodiments are not limited thereto.

[0349] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0350] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0351] The alkali metal compound, the alkaline earth-metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.

[0352] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O , Cs_2O , or K_2O , and alkali metal halides, such as LiF , NaF , CsF , KF , LiI , NaI , CsI , or KI . In one exemplary embodiment, the alkali metal compound may be selected from LiF , Li_2O , NaF , LiI , NaI , CsI , and KI , but exemplary embodiments are not limited thereto.

[0353] The alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO , SrO , CaO , $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$). In one exemplary embodiment, the alkaline earth-metal compound may be selected from BaO , SrO , and CaO , but exemplary embodiments are not limited thereto.

[0354] The rare earth metal compound may be selected from YbF_3 , ScF_3 , ScO_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 . In one exemplary embodiment, the rare earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , Yb_3 , ScI_3 , and Tb_3 , but exemplary embodiments are not limited thereto.

[0355] The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal

as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenyloxazole, hydroxy phenylthiazole, hydroxy diphenyloxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene. However, exemplary embodiments are not limited thereto.

[0356] The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more exemplary embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0357] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0358] (Second Electrode **190**)

[0359] The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode which is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be selected from metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function.

[0360] The second electrode **190** may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO. However, exemplary embodiments are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0361] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

[0362] (Description of FIGS. 2 to 4)

[0363] An organic light-emitting device **20** of FIG. 2 includes a first capping layer **210**, a first electrode **110**, an organic layer **150**, and a second electrode **190** which are sequentially stacked in this stated order, an organic light-emitting device **30** of FIG. 3 includes a first electrode **110**, an organic layer **150**, a second electrode **190**, and a second capping layer **220** which are sequentially stacked in this stated order, and an organic light-emitting device **40** of FIG.

4 includes a first capping layer 210, a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220.

[0364] Regarding FIGS. 2 to 4, the first electrode 110, the organic layer 150, and the second electrode 190 may be understood by referring to the description presented in connection with FIG. 1.

[0365] In the organic layer 150 of each of the organic light-emitting devices 20 and 40, light generated in an emission layer may pass through the first electrode 110, which is a semi-transmissive electrode or a transmissive electrode, and the first capping layer 210 toward the outside, and in the organic layer 150 of each of the organic light-emitting devices 30 and 40, light generated in an emission layer may pass through the second electrode 190, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer 220 toward the outside.

[0366] The first capping layer 210 and the second capping layer 220 may increase external luminescent efficiency according to the principle of constructive interference.

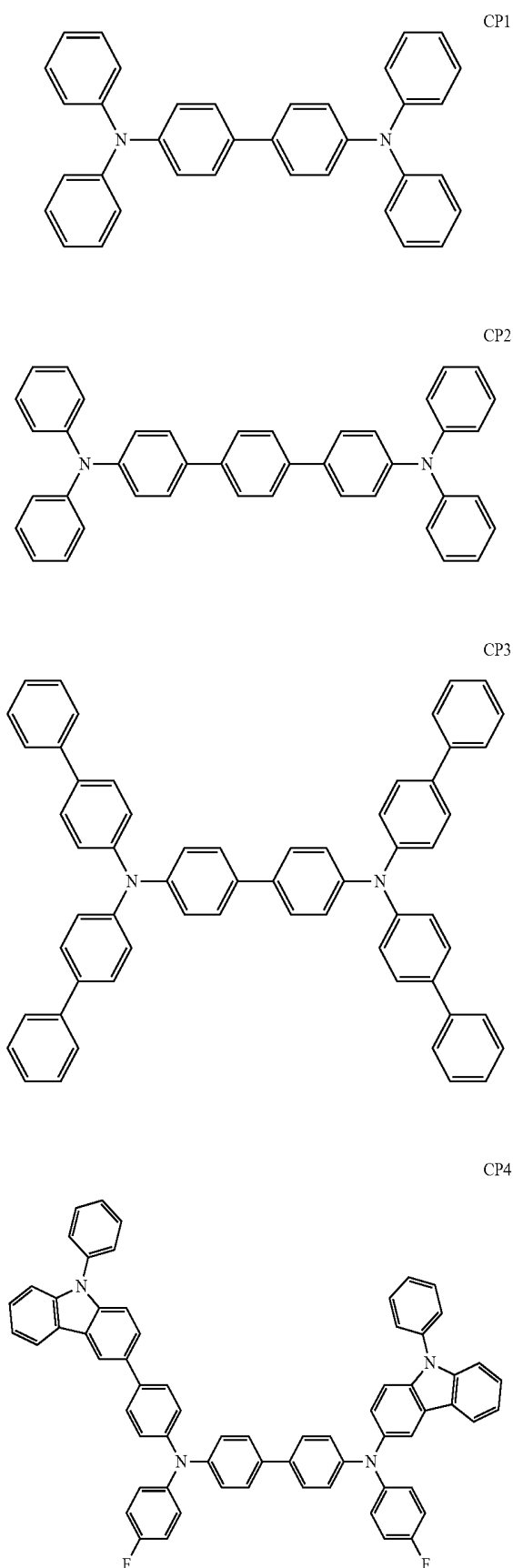
[0367] The first capping layer 210 and the second capping layer 220 may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

[0368] The first capping layer 210 or the second capping layer 220 may include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, a naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-based complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I. In one exemplary embodiment, the first capping layer 210 and the second capping layer 220 may each independently include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, a naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-based complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I.

[0369] In one exemplary embodiment, the first capping layer 210 or the second capping layer 220 may include an amine-based compound. In another exemplary embodiment, the first capping layer 210 and the second capping layer 220 may each independently include an amine-based compound.

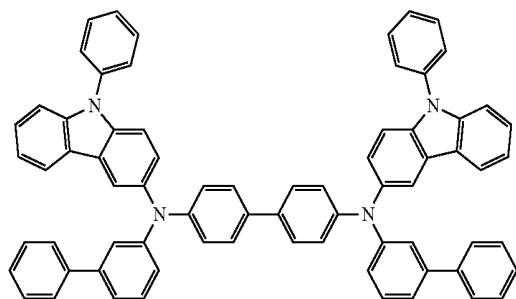
[0370] In one exemplary embodiment, at least one selected from the first capping layer 210 and the second capping layer 220 may each independently include the compound represented by Formula 201 or the compound represented by Formula 202.

[0371] In one or more exemplary embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may each independently include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5, but exemplary embodiments are not limited thereto:



-continued

CP5



[0372] Hereinbefore, the organic light-emitting device according to an exemplary embodiment has been described in connection with FIGS. 1 to 4. However, exemplary embodiments are not limited thereto.

[0373] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0374] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by vacuum deposition, the deposition may be performed at a deposition temperature of about 100° C. to about 500° C., a vacuum degree of about 10⁻⁸ torr to about 10⁻³ torr, and a deposition speed of about 0.01 Å/sec to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0375] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2000 rpm to about 5000 rpm and at a heat treatment temperature of about 80° C. to 200° C. by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0376] (General Definition of Substituents)

[0377] The term “C₁-C₆₀ alkyl group” as used herein refers to a linear or branched aliphatic saturated hydrocarbon monovalent group having 1 to 60 carbon atoms, and examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an isoamyl group, and a hexyl group. The term “C₁-C₆₀ alkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

[0378] The term “C₂-C₆₀ alkenyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon double bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

[0379] The term “C₂-C₆₀ alkynyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon triple bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and examples thereof include an ethynyl group, and a propynyl group. The term “C₂-C₆₀ alkynylene

group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

[0380] The term “C₁-C₆₀ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

[0381] The term “C₃-C₁₀ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

[0382] The term “C₁-C₁₀ heterocycloalkyl group” as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuran group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0383] The term “C₃-C₁₀ cycloalkenyl group” as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity, and examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

[0384] The term “C₁-C₁₀ heterocycloalkenyl group” as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuran group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0385] The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C₆-C₆₀ arylene group as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

[0386] The term “C₁-C₆₀ 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, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term “C₁-C₆₀ 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, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a

tuted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0393] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0394] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

[0395] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0396] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

[0397] $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$, and

[0398] Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent

non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0399] The term “Ph” as used herein represents a phenyl group, the term “Me” as used herein represents a methyl group, the term “Et” as used herein represents an ethyl group, the term “ter-Bu” or “But,” as used herein, represents a tert-butyl group, and the term “OMe” as used herein represents a methoxy group.

[0400] The term “biphenyl group” used herein refers to a “phenyl group” substituted with a phenyl group. The “biphenyl group” is a “substituted phenyl group” having a “C₆-C₆₀ aryl group” as a substituent.

[0401] The term “terphenyl group” used herein refers to a “phenyl group” substituted with a biphenyl group. The “terphenyl group” is a “phenyl group” having, as a substituent, a “C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group.”

[0402] * and * used herein, unless defined otherwise, each indicate to a binding site to a neighboring atom in a corresponding formula.

[0403] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in detail with reference to Synthesis Examples and Examples. The expression “B was used instead of A” used in describing Synthesis Examples means that an identical number of molar equivalents of B was used in place of molar equivalents of A.

Synthesis Example

Synthesis Example 1: Synthesis of Compound T-1

[0404] To a flask containing 2,7-dibromo-9,9-dimethyl-9H-thioxanthene 10,10-dioxide (1 equivalent weight (eq.)) and 9H-tribenzo[b,d,f]azepine (2.2 eq.), Pd(dba)₃ (0.03 eq.), (t-Bu)₃P (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using methylene chloride (MC), and the resulting product was washed with distilled water, and moisture therein was dried by using anhydrous magnesium sulfate (MgSO₄). The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-1 (yield: 77.64%).

[0405] High resolution mass spectrometry (HRMS) for C₅₁H₃₆N₂O₂S [M]⁺: calcd: 740, found: 739.

[0406] Elemental Analysis for calcd: C, 82.68; H, 4.90; N, 3.78; O, 4.32; S, 4.33.

Synthesis Example 2: Synthesis of Compound T-5

[0407] To a flask containing 2-(2,6-dichlorophenyl)-4,6-diphenyl-1,3,5-triazine (1 eq.) and 9H-tribenzo[b,d,f]azepine (2.2 eq.), Pd(dba)₃ (0.03 eq.), (t-Bu)₃P (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO₄. The resulting mixture was then distilled under reduced pressure, and the

residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-5 (yield: 55.7%).

[0408] HRMS for C₅₇H₃₇N₅ [M]⁺: calcd: 791, found: 790.

[0409] Elemental Analysis for calcd: C, 86.45; H, 4.71; N, 8.84.

Synthesis Example 3: Synthesis of Compound T-7

[0410] To a flask containing 2-bromo-7-(9H-carbazol-9-yl)-9,9-dimethyl-9H-thioxanthene 10,10-dioxide (1 eq.) and 9H-tribenzo[b,d,f]azepine (1.2 eq.), Pd(dba)₃ (0.03 eq.), (t-Bu)₃P (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO₄. The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-7 (yield: 71.4%).

[0411] HRMS for C₄₅H₃₂N₂O₂S [M]⁺: calcd: 664, found: 663.

[0412] Elemental Analysis for calcd: C, 81.30; H, 4.85; N, 4.21; O, 4.81; S, 4.82.

Synthesis Example 4: Synthesis of Compound T-8

[0413] To a flask containing 9-(7-bromo-9,9-dimethyl-9H-xanthen-2-yl)-9H-carbazole (1 eq.) and 9H-tribenzo[b,d,f]azepine (1.2 eq.), Pd(dba)₃ (0.03 eq.), (t-Bu)₃P (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO₄. The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-8 (yield: 68.7%).

[0414] HRMS for C₄₅H₃₂N₂O [M]⁺: calcd: 616, found: 615.

[0415] Elemental Analysis for calcd: C, 87.63; H, 5.23; N, 4.54; O, 2.59.

Synthesis Example 5: Synthesis of Compound T-11

[0416] To a flask containing 9-(3-chloro-2-(4,6-diphenyl-1,3,5-triazin-2-yl)phenyl)-9H-carbazole (1 eq.) and 9H-tribenzo[b,d,f]azepine (1.2 eq.), Pd(dba)₃ (0.03 eq.), (t-Bu)₃P (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO₄. The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-11 (yield: 65.1%).

[0417] HRMS for C₅₁H₃₃N₅ [M]⁺: calcd: 715, found: 714.

[0418] Elemental Analysis for calcd: C, 85.57; H, 4.65; N, 9.78.

Synthesis Example 6: Synthesis of Compound T-12

[0419] To a flask containing 4-(9H-carbazol-9-yl)-6-chloro-5-(4,6-diphenyl-1,3,5-triazin-2-yl)isophthalonitrile (1 eq.) 9H-tribenzo[b,d,f]azepine (1.2 eq.), were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO_4 . The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-12 (yield: 73.1%).

[0420] HRMS for $\text{C}_{53}\text{H}_{31}\text{N}_7[\text{M}]^+$: calcd: 765, found: 764.

[0421] Elemental Analysis for calcd: C, 83.12; H, 4.08; N, 12.80.

Synthesis Example 7: Synthesis of Compound T-15

[0422] To a flask containing 2,8-dichlorodibenzo[b,d]thiophene 5,5-dioxide (1 eq.) and 8,10-dimethyl-9H-tribenzo[b,d,f]azepine (2.2 eq.), $\text{Pd}(\text{dba})_3$ (0.03 eq.), (t-Bu) $_3\text{P}$ (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO_4 . The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-15 (yield: 77.4%).

[0423] HRMS for $\text{C}_{52}\text{H}_{38}\text{N}_2\text{O}_2\text{S} [\text{M}]^+$: calcd: 754, found: 753.

[0424] Elemental Analysis for calcd: C, 82.73; H, 5.07; N, 3.71; O, 4.24; S, 4.25.

Synthesis Example 8: Synthesis of Compound T-17

[0425] To a flask containing 4-(9H-carbazol-9-yl)-6-chloro-5-(4,6-diphenyl-1,3,5-triazin-2-yl)isophthalonitrile (1 eq.) and 8,10-dimethyl-9H-tribenzo[b,d,f]azepine (1.2 eq.), $\text{Pd}(\text{dba})_3$ (0.03 eq.), (t-Bu) $_3\text{P}$ (0.06 eq.), and toluene (on the basis of 0.1M 1 eq. of reagent) were added thereto. Then, a mixed solution was stirred under reflux for 5 hours, and cooled to room temperature. An extraction process was performed thereon by using MC, and the resulting product was washed with distilled water, and moisture therein was dried by using MgSO_4 . The resulting mixture was then distilled under reduced pressure, and the residue obtained therefrom was separated and purified by column chromatography to obtain Compound T-17 (yield: 73.1%).

[0426] HRMS for $\text{C}_{55}\text{H}_{35}\text{N}_7[\text{M}]^+$: calcd: 793, found: 792.

[0427] Elemental Analysis for calcd: C, 83.21; H, 4.44; N, 12.35.

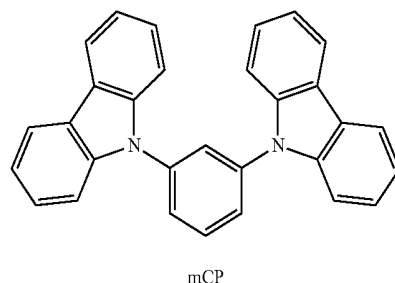
[0428] Compounds other than the compounds synthesized according to Synthesis Examples 1 to 8 may be easily recognized by those skilled in the art by referring to synthesis routes and raw materials described above.

EXAMPLES

Evaluation Example 1: Evaluation of Characteristics of TADF Compound

[0429] 1,3-di(9H-carbazole-9-yl)benzene (mCP) and each of the compounds synthesized according to Synthesis

Examples were mixed at a weight ratio of 20:1, and the mixture was dissolved in 1,2-dichloroethane. The resulting solution was then spin-coated on a quartz for measurement:



[0430] Here, a highest occupied molecular orbital (HOMO) energy level was measured by cyclic voltammeter (CV), and a LUMO energy level was measured by calculating the difference in an optical band-gap at the HOMO energy level. The triplet (T_1) energy level was measured with a 77K PL spectrum. The measured results are shown in Table 1.

[0431] In addition, measurements for LUMO and HOMO energy levels based on time-dependent density function theory (TD-DFT) and T_1 energy level of the compounds synthesized according to Synthesis Examples were simulated, and the results obtained from the simulation are shown in Table 1.

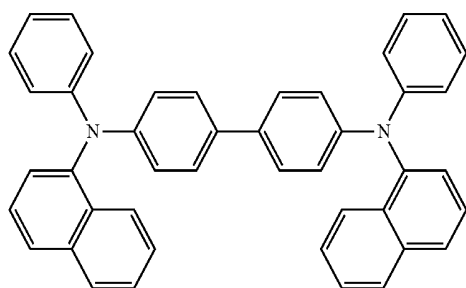
TABLE 1

Compound	LUMO (eV)/ HOMO (eV)		T_1 (eV)	
	TD-DFT	Measured.	TD-DFT	Measured.
T-1	1.42/5.38	2.6/5.8	3.05	3.02
T-5	1.23/5.22	2.7/5.9	3.05	3.02
T-7	1.48/5.29	2.6/5.8	3.08	2.92
T-8	1.42/5.38	2.6/5.7	3.05	3.02
T-11	1.33/5.32	2.5/5.9	3.02	3.01
T-15	1.42/5.38	2.6/6.0	3.05	3.02
T-17	1.42/5.38	2.6/6.0	3.05	3.02

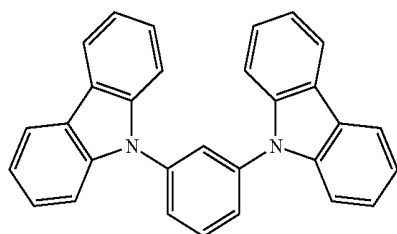
Example 1

[0432] An ITO glass substrate was cut to a size of 50 mm×50 mm×0.5 mm, sonicated with isopropyl alcohol and pure water each for 10 minutes, and then, cleaned by exposure to ultraviolet rays and ozone for 10 minutes. Then the ITO glass substrate was mounted on a vacuum deposition apparatus. On the substrate, first, NPB which is known as a material for forming a hole injection layer was vacuum deposited to form a hole injection layer having a thickness of 40 Å, and then, mCP which is known as a hole transporting material was vacuum deposited on the hole injection layer to form a hole transport layer having a thickness of 10 Å. Compound T-1 as a dopant and Compound BH-1 as a host were co-deposited on the hole transport layer at a weight ratio of 15:85 to form an emission layer having a thickness of 200 Å. Then, Compound ETL 1 was deposited on the emission layer to form an electron transport layer having a thickness of 300 Å, and Al was formed on electron transport layer to form an Al electrode (i.e., a cathode electrode)

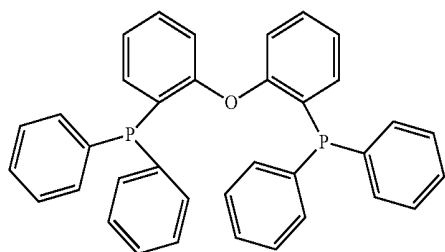
having a thickness of 1,200 Å, thereby completing the manufacture of an organic light-emitting device.



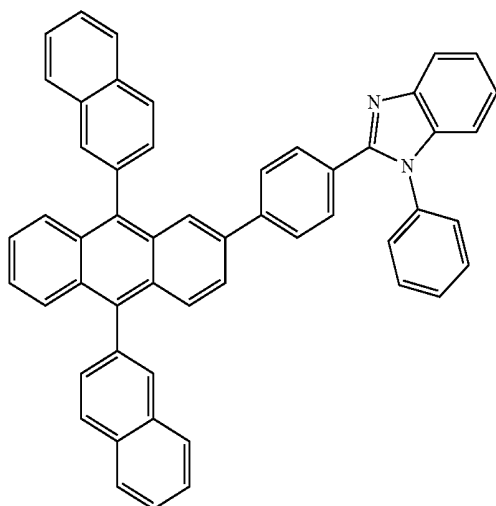
NPB



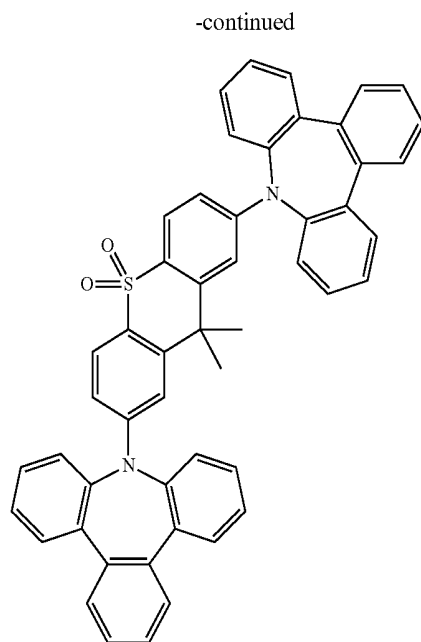
mCP



BH-1



ETL1



-continued

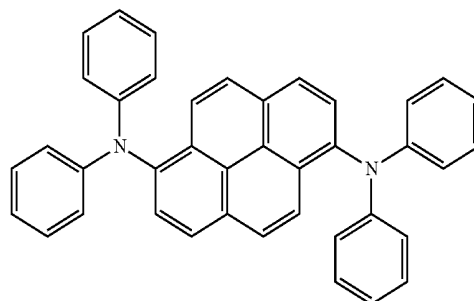
T-1

Examples 2 to 8

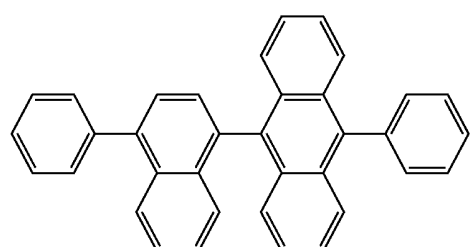
[0433] Organic light-emitting devices were manufactured substantially in the same manner as in Example 1, except that Compounds shown in Table 2 were each used as a dopant in forming an emission layer.

Comparative Example 1

[0434] An organic light-emitting device was manufactured substantially in the same manner as in Example 1, except that Compound FD1 and Compound H8 were used instead of Compound T-1 and Compound BH-1, respectively, in forming an emission layer:



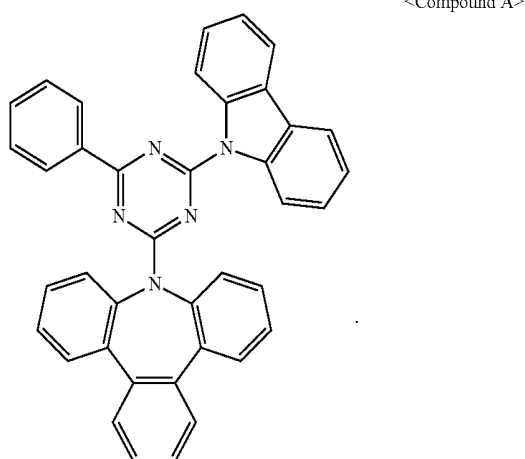
FD1



H8

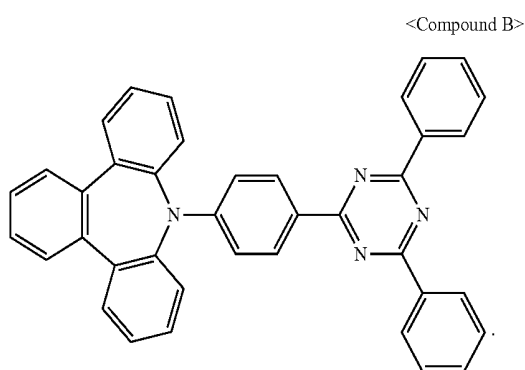
Comparative Example 2

[0435] An organic light-emitting device was manufactured substantially in the same manner as in Example 1, except that Compound A was used instead of Compound T-1 in forming an emission layer:



Comparative Example 3

[0436] An organic light-emitting device was manufactured substantially in the same manner as in Example 1, except that Compound B was used instead of Compound T-1 in forming an emission layer:



Evaluation Example 2: Evaluation of Characteristics of Organic Light-Emitting Devices

[0437] A driving voltage (V), an efficiency (cd/A), and an external quantum efficiency (%) at a current density of 10 mA/cm² of each of the organic light-emitting devices manufactured according to Examples 1 to 8 and Comparative Examples 1 to 3 were measured, and the results thereof are shown in Table 2:

TABLE 2

	Dopant	Host	Driving Voltage (V)	Efficiency (cd/A)	External quantum efficiency (%)
Example 1	T-1	BH-1	4.4	9.22	7.1
Example 2	T-5	BH-1	4.44	9.1	5.78
Example 3	T-7	BH-1	4.62	9.7	5.98
Example 4	T-8	BH-1	4.7	10.76	5.88
Example 5	T-11	BH-1	4.68	10.54	6.8
Example 6	T-12	BH-1	4.1	9.88	6.87
Example 7	T-15	BH-1	4.2	10.1	6.1
Example 8	T-17	BH-1	4.7	12.6	6.8
Comparative Example 1	FD1	H8	7.44	4.84	2.99
Comparative Example 2	Compound A	BH-1	5.2	9.8	5.7
Comparative Example 3	Compound B	BH-1	5.1	10.1	5.9

[0438] Referring to Table 2, it was confirmed that the organic light-emitting devices in which the compound disclosed in the present disclosure was used in forming an emission layer had a low driving voltage and excellent efficiency and external quantum efficiency, as compared with those of the organic light-emitting devices of Comparative Example 1 using a fluorescent dopant and Comparative Examples 2 and 3 using Compound A and B. That is, when the compound disclosed in the present disclosure is used as the electron transporting material in the organic light-emitting device, the organic light-emitting device was found to exhibit excellent effects in terms of driving voltage, luminance, efficiency, and lifespan.

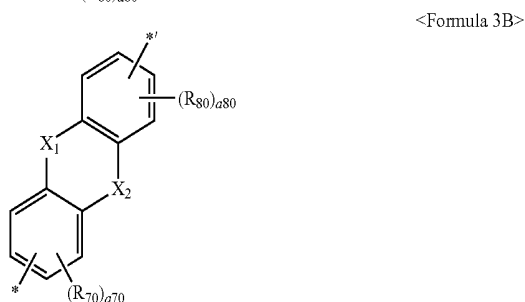
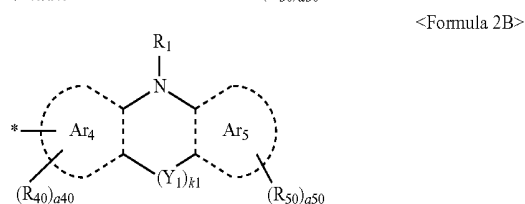
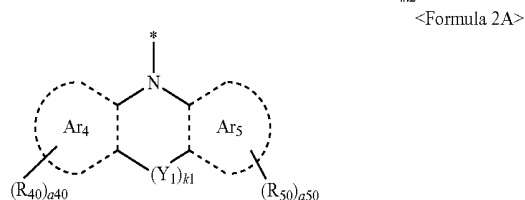
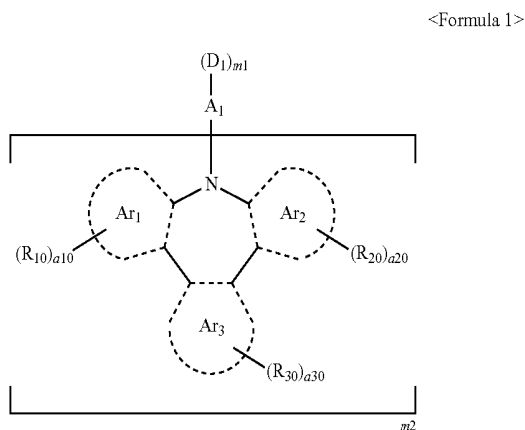
[0439] According to one or more exemplary embodiments, the organic light-emitting device including the heterocyclic compound may have a low driving voltage, a high efficiency, a long lifespan, and a high maximum quantum efficiency.

[0440] It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

[0441] Although certain exemplary embodiments have been described herein, other embodiments and modifications will be apparent from this description. Accordingly, the inventive concepts are not limited to such embodiments, but rather to the broader scope of the appended claims and various obvious modifications and equivalent arrangements as would be apparent to a person of ordinary skill in the art.

What is claimed is:

1. A heterocyclic compound represented by Formula 1:



wherein, in Formulas 1, 2A, and 2B,

Ar₁ to Ar₅ are each independently a C₅-C₆₀ carbocyclic group or a π electron-depleted nitrogen-free heterocyclic group,

D₁ is a group represented by Formula 2 A or Formula 2B, Y₁ is selected from a single bond, *—N(R₂)—*, *—C(R₂)(R₃)—*, and *—C(R₂)=C(R₃)—*,

k₁ is 1 or 2,

m₁ is 0 or 1,

m₂ is 1 or 2,

m₁ and m₂ satisfy m₁+m₂=2,

A₁ is a group represented by Formula 3A or Formula 3B,

R_w is a cyano group or a substituted or unsubstituted π electron-depleted nitrogen-containing heterocyclic group,

n₁ is an integer of 1 to 4,

X₁ is *—O—*, *—S—*, or *—S(=O)₂—*, and X₂ is a single bond or *—C(R₄)(R₅)—*, wherein X₁ is *—S(=O)₂—* or X₂ is *—C(R₄)(R₅)—*,

R₁ to R₅, R₁₀, R₂₀, R₃₀, R₄₀, R₅₀, R₆₀, R₇₀, and R₈₀ are each independently hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₂-C₆₀ alkoxy group, a substituted or unsubstituted C₁-C₆₀ cycloalkyl group, a substituted or unsubstituted C₃-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)(Q₁), or —P(=O)(Q₁)(Q₂),

R₂ and R₃; or R₄ and R₅ are optionally linked to form a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₂-C₆₀ heterocyclic group,

a₁₀, a₂₀, a₃₀, a₄₀, and a₅₀ are each independently an integer of 1 to 8,

a₆₀ is an integer of 0 to 3,

a₇₀ and a₈₀ are each independently an integer of 1 to 3,

at least one substituent of the substituted C₅-C₆₀ carbocyclic group, the substituted C₂-C₆₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a

C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

—Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂).

Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

* and *' each indicate a binding site to a neighboring atom.

2. The heterocyclic compound of claim 1, wherein Ar₁ to Ar₅ are each independently selected from a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, a dibenzothiophene group, and a dibenzosilole group.

3. The heterocyclic compound of claim 1, wherein D₁ is selected from:

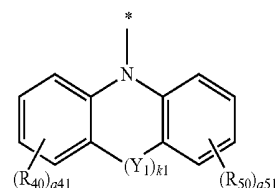
an acridinyl group, a carbazolyl group, a phenazinyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an indeno carbazolyl group, a 11,12-dihydroindeno-

dolocarbazolyl group, a dibenzoazepine group, a 10,11-dihydrodibenzoazepine group, and a tribenzoazepine group; and

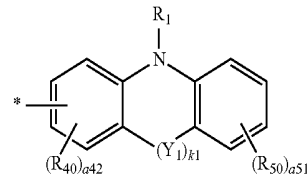
an indolyl group, an acridinyl group, a carbazolyl group, a phenazinyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an indeno carbazolyl group, an indolocarbazolyl group, a dibenzoazepine group, a dihydrodibenzoazepine group, and a tribenzoazepine group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a biphenyl group, and a terphenyl group.

4. The heterocyclic compound of claim 1, wherein D₁ is a group represented by Formula 2A-1 or Formula 2B-1:

<Formula 2A-1>



<Formula 2B-1>



wherein, in Formulas 2A-1 and 2B-1,

Y₁ and k₁ are respectively defined the same as those of claim 1,

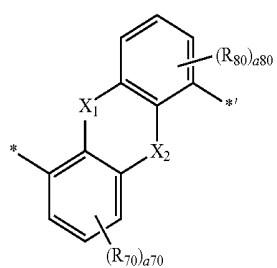
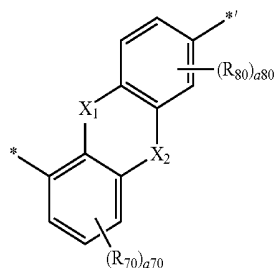
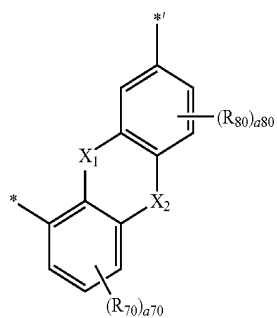
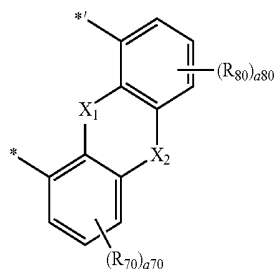
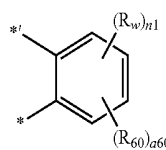
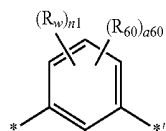
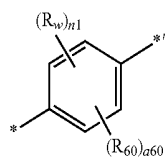
R₁ to R₃, R₄₀, and R₅₀ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a biphenyl group, and a terphenyl group,

a₄₁ and a₅₁ are each independently an integer of 1 to 4, a₄₂ is an integer of 1 to 3, and

* and *' each indicate a binding site to a neighboring atom.

5. The heterocyclic compound of claim 1, wherein A₁ is represented by one selected from Formulas 3A-1 to 3A-3 and 3B-1 to 3B-10:

-continued



3A-1

3A-2

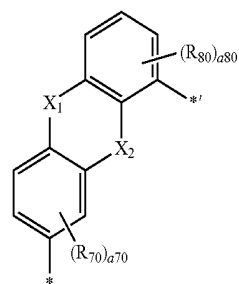
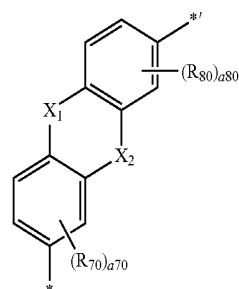
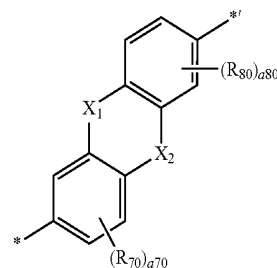
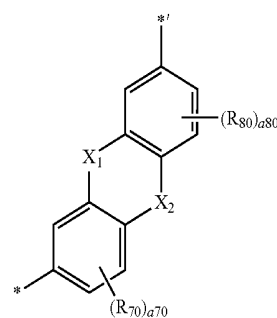
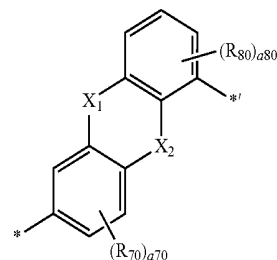
3A-3

3B-1

3B-2

3B-3

3B-4



3B-5

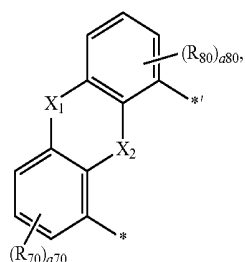
3B-6

3B-7

3B-8

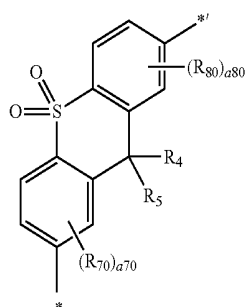
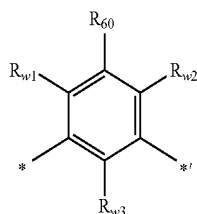
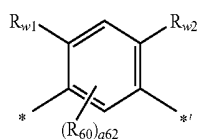
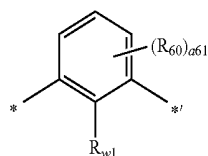
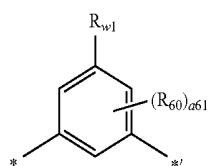
3B-9

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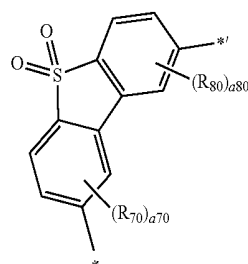
wherein, in Formulas 3A-1 to 3A-3 and 3B-1 to 3B-10, R_w , n_1 , X_1 , X_2 , R_{60} , R_{70} , R_{80} , a_{60} , a_{70} , and a_{80} are respectively defined the same as those of claim 1, and * and *' each indicate a binding site to a neighboring atom.

6. The heterocyclic compound of claim 1, wherein A_1 is represented by one formula selected from Formulas 3A-2-1 to 3A-2-4 and 3B-8-1 to 3B-8-4:

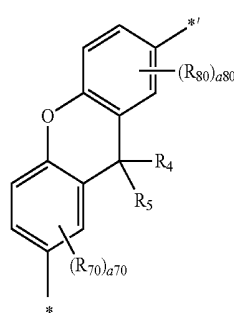


3B-10

-continued

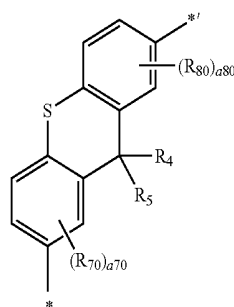


3B-8-2



3B-8-3

3A-2-1



3B-8-4

3A-2-2

3A-2-3

3A-2-4

wherein, in Formulas 3A-2-1 to 3A-2-4 and 3B-8-1 to 3B-8-4,

R_4 , R_5 , R_{60} , R_{70} , R_{80} , a_{70} , and a_{80} are respectively defined the same as those of claim 1,

R_{w1} , R_{w2} , and R_{w3} are each independently defined the same as R_w in claim 1,

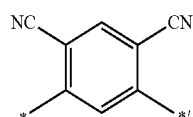
a_{61} is an integer of 1 to 3,

a_{62} is 1 or 2, and

* and *' each indicate a binding site to a neighboring atom.

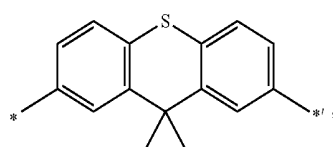
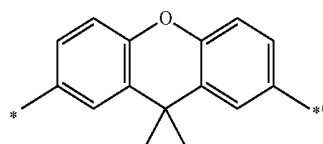
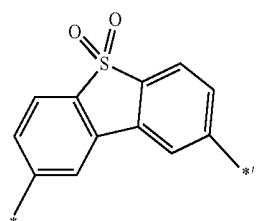
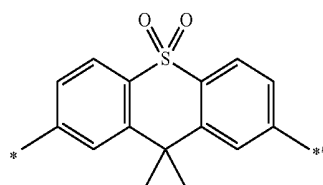
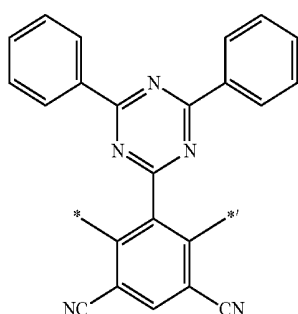
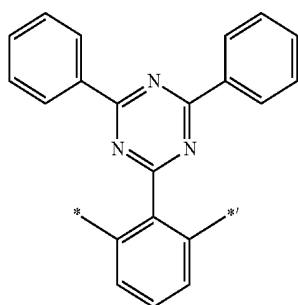
3B-8-1

7. The heterocyclic compound of claim 1, wherein A_1 is represented by one formula selected from Formulas 4-1 to 4-7:



4-1

-continued



wherein, in Formulas 4-1 to 4-7,
 * and *' each indicate a binding site to a neighboring atom.

8. The heterocyclic compound of claim 1, wherein R_w is selected from:

- 4-2 a cyano group, a pyridinyl group, a pyrimidyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, and a quinazolinyl group; and
- 4-3 a pyridinyl group, a pyrimidyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, and a quinazolinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, pentyl group, an isoamyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a biphenyl group, and a terphenyl group.

9. The heterocyclic compound of claim 1, wherein R_1 to R_5 are each independently selected from:

- 4-5 hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, and a phenyl group; and
- 4-6 a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, and a phenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, and a ter-butyl group.

10. The heterocyclic compound of claim 1, wherein R_{10} , R_{20} , R_{30} , R_{40} , and R_{50} are each independently selected from:

- 4-7 hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group; and

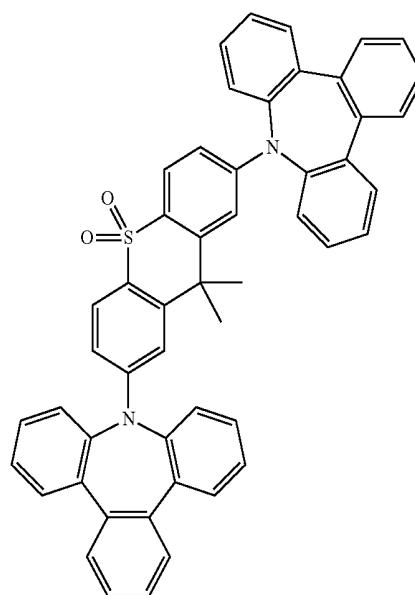
a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group.

11. The heterocyclic compound of claim 1, wherein R₆₀, R₇₀, and R₈₀ are each independently selected from:

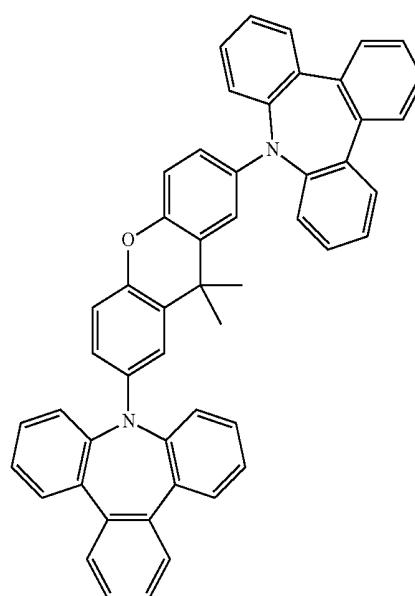
hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group; and

a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a biphenyl group, and a terphenyl group.

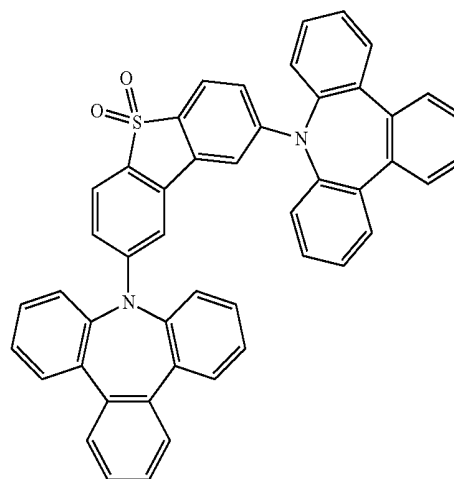
12. The heterocyclic compound of claim 1, wherein the heterocyclic compound represented by Formula 1 is selected from compounds T-1 to T-17 below:



T-1

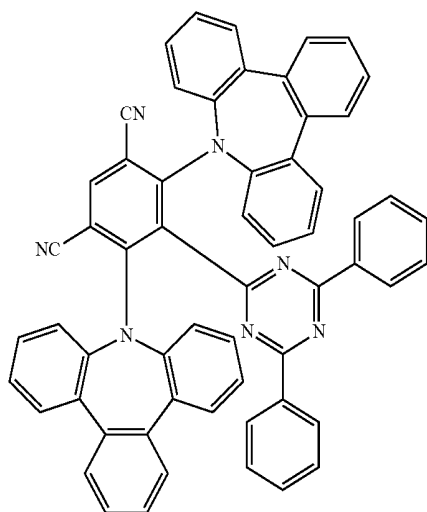
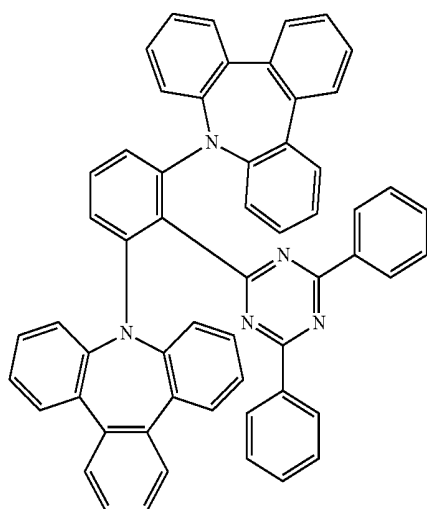
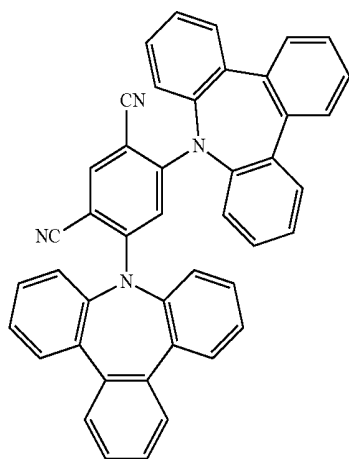


T-2



T-3

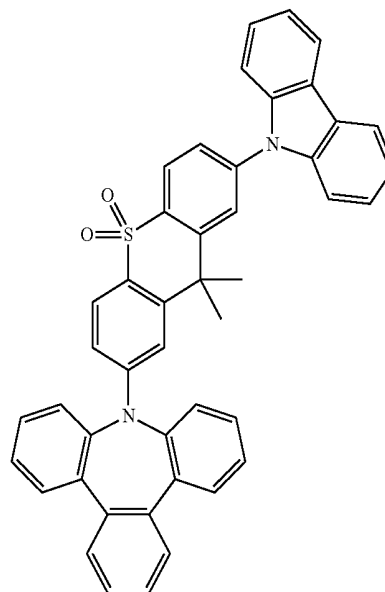
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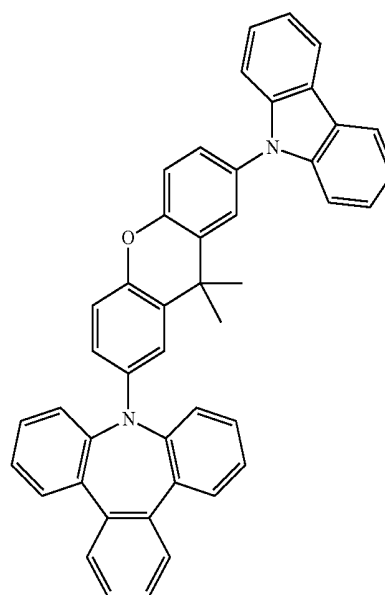
T-7

T-4



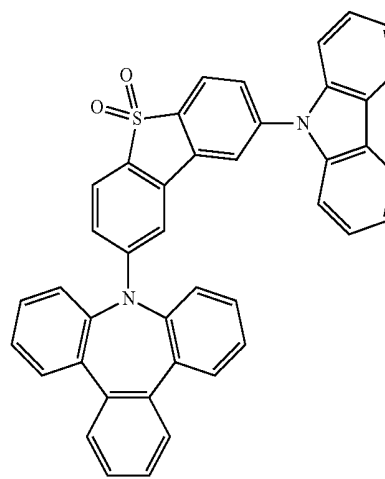
T-5

T-8

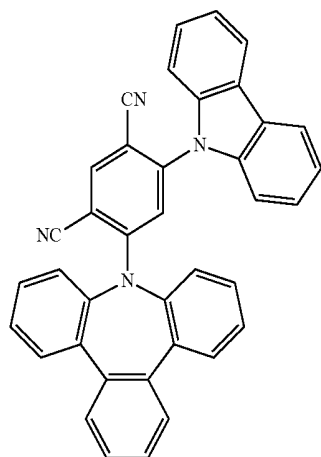


T-6

T-9

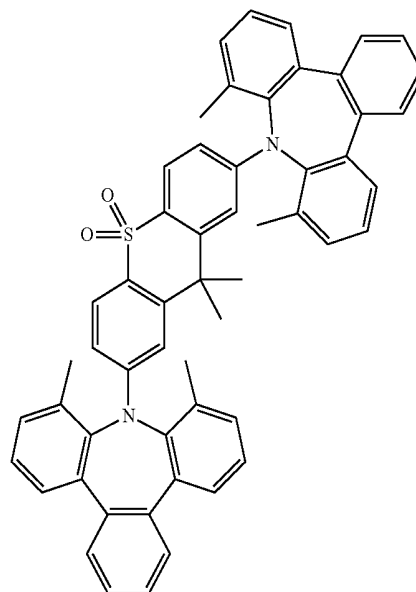


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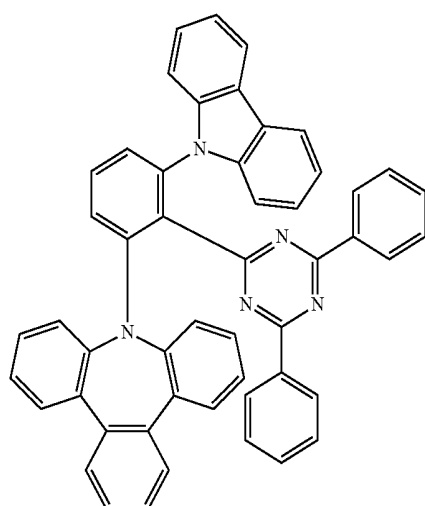


T-10

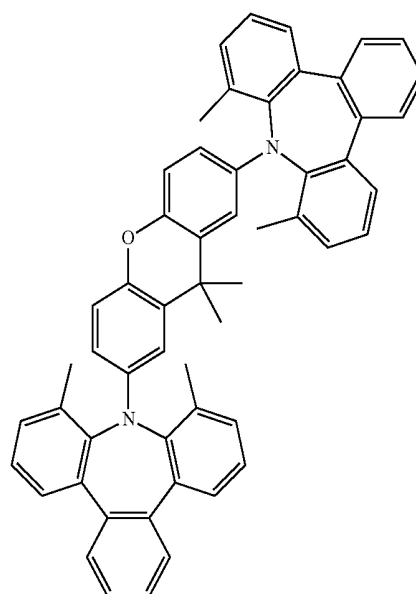
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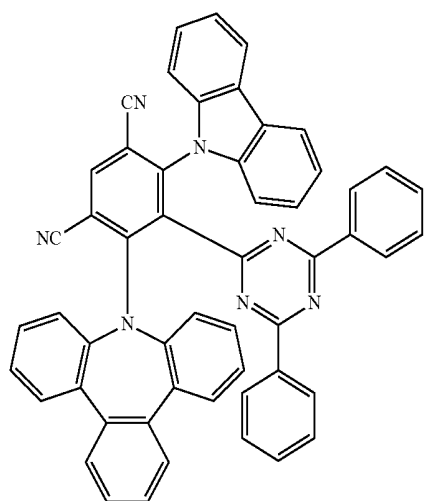
T-13



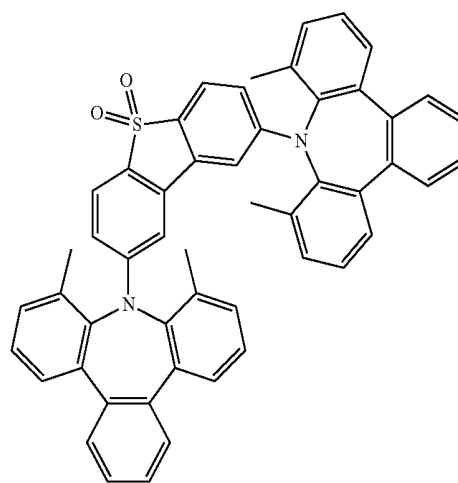
T-11



T-14

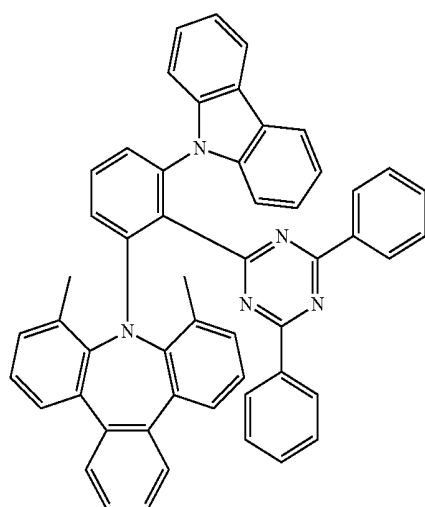


T-12

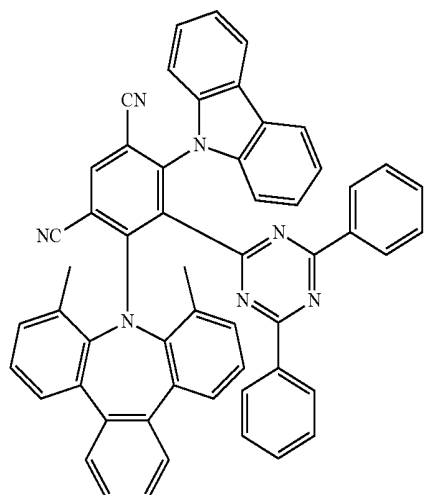


T-15

-continued



T-16



T-17

13. An organic light-emitting device comprising:
a first electrode;
a second electrode facing the first electrode; and
an organic layer disposed between the first electrode and
the second electrode,

wherein the organic layer comprises an emission layer
and at least one heterocyclic compound of claim 1.

14. The organic light-emitting device of claim 13, wherein
the first electrode is an anode, the second electrode is a
cathode, and the organic layer further comprises a hole
transport region between the first electrode and the emission
layer and an electron transport region between the emission
layer and the second electrode,

wherein the hole transport region comprises a hole injection
layer, a hole transport layer, an emission auxiliary
layer, an electron blocking layer, or any combination
thereof, and

the electron transport region comprises a hole blocking
layer, electron transport layer, electron injection layer,
or any combination thereof.

15. The organic light-emitting device of claim 14, wherein
the emission layer comprises the heterocyclic compound.

16. The organic light-emitting device of claim 14, wherein
the emission layer comprises the heterocyclic compound as
a host, and further comprises a dopant.

17. The organic light-emitting device of claim 15, wherein
the heterocyclic compound comprised in the emission layer
is a thermally activated delayed fluorescence (TADF) emitter,
and the emission layer is configured to emit delayed
fluorescence.

18. The organic light-emitting device of claim 15, wherein
the emission layer consists of the heterocyclic compound or
the emission layer further comprises a host,

wherein an amount of the heterocyclic compound per 100
parts by weight of the emission layer is in a range of
about 0.1 parts to about 50 parts by weight.

19. The organic light-emitting device of claim 14, wherein
the hole transport region comprises a p-dopant having a
lowest unoccupied molecular orbital (LUMO) energy level
of less than -3.5 eV.

20. The organic light-emitting device of claim 14, wherein
the electron transport region comprises a triazole-containing
compound or a benzotriazole-containing compound, or an
alkali metal, an alkaline earth metal, a rare earth metal, an
alkali metal compound, an alkaline earth metal compound,
a rare earth metal compound, an alkali metal complex, an
alkaline earth metal complex, a rare earth metal complex, or
any combination thereof.

* * * * *

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	US20190237679A1	公开(公告)日	2019-08-01
申请号	US16/263103	申请日	2019-01-31
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	LEE JUNGSUB KIM TAEKYUNG SHIN DAEYUP		
发明人	LEE, JUNGSUB KIM, TAEKYUNG SHIN, DAEYUP		
IPC分类号	H01L51/00 C07D409/14 C09K11/06 C07D403/14 C07D405/14		
CPC分类号	H01L51/0067 C07D403/14 H01L51/0073 H01L51/5012 H01L51/5004 H01L2251/552 H01L51/5206 H01L2251/308 H01L51/56 H01L51/001 H01L51/5088 H01L2251/558 H01L51/5056 H01L51/5072 H01L51/5221 H01L2251/301 C09K2211/1018 C07D409/14 H01L51/0072 C09K2211/1007 C09K11/06 H01L51/0074 C07D405/14 C07D223/14 C07D403/10 C09K2211/1029 C09K2211/1059 C09K2211 /1088 C09K2211/1092		
优先权	1020180013082 2018-02-01 KR		
外部链接	Espacenet USPTO		

摘要(译)

本发明提供杂环化合物和包含该杂环化合物的有机发光装置。

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150
110
210