



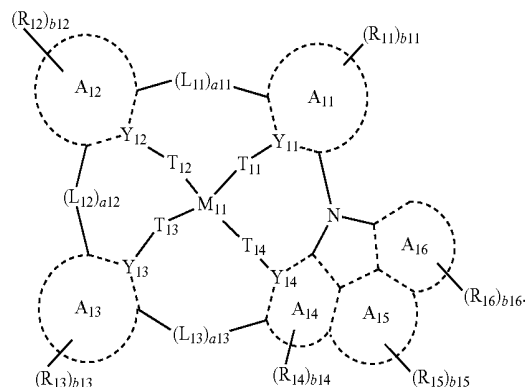
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(19) **United States**(12) **Patent Application Publication** (10) **Pub. No.: US 2019/0157579 A1**
(43) **Pub. Date: May 23, 2019**(54) **ORGANOMETALLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME**(57) **ABSTRACT**(71) Applicant: **Samsung Display Co., Ltd.**, Yongin-si (KR)(72) Inventors: **Mina JEON**, Yongin-si (KR);
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An organometallic compound and an organic light-emitting device including the same are provided. The organometallic compound may be represented by Formula 1. In the compound of Formula 1, M_{11} may be selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm). The structural characteristics of the organometallic compound may promote energy transfer, improve luminescent efficiency, and implement high color purity when applied to an organic light-emitting device.

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ORGANOMETALLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

Formula 1

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0155814, filed on Nov. 21, 2017, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

[0002] One or more embodiments of the present disclosure relate to an organometallic compound and an organic light-emitting device including the same.

2. Description of the Related Art

[0003] Organic light-emitting devices are self-emission devices that can produce full-color images, and may 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 devices in the related art.

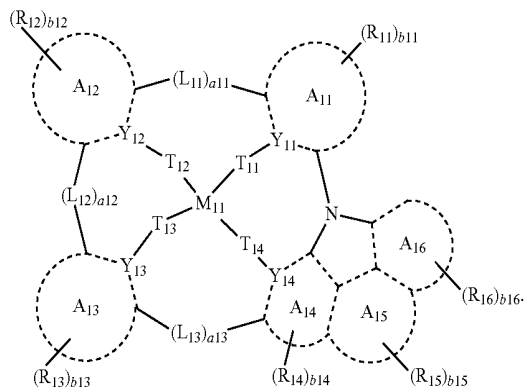
[0004] An example organic light-emitting device may include a first electrode on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode sequentially stacked on the first electrode. Holes provided from the first electrode may move toward the emission 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) may recombine in the emission layer to produce excitons. These excitons may transition from an excited state to a ground state to thereby generate light.

SUMMARY

[0005] One or more embodiments of the present disclosure relate to a novel organometallic compound and an organic light-emitting device including the same.

[0006] Additional aspects of embodiments 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.

[0007] One or more aspects of embodiments of the present disclosure provide an organometallic compound represented by Formula 1:



[0008] In Formula 1,

[0009] M_{11} may be selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm),

[0010] A_{11} to A_{16} may each independently be selected from a C_5 - C_{60} carbocyclic group and a C_1 - C_{60} heterocyclic group,

[0011] Y_{11} to Y_{14} may each independently be N or C,

[0012] T_{11} to T_{14} may each independently be selected from a single bond, $^*O^*$, and $^*S^*$,

[0013] L_{11} to L_{13} may each independently be selected from a single bond, $^*O^*$, $^*S^*$, $^*C(R_{17})(R_{18})^*$, $^*C(R_{17})=^*$, $^*C(R_{17})-^*$, $^*C(R_{17})=C(R_{18})^*$, $^*C(=O)^*$, $^*C(=S)^*$, $^*C=C^*$, $^*B(R_{17})^*$, $^*N(R_{17})^*$, $^*P(R_{17})^*$, $^*Si(R_{17})(R_{18})^*$, $^*P(R_{17})(R_{18})^*$, and $^*Ge(R_{17})(R_{18})^*$,

[0014] a_{11} to a_{13} may each independently be selected from 0, 1, 2, and 3,

[0015] when a_{11} is zero, A_{11} and A_{12} may not be linked (e.g., bonded) to each other,

[0016] when a_{12} is zero, A_{12} and A_{13} may not be linked (e.g., bonded) to each other,

[0017] when a_{13} is zero, A_{13} and A_{14} may not be linked (e.g., bonded) to each other,

[0018] R_{11} to R_{18} 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_{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 - O_{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 C_1 - C_{60} heteroaryloxy group, a substituted or unsubstituted C_1 - C_{60} heteroarylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycy-

clic group, $-\text{Si}(\text{Q}_1)(\text{Q}_2)(\text{Q}_3)$, $-\text{B}(\text{Q}_1)(\text{Q}_2)$, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{P}(\text{Q}_1)(\text{Q}_2)$, $-\text{C}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, and $-\text{P}(=\text{S})(\text{Q}_1)(\text{Q}_2)$.

[0019] R_{16} and R_{11} , or R_{17} and R_{14} may optionally be linked (e.g., coupled) to form a substituted or unsubstituted $\text{C}_5\text{-C}_{60}$ carbocyclic group or a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group,

[0020] R_{14} and R_{15} , or R_{15} and R_{16} may optionally be linked (e.g., coupled) to form a substituted or unsubstituted $\text{C}_5\text{-C}_{60}$ carbocyclic group or a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group,

[0021] R_{17} and R_{11} , R_{17} and R_{12} , or R_{17} and R_{13} may optionally be linked (e.g., coupled) to form a substituted or unsubstituted $\text{C}_5\text{-C}_{60}$ carbocyclic group or a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group,

[0022] b11 to b16 may each independently be selected from 1, 2, 3, 4, 5, 6, 7, and 8,

[0023] * and * may each indicate a binding site to a neighboring atom,

[0024] at least one substituent of the substituted $\text{C}_5\text{-C}_{60}$ carbocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ heterocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ alkyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkenyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkynyl group, the substituted $\text{C}_1\text{-C}_{60}$ alkoxy group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, the substituted $\text{C}_6\text{-C}_{60}$ aryl group, the substituted $\text{C}_6\text{-C}_{60}$ aryloxy group, the substituted $\text{C}_6\text{-C}_{60}$ arylthio group, the substituted $\text{C}_1\text{-C}_{60}$ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0025] deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, and a $\text{C}_1\text{-C}_{60}$ alkoxy group;

[0026] a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, and a $\text{C}_1\text{-C}_{60}$ alkoxy group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{11})(\text{Q}_{12})(\text{Q}_{13})$, $-\text{N}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{B}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{C}(=\text{O})(\text{Q}_{11})$, $-\text{S}(=\text{O})_2(\text{Q}_{11})$, and $-\text{P}(=\text{O})(\text{Q}_{11})(\text{Q}_{12})$;

[0027] a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0028] a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{21})(\text{Q}_{22})(\text{Q}_{23})$, $-\text{N}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{B}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{C}(=\text{O})(\text{Q}_{21})$, $-\text{S}(=\text{O})_2(\text{Q}_{21})$, and $-\text{P}(=\text{O})(\text{Q}_{21})(\text{Q}_{22})$; and

[0029] $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$; and

[0030] 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a $\text{C}_1\text{-C}_{60}$ alkyl group substituted with at least one selected from deuterium, $-\text{F}$, and a cyano group; a $\text{C}_6\text{-C}_{60}$ aryl group substituted with at least one selected from deuterium, $-\text{F}$, and a cyano group; a biphenyl group, and a terphenyl group.

[0031] One or more aspects of embodiments of the present disclosure provide 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 species of the organometallic compound.

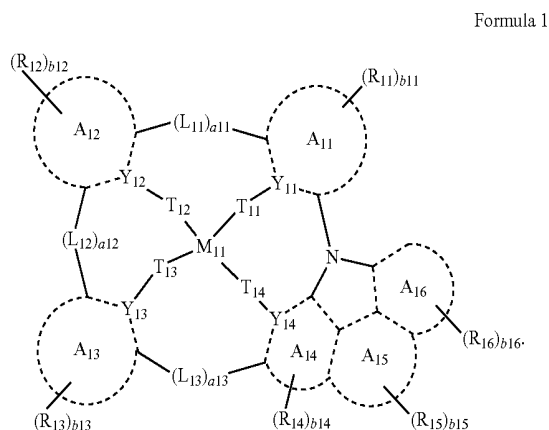
BRIEF DESCRIPTION OF THE DRAWING

[0032] These and/or other aspects of embodiments will become apparent and more readily appreciated from the following description of the example embodiments, taken in conjunction with the accompanying drawing, which is a schematic view of an organic light-emitting device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0033] Reference will now be made in more detail to embodiments, examples of which are illustrated in the accompanying drawing, wherein like reference numerals refer to like elements throughout and duplicative descriptions thereof may not be provided. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the accompanying drawing, to explain aspects of embodiments of the present disclosure. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions

such as “at least one of” and “one of”, when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list. An organometallic compound according to an embodiment of the present disclosure is represented by Formula 1:



[0034] M_{11} in Formula 1 may be selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm).

[0035] In some embodiments, M_{11} may be selected from Pt, Pd, Cu, Ag, and Au.

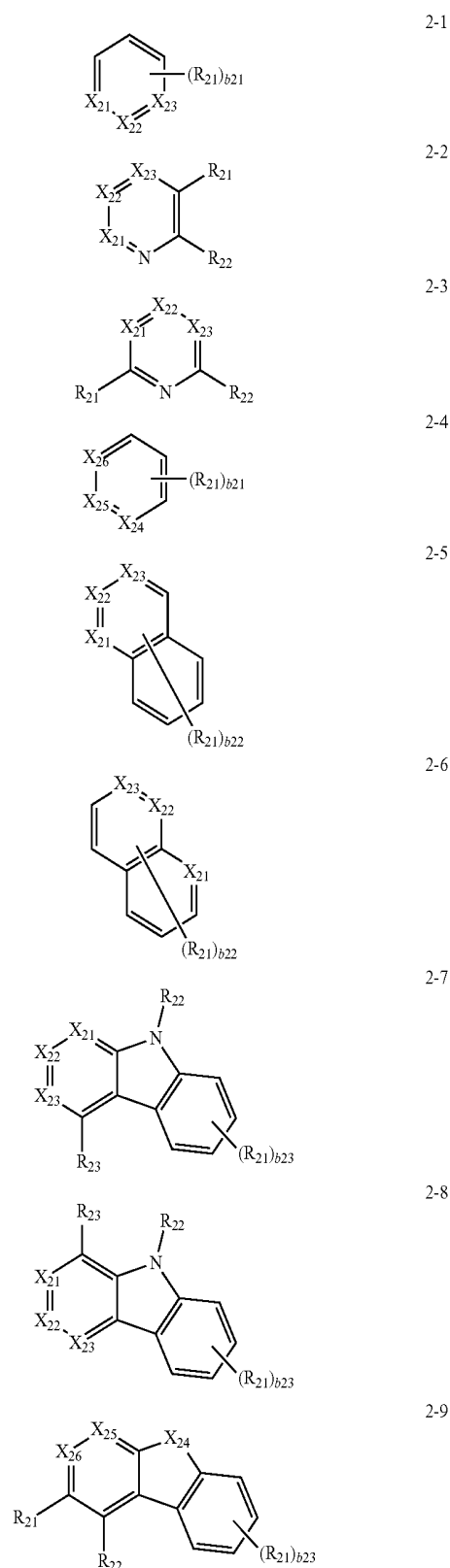
[0036] For example, M_{11} may be Pt, but embodiments of the present disclosure are not limited thereto.

[0037] A_{11} to A_{16} in Formula 1 may each independently be selected from a C_5 - C_{60} carbocyclic group and a C_1 - C_{60} heterocyclic group.

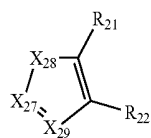
[0038] In some embodiments, A_{11} to A_{16} may each independently be selected from a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an indeno pyridine group, an indolopyridine group, a benzofuopyridine group, a benzothienopyridine group, a benzosilolopyridine group, an indenopyrimidine group, an indolopyrimidine group, a benzofuopyrimidine group, a benzothienopyrimidine group, a benzosilolopyrimidine group, a dihydropyridine group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a 2,3-dihydroimidazole group, a triazole group, a 2,3-dihydrotriazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a 2,3-dihydrobenzimidazole group, an imidazopyridine group, a 2,3-dihydroimidazopyridine group, an imidazopyrimidine group, a 2,3-dihydroimidazopyrimidine group, an imidazopyrazine group, a 2,3-dihydroimidazopyrazine group, a benzoxazole group, a benzothiazole group, a benzoxadiaz-

ole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group.

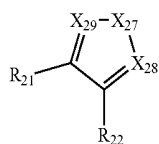
[0039] In some embodiments, A_{11} to A_{13} may each independently be represented by one of Formulae 2-1 to 2-43:



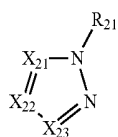
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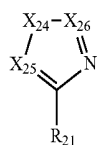
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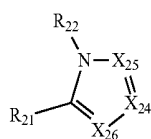
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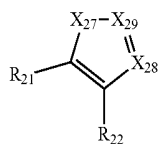
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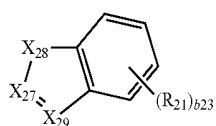
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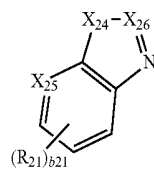
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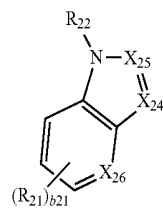
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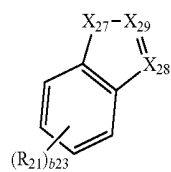
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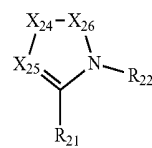


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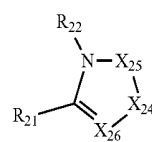


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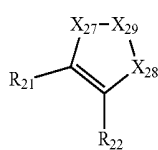
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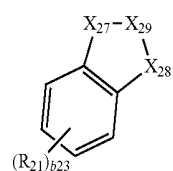
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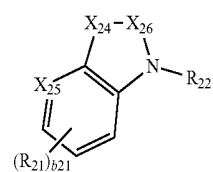
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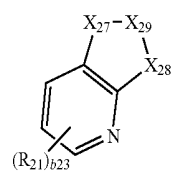
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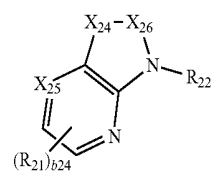
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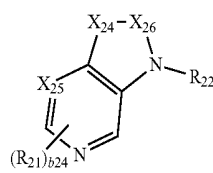
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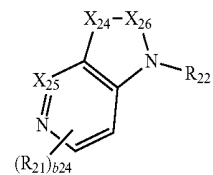
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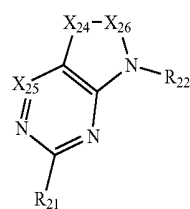


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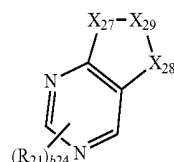


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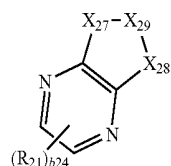
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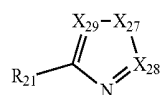
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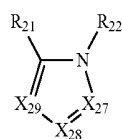
2-30



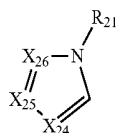
2-31



2-32



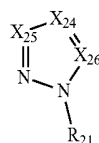
2-33



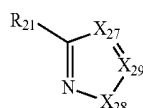
2-34



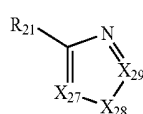
2-35



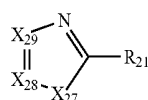
2-36



2-37

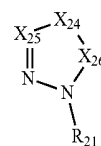


2-38

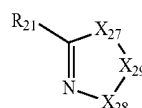


2-39

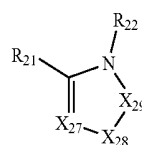
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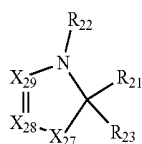
2-40



2-41



2-42

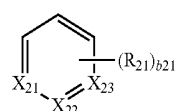


2-43

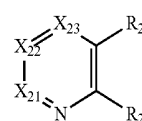
[0040] In Formulae 2-1 to 2-43,

[0041] X₂₁ to X₂₃ may each independently be selected from C(R₂₄) and C—*, provided that at least two of X₂₁ to X₂₃ are C—*,[0042] X₂₄ may be N—*, and X₂₅ and X₂₆ may each independently be selected from C(R₂₄) and C—*, provided that at least one of X₂₅ and X₂₆ is C—*,[0043] X₂₇ and X₂₈ may each independently be selected from N, N(R₂₅), and N—*, and X₂₉ may be selected from C(R₂₄) and C—*, provided that i) at least one of X₂₇ and X₂₈ is N—*, and X₂₉ is C—*, or ii) X₂₇ and X₂₈ are each N—*, and X₂₉ is C(R₂₄),[0044] R₂₁ to R₂₄ are each independently the same as described in connection with R₁₁ in Formula 1,[0045] b₂₁ may be selected from 1, 2, and 3,[0046] b₂₂ may be selected from 1, 2, 3, 4, and 5,[0047] b₂₃ may be selected from 1, 2, 3, and 4,[0048] b₂₄ may be selected from 1 and 2, and

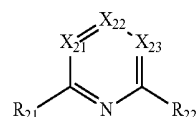
[0049] * indicates a binding site to a neighboring atom.

[0050] In one or more embodiments, A₁₄ to A₁₆ may each independently be represented by one of Formulae 2-1 to 2-4:

2-1



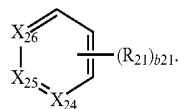
2-2



2-3

-continued

2-4



[0051] In Formulae 2-1 to 2-4,

[0052] X_{21} to X_{23} may each independently be selected from $C(R_{24})$ and C^{*} , provided that at least two of X_{21} to X_{23} are C^{*} ,

[0053] X_{24} may be N^* , and X_{25} and X_{26} may each independently be selected from $C(R_{24})$ and C^* , provided that at least one of X_{25} and X_{26} is C^* ,

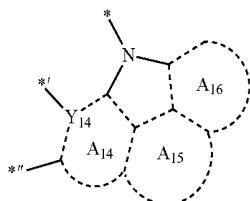
[0054] R_{21} to R_{22} are each independently the same as described in connection with R_{11} in Formula 1.

[0055] b21 may be selected from 1, 2, and 3, and

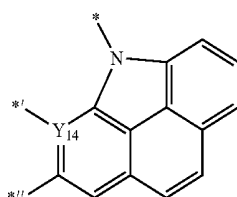
[0056] * may indicate a binding site to a neighboring atom.

[0057] In some embodiments, in Formula 1,

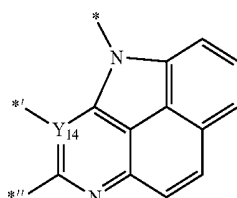
[0058] a moiety represented by



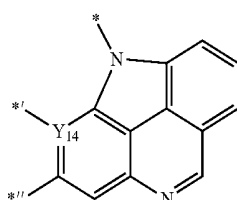
may be a moiety represented by one of Formulae 1-1 to 1-64:



1-1



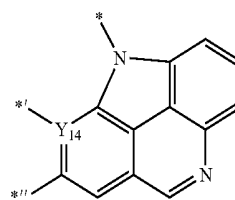
1-2



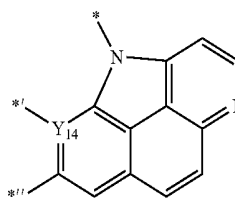
1-3

-continued

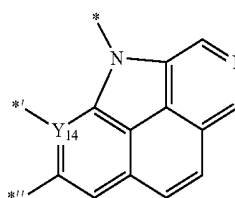
1-4



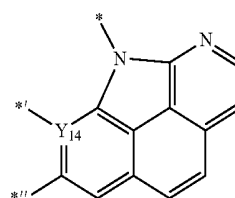
1-5



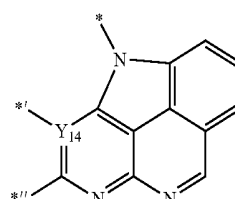
1-6



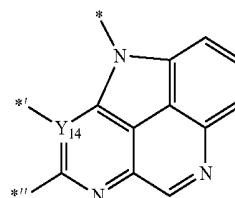
1-7



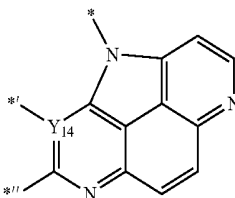
1-8



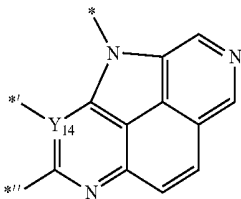
1-9



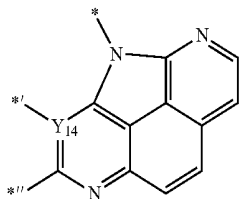
1-10



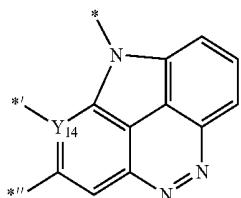
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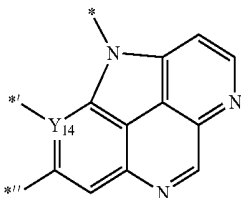
1-11



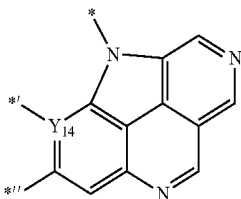
1-12



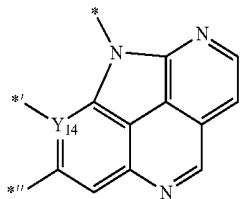
1-13



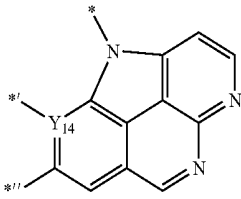
1-14



1-15

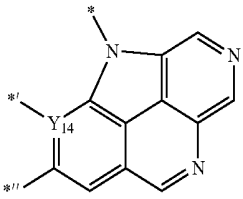


1-16

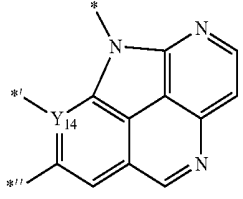


1-17

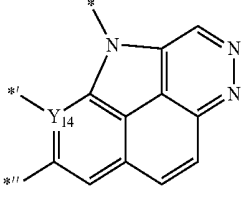
-continued



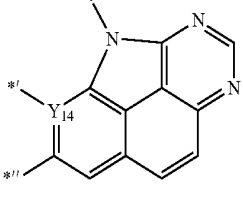
1-18



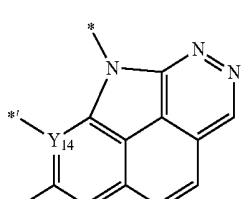
1-19



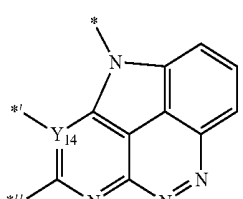
1-20



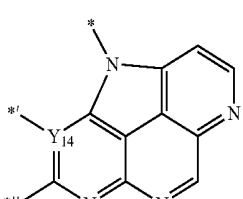
1-21



1-22

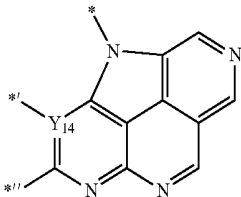


1-23

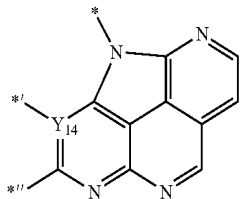


1-24

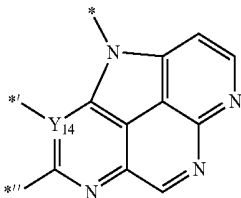
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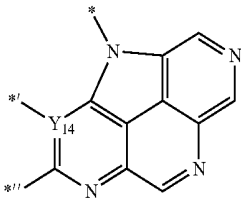
1-25



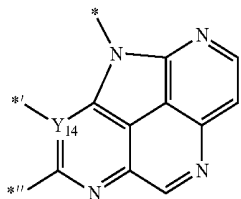
1-26



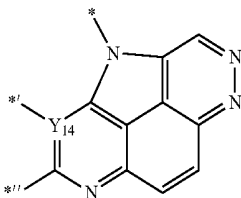
1-27



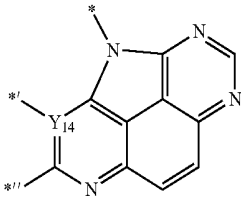
1-28



1-29

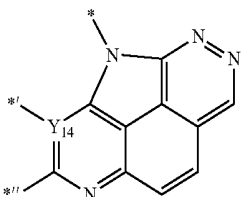


1-30

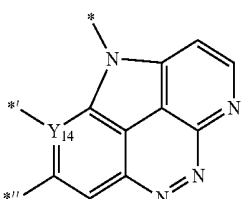


1-31

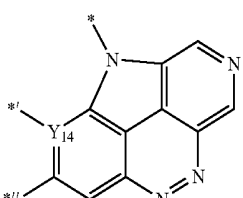
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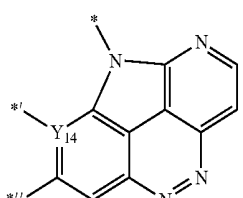
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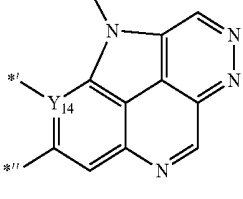
1-33



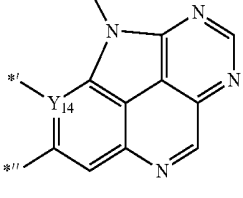
1-34



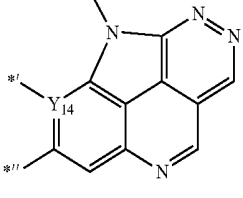
1-35



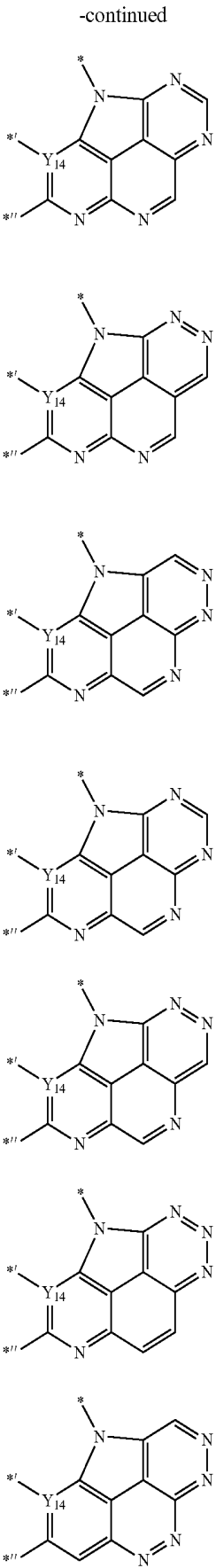
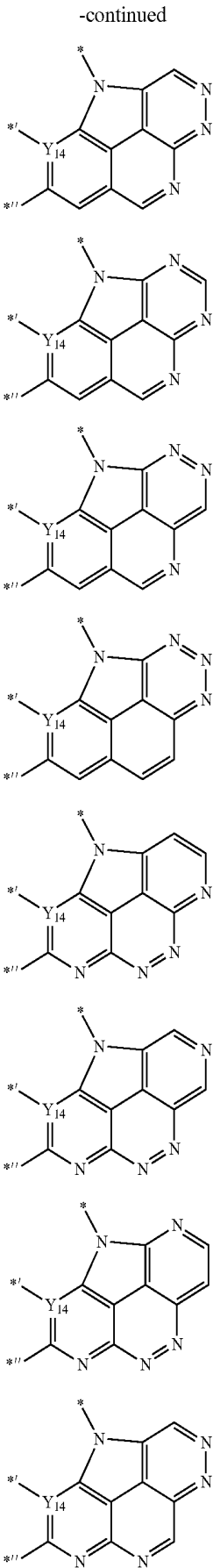
1-36



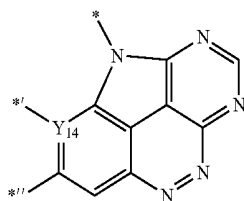
1-37



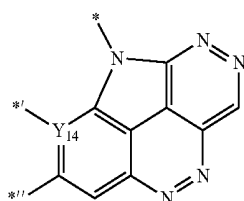
1-38



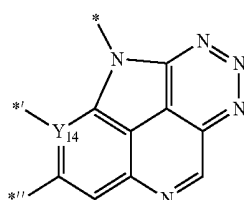
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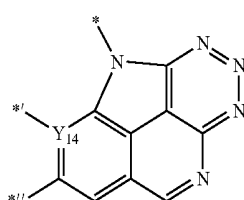
1-54



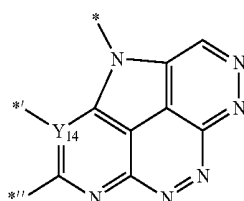
1-55



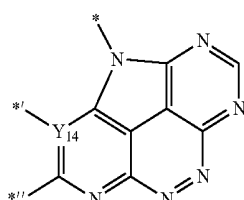
1-56



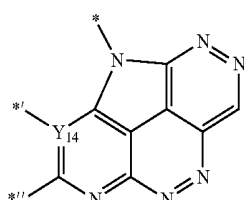
1-57



1-58

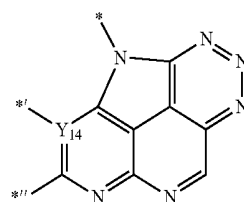


1-59

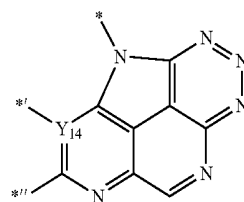


1-60

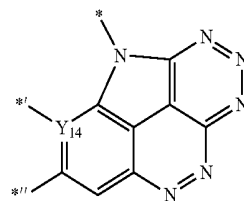
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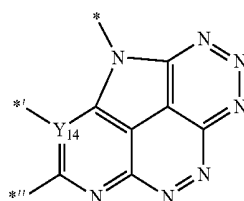
1-61



1-62



1-63



1-64

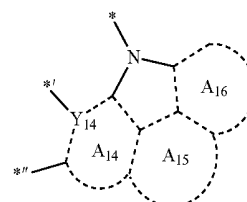
[0059] In Formulae 1-1 to 1-64,

[0060] Y_{14} may be the same as described above, and

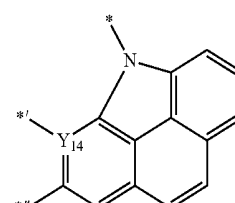
[0061] *, *', and *'' may each indicate a binding site to a neighboring atom.

[0062] In one or more embodiments, in Formula 1,

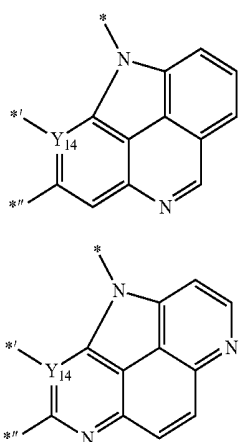
[0063] a moiety represented by



may be a moiety represented by one of Formulae 1-1, 1-3, and 1-10:



1-1


$$\begin{array}{c} \text{(R}_{17}\text{)}\text{(R}_{18}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{C(R}_{17}\text{)}=\text{C}^{\ast}, \text{ }^{\ast}=\text{C(R}_{17}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{C(R}_{17}\text{)} \\ =\text{C(R}_{18}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{C(=O)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{C(=S)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{C=C} \\ \text{C}^{\ast}, \text{ }^{\ast}-\text{B(R}_{17}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{N(R}_{17}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{P(R}_{17}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{Si} \\ \text{(R}_{17}\text{)}\text{(R}_{18}\text{)}-\text{C}^{\ast}, \text{ }^{\ast}-\text{P(R}_{17}\text{)}\text{(R}_{18}\text{)}-\text{C}^{\ast}, \text{ and }^{\ast}-\text{Ge(R}_{17}\text{)} \\ \text{(R}_{18}\text{)}-\text{C}^{\ast}. \end{array}$$

[0085] L_{11} to L_{13} may each independently be selected from a single bond, $^*O^*$, $^*S^*$, $^*C(R_{17})(R_{18})^*$, $^*C(R_{17})=^*$, $^*C(R_{17})^*$, $^*B(R_{17})^*$, $^*N(R_{17})^*$, $^*Si(R_{17})(R_{18})^*$, and $^*P(R_{17})(R_{18})^*$.

[0086] In one or more embodiments, L_{11} may be $^*N(R_{17})-^*$, $^*C(R_{17})(R_{18})-^*$, or $^*Si(R_{17})(R_{18})-^*$, and R_{17} and R_{12} may be linked (e.g., coupled) to form a substituted or unsubstituted C_1-C_{60} heterocyclic group.

[0087] L₁₂ may be *—N(R₁₇)—*, *—C(R₁₇)(R₁₈)—*, or *—Si(R₁₇)(R₁₈)—*, and R₁₇ and R₁₃ may be linked (e.g., coupled) to form a substituted or unsubstituted C₁-C₆₀ heterocyclic group.

[0088] In Formula 1, a11 to a13 may each independently be selected from 0, 1, 2, and 3.

[0089] when a_{11} is zero, A_{11} and A_{12} may not be linked (e.g., coupled) to each other, when a_{12} is zero, A_{12} and A_{13} may not be linked (e.g., coupled) to each other, and when a_{13} is zero, A_{13} and A_{14} may not be linked (e.g., coupled) to each other.

[0090] In some embodiments, a11, a12, and a13 may each independently be selected from 1, 2, and 3;

[0091] when a11 is zero, a12 and a13 may each independently be selected from 0, 1, 2, and 3;

[0092] when a12 is zero, a11 and a13 may each independently be selected from 0, 1, 2, and 3; or

[0093] when a13 is zero, a11 and a12 may each independently be selected from 0, 1, 2, and 3.

[0094] In one or more embodiments, a11 may be 0, and a12 and a13 may each independently be selected from 1, 2, and 3;

[0095] when a12 is zero, a11 and a13 may each independently be selected from 1, 2, and 3; or

[0096] when a13 is zero, a11 and a12 may each independently be selected from 1, 2, and 3.

[0097] In some embodiments, all may be zero, but embodiments of the present disclosure are not limited thereto.

[0098] In Formula 1, R₁₁ to R₁₈ 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 C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ heteroarylthio 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), —B(Q₁)(Q₂),

—N(Q₁)(Q₂), —P(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)(Q₁), —S(=O)₂(Q₁), —P(=O)(Q₁)(Q₂), and —P(=S)(Q₁)(Q₂),

[0099] R₁₆ and R₁₁, or R₁₇ and R₁₄ may optionally be linked (e.g., coupled) to form a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

[1010] R₁₄ and R₁₅, or R₁₅ and R₁₆ may optionally be linked (e.g., coupled) to form a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group, and

[1011] R₁₇ and R₁₁, R₁₇ and R₁₂, or R₁₇ and R₁₃ may optionally be linked (e.g., coupled) to form a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group.

[1012] b11 to b16 in Formula 1 may each independently be selected from 1, 2, 3, 4, 5, 6, 7, and 8.

[1013] In some embodiments, R₁₁ to R₁₈ may each independently be selected from the group consisting of:

[1014] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[1015] 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 cyano group, a phenyl group, and a biphenyl group;

[1016] 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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a benzoquinolyl group, an isoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indeno pyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

[1017] 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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a benzoquinolyl group, an isoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indeno pyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano 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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a benzoquinolyl group, an isoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a ben-

zofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazopyridinyl group, a thiazopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indeno pyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$, and $-\text{P}(=\text{S})(\text{Q}_{31})(\text{Q}_{32})$; and

[0108] $-\text{Si}(\text{Q}_1)(\text{Q}_2)(\text{Q}_3)$, $-\text{B}(\text{Q}_1)(\text{Q}_2)$, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{P}(\text{Q}_1)(\text{Q}_2)$, $-\text{C}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, and $-\text{P}(=\text{S})(\text{Q}_1)(\text{Q}_2)$, and

[0109] Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a $\text{C}_1\text{-C}_{60}$ heteroaryloxy group, a $\text{C}_1\text{-C}_{60}$ heteroarylthio group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a $\text{C}_1\text{-C}_{60}$ alkyl group substituted with at least one selected from deuterium, $-\text{F}$, and a cyano group; a $\text{C}_6\text{-C}_{60}$ aryl group substituted with at least one selected from deuterium, $-\text{F}$, and a cyano group; a biphenyl group, and a terphenyl group.

[0110] For example, R_{11} to R_{18} may each independently be selected from the group consisting of:

[0111] hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a cyano group, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group;

[0112] a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, and a cyano group; and

[0113] a phenyl group, a naphthyl group, and a pyridinyl group, but embodiments of the present disclosure are not limited thereto.

[0114] In Formula 1, * and *' may each independently indicate a binding site to a neighboring atom.

[0115] At least one substituent of the substituted $\text{C}_5\text{-C}_{60}$ carbocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ heterocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ alkyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkenyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkynyl group, the substituted $\text{C}_1\text{-C}_{60}$ alkoxy group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, the sub-

stituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, the substituted $\text{C}_6\text{-C}_{60}$ aryl group, the substituted $\text{C}_6\text{-C}_{60}$ aryloxy group, the substituted $\text{C}_6\text{-C}_{60}$ arylthio group, the substituted $\text{C}_1\text{-C}_{60}$ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0116] deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, and a $\text{C}_1\text{-C}_{60}$ alkoxy group;

[0117] a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, and a $\text{C}_1\text{-C}_{60}$ alkoxy group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{11})(\text{Q}_{12})(\text{Q}_{13})$, $-\text{N}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{B}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{C}(=\text{O})(\text{Q}_{11})$, $-\text{S}(=\text{O})_2(\text{Q}_{11})$, and $-\text{P}(=\text{O})(\text{Q}_{11})(\text{Q}_{12})$;

[0118] a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

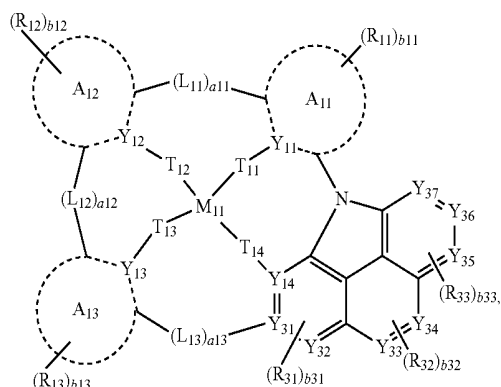
[0119] a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{21})(\text{Q}_{22})(\text{Q}_{23})$, $-\text{N}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{B}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{C}(=\text{O})(\text{Q}_{21})$, $-\text{S}(=\text{O})_2(\text{Q}_{21})$, and $-\text{P}(=\text{O})(\text{Q}_{21})(\text{Q}_{22})$; and

[0120] $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$, and

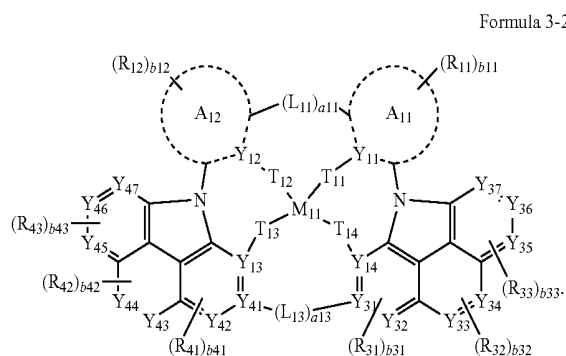
[0121] Q_1 to Q_3 , Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

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 C₁-C₆₀ alkyl group substituted with at least one selected from deuterium, —F, and a cyano group; a C₆-C₆₀ aryl group substituted with at least one selected from deuterium, —F, and a cyano group; a biphenyl group, and a terphenyl group.

[0122] In some embodiments, the organometallic compound may be represented by Formula 3-1 or Formula 3-2:



Formula 3-1



Formula 3-2

[0123] In Formulae 3-1 and 3-2,

[0124] M_{11} , A_{11} to A_{13} , Y_{11} to Y_{14} , T_{11} to T_{14} , L_{11} to L_{13} , a_{11} to a_{13} , R_{11} to R_{13} , and b_{11} to b_{13} may each independently be the same as described herein.

[0125] Y₃₁ to Y₃₇ may each independently be N or C,

[0126] Y₄₁ to Y₄₇ may each independently be N or C,

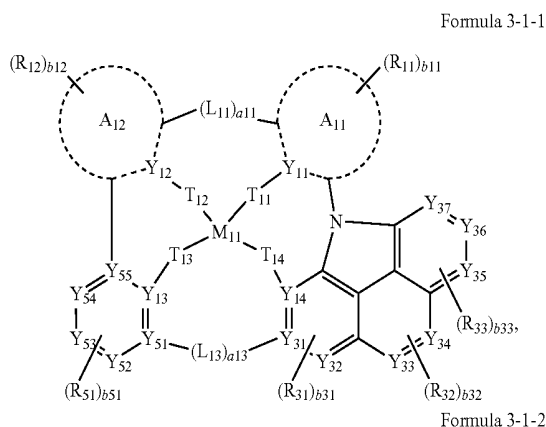
[0127] R₃₁ to R₃₃ may each independently be the same as described in connection with R₁₄,

[0128] R₄₁ to R₄₃ may each independently be the same as described in connection with R₁₃,

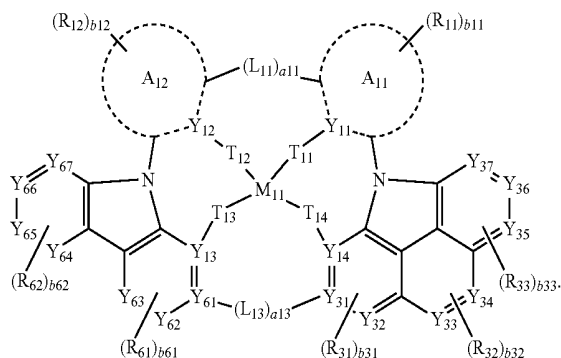
[0129] b31, b32, b41, and b42 may each independently be 1 or 2, and

[0130] b33 and b43 may each independently be 1, 2, or 3.

[0131] In one or more embodiments, when the organometallic compound is represented by Formula 3-1, the organometallic compound may be represented by Formula 3-1-1 or 3-1-2:



Formula 3-1-1



Formula 3-1-2

[0132] In Formulae 3-1-1 and 3-1-2,

[0133] M_{11} , A_{11} , A_{12} , Y_{11} to Y_{14} , Y_{31} to Y_{37} , T_{11} to T_{14} , L_{11} , L_{13} , a_{11} , a_{13} , R_{11} , R_{12} , R_{31} to R_{33} , b_{11} , b_{12} , and b_{31} to b_{33} are the same as described herein.

[0134] Y₅₁ to Y₅₅ may each independently be N or C,

[0135] Y_{61} to Y_{67} may each independently be N or C,

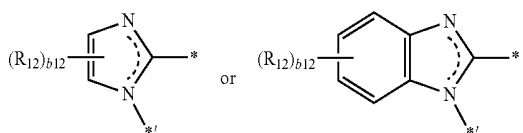
[0136] R_{51} , R_{61} , and R_{62} may each independently be the same as described in connection with R_{13} ,

[0137] b51 may be 1, 2, 3, or 4,

[0138] b61 may be 1, 2, or 3, and

[0139] b62 may be 1, 2, 3, or 4.

[0140] In one or more embodiments, when the organometallic compound is a compound represented by Formula 3-1-1, A₁₂ may be a group represented by

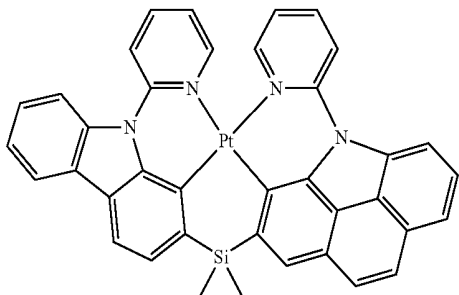
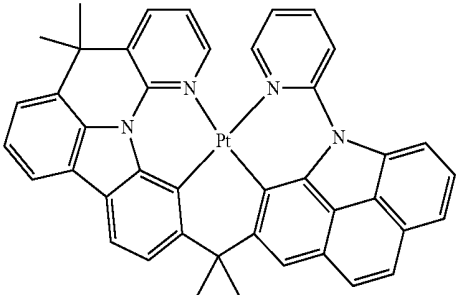
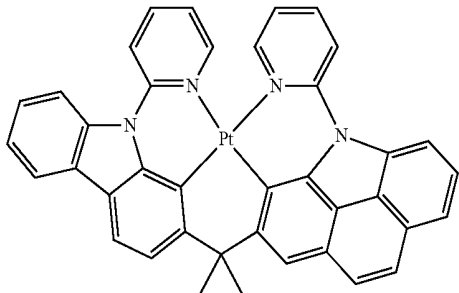
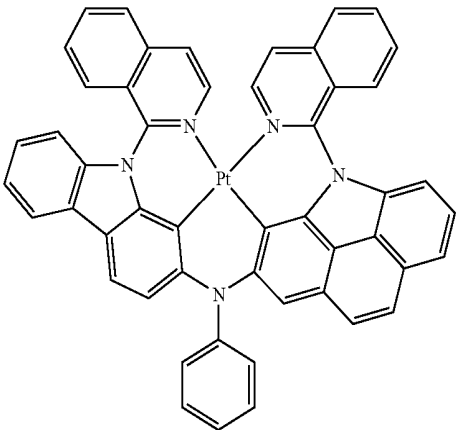
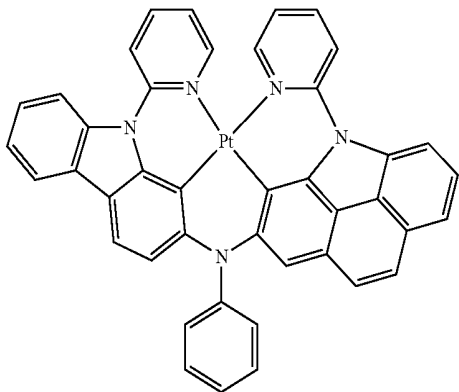
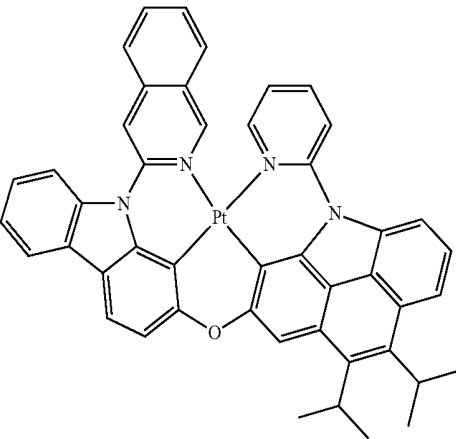
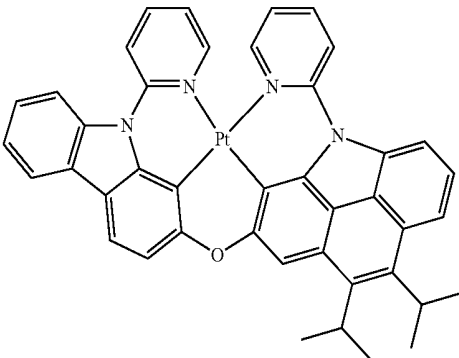
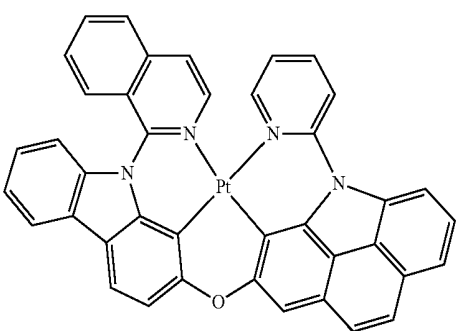
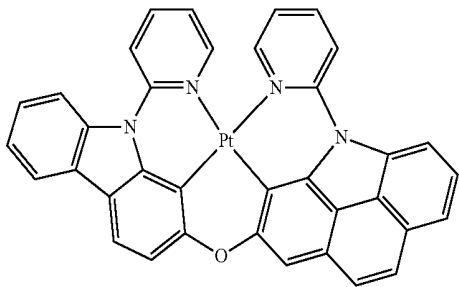


R₁₂ and b₁₂ may each independently be the same as described herein, and * and *' may each indicate a binding site to a neighboring atom.

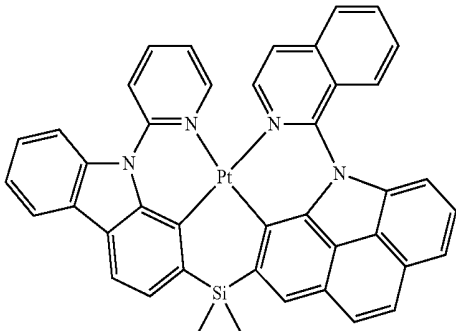
[0141] In one or more embodiments, when the organometallic compound is a group represented by Formula 3-1-1, 3-1-2, or 3-2, all may be zero.

[0142] In some embodiments, the organometallic compound may be selected from Compounds 1 to 45, but embodiments of the present disclosure are not limited thereto:

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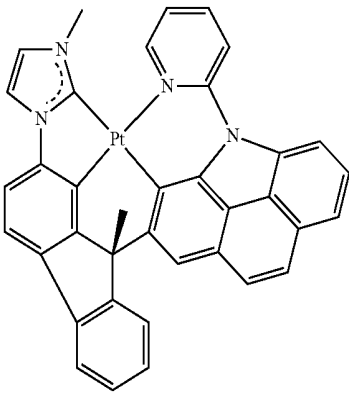


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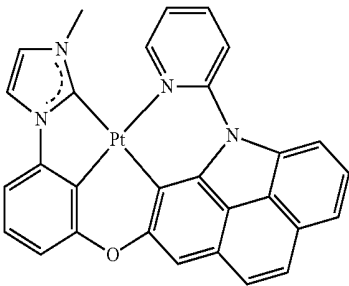


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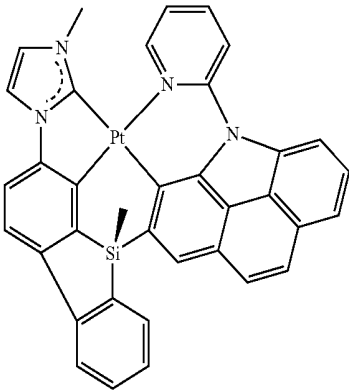
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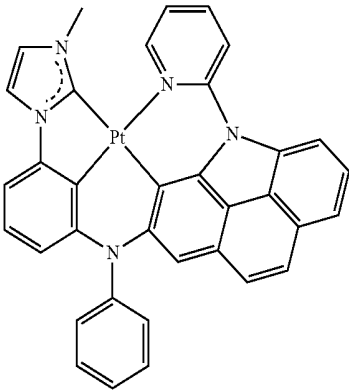
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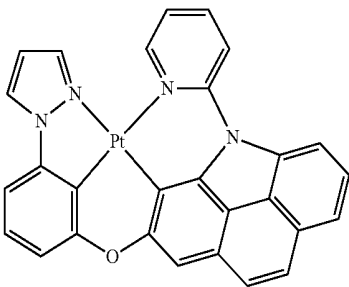
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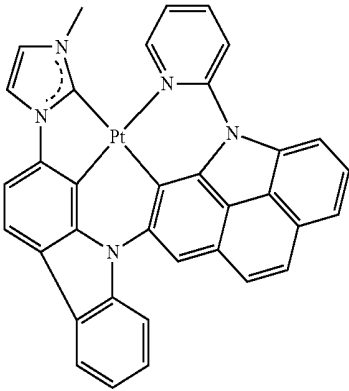
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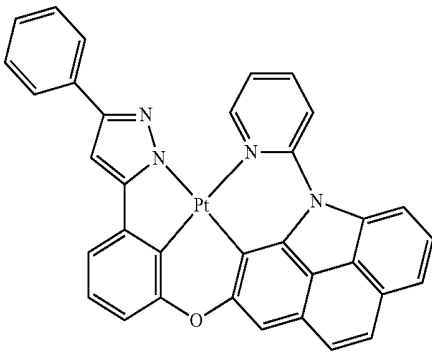
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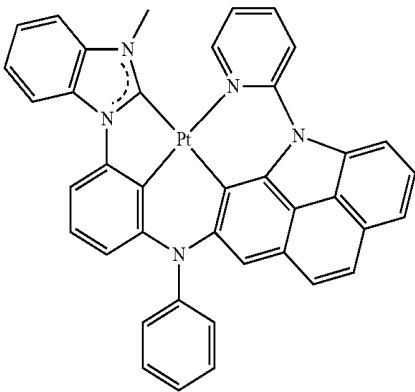
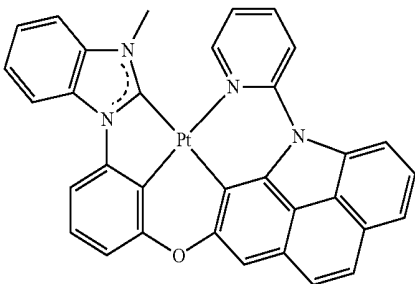
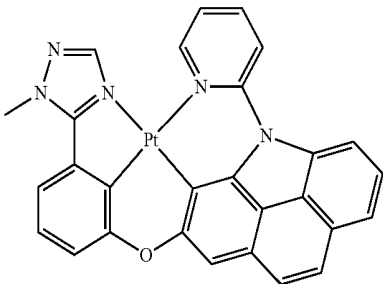
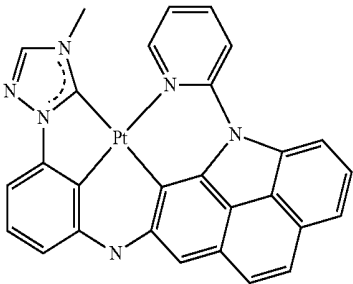
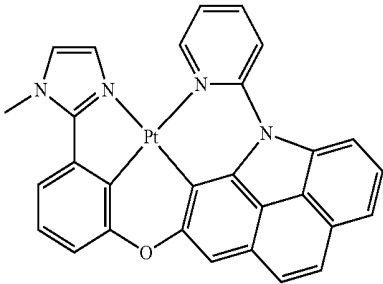


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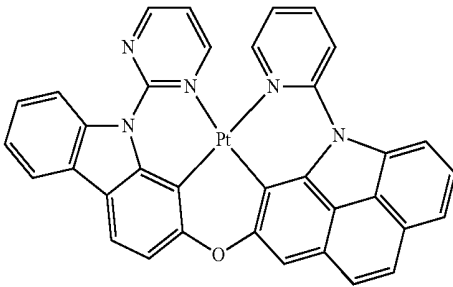
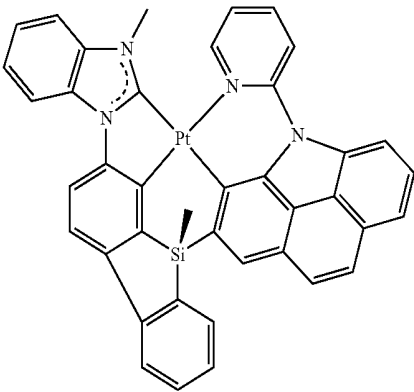
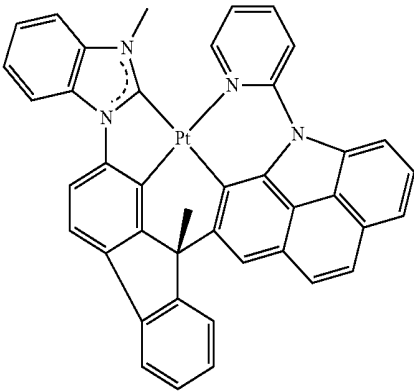
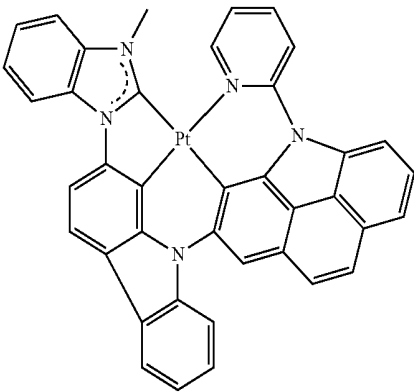


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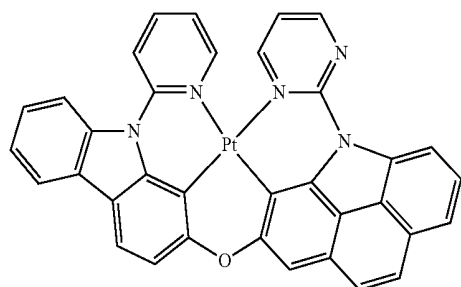
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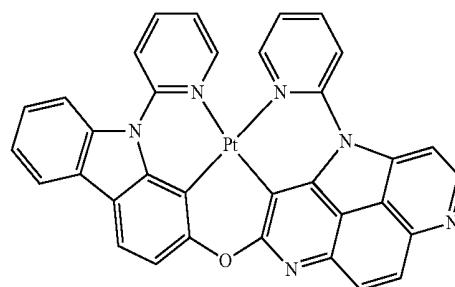


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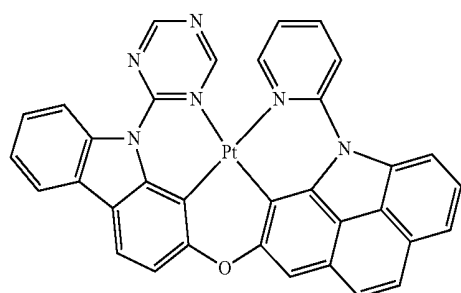


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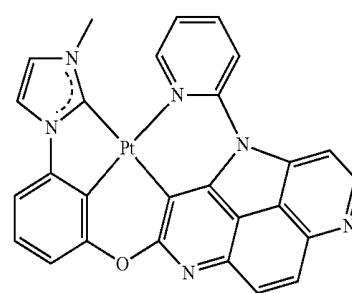
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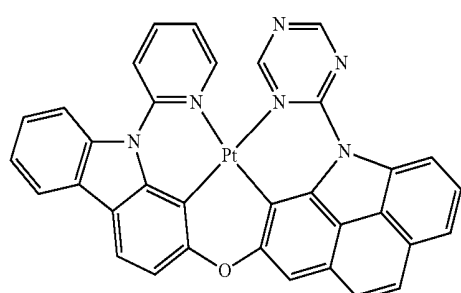
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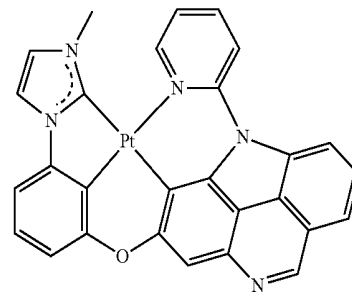
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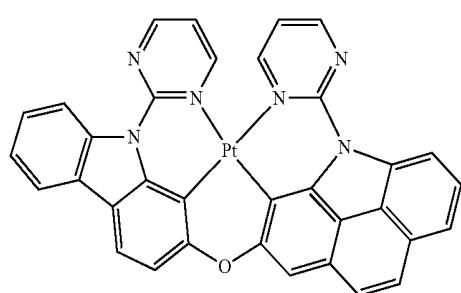
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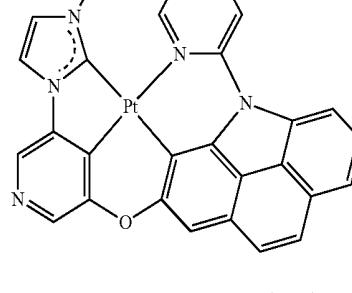
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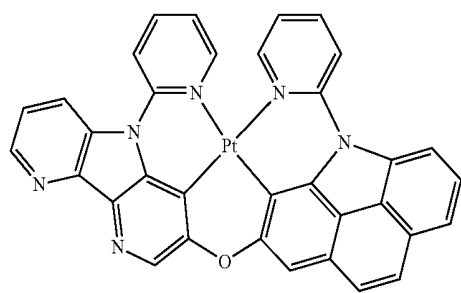
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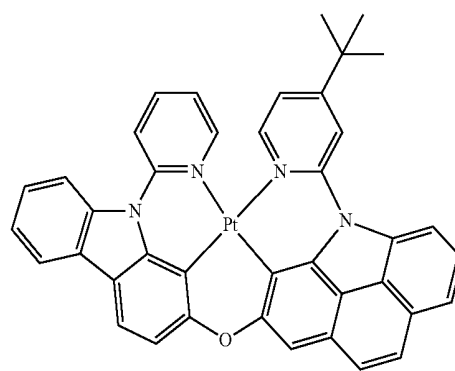
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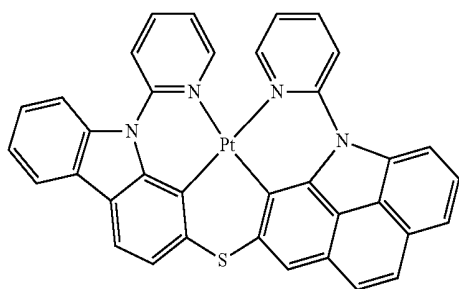


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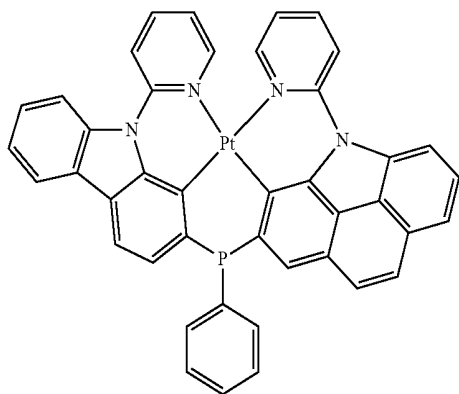


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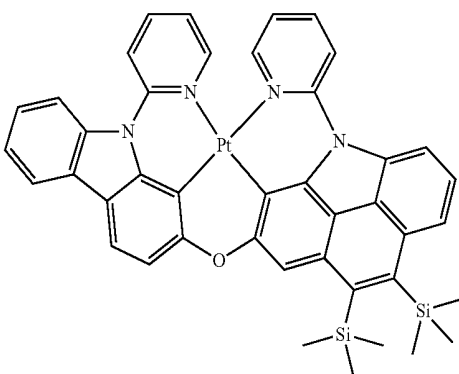
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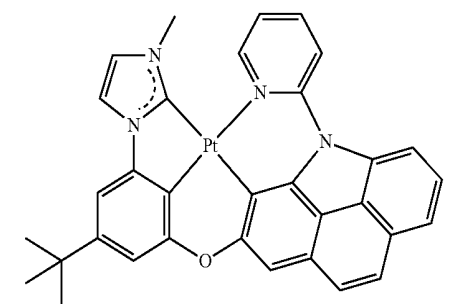
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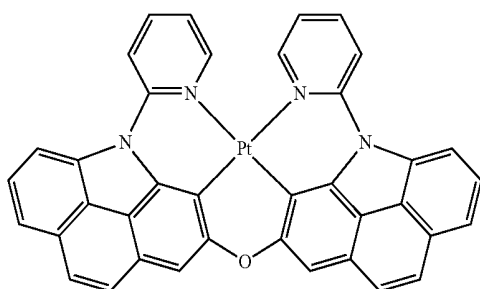
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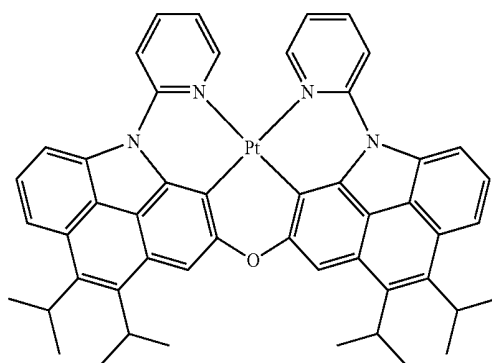


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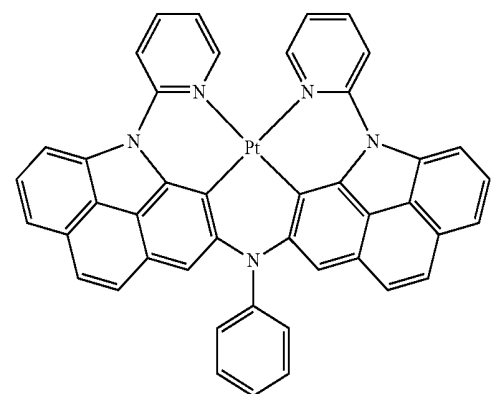


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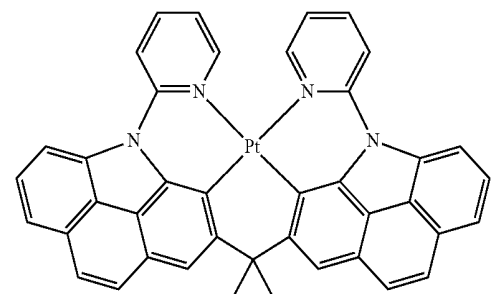
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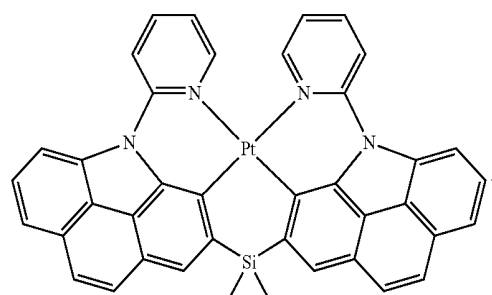
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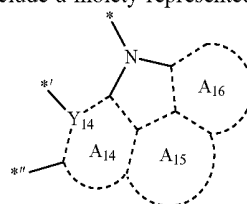


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[0143] The organometallic compound represented by Formula 1 may include a moiety represented by



Because of the structural characteristics arising from the way in which the aromatic rings (A_{14} , A_{15} , and A_{16}) constituting the moiety are condensed, the organometallic compound may have a feature of improved energy transfer (e.g., may promote energy transfer), improve luminescent efficiency, and implement high color purity when applied to an organic light-emitting device.

[0144] When the organometallic compound represented by Formula 1 has a rigid (or substantially rigid) structure due to the inclusion of the moiety, an organic light-emitting device including the organometallic compound may have high durability and a long lifespan.

[0145] The organometallic compound may emit green light or red light. For example, the organometallic compound may emit green light or red light (bottom-emission $CIE_{x,y}$ color coordinates (0.14, 0.06 to 0.08)) having a maximum emission wavelength of about 500 nm to about 800 nm, for example, about 530 nm to about 750 nm, but embodiments of the present disclosure are not limited thereto. Therefore, the organometallic compound represented by Formula 1 may be suitably used for manufacturing an organic light-emitting device that emits deep green light and/or deep red light.

[0146] Suitable synthesis methods of the organometallic compound represented by Formula 1 may be recognized by those of ordinary skill in the art with reference to the Examples provided below.

[0147] At least one kind or species of the organometallic compound of Formula 1 may be used between a pair of electrodes in an organic light-emitting device. For example, the organometallic compound may be included in an emission layer. The organometallic compound included in the emission layer may act as a dopant.

[0148] 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 organometallic cyclic compound represented by Formula 1.

[0149] The expression “(an organic layer) includes at least one organometallic compound” as used herein may include a case in which “(an organic layer) includes identical (e.g., substantially identical) compounds represented by Formula 1” (e.g., all molecules having the structure of Formula 1 are the same) as well as a case in which “(an organic layer) includes two or more different organometallic compounds (e.g., two or more compounds having different structures) represented by Formula 1.”

[0150] For example, the organic layer may include, as the organometallic compound, only Compound 1. In this regard, Compound 1 may be included in an emission layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the organometallic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may be included in the same layer (for example, Compound 1 and Compound 2 may both be included in an emission layer), or in different layers (for

example, Compound 1 may be included in an emission layer and Compound 2 may be included in an electron transport region).

[0151] According to one or more embodiments,

[0152] the first electrode of the organic light-emitting device may be an anode,

[0153] the second electrode of the organic light-emitting device may be a cathode,

[0154] the organic layer 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,

[0155] 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

[0156] the electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0157] The term “organic layer” as used herein may refer to a single layer and/or a plurality of layers between the first electrode and the second electrode of the organic light-emitting device. The material included in the “organic layer” is not limited to being an organic material.

[0158] In one or more embodiments, the emission layer may include the organometallic compound represented by Formula 1, the emission layer may further include a host, and an amount of the host in the emission layer may be larger than an amount of the organometallic compound in the emission layer.

[0159] In some embodiments, for example, the host may include a carbazole-containing compound.

[0160] In some embodiments, the hole transport region may include an electron blocking layer, and the electron blocking layer may include the organometallic compound.

[0161] In some embodiments, the electron transport region may include a hole blocking layer, which may include the organometallic compound.

[0162] In some embodiments, the hole transport region may include a p-dopant having a lowest unoccupied molecular orbital (LUMO) energy level of about -3.5 eV.

[0163] In some embodiments, the electron transport region may include a hole blocking layer, and the hole blocking layer may include a phosphine oxide-containing compound and/or a silyl-containing compound.

DESCRIPTION OF THE ACCOMPANYING DRAWING

[0164] The accompanying drawing is a schematic view of an organic light-emitting device **10** according to an embodiment of the present disclosure. The organic light-emitting device **10** includes a first electrode **110**, an organic layer **150**, and a second electrode **190**.

[0165] Hereinafter, the structure of the organic light-emitting device **10** according to an embodiment of the present disclosure and a method of manufacturing the organic light-emitting device **10** will be described in connection with the accompanying drawing.

First Electrode 110

[0166] In the accompanying drawing, a substrate may be 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/or water resistance.

[0167] The first electrode 110 may be formed by depositing and/or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for the first electrode may be selected from materials with a high work function in order to facilitate hole injection.

[0168] 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, the material for forming the first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combination thereof, but embodiments of the present disclosure are not limited thereto. In one or more embodiments, when the first electrode 110 is a semi-transmissive electrode or a reflective 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 combination thereof, but embodiments of the present disclosure are not limited thereto.

[0169] 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.

Organic Layer 150

[0170] The organic layer 150 may be on the first electrode 110. The organic layer 150 may include an emission layer.

[0171] 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.

Hole Transport Region in Organic Layer 150

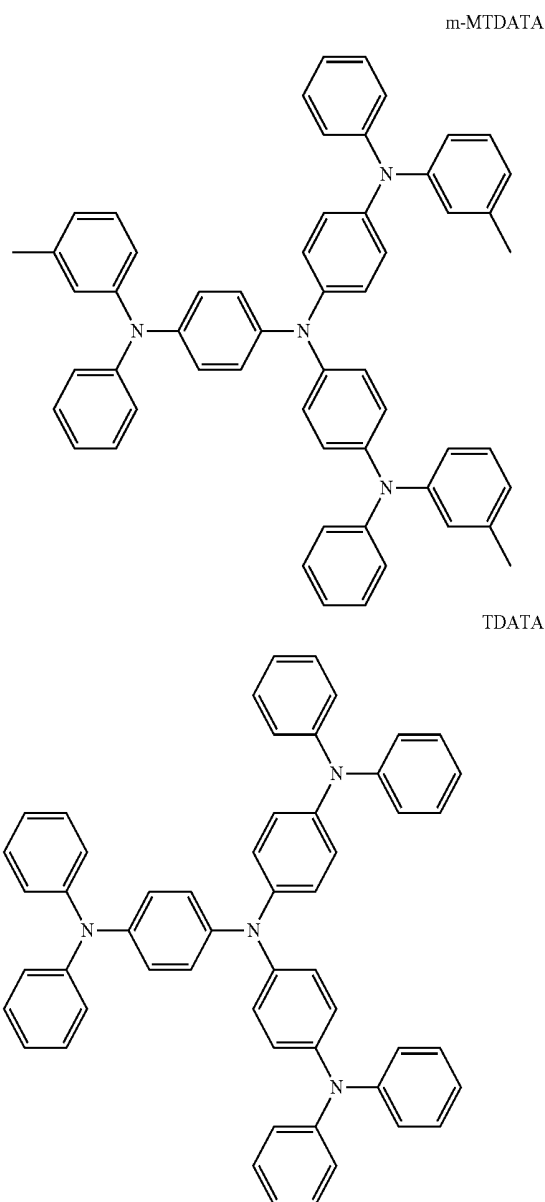
[0172] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0173] 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.

[0174] 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

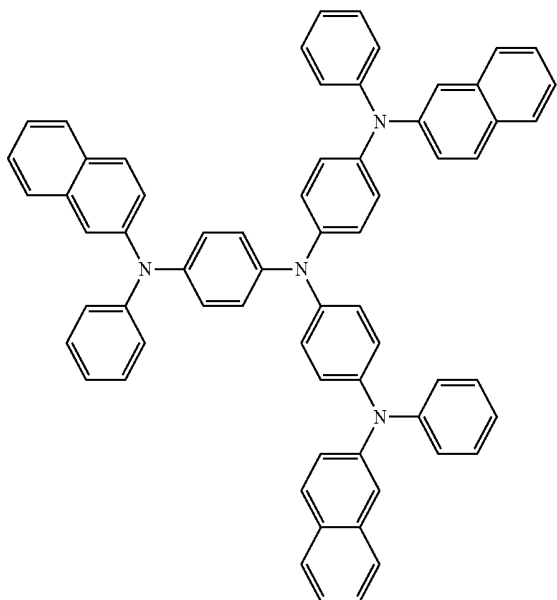
layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/emission auxiliary layer structure, wherein the constituting layers in each structure are sequentially stacked from the first electrode 110 in the stated order, but the structure of the hole transport region is not limited thereto.

[0175] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPB), 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:



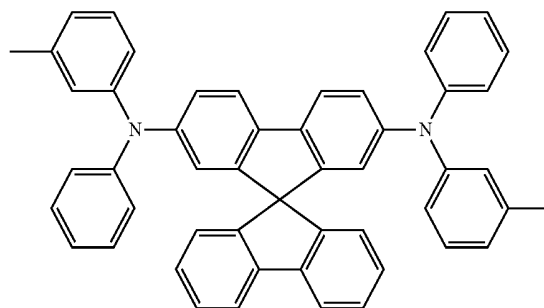
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2-TNATA

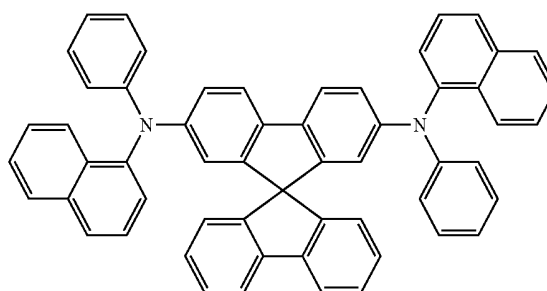


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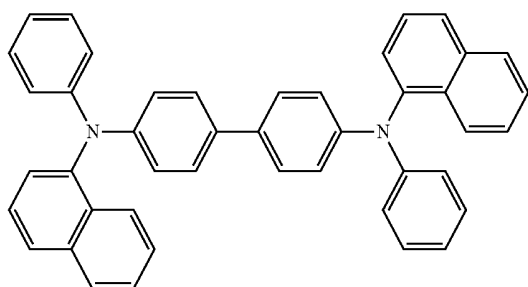
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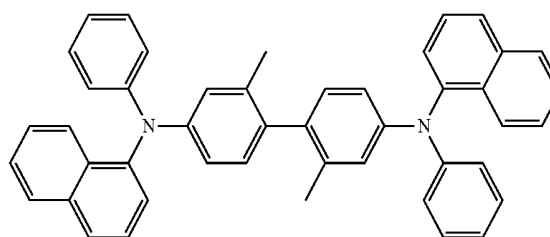
Spiro-NPB



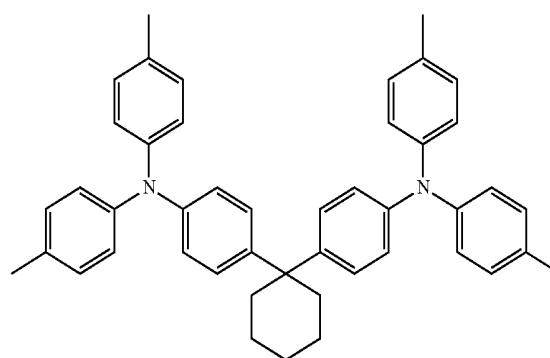
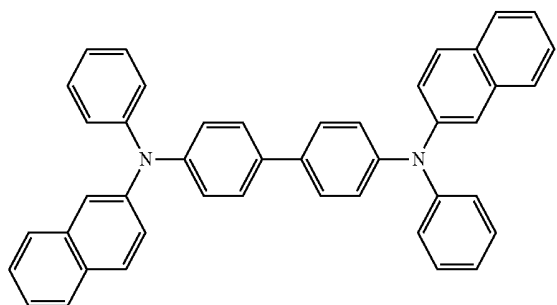
NPB



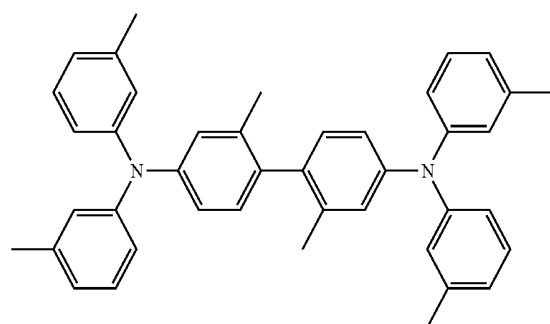
methylated NPB



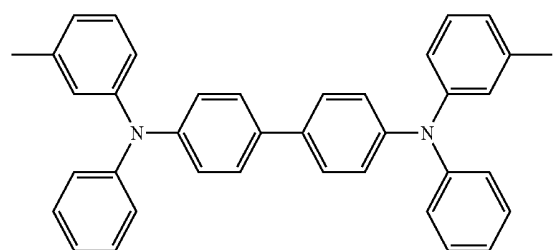
TAPC

 β -NPB

HMPD



TPD



[0177] L₂₀₁ to L₂₀₄ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0179] xa1 to xa4 may each independently be an integer of 0 to 3.

[0181] R₂₀₁ to R₂₀₄ and Q₂₀₁ may each independently be selected from 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 C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0182] For example, in Formula 202, R₂₀₁ and R₂₀₂ may optionally be linked (e.g., coupled) via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R₂₀₃ and R₂₀₄ may optionally be linked (e.g., coupled) via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0185] 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 carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylene group, and a pyridinylene group; and

[0186] 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 carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene 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 carbazolylenylene 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, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, and $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, and Q_{31} to Q_{33} may each independently be selected from a $\text{C}_1\text{-C}_{10}$ alkyl group, a $\text{C}_1\text{-C}_{10}$ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0187] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0188] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0189] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from 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

[0190] 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ 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 $\text{C}_1\text{-C}_{10}$ alkyl group, a phenyl group substituted with $-\text{F}$, 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, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$ and $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, and

[0191] Q_{31} to Q_{33} may each independently be the same as described above.

[0192] In one or more embodiments, in Formula 201, at least one of R_{201} to R_{203} may each independently be selected from the group consisting of:

[0193] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0194] 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ 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 $\text{C}_1\text{-C}_{10}$ alkyl group, a phenyl group substituted with $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

[0195] but embodiments of the present disclosure are not limited thereto.

[0196] In one or more embodiments, in Formula 202, i) R_{201} and R_{202} may be linked (e.g., coupled) via a single bond, and/or ii) R_{203} and R_{204} may be linked (e.g., coupled) via a single bond.

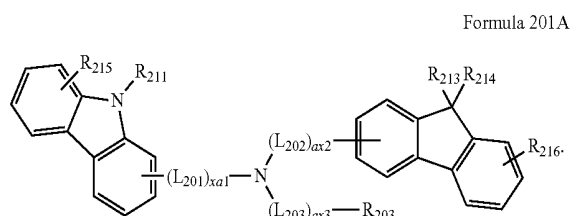
[0197] In one or more embodiments, in Formula 202, at least one of R_{201} to R_{204} may be selected from the group consisting of:

[0198] a carbazolyl group; and

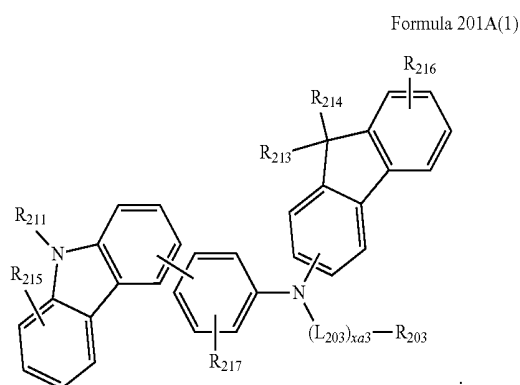
[0199] a carbazolyl group substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ 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 $\text{C}_1\text{-C}_{10}$ alkyl group, a phenyl group substituted with $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

[0200] but embodiments of the present disclosure are not limited thereto.

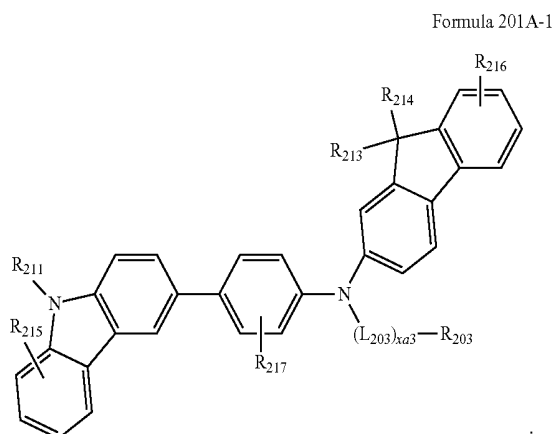
[0201] The compound represented by Formula 201 may be represented by Formula 201A:



[0202] In some embodiments, the compound represented by Formula 201 may be further represented by Formula 201A(1), but embodiments of the present disclosure are not limited thereto:

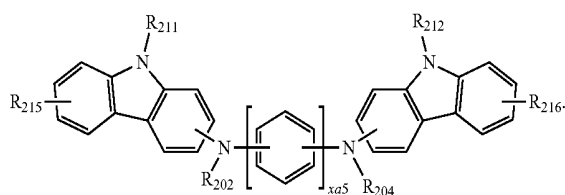


[0203] In some embodiments, the compound represented by Formula 201 may be further represented by Formula 201A-1, but embodiments of the present disclosure are not limited thereto:



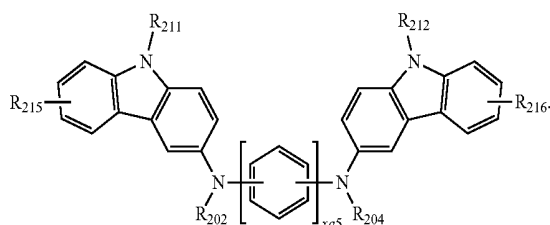
[0204] In some embodiments, the compound represented by Formula 202 may be further represented by Formula 202A:

Formula 202A



[0205] In some embodiments, the compound represented by Formula 202 may be further represented by Formula 202A-1:

Formula 202A-1



[0206] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

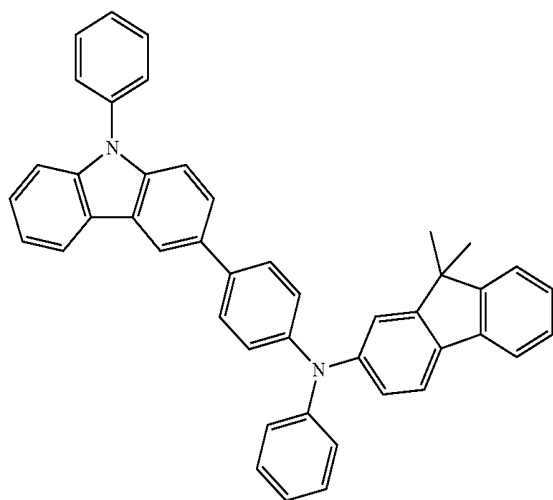
[0207] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} may each independently be the same as described above,

[0208] R_{211} and R_{212} may each independently be the same as described in connection with R_{203} , and

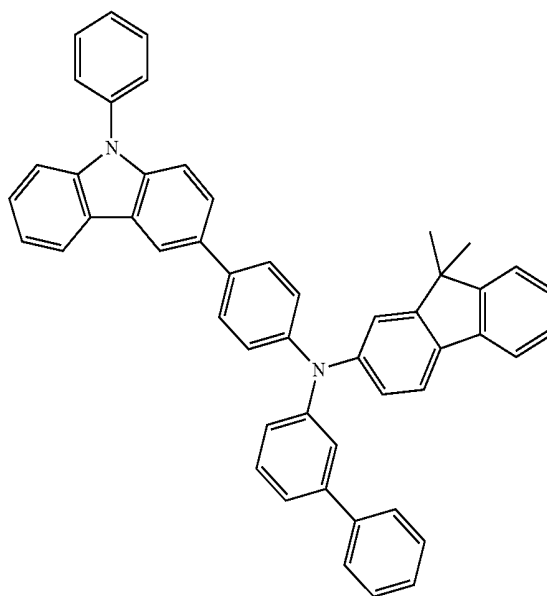
[0209] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl 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.

[0210] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

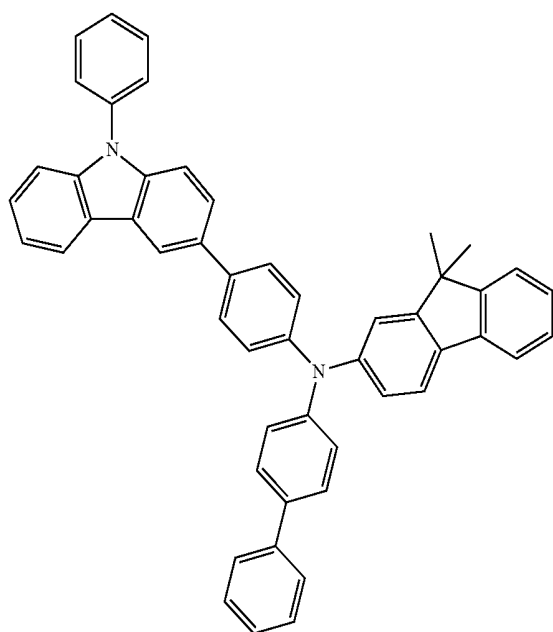
HT1



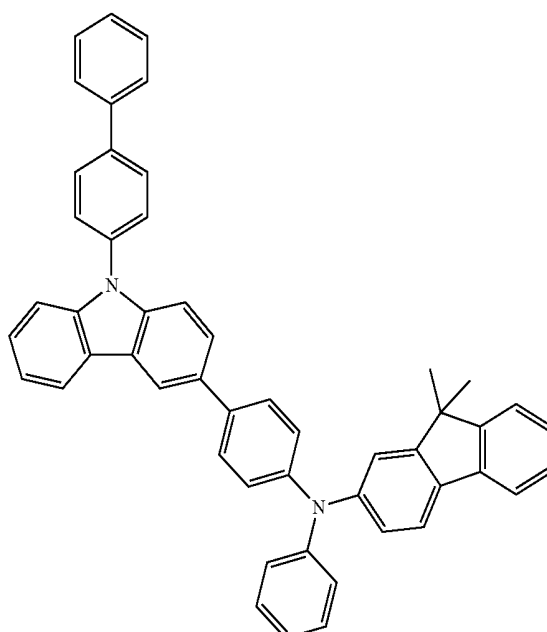
HT2



HT3

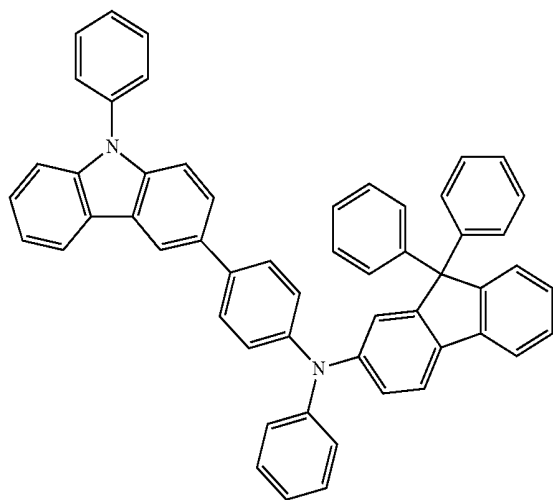


HT4

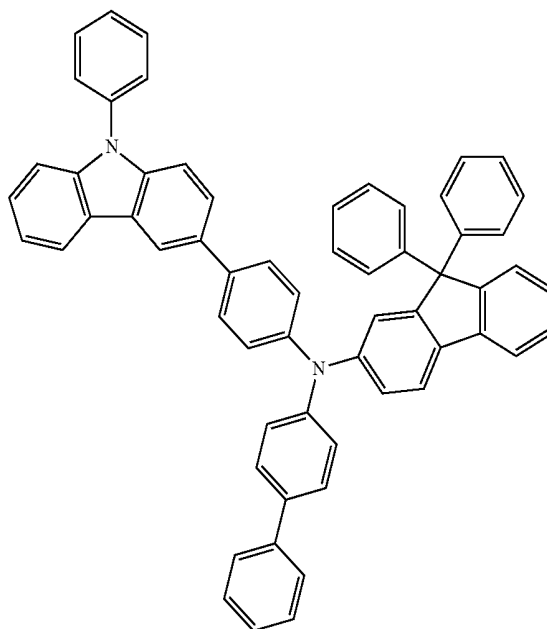


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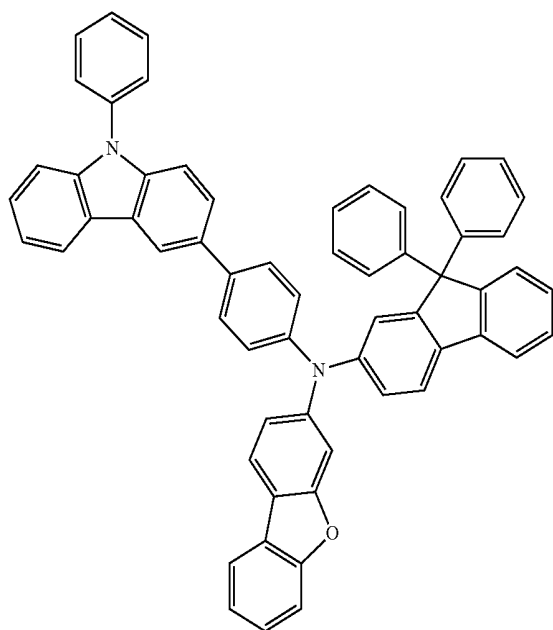
HT5



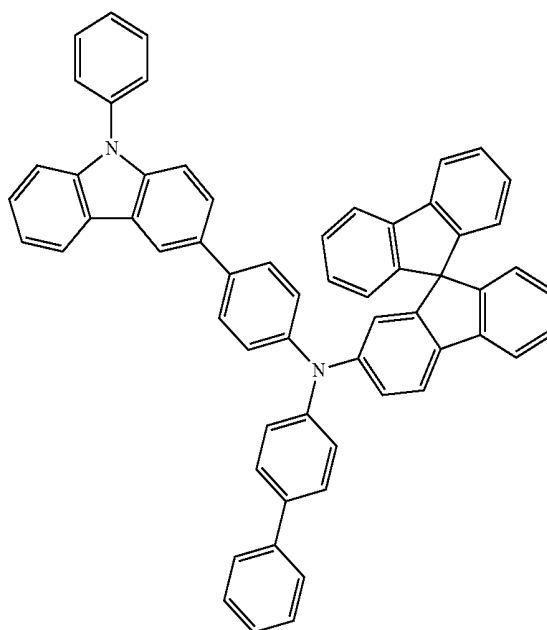
HT6



HT7

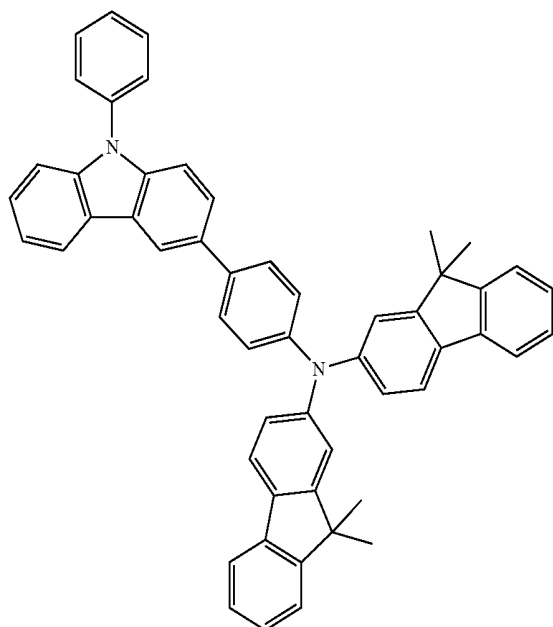


HT8

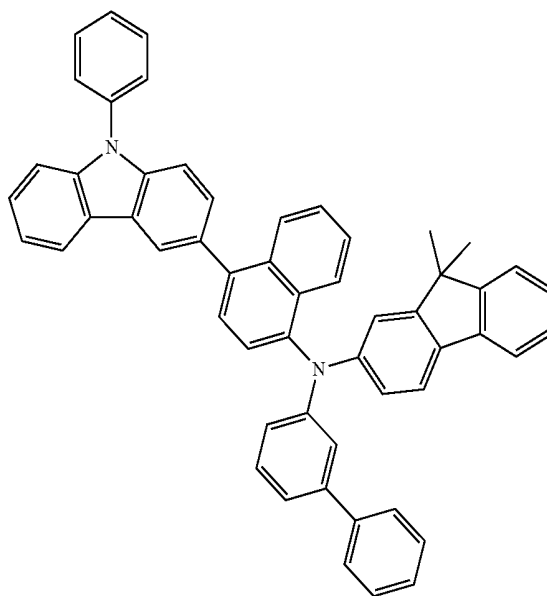


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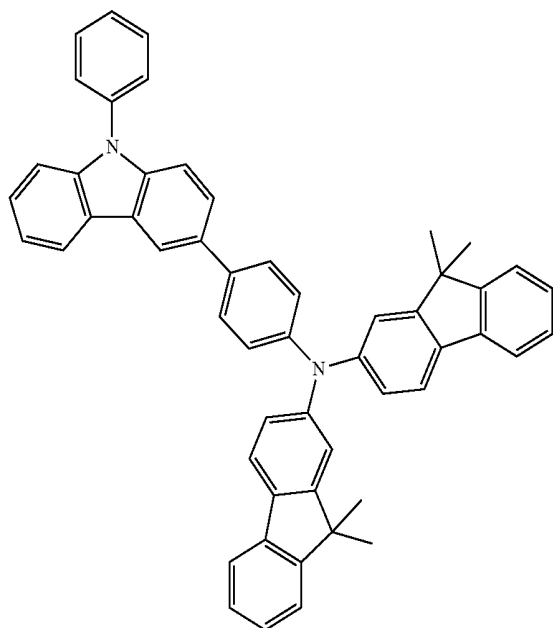
HT9



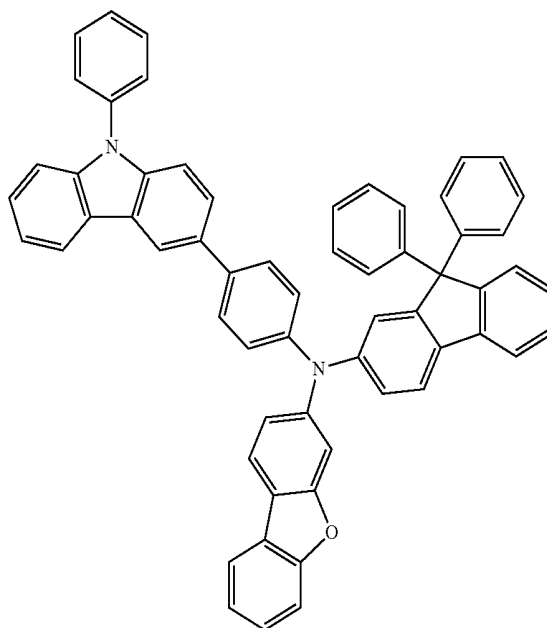
HT10



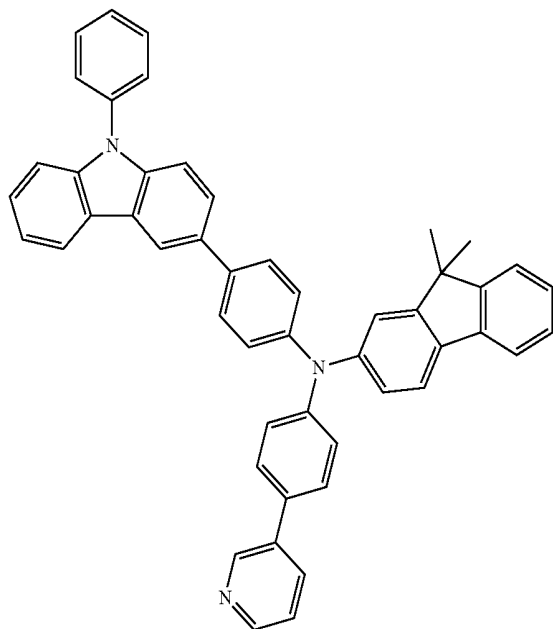
HT11



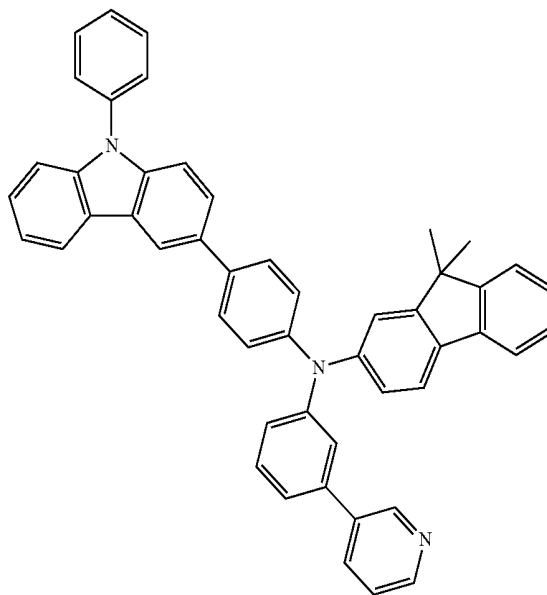
HT12



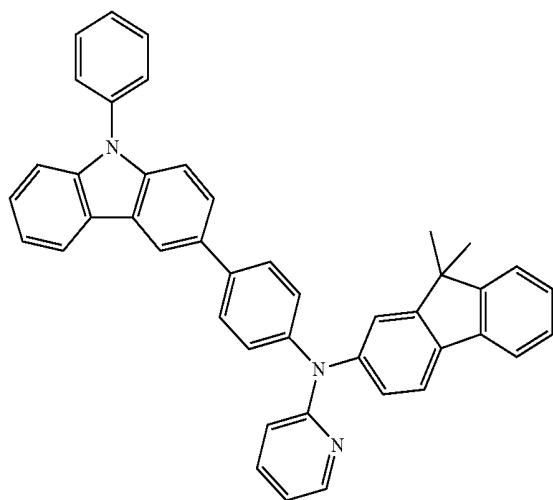
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HT13



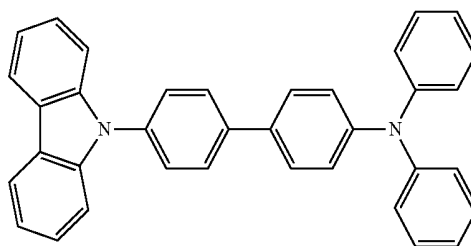
HT14



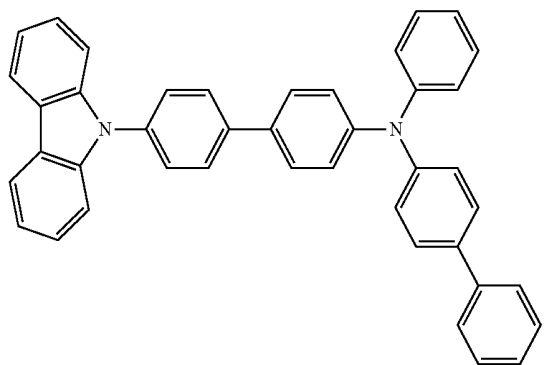
HT15



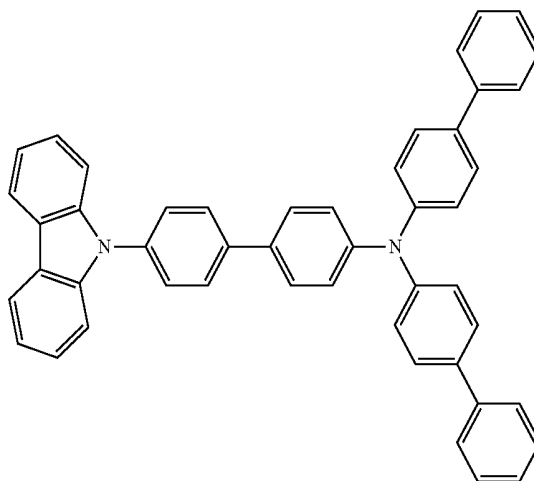
HT16



HT17

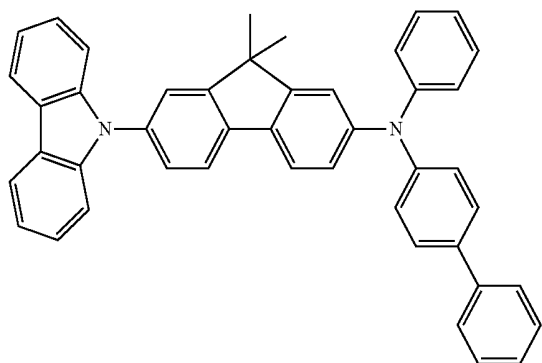


HT18

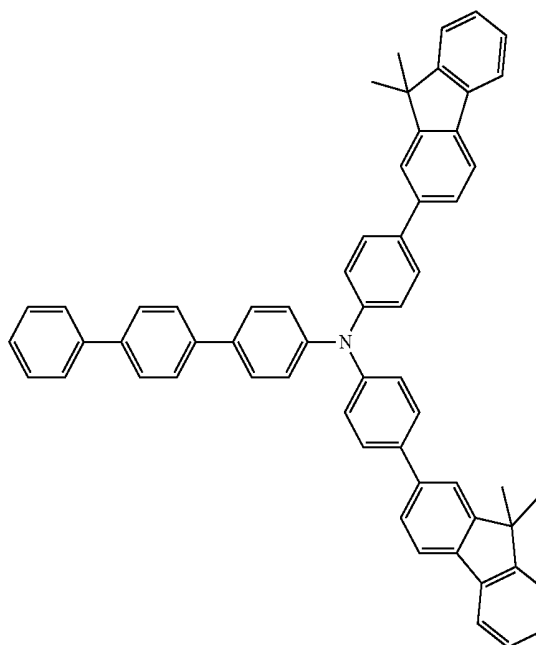


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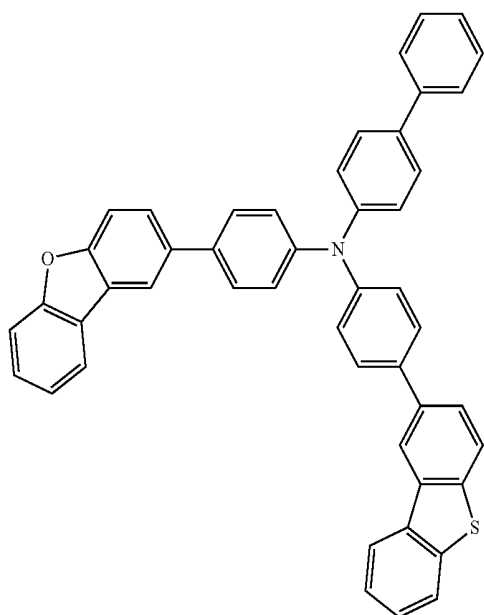
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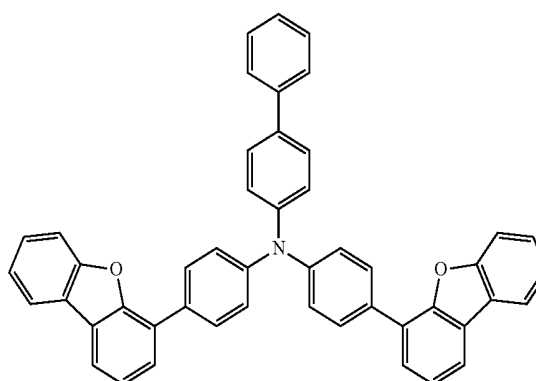
HT20



HT21

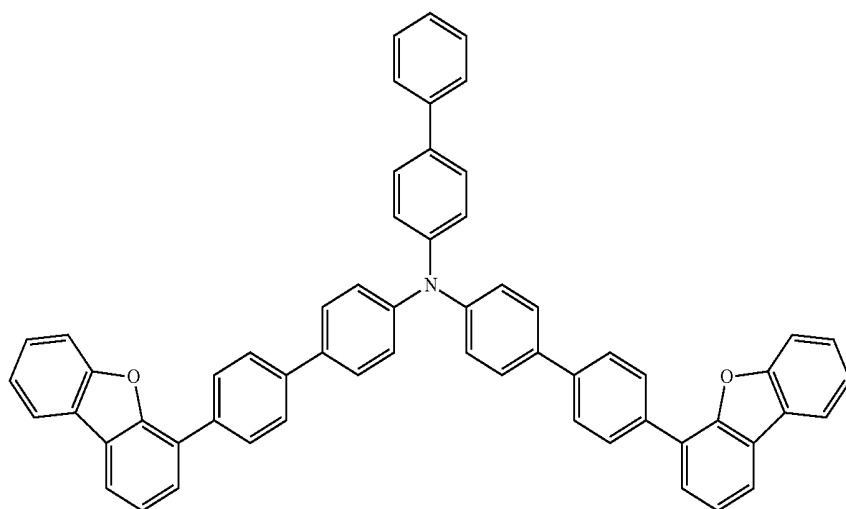


HT22

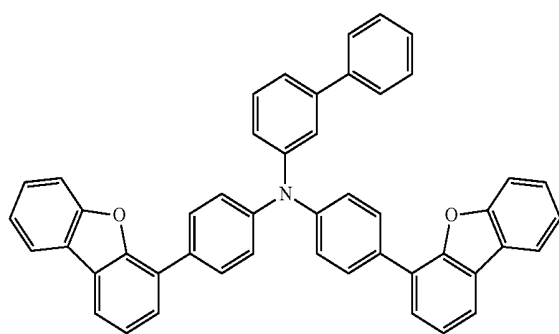


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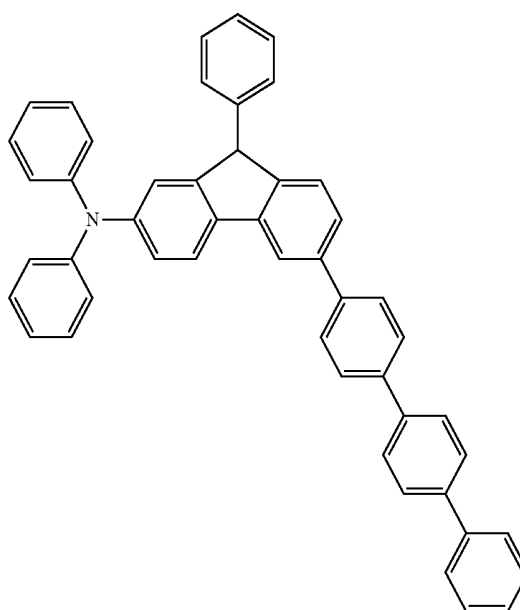
HT23



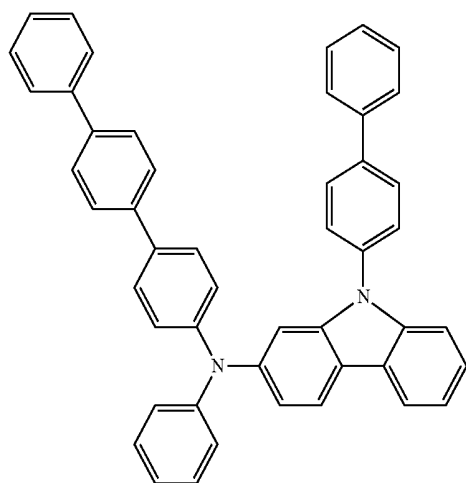
HT24



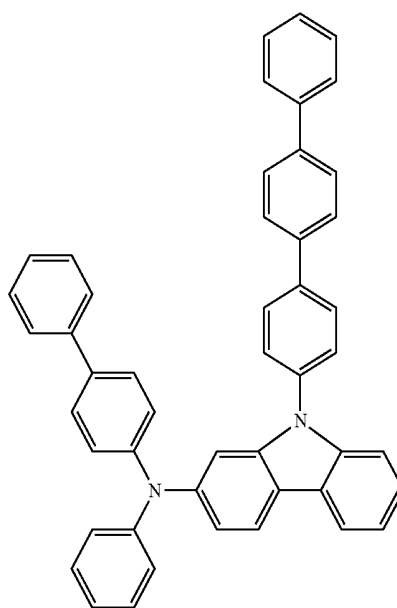
HT25



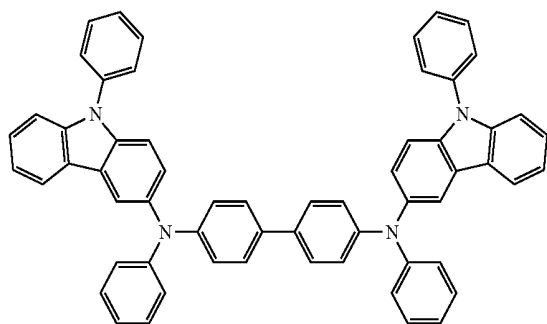
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HT26



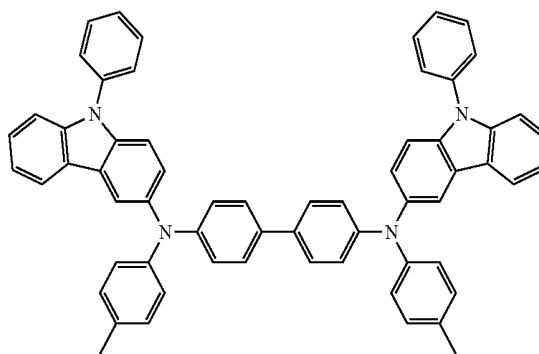
HT27



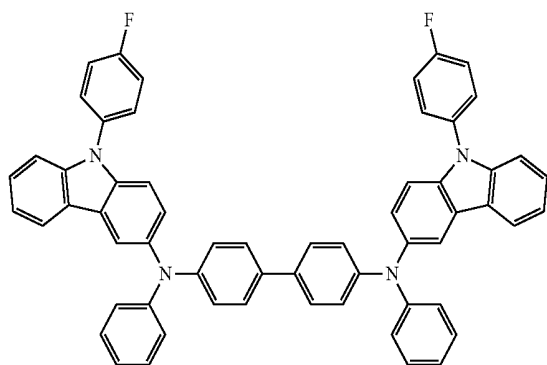
HT28



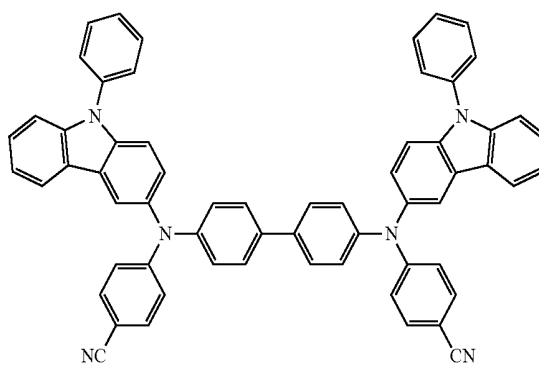
HT29



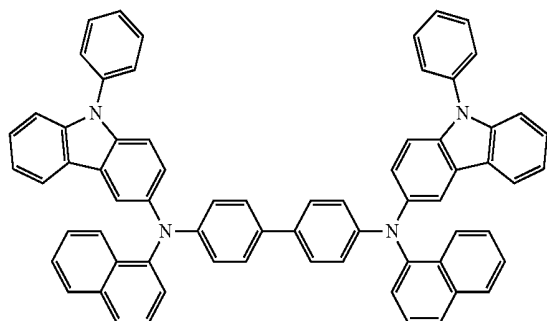
HT30



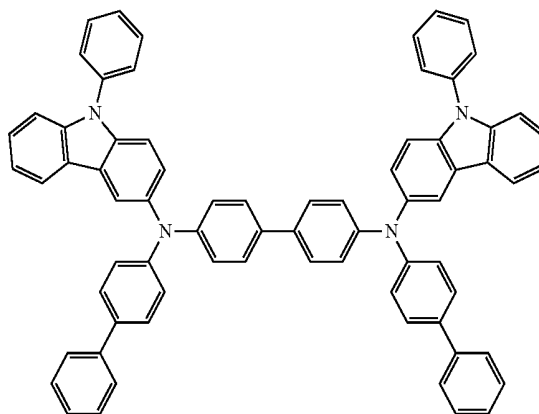
HT31



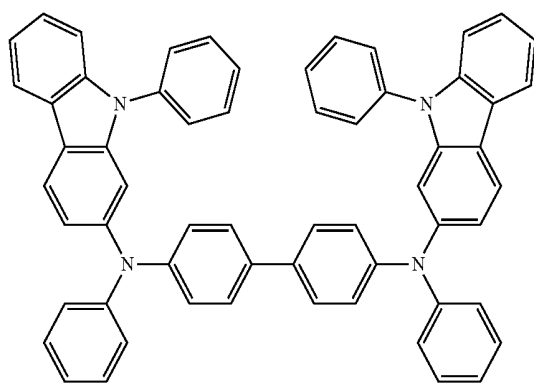
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HT32



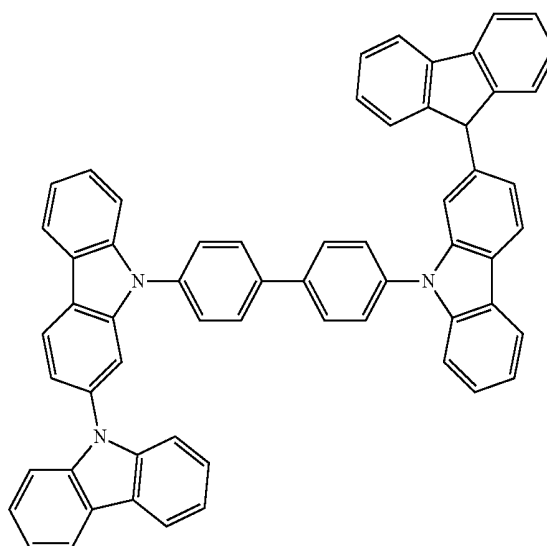
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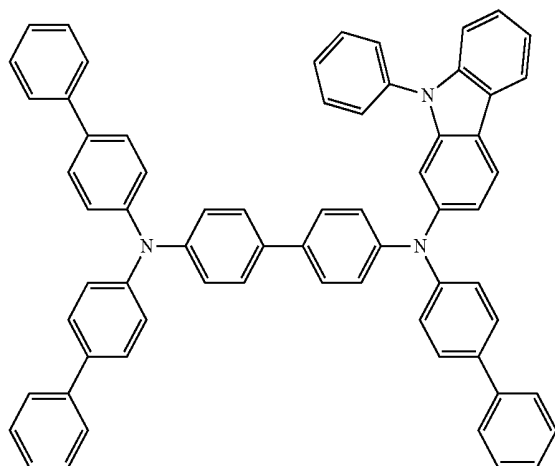
HT34



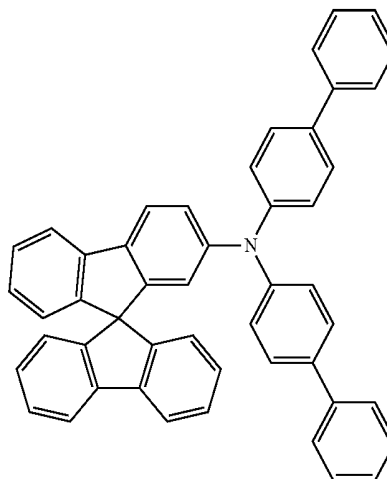
HT35



HT36

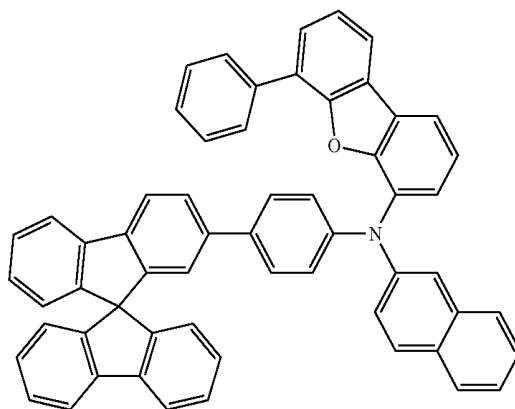
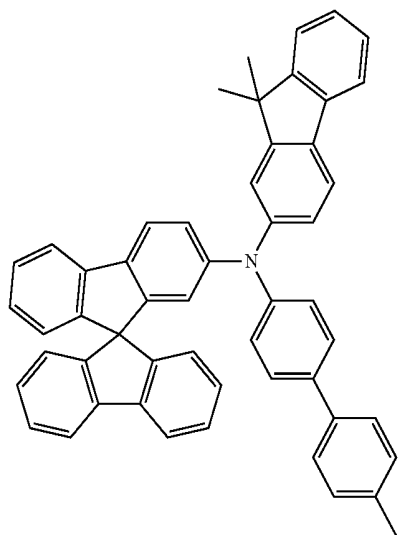


HT37



-continued
HT38

HT39



[0211] The thickness of the hole transport region may be 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, the thickness of the hole injection layer may be about 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be 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, suitable or satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0212] 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 (e.g., by adjusting the optical resonance distance in the device to match the wavelength of light emitted from the emission layer), and the electron blocking layer may block or reduce 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.

p-Dopant

[0213] 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.

[0214] The charge-generation material may be, for example, a p-dopant.

[0215] In some embodiments, the p-dopant may have a lowest unoccupied molecular (LUMO) energy level of -3.5 eV or less.

[0216] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto.

[0217] For example, the p-dopant may include at least one selected from the group consisting of:

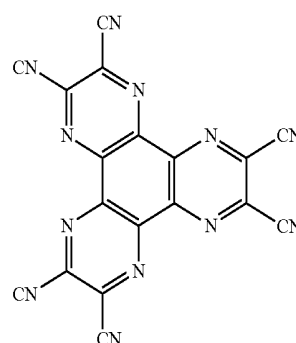
[0218] a quinone derivative (such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ));

[0219] a metal oxide (such as tungsten oxide or molybdenum oxide);

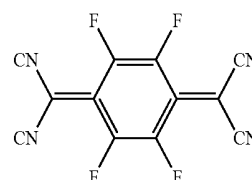
[0220] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0221] a compound represented by Formula 221,

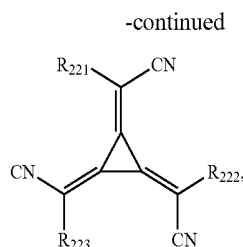
[0222] but embodiments of the present disclosure are not limited thereto:



HAT-CN



F4-TCNQ



[0223] In Formula 221,

[0224] 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 of R_{221} to R_{223} has 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 $-I$.

Emission Layer in Organic Layer 150

[0225] 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 (e.g., corresponding to a group of sub-pixels). In one or more embodiments, the emission layer may have a stacked structure including 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 may contact each other or may be separated from each other. In one or more 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.

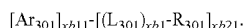
[0226] The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0227] An amount of the dopant in the emission layer may be about 0.01 parts by weight 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.

[0228] The thickness of the emission layer may be 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.

Host in Emission Layer

[0229] In one or more embodiments, the host may include a compound represented by Formula 301.



Formula 301

[0230] In Formula 301,

[0231] 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,

[0232] $xb11$ may be 1, 2, or 3,

[0233] 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,

[0234] $xb1$ may be an integer of 0 to 5,

[0235] 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 O_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 - G_{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 $-P(=O)(Q_{301})(Q_{302})$,

[0236] $xb21$ may be an integer from 1 to 5,

[0237] 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.

[0238] In some embodiments, Ar_{301} in Formula 301 may be selected from the group consisting of:

[0239] 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

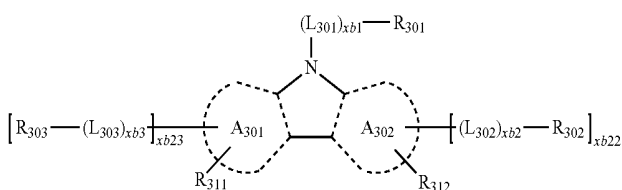
[0240] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, 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(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

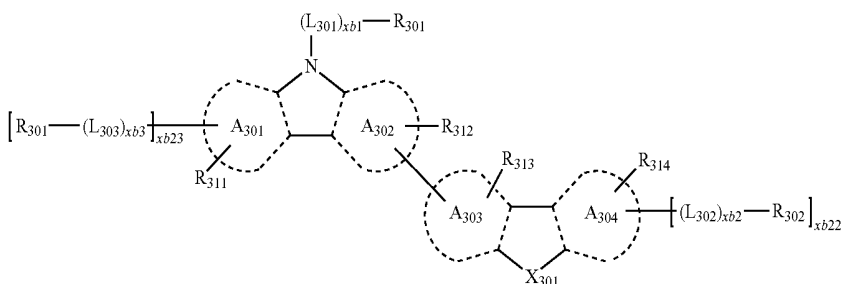
[0241] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0242] When xb11 in Formula 301 is two or more, two or more Ar301(s) may be linked (e.g., coupled) via a single bond.

[0243] In one or more embodiments, the compound represented by Formula 301 may be further represented by Formula 301-1 or 301-2:



Formula 301-1



Formula 301-2

[0244] In Formulae 301-1 and 301-2,

[0245] A₃₀₁ to A₃₀₄ may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a naphthyl group, a biphenyl group, a terphenyl group, a naphthyl group —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0246] X₃₀₁ may be O, S, or N—[(L₃₀₄)xb4-R₃₀₄],

[0247] R₃₁₁ to R₃₁₄ 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, a naphthyl group —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0248] xb22 and xb23 may each independently be 0, 1, or 2,

[0249] L₃₀₁, xb1, R₃₀₁, and Q₃₁ to Q₃₃ may each independently be the same as described above,

[0250] L₃₀₂ to L₃₀₄ may each independently be the same as described in connection with L₃₀₁,

[0251] xb2 to xb4 may each independently be the same as described in connection with xb1, and

[0252] R₃₀₂ to R₃₀₄ may each independently be the same as described in connection with R₃₀₁.

[0253] For example, in Formulae 301, 301-1, and 301-2, L₃₀₁ to L₃₀₄ may each independently be selected from the group consisting of:

[0254] 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 triphenylenylene group, a pyrenylene group, a chrysénylene group, a perylenylene 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 triazininylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolininylylene 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

[0255] a phenylene group, a naphthylene group, a fluorenylylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysénylylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a

thiophenylene group, a furanylene group, a carbazolyene group, an indolyene group, an isoindolyene group, a benzofuranylene group, a benzothiophenylene group, a benzofuranylene group, a benzothiophenylene group, a benzocarbazolyene group, a dibenzocarbazolyene group, a dibenzosilolyene group, a pyridinylene group, an imidazolyene group, a pyrazolyene group, a thiazolyene group, an isothiazolyene group, an oxazolyene group, an isoxazolyene group, a thiadiazolyene group, an oxadiazolyene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolyene group, an isobenzothiazolyene group, a benzoxazolyene group, an isobenzoxazolyene group, a triazolyene group, a tetrazolyene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolyene 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 - O_{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 quinolyl group, an isoquinolyl group, a benzoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalyl group, a quinazolyl group, a cinnolyl 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, —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

[0256] Q_{31} to Q_{33} may each independently be the same as described above.

[0257] In some embodiments, in Formulae 301, 301-1, and 301-2, R_{301} to R_{304} may each independently be selected from the group consisting of:

[0258] 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 quinolyl group, an isoquinolyl group, a benzoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalyl group, a quinazolyl group, a cinnolyl 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; and

[0259] 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 quinolyl group, an isoquinolyl group, a benzoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalyl group, a quinazolyl group, a cinnolyl 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 quinolyl group, an isoquinolyl group, a benzoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalyl group, a quinazolyl group, a

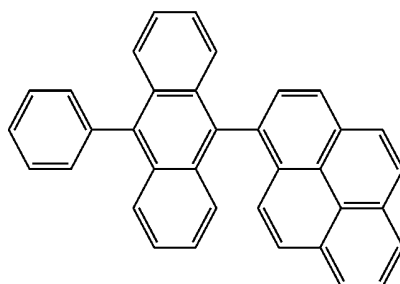
cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, 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

[0260] Q_{31} to Q_{33} may each independently be the same as described above.

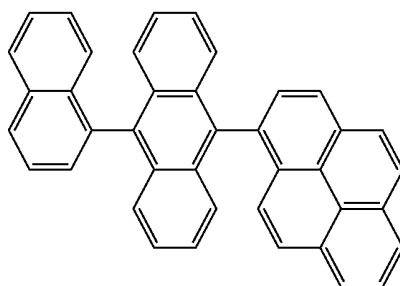
[0261] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), an Mg complex, and a Zn complex.

[0262] 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-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:

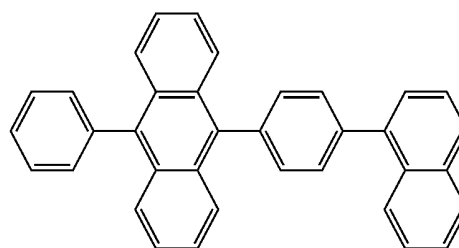
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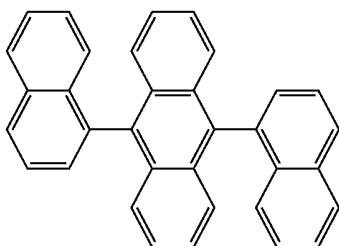
H5



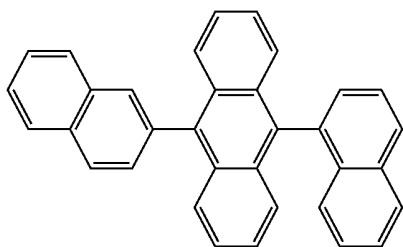
H6



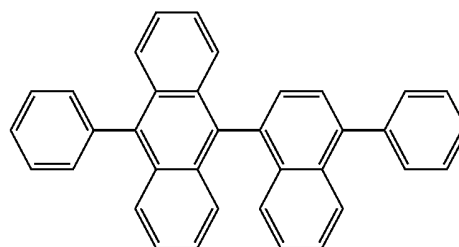
H7



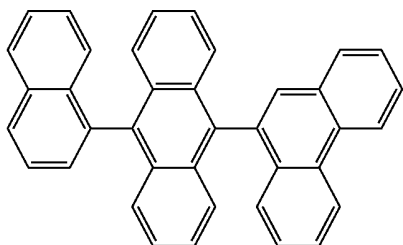
H1



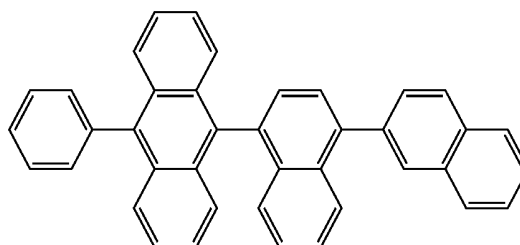
H2



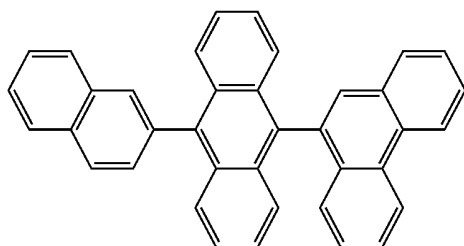
H8



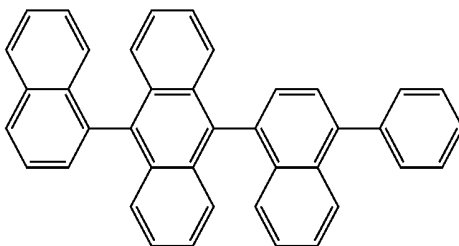
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H9

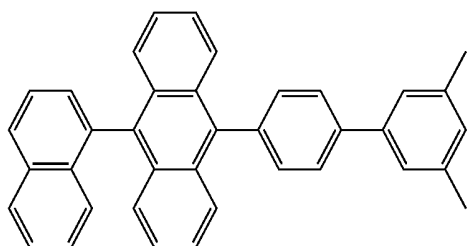


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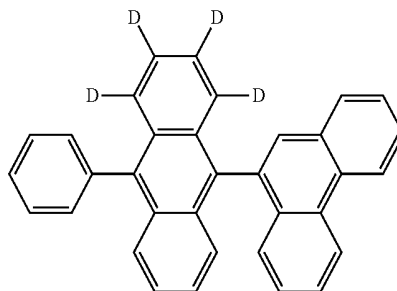
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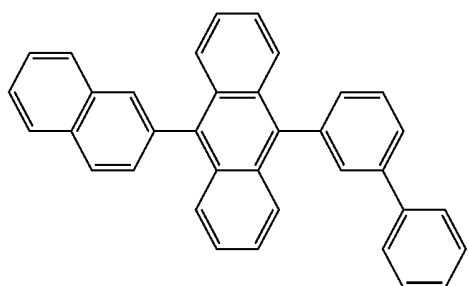


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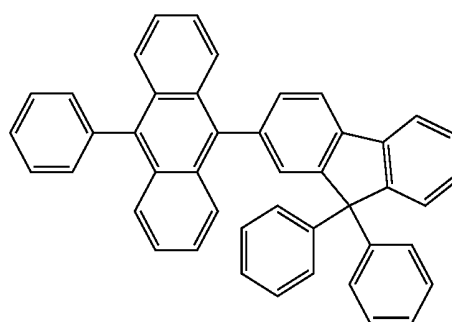
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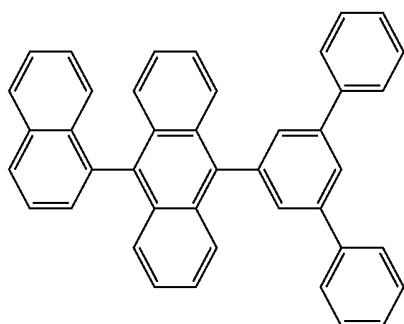
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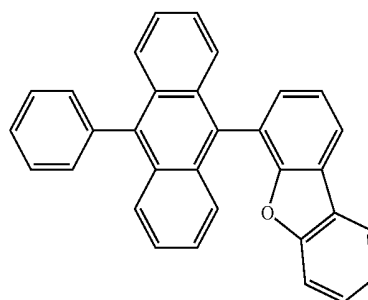
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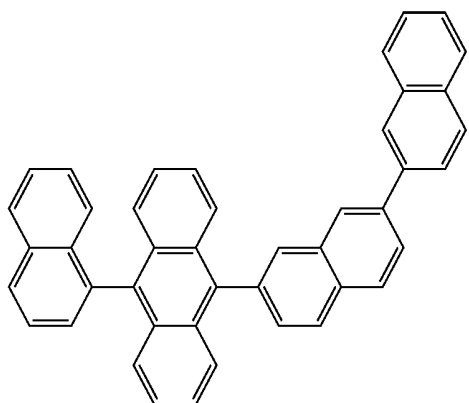
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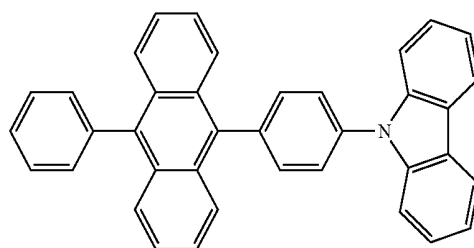
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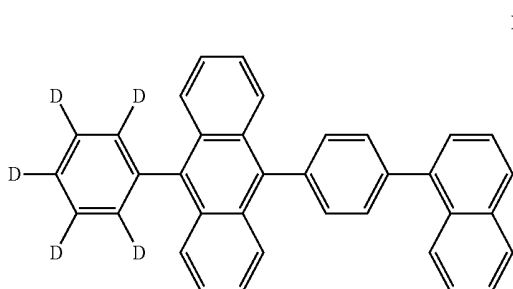
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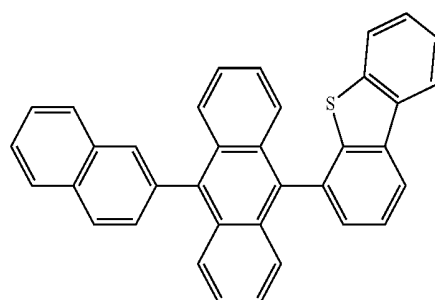
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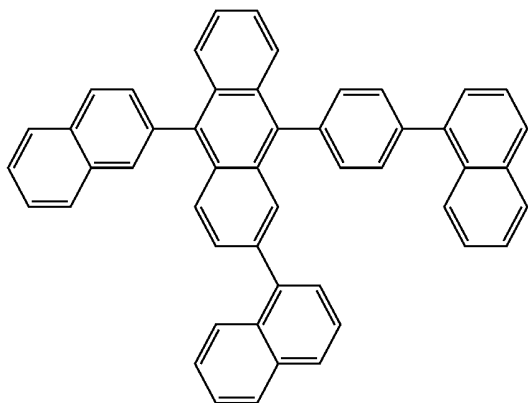
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H20

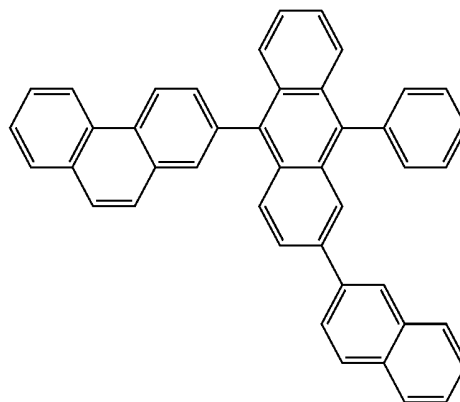
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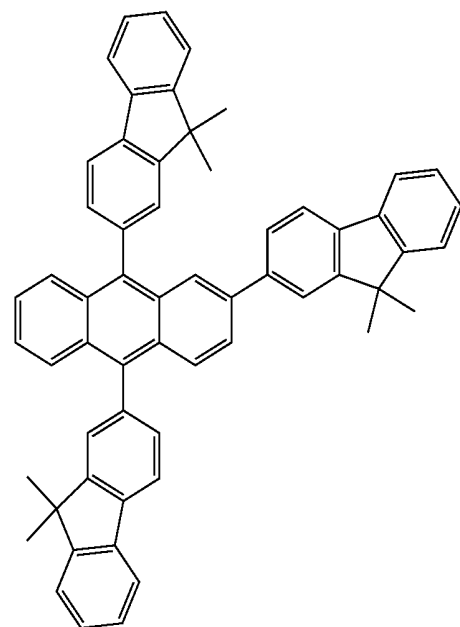


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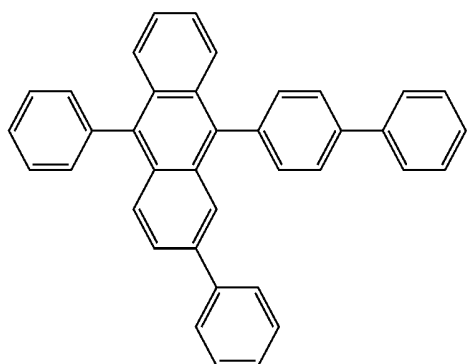
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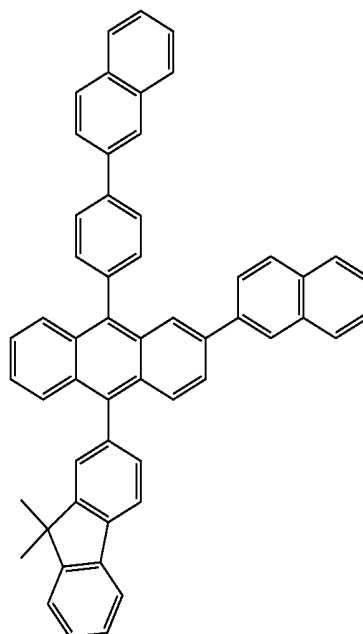
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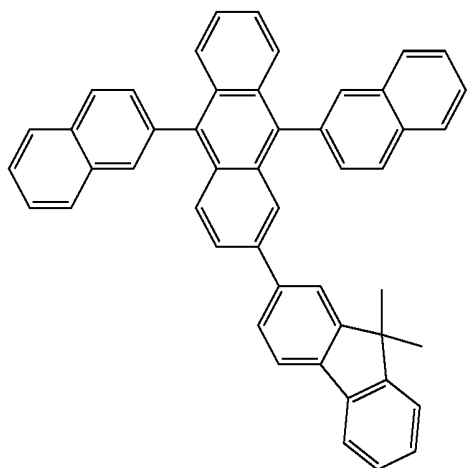
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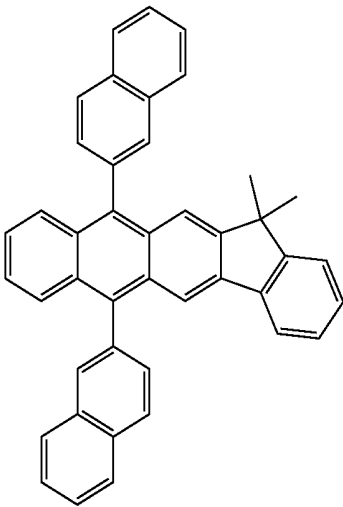
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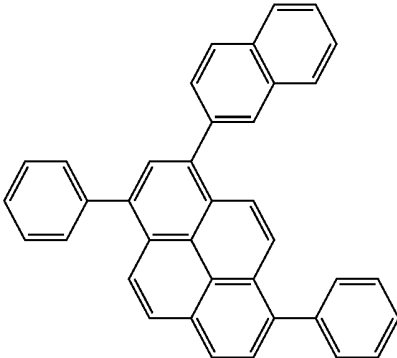


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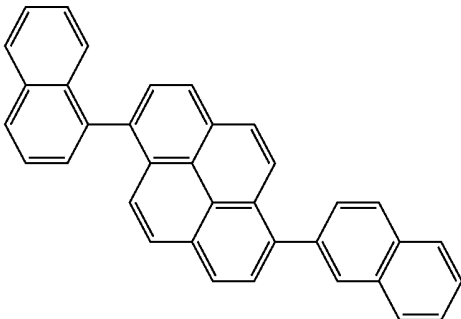


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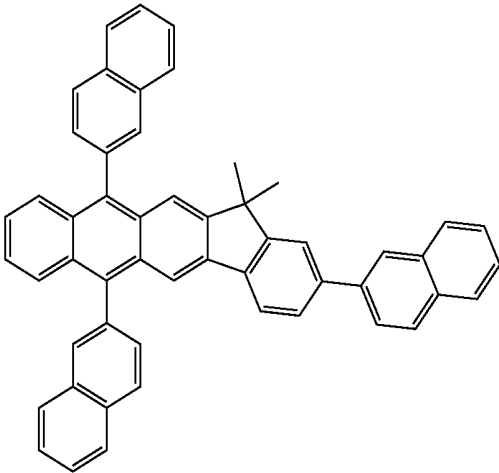


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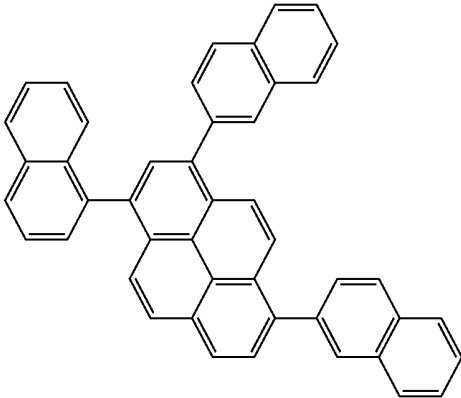


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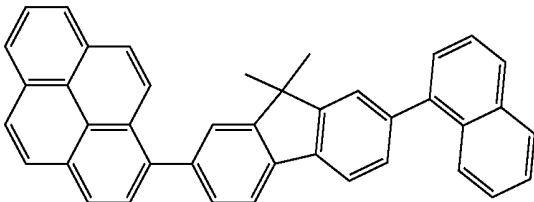
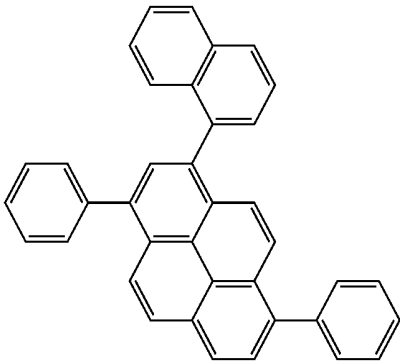


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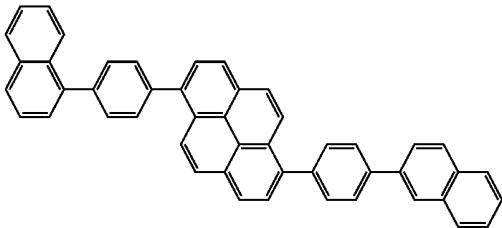


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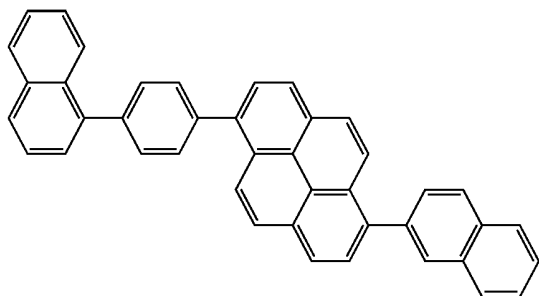


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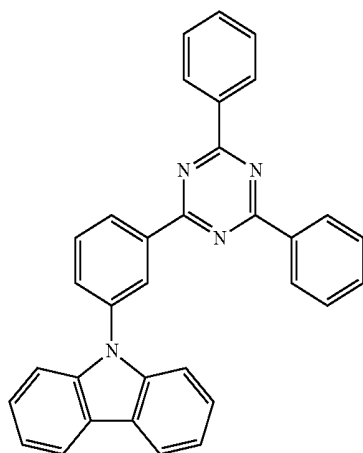


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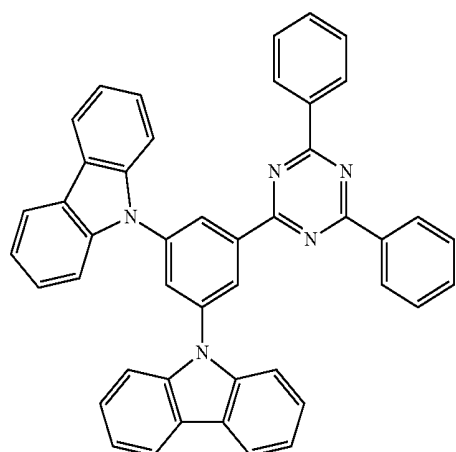
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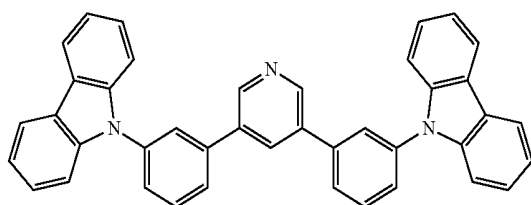
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H37

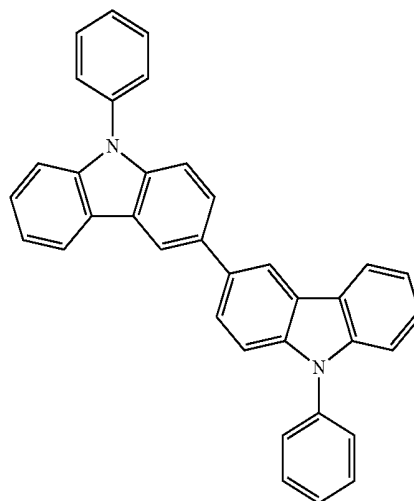


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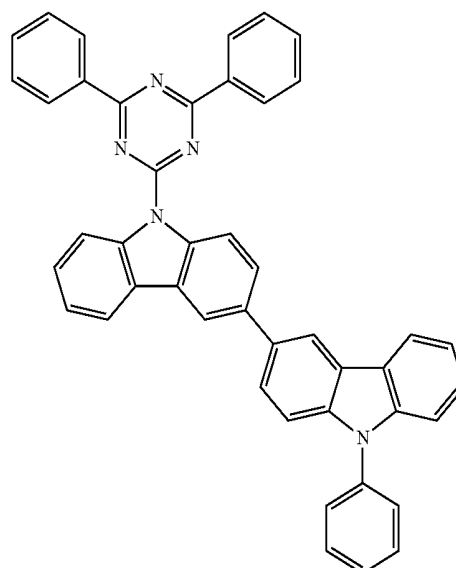


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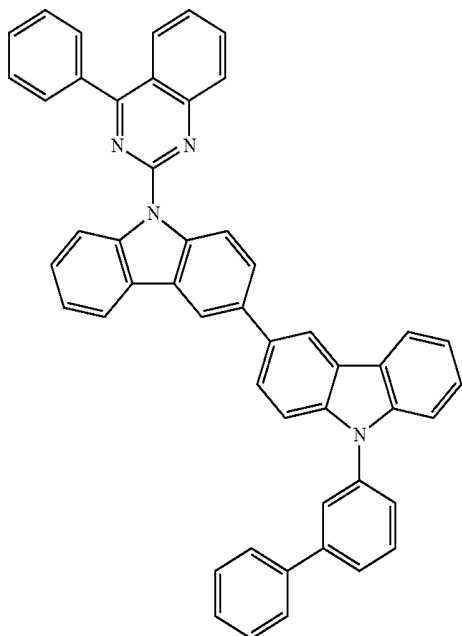
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H40

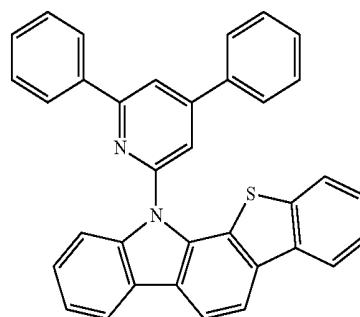


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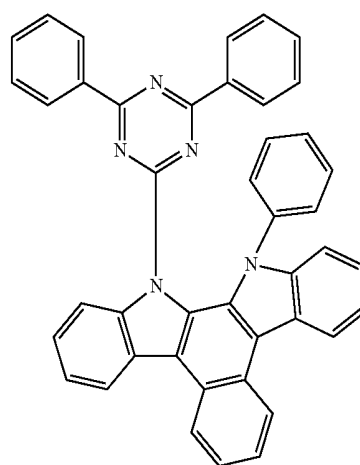


H41

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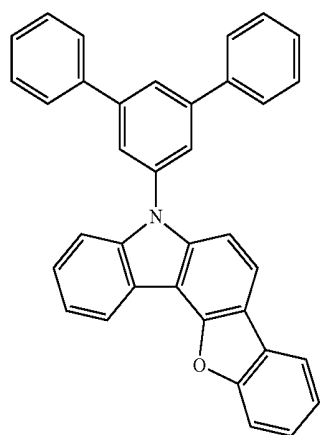


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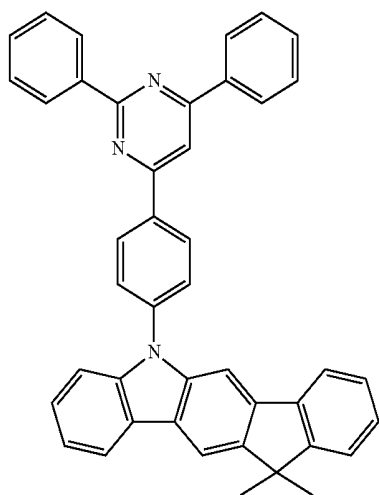


H45

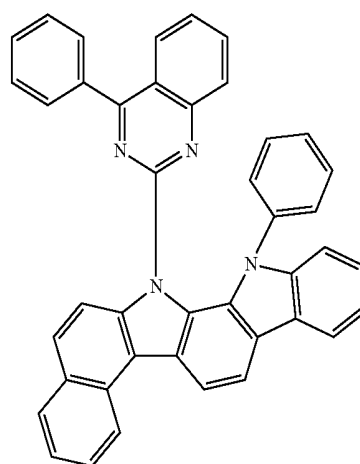
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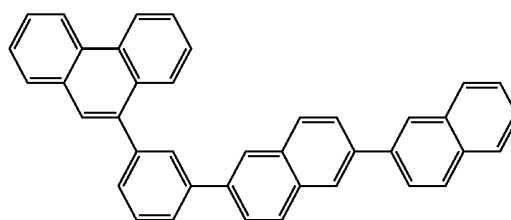
H43



H46

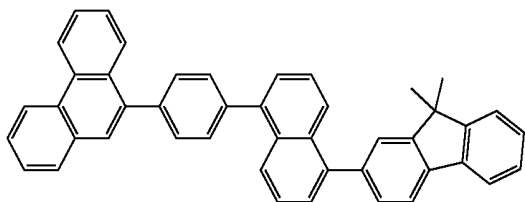


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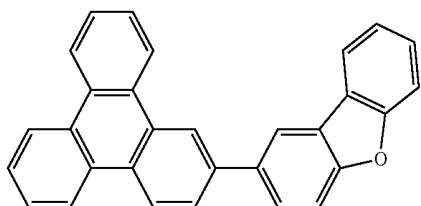


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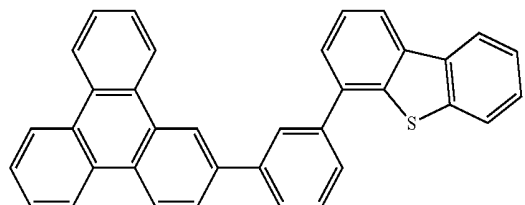
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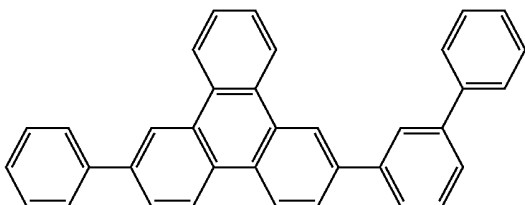
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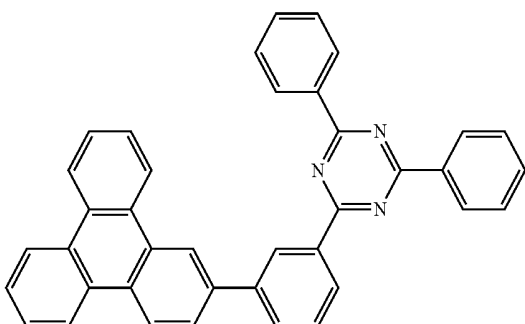
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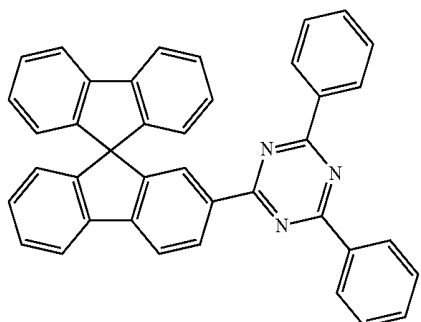
H51



H52

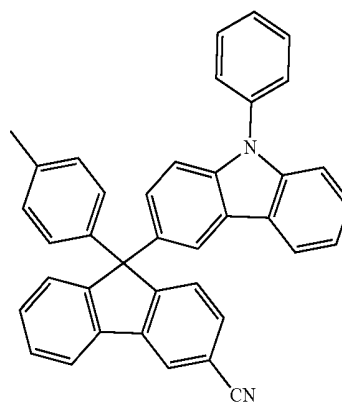


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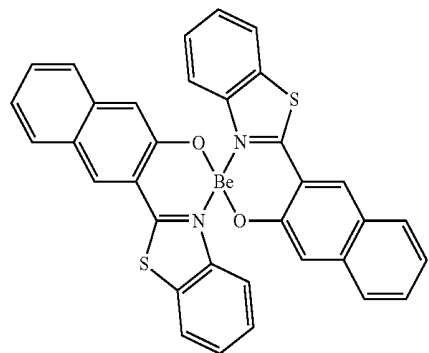


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H54



H55



[0263] In some embodiments, the host may include at least one selected from a silicon-containing compound (for example, BCPDS as used in the examples and/or the like) and a phosphine oxide-containing compound (for example, POPCPA as used in the examples and/or the like).

[0264] However, embodiments of the present disclosure are not limited thereto. In some embodiments, the host may include only one compound, or two or more different compounds (for example, BCPDS and/or POPCPA).

Phosphorescent Dopant Included in Emission Layer in Organic Layer 150

[0265] The phosphorescent dopant may include an organometallic compound represented by Formula 1.

Electron Transport Region in Organic Layer 150

[0266] 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.

[0267] 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.

[0268] 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 the constituting layers in each structure are sequentially stacked on the emission layer. However, embodiments of the structure of the electron transport region are not limited thereto.

[0269] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, and/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.

[0270] The term “ π electron-depleted nitrogen-containing ring” as used herein may refer to a ring-forming moiety, and for example, may be a C_1 - C_{60} heterocyclic group including at least one $*-N=*$ moiety.

[0271] For example, the “ π electron-depleted nitrogen-containing ring” may be i) a 5-membered to 7-membered heteromonocyclic group including at least one $*-N=*$ moiety, ii) a heteropolycyclic group including two or more condensed 5-membered to 7-membered heteromonocyclic groups, wherein each 5-membered to 7-membered heteromonocyclic group includes at least one $*-N=*$ moiety, or iii) a heteropolycyclic group in which at least one 5-membered to 7-membered heteromonocyclic group is condensed with at least one C_5 - C_{60} carbocyclic group, wherein each 5-membered to 7-membered heteromonocyclic group includes at least one $*-N=*$ moiety.

[0272] Non-limiting examples of the π electron-depleted nitrogen-containing ring may include 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, but embodiments of the present disclosure are not limited thereto.

[0273] For example, the electron transport region may include a compound represented by Formula 601:



[0274] In Formula 601,

[0275] 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,

[0276] $xe11$ may be 1, 2, or 3,

[0277] 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,

[0278] $xe1$ may be an integer from 0 to 5,

[0279] 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 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, $-Si(Q_{601})(Q_{602})(Q_{603})$, $-C(=O)(Q_{601})$, $-S(=O)_2(Q_{601})$, and $-P(=O)(Q_{601})(Q_{602})$, 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

[0280] $xe21$ may be an integer from 1 to 5.

[0281] In some embodiments, at least one Ar_{601} group and R_{601} group (among the total number of groups provided by $xe11$ and $xe21$, respectively) may include the π electron-depleted nitrogen-containing ring described above.

[0282] In some embodiments, in Formula 601, ring Ar_{601} may be selected from the group consisting of:

[0283] 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 indenanthracene 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

[0284] 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 indenanthracene 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

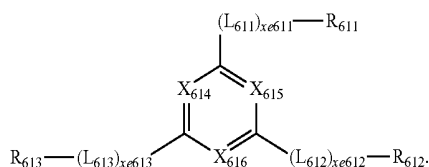
[0285] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0286] When xe11 in Formula 601 is two or more, two or more Ar₆₀₁(s) may be linked (e.g., coupled) via a single bond.

[0287] In one or more embodiments, Ar₆₀₁ in Formula 601 may be an anthracene group.

[0288] In one or more embodiments, a compound represented by Formula 601 may be further represented by Formula 601-1:

Formula 601-1



[0289] In Formula 601-1,

[0290] X₆₁₄ may be N or C(R₆₁₄), X₆₁₅ may be N or C(R₆₁₅), and X₆₁₆ may be N or C(R₆₁₆), wherein at least one of X₆₁₄ to X₆₁₆ may be N,

[0291] L₆₁₁ to L₆₁₃ may each independently be the same as described in connection with L₆₀₁,

[0292] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0293] R₆₁₁ to R₆₁₃ may each independently be the same as described in connection with R₆₀₁, and

[0294] 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.

[0295] In some embodiments, in Formulae 601 and 601-1, L₆₀₁ and L₆₁₁ to L₆₁₃ may each independently be selected from the group consisting of:

[0296] 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, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isox-

azolylenylene 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 imidazopyridinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

[0297] 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, 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

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, but embodiments of the present disclosure are not limited thereto.

[0298] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0299] In one or more embodiments, in Formulae 601 and 601-1, R₆₀₁ and R₆₁₁ to R₆₁₃ may each independently be selected from the group consisting of:

[0300] 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;

[0301] 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

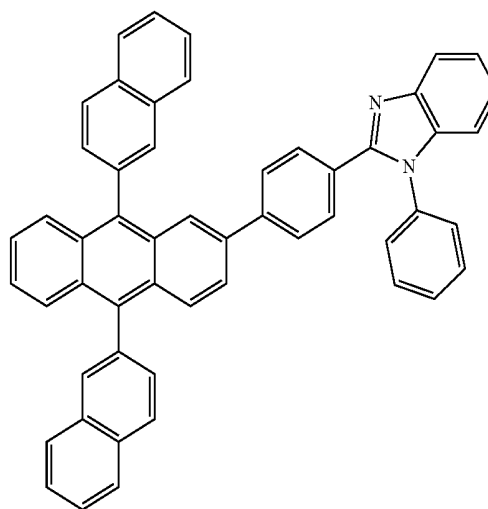
group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 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; and

[0302] —S(=O)₂(Q₆₀₁) and —P(=O)(Q₆₀₁)(Q₆₀₂), and

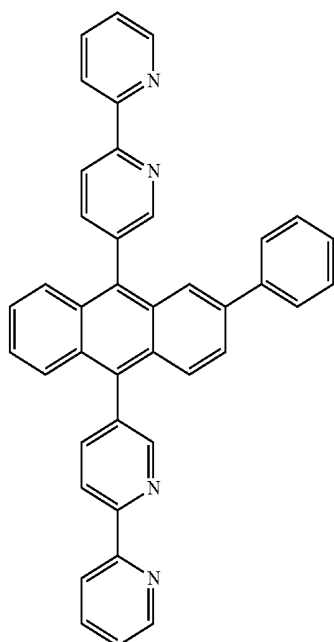
[0303] Q₆₀₁ and Q₆₀₂ may each independently be the same as described above.

[0304] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:

ET1



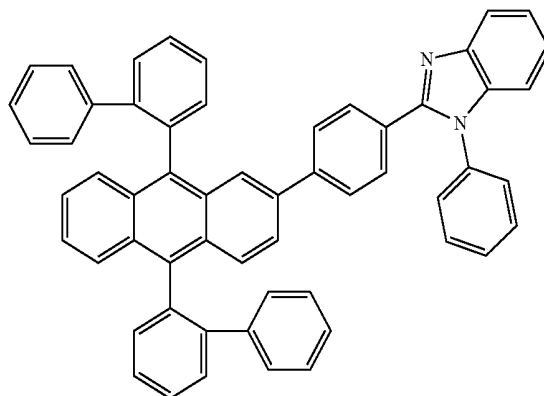
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ET2

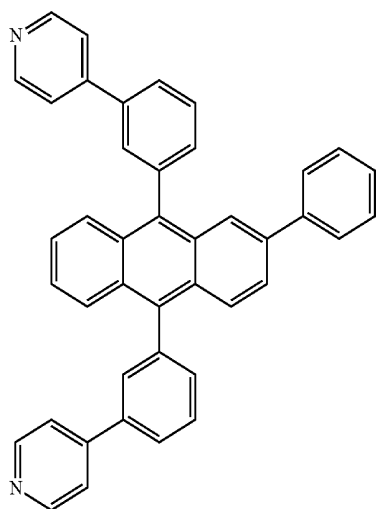
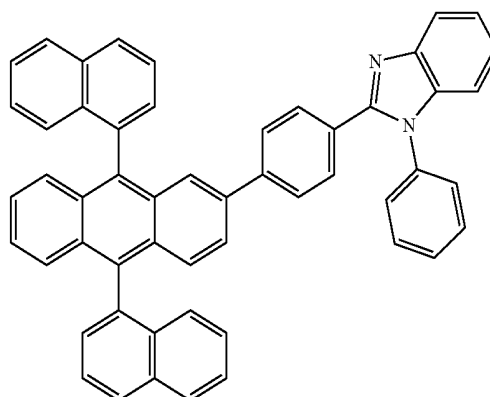
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ET5



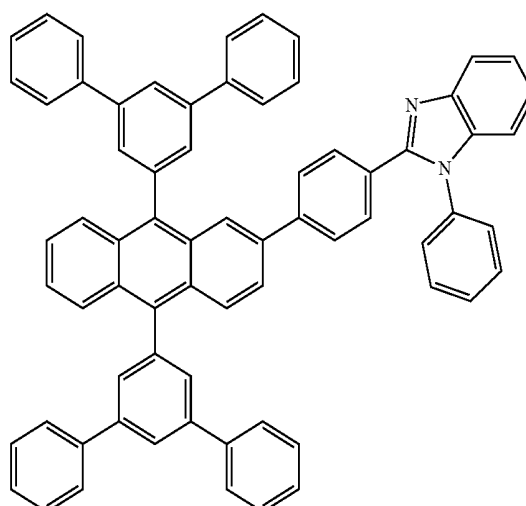
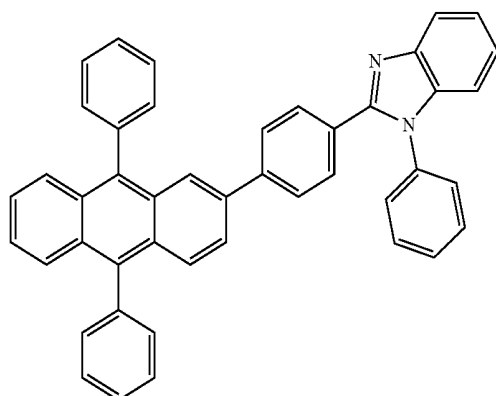
ET3

ET6

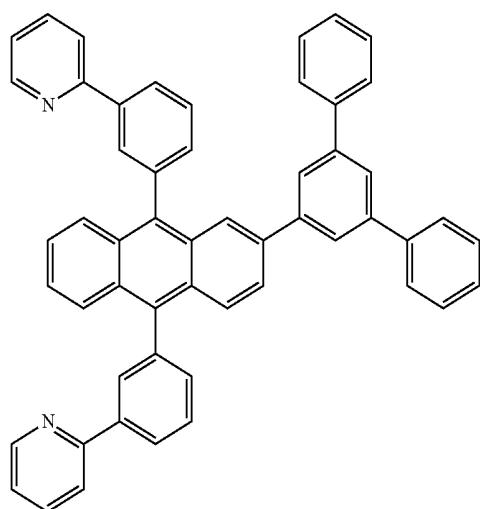


ET4

ET7

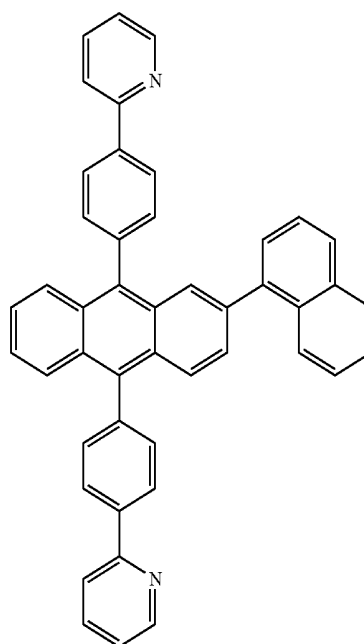


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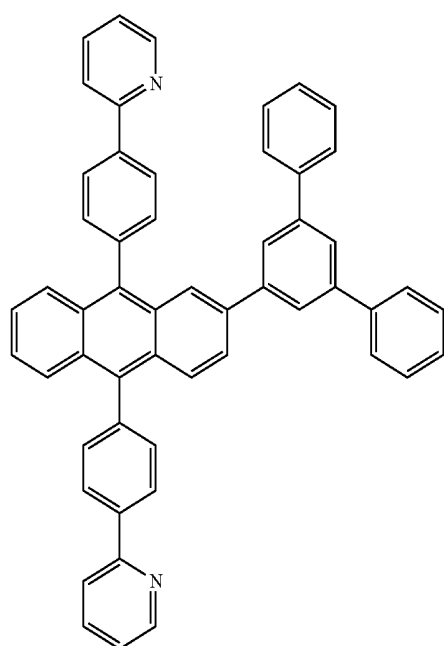


ET8

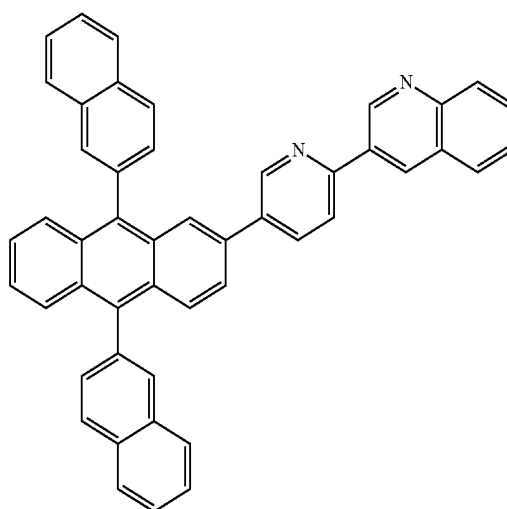
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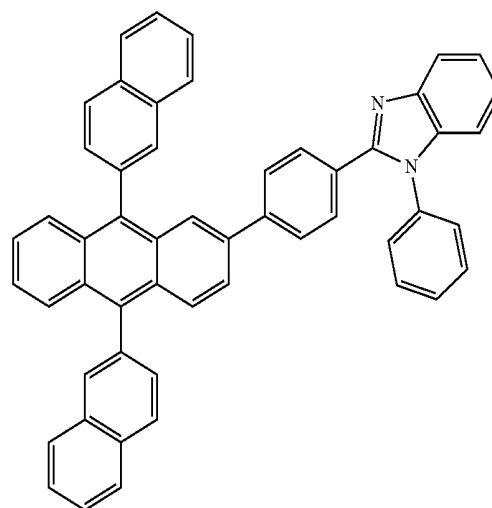
ET10



ET9



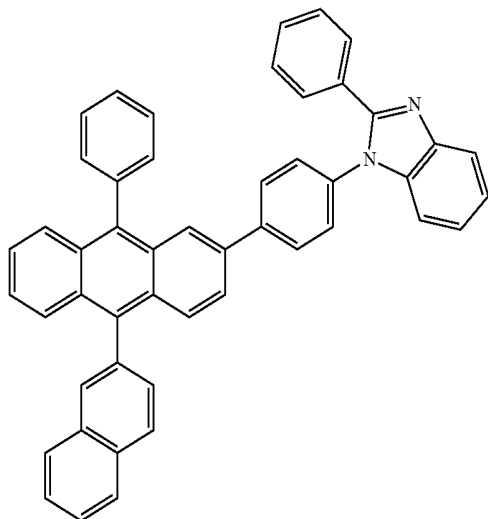
ET11



ET12

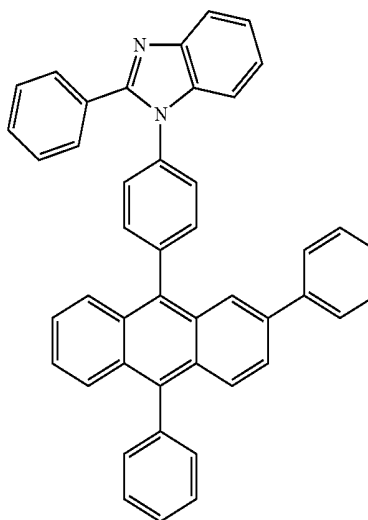
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ET13

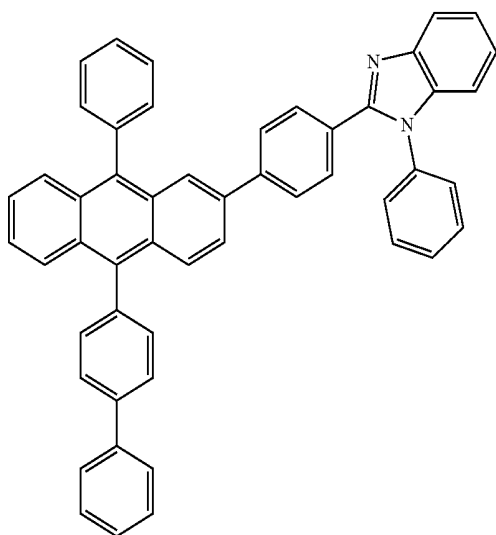


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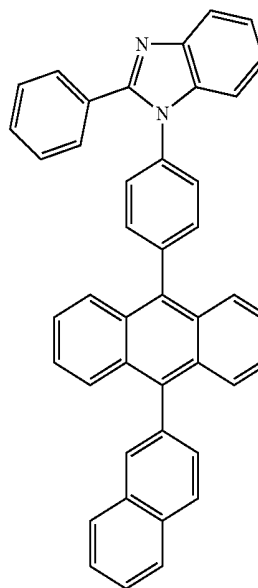
ET16



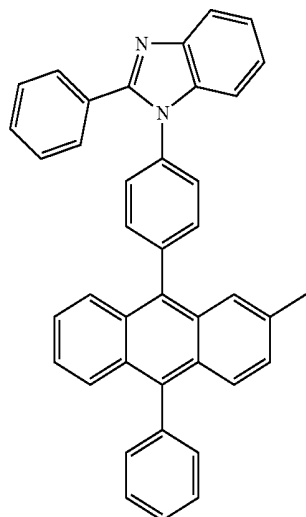
ET14



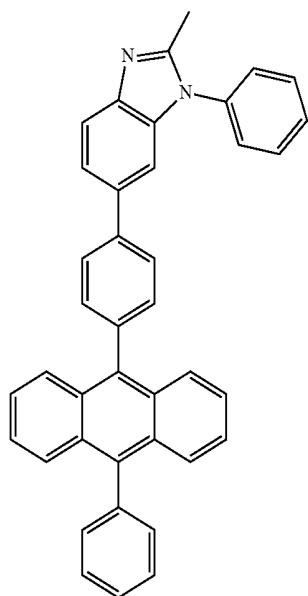
ET17



ET15

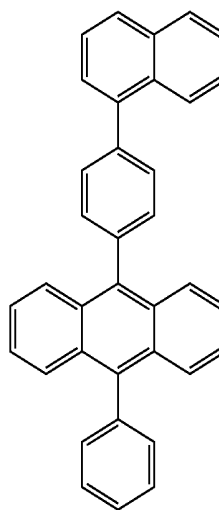


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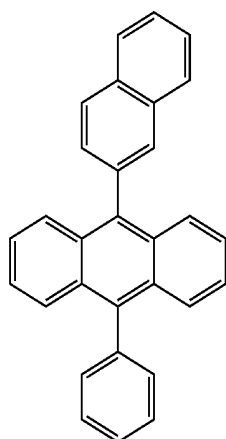
ET18

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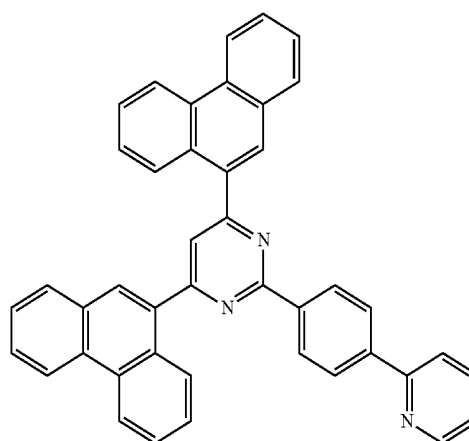


ET21

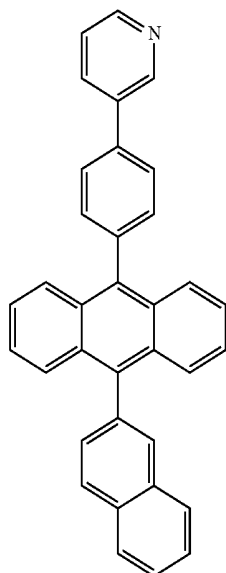
ET19



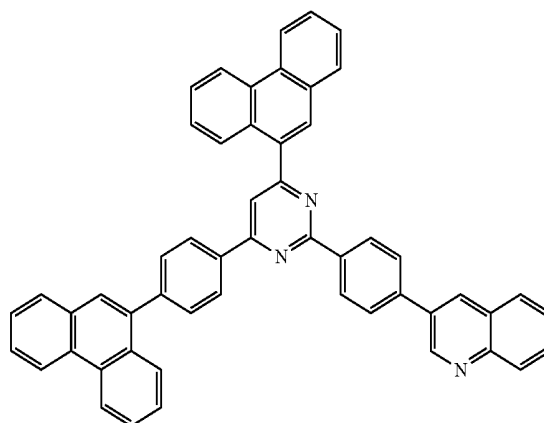
ET22



ET20

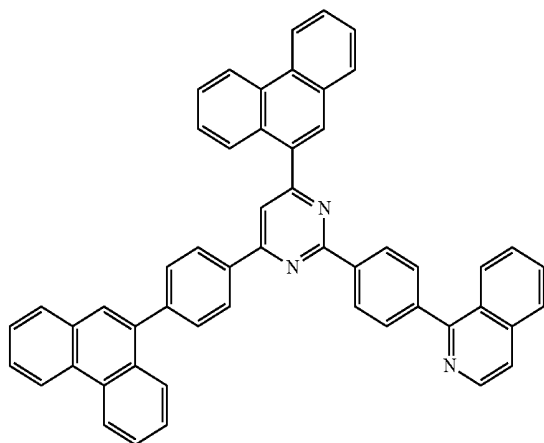


ET23



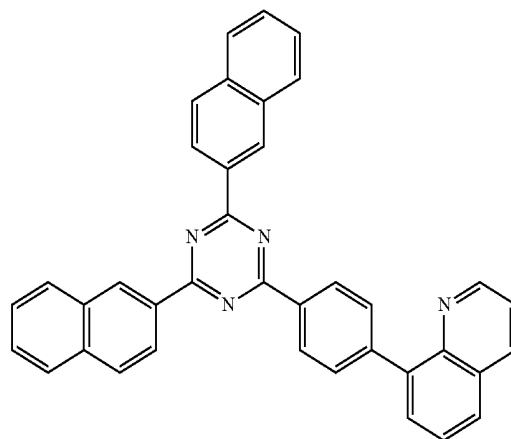
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ET24

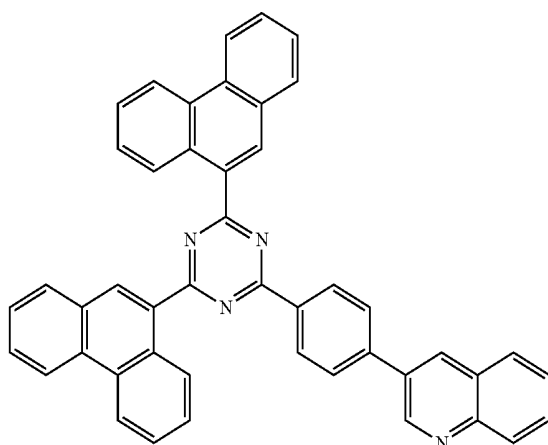


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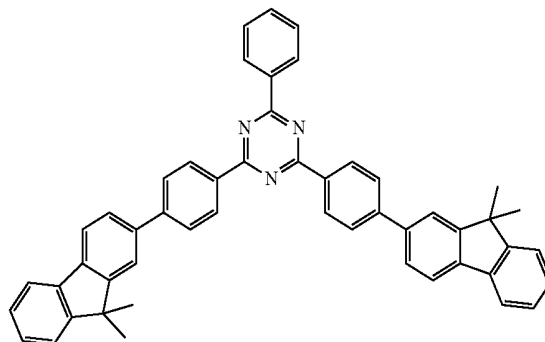
ET27



ET25

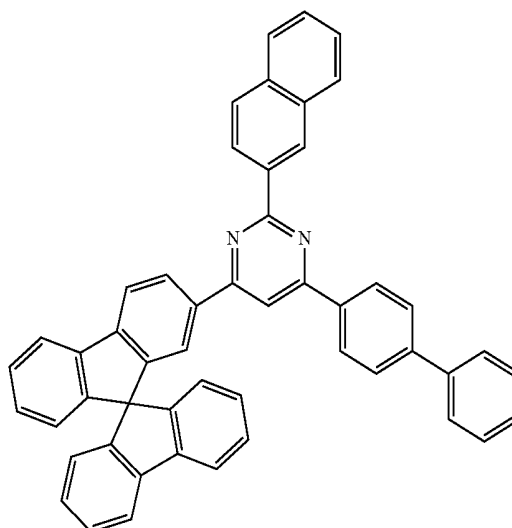
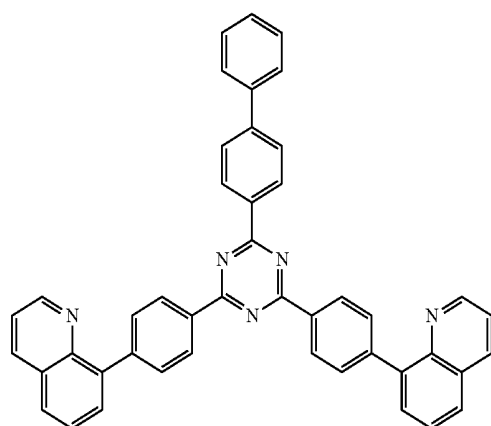


ET28

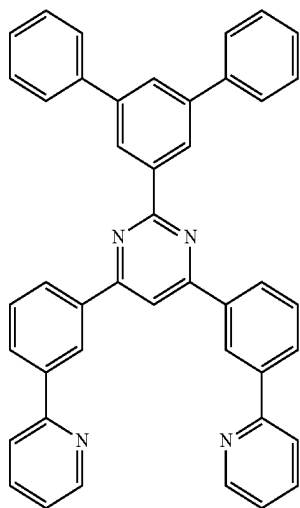


ET29

ET26

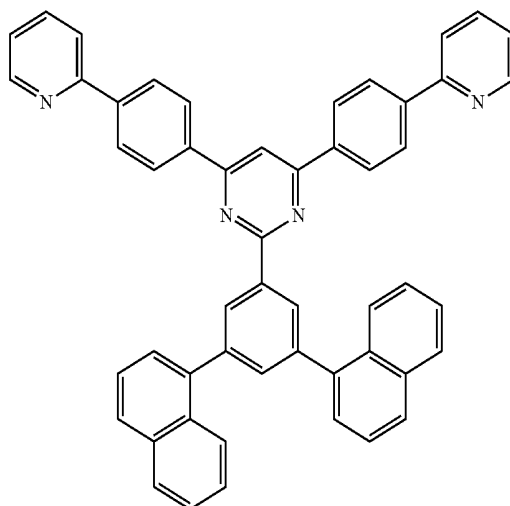


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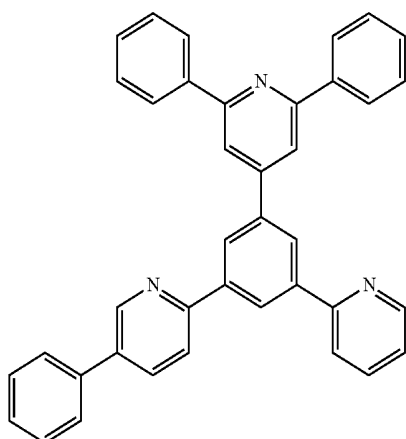


ET30

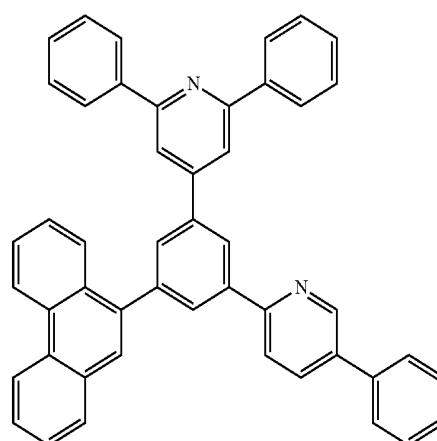
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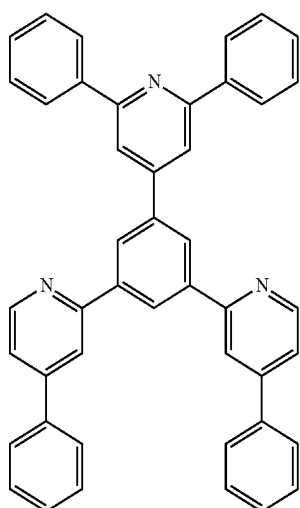
ET33



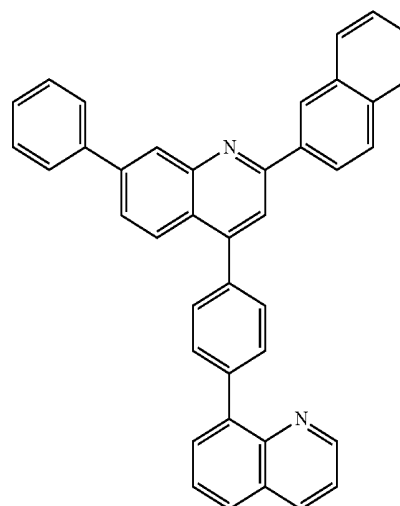
ET31



ET34



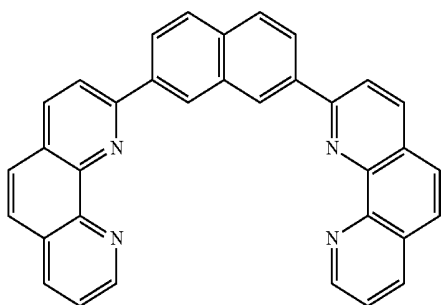
ET32



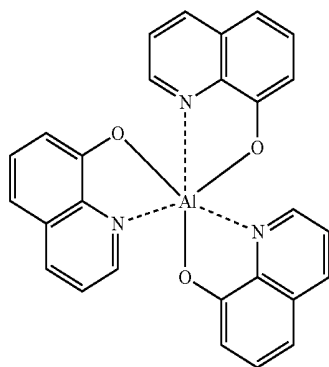
ET35

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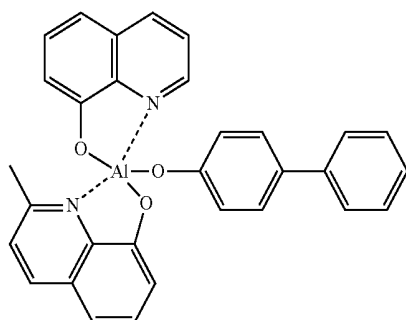
ET36



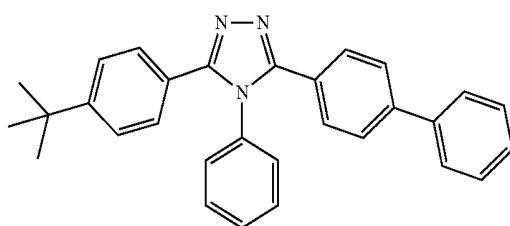
[0305] In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:



Alq3

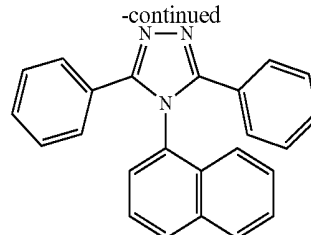


BAlq



TAZ

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NTAZ

[0306] In some embodiments, the electron transport region may include a phosphine oxide-containing compound (for example, TSPO1 as used in the examples and/or the like), but embodiments of the present disclosure are not limited thereto. In some embodiments, the phosphine oxide-containing compound may be used in a hole blocking layer in the electron transport region, but embodiments of the present disclosure are not limited thereto.

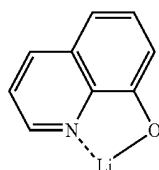
[0307] The thicknesses of the buffer layer, the hole blocking layer, or the electron control layer may each independently be about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and/or the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics and/or electron control characteristics without a substantial increase in driving voltage.

[0308] The thickness of the electron transport layer may be 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 suitable or satisfactory electron transport characteristics without a substantial increase in driving voltage.

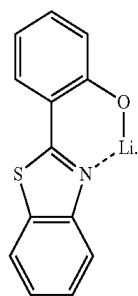
[0309] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0310] The metal-containing material may include at least one selected from an alkali metal complex and an alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a lithium (Li) ion, a sodium (Na) ion, a potassium (K) ion, a rubidium (Rb) ion, and a cesium (Cs) ion, and the alkaline earth-metal complex may include a metal ion selected from a beryllium (Be) ion, a magnesium (Mg) ion, a calcium (Ca) ion, a strontium (Sr) ion, and a barium (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 diphenyloxadiazole, a hydroxy diphenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0311] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) and/or Compound ET-D2:



ET-D1



ET-D2

[0312] 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**.

[0313] 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.

[0314] 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.

[0315] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In some embodiments, the alkali metal may be Li, Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs, but embodiments of the present disclosure are not limited thereto.

[0316] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0317] The rare earth metal may be selected from scandium (Sc), yttrium (Y), cerium (Ce), terbium (Tb), ytterbium (Yb), and gadolinium (Gd).

[0318] 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, and/or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.

[0319] The alkali metal compound may be selected from alkali metal oxides (such as Li_2O , Cs_2O , and/or K_2O), and alkali metal halides (such as LiF , NaF , CsF , KF , LiI , NaI , CsI , and/or KI). In some embodiments, the alkali metal compound may be selected from LiF , Li_2O , NaF , LiI , NaI , CsI , and KI , but embodiments of the present disclosure are not limited thereto.

[0320] The alkaline earth-metal compound may be selected from alkaline earth-metal oxides (such as BaO , SrO , CaO , $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), and/or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$)).

[0321] In some embodiments, the alkaline earth-metal compound may be selected from BaO , SrO , and CaO , but embodiments of the present disclosure are not limited thereto.

[0322] 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 some embodiments, the rare earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 , but embodiments of the present disclosure are not limited thereto.

[0323] The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an alkali metal ion, alkaline earth-metal ion, and/or a rare earth metal ions described above, and a ligand coordinated with the metal ion of the alkali metal complex, the alkaline earth-metal complex, and/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 diphenylthiadiazole, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0324] The electron injection layer may include (e.g., 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 combination thereof, as described above. In one or more 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 combination thereof, that material may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0325] The thickness of the electron injection layer may be 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 suitable or satisfactory electron injection characteristics without a substantial increase in driving voltage.

Second Electrode **190**

[0326] The second electrode **190** may be on the organic layer **150** having the above-described structure. The second electrode **190** may be a cathode that is an electron injection electrode, and in this regard, the material for forming the second electrode **190** may be selected from a metal, an alloy, an electrically conductive compound, or a combination thereof, each having a relatively low work function.

[0327] 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), indium titanium oxide (ITO), and indium zinc oxide (IZO), but embodiments of the present disclosure are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0328] The second electrode 190 may have a single-layered structure, or a multi-layered structure including two or more layers.

[0329] The layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region may be formed in a particular region or position using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0330] When each layer is formed by vacuum deposition, the deposition conditions may be selected depending on the compound used to form the hole injection layer, and the structure and thermal characteristics of the hole injection layer. For example, the deposition conditions may include a deposition temperature of about 100° C. to about 500° C., a vacuum pressure of about 10⁻⁸ torr to about 10⁻³ torr, and a deposition rate of about 0.01 Å/sec to about 100 Å/sec.

[0331] When the layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to about 200° C. depending on the material to be included in a layer to be formed, and the structure of the layer to be formed.

General Definition of Some of the Substituents

[0332] The term “C₁-C₆₀ alkyl group” as used herein may refer to a linear or branched aliphatic saturated hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof may 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 may refer to a divalent group having substantially the same structure as the C₁-C₆₀ alkyl group.

[0333] The term “C₂-C₆₀ alkenyl group” as used herein may refer to a hydrocarbon group having at least one carbon-carbon double bond at a main chain (e.g., in the middle) or at a terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof may include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group” as used herein may refer to a divalent group having substantially the same structure as the C₂-C₆₀ alkenyl group.

[0334] The term “C₂-C₆₀ alkynyl group” as used herein may refer to a hydrocarbon group having at least one carbon-carbon triple bond at a main chain (e.g., in the middle) or at a terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof may include an ethynyl group and a propynyl group. The term “C₂-C₆₀ alkynylene group” as used herein may refer to a divalent group having substantially the same structure as the C₂-C₆₀ alkynyl group.

[0335] The term “C₁-C₆₀ alkoxy group” as used herein may refer to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is a C₁-C₆₀ alkyl group), and non-limiting examples thereof may include a methoxy group, an ethoxy group, and an isopropoxy group.

[0336] The term “C₃-C₁₀ cycloalkyl group” as used herein may refer to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof may 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 may refer to a divalent group having substantially the same structure as the C₃-C₁₀ cycloalkyl group.

[0337] The term “C₁-C₁₀ heterocycloalkyl group” as used herein may refer 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 non-limiting examples thereof may include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein may refer to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0338] The term “C₃-C₁₀ cycloalkenyl group” as used herein may refer to a monovalent monocyclic group having 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity (e.g., the C₃-C₁₀ cycloalkenyl group is not aromatic), and non-limiting examples thereof may include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein may refer to a divalent group having substantially the same structure as the C₃-C₁₀ cycloalkenyl group.

[0339] The term “C₁-C₁₀ heterocycloalkenyl group” as used herein may refer 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 may include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein may refer to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0340] The term “C₆-C₆₀ aryl group” as used herein may refer to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylenylene group” as used herein may refer to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group may 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 arylenylene group each include two or more rings, the rings may be fused to each other.

[0341] The term “C₁-C₆₀ heteroaryl group” as used herein may refer 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 may refer 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 may include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be condensed with (e.g., fused to) each other.

[0342] The term “C₆-C₆₀ aryloxy group” as used herein may refer to -OA₁₀₂ (wherein A₁₀₂ is a C₆-C₆₀ aryl group), and the term “C₆-C₆₀ arylthio group” as used herein may

refer to $-\text{SA}_{103}$ (wherein A_{103} is a $\text{C}_6\text{-C}_{60}$ aryl group). The term “ $\text{C}_1\text{-C}_{60}$ heteroaryloxy group” as used herein may refer to $-\text{OA}_{104}$ (wherein A_{104} is a $\text{C}_1\text{-C}_{60}$ heteroaryl group), and the term “ $\text{C}_1\text{-C}_{60}$ heteroarylthio group” as used herein may refer to $-\text{SA}_{105}$ (wherein A_{105} is a $\text{C}_1\text{-C}_{60}$ heteroaryl group).

[0343] The term “monovalent non-aromatic condensed polycyclic group” as used herein may refer to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure (e.g., the entire molecule is not aromatic). A non-limiting example of the monovalent non-aromatic condensed polycyclic group may be a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group” as used herein may refer to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group.

[0344] The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein may refer to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, and no aromaticity in its entire molecular structure (e.g., the entire molecule is not aromatic). A non-limiting example of the monovalent non-aromatic condensed heteropolycyclic group may be a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group” as used herein may refer to a divalent group having substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0345] The term “ $\text{C}_5\text{-C}_{60}$ carbocyclic group” as used herein may refer to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The $\text{C}_5\text{-C}_{60}$ carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The $\text{C}_5\text{-C}_{60}$ carbocyclic group may be a ring (such as benzene group), a monovalent group (such as a phenyl group), or a divalent group (such as a phenylene group). In one or more embodiments, depending on the number of substituents connected to the $\text{C}_5\text{-C}_{60}$ carbocyclic group, the $\text{C}_5\text{-C}_{60}$ carbocyclic group may be a trivalent group or a quadrivalent group.

[0346] The term “ $\text{C}_1\text{-C}_{60}$ heterocyclic group” as used herein may refer to a group having substantially the same structure as the $\text{C}_5\text{-C}_{60}$ carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

[0347] At least one substituent of the substituted $\text{C}_5\text{-C}_{60}$ carbocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ heterocyclic group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkylene group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkylene group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkenylene group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenylene group, the substituted $\text{C}_6\text{-C}_{60}$ arylene group, the substituted $\text{C}_1\text{-C}_{60}$ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted $\text{C}_1\text{-C}_{60}$ alkyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkenyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkynyl group, the substituted $\text{C}_1\text{-C}_{60}$ alkoxy group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, the substituted $\text{C}_6\text{-C}_{60}$ aryl group, the substituted $\text{C}_6\text{-C}_{60}$ aryloxy

group, the substituted $\text{C}_6\text{-C}_{60}$ arylthio group, the substituted $\text{C}_1\text{-C}_{60}$ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0348] deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, and a $\text{C}_1\text{-C}_{60}$ alkoxy group;

[0349] a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, and a $\text{C}_1\text{-C}_{60}$ alkoxy group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{11})(\text{Q}_{12})(\text{Q}_{13})$, $-\text{N}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{B}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{C}(=\text{O})(\text{Q}_{11})$, $-\text{S}(=\text{O})_2(\text{Q}_{11})$, and $-\text{P}(=\text{O})(\text{Q}_{11})(\text{Q}_{12})$;

[0350] a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0351] a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{21})(\text{Q}_{22})(\text{Q}_{23})$, $-\text{N}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{B}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{C}(=\text{O})(\text{Q}_{21})$, $-\text{S}(=\text{O})_2(\text{Q}_{21})$, and $-\text{P}(=\text{O})(\text{Q}_{21})(\text{Q}_{22})$; and

[0352] $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$; and

[0353] Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent

non-aromatic condensed heteropolycyclic group, a C_1 - C_{60} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group; a C_6 - C_{60} aryl group substituted with at least one selected from deuterium, —F, and a cyano group; a biphenyl group, and a terphenyl group.

[0354] The term “Ph” as used herein may represent a phenyl group, the term “Me” as used herein may represent a methyl group, the term “Et” as used herein may represent an ethyl group, the term “ter-Bu” or “Bu^t,” as used herein, may represent a tert-butyl group, and the term “OMe” as used herein may represent a methoxy group.

[0355] The term “biphenyl group” as used herein may refer to a “phenyl group substituted with a phenyl group”. A “biphenyl group” is an example of “a substituted phenyl group” including a “ C_6 - C_{60} aryl group” (specifically, a phenyl group) as a substituent.

[0356] The term “terphenyl group” as used herein may refer to a “phenyl group substituted with a biphenyl group”. A “terphenyl group” is an example of a “phenyl group” including a “ C_6 - C_{60} aryl group substituted with a C_6 - C_{60} aryl group” (specifically, a phenyl group substituted with a phenyl group) as a substituent.

[0357] * and * used herein, unless defined otherwise, may each refer to a binding site to a neighboring atom in a corresponding formula.

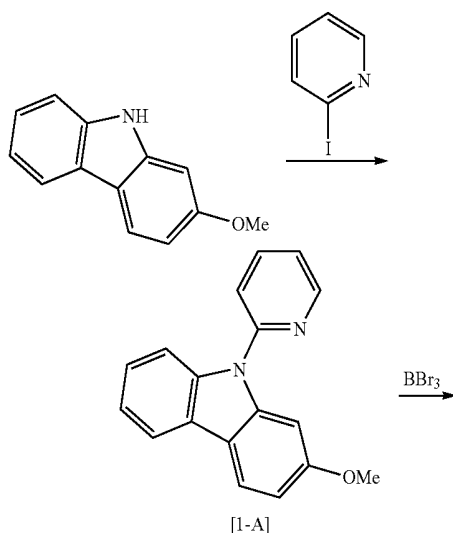
[0358] Hereinafter, a compound according to embodiments of the present disclosure and an organic light-emitting device according to embodiments of the present disclosure will be described in more detail with reference to Synthesis Examples and Examples. The expression “B was used instead of A” used in describing the Synthesis Examples means that an identical number of molar equivalents of A was used in place of molar equivalents of B.

SYNTHESIS EXAMPLES

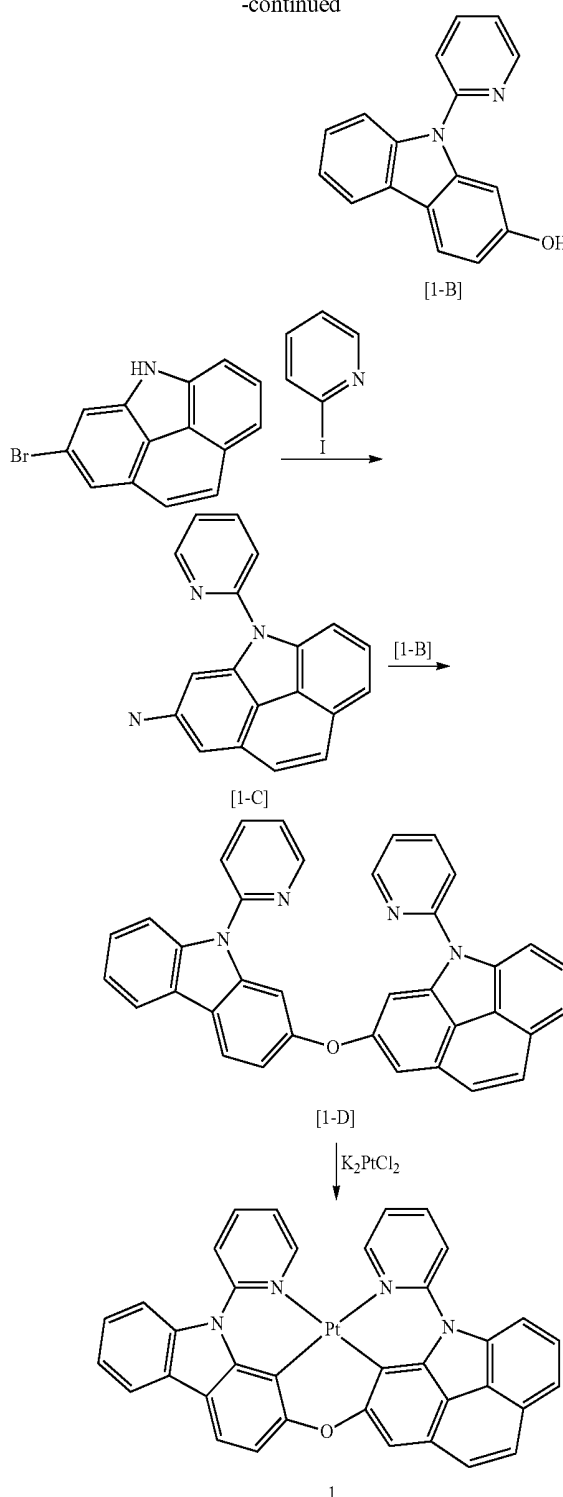
Synthesis Example 1

Synthesis of Compound 1

[0359]



-continued



1) Synthesis of Intermediate [1-A]

[0360] 2-methoxy-9H-carbazole (1.0 eq), 2-iodopyridine (1.2 eq), $Pd_2(dba)_3$ (0.05 eq), SPhos (0.10 eq), and K_2CO_3 (1.0 eq) were dissolved in toluene (0.1 M) and stirred at a temperature of 120° C. for 18 hours. After the reaction mixture was cooled to room temperature, an organic layer was extracted therefrom three times using dichloromethane

and water. The extracted organic layer was dried over magnesium sulfate and concentrated, and column chromatography was performed thereon to obtain Intermediate [1-A] (yield: 91%).

2) Synthesis of Intermediate [1-B]

[0361] Compound [1-A] (1.0 eq) was dissolved in dichloromethane (0.1 M) and stirred at a temperature of -78°C ., and boron tribromide solution (1.0 M in hexane, 2.0 eq) was slowly added thereto and stirred for 2 hours. The reaction mixture was neutralized using sodium bicarbonate aqueous solution, and an organic layer was extracted therefrom three times using ethyl acetate and water. The extracted organic layer was dried over magnesium sulfate and concentrated to obtain Intermediate [1-B] (yield: 64%).

3) Synthesis of Intermediate [1-C]

[0362] 2-bromo-4H-benzo[def]carbazole (1.0 eq), 2-iodopyridine (1.2 eq), $\text{Pd}_2(\text{dba})_3$ (0.05 eq), SPhos (0.10 eq), and K_2CO_3 (1.0 eq) were dissolved in toluene (0.1 M) and stirred at a temperature of 120°C . for 18 hours. After the reaction mixture was cooled to room temperature, an organic layer was extracted therefrom three times using dichloromethane and water. The extracted organic layer was dried over magnesium sulfate and concentrated, and column chromatography was performed thereon to obtain Intermediate [1-C] (yield: 93%).

4) Synthesis of Intermediate [1-D]

[0363] Compound [1-B] (1.0 eq), Compound [1-C] (1.2 eq), CuI (0.02 eq), K_2CO_3 (2.0 eq), and L-Proline (0.04 eq) were dissolved in dimethyl sulfoxide (0.1M) and stirred at a temperature of 160°C . for 48 hours. After the reaction mixture was cooled to room temperature, an organic layer was extracted therefrom three times using dichloromethane and water. The extracted organic layer was dried over magnesium sulfate and concentrated, and column chromatography was performed thereon to obtain Intermediate [1-D] (yield: 44%).

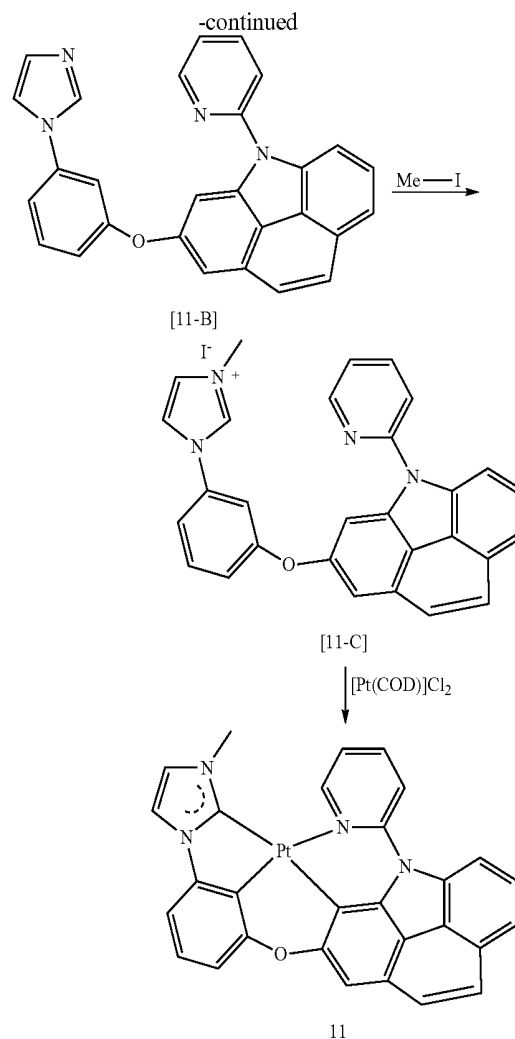
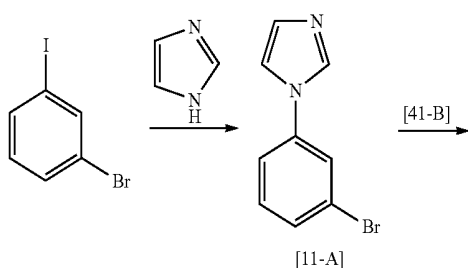
5) Synthesis of Compound 1

[0364] Compound [1-D] (1.0 eq), potassium tetrachloroplatinate (K_2PtCl_4) (1.1 eq), and tetrabutylammonium bromide (0.1 eq) were dissolved in acetic acid (0.1M) and stirred at a temperature of 120°C . for 72 hours. After the reaction mixture was cooled to room temperature, an organic layer was extracted therefrom three times using dichloromethane and water. The extracted organic layer was dried over magnesium sulfate and concentrated, and column chromatography was performed thereon to obtain Compound 1 (yield: 31%).

Synthesis Example 2

Synthesis of Compound 11

[0365]



1) Synthesis of Intermediate [11-A]

[0366] 3-bromo iodobenzene (1.0 eq), 1H-imidazole (1.2 eq), CuI (0.02 eq), K_2CO_3 (2.0 eq), and L-Proline (0.04 eq) were dissolved in dimethylsulfoxide (0.1M) and stirred at a temperature of 130°C . for 12 hours. After the reaction mixture was cooled to room temperature, an organic layer was extracted therefrom three times using dichloromethane and water. The extracted organic layer was dried over magnesium sulfate and concentrated, and column chromatography was performed thereon to obtain Intermediate [11-A] (yield: 65%).

2) Synthesis of Intermediate [11-B]

[0367] Intermediate [11-B] (yield: 32%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-D], except that Intermediate [11-A] was used instead of Intermediate [1-C], and Intermediate [41-B] as described in Synthesis Example 5 was used instead of Intermediate [1-B].

3) Synthesis of Intermediate [11-C]

[0368] Compound [11-B] (1.0 eq) and iodomethane (1.5 eq) were dissolved in tetrahydrofuran (0.1 M) and stirred at

a temperature of 70° C. for 12 hours. After the reaction mixture was cooled to room temperature, a solvent was removed therefrom. The resultant mixture was filtered and washed using diethyl ether to obtain Intermediate [11-C] (yield: 85%).

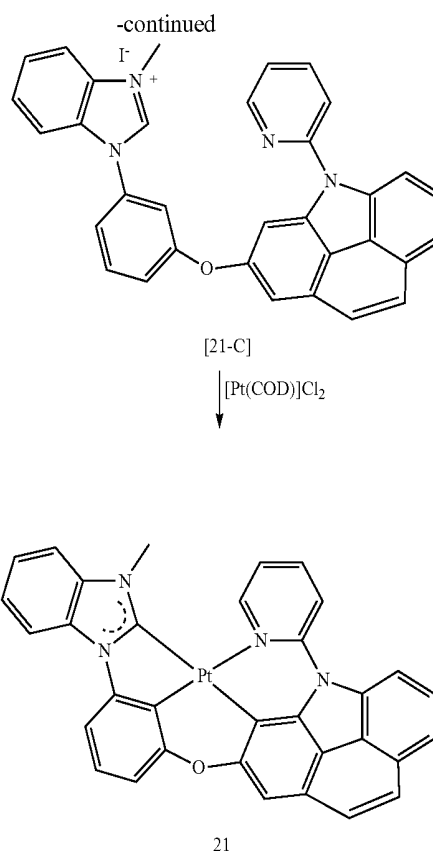
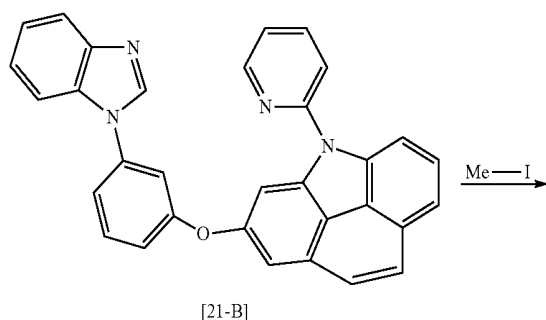
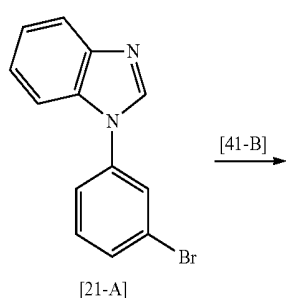
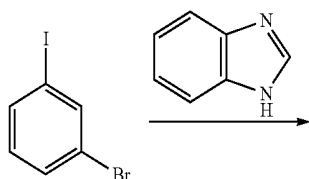
4) Synthesis of Compound 11

[0369] Compound [11-C] (1.0 eq), dichloro(1,5-cyclooctadienyl) platinum(II) (1.05 eq), and sodium acetate (3.0 eq) were dissolved in tetrahydrofuran (0.1 M) and stirred at a temperature of 120° C. in a nitrogen atmosphere for 72 hours. The reaction mixture was cooled to room temperature and depressurized to remove a solvent therefrom. The concentrated reaction mixture was dissolved in dichloromethane, and a remaining precipitate was filtered. A filtrate was purified by column chromatography to obtain Compound 11 (yield: 35%).

Synthesis Example 3

Synthesis of Compound 21

[0370]



1) Synthesis of Intermediate [21-A]

[0371] Intermediate [21-A] (yield: 57%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [11-A], except that benzimidazole was used instead of 1H-imidazole.

2) Synthesis of Intermediate [21-B]

[0372] Intermediate [21-B] (yield: 31%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-D], except that Intermediate [21-A] was used instead of Intermediate [1-C], and Intermediate [41-B] as described in Synthesis Example 5 was used instead of Intermediate [1-B].

3) Synthesis of Intermediate [21-C]

[0373] Intermediate [21-C] (yield: 84%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [11-C], except that Intermediate [21-B] was used instead of Intermediate [11-B].

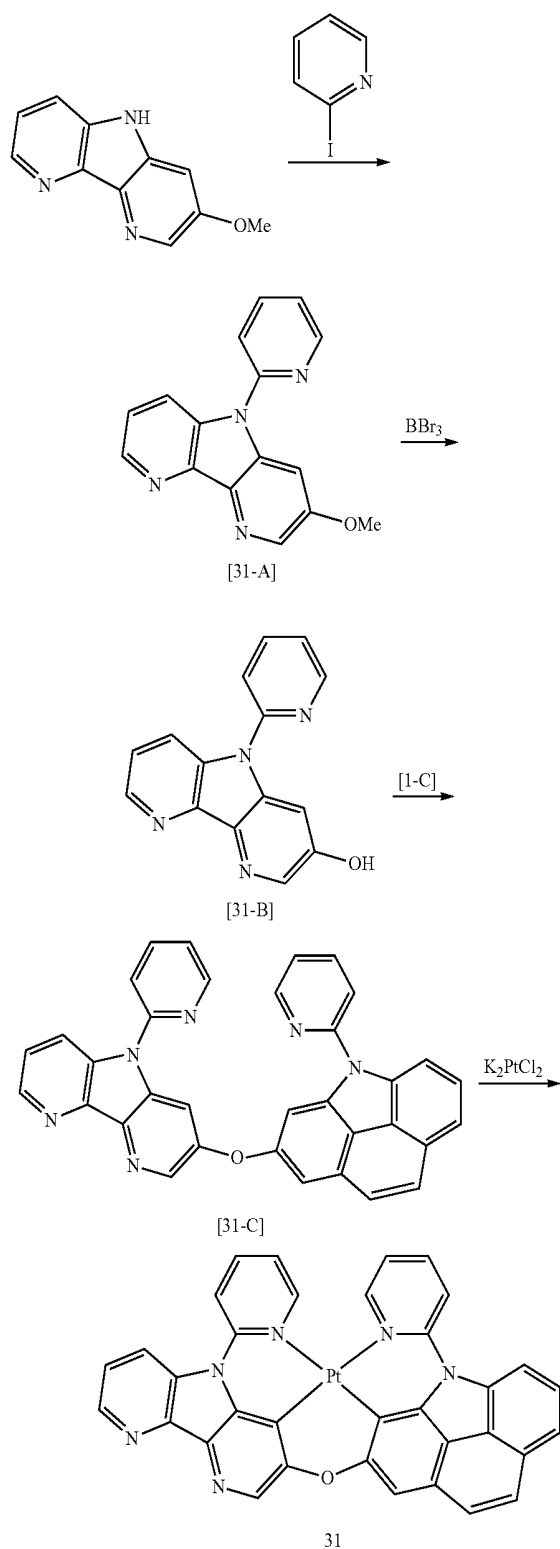
4) Synthesis of Compound 21

[0374] Synthesis 21 (yield: 28%) was synthesized in substantially the same manner as in the Synthesis of Compound 11, except that Intermediate [21-C] was used instead of Intermediate [11-C].

Synthesis Example 4

Synthesis of Compound 31

[0375]



1) Synthesis of Intermediate [31-A]

[0376] Intermediate [31-A] (yield: 86%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-A], except that 3-methoxy-5H-pyrrolo[3,2-b:4,5-b']dipyridine was used instead of 2-methoxy-9H-carbazole.

2) Synthesis of Intermediate [31-B]

[0377] Intermediate [31-B] (yield: 68%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-B], except that Intermediate [31-A] was used instead of Intermediate [1-A].

3) Synthesis of Intermediate [31-C]

[0378] Intermediate [31-C] (yield: 24%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-D], except that Intermediate [31-B] was used instead of Intermediate [1-B].

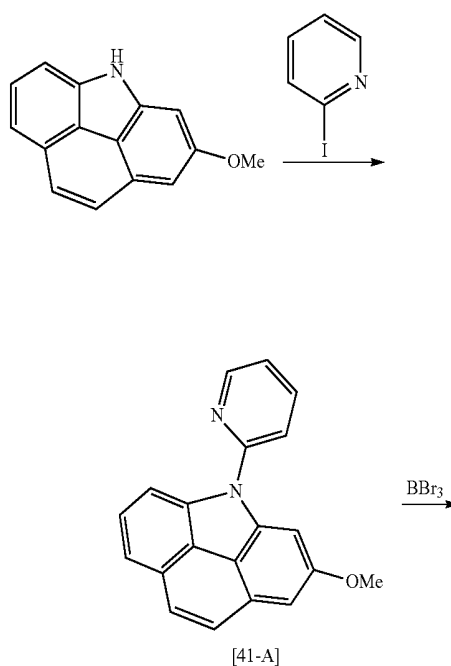
4) Synthesis of Compound 31

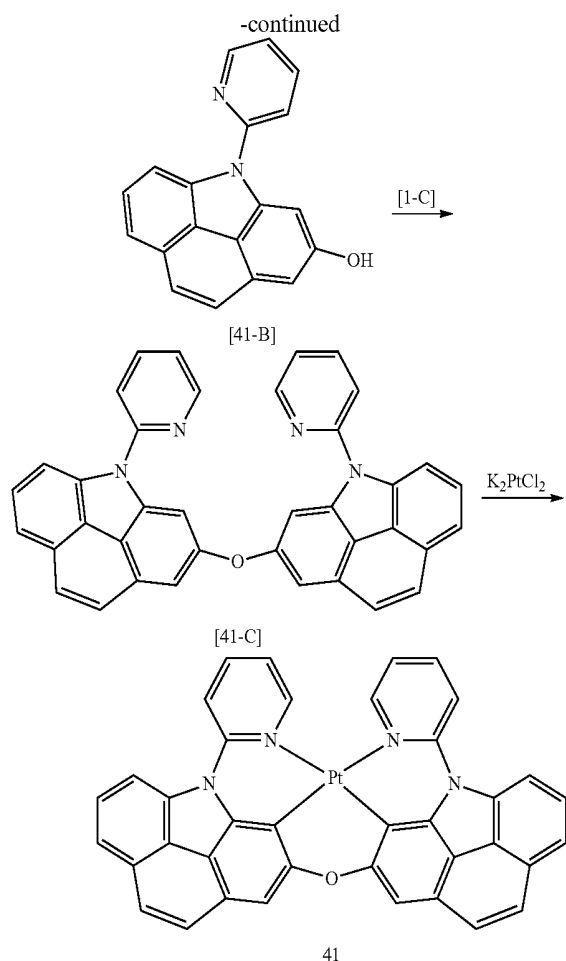
[0379] Compound 31 (yield: 37%) was synthesized in substantially the same manner as in the Synthesis of Compound 1, except that Intermediate [31-C] was used instead of Intermediate [1-D].

Synthesis Example 5

Synthesis of Compound 41

[0380]





1) Synthesis of Intermediate [41-A]

[0381] Intermediate [41-A] (yield: 88%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-A], except that 2-methoxy-4H-benzo[def]carbazole was used instead of 2-methoxy-9H-carbazole.

2) Synthesis of Intermediate [41-B]

[0382] Intermediate [41-B] (yield: 66%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-B], except that Intermediate [41-A] was used instead of Intermediate [1-A].

3) Synthesis of Intermediate [31-C]

[0383] Intermediate [31-C] (yield: 31%) was synthesized in substantially the same manner as in the Synthesis of Intermediate [1-D], except that Intermediate [41-B] was used instead of Intermediate [1-B].

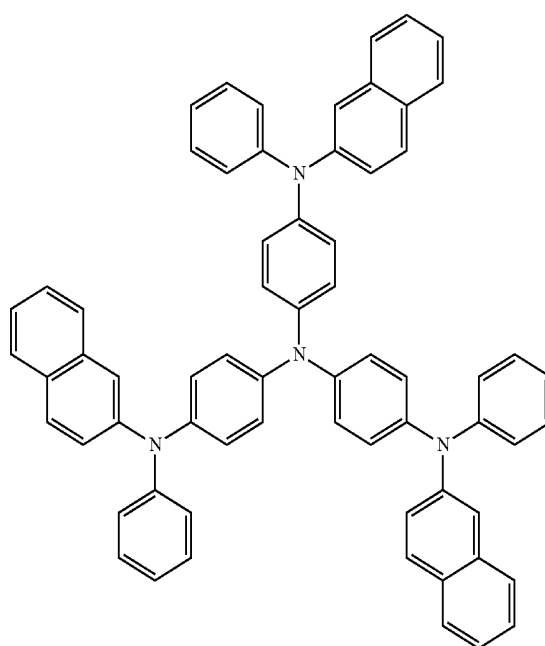
4) Synthesis of Compound 31

[0384] Compound 31 (yield: 33%) was synthesized in substantially the same manner as in the Synthesis of Compound 1, except that Intermediate [41-C] was used instead of Intermediate [1-D].

EXAMPLES

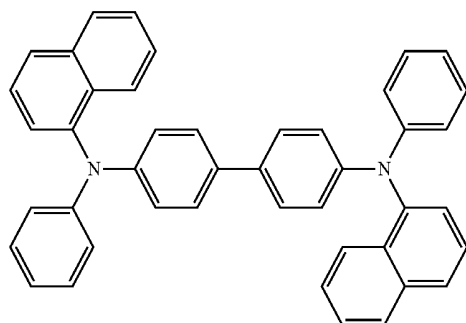
Example 1

[0385] As an anode, a Corning 15 Ω/cm^2 (1,200 Å) ITO glass substrate was cut to a size of 50 mm×50 mm×0.7 mm, sonicated with isopropyl alcohol and pure water for 5 minutes each, and then cleaned by exposure to ultraviolet rays and ozone for 30 minutes. Then, the ITO glass substrate was provided to a vacuum deposition apparatus. Compound 2-TNATA was vacuum-deposited on the ITO glass substrate to form a hole injection layer having a thickness of 600 Å, and 4,4'-bis[N-(1-naphthyl)-N-phenyl aminobiphenyl (NPB) (hole transport compound) was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å. 3,3-di(9H-carbazol-9-yl)biphenyl (mCBP) (host) and Compound 1 (dopant) were co-deposited on the hole transport layer in a ratio of 10% dopant (e.g., and 90% host) to form a green phosphorescent emission layer having a thickness of 300 Å. Then, diphenyl(4-(triphenylsilyl)phenyl)-phosphine oxide (TSPO1) was vacuum-deposited on the emission layer to form a hole blocking layer having a thickness of 50 Å. Then, Alq₃ was deposited on the hole blocking layer to form an electron transport layer having a thickness of 300 Å. LiF, which is an alkali metal halide, was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Al was vacuum-deposited on the electron injection layer to form a cathode electrode having a thickness of 3,000 Å, thereby forming a LiF/Al electrode. In this manner, an organic light-emitting device was manufactured.

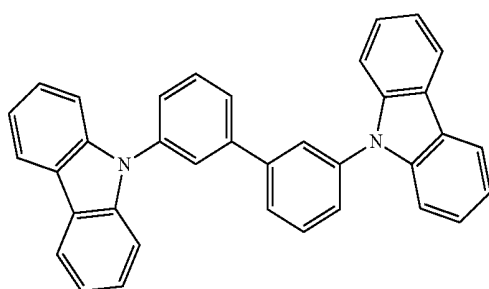


2-TNATA

-continued

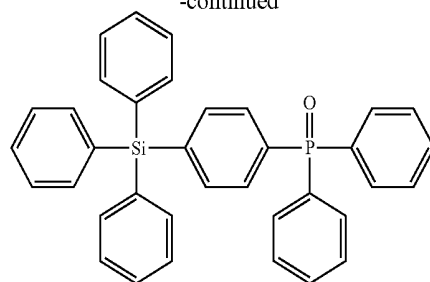


NPB



mCBP

-continued



TSP01

Examples 2 to 5 and Comparative Examples 1 to 4

[0386] Additional organic light-emitting devices were manufactured in each the same manner as in Example 1, except that the Compounds shown in Table 1 were used instead of Compound 1 as a dopant in forming each an emission layer.

Evaluation Example 1

[0387] The driving voltage, current density, luminance, luminescent efficiency, and maximum emission wavelength of the organic light-emitting devices manufactured according to Examples 1 to 5 and Comparative Examples 1 to 4 were measured using a Keithley SMU 236 and a luminance meter PR650 (Tektronix, Inc., Beaverton, Oreg.), and results thereof are shown in Table 1.

TABLE 1

	Emission layer	Driving voltage (V)	Current density (mA/cm ²)	Luminance (cd/m ²)	Efficiency (cd/A)	Emission color	Emission wavelength (nm)	Lifespan (RT _{80%} @ J = 40 mA/cm ²) (hr)
Example 1	Compound 1	5.11	50	4125	8.25	Green	532	360
Example 2	Compound 11	5.17	50	4025	8.05	Green	529	327
Example 3	Compound 21	5.15	50	4033	8.07	Green	535	348
Example 4	Compound 31	5.20	50	4024	8.05	Green	533	351
Example 5	Compound 41	5.13	50	4055	8.11	Red	591	369
Comparative Example 1	Ir(ppy) ₃	6.74	50	3870	7.74	Green	516	278
Comparative Example 2	Compound 46	6.68	50	3790	7.58	Green	515	194
Comparative Example 3	Compound 47	6.72	50	3535	7.07	Green	537	307
Comparative Example 4	Compound 48	6.81	50	3325	6.65	Red	592	312

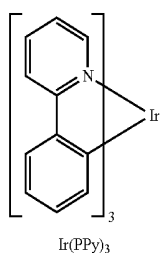
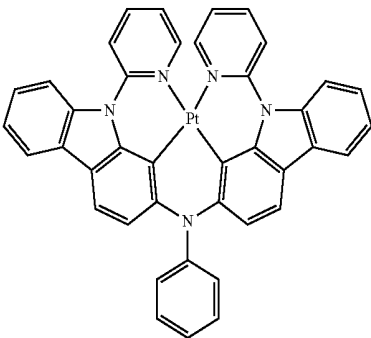
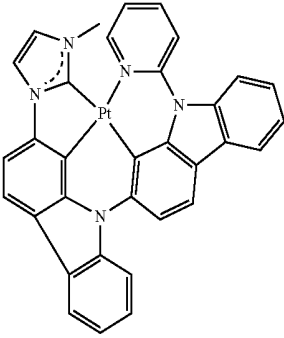
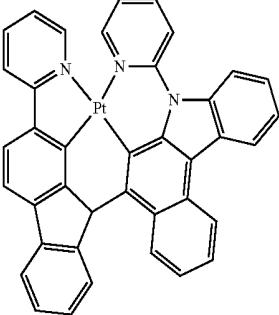


TABLE 1-continued

Emission layer	Driving voltage (V)	Current density (mA/cm ²)	Luminance (cd/m ²)	Efficiency (cd/A)	Emission color	Emission wavelength (nm)	Lifespan (RT _{80%} @ J = 40 mA/cm ²) (hr)
							
46							
							
47							
							
48							

[0388] Referring to Table 1, it is confirmed that the organic light-emitting devices of Examples 1 to 5 have a low driving voltage, high luminance, high luminescent efficiency, and a long lifespan, compared with the organic light-emitting devices of Comparative Examples 1 to 4.

[0389] An organic light-emitting device including the organometallic compound according to embodiments of the present disclosure may have a low driving voltage, high efficiency, high luminance, and a long lifespan.

[0390] As used herein, the terms “use”, “using”, and “used” may be considered synonymous with the terms “utilize”, “utilizing”, and “utilized”, respectively. Further, the use of “may” when describing embodiments of the present disclosure refers to “one or more embodiments of the present disclosure”.

[0391] As used herein, the terms “substantially”, “about”, and similar terms are used as terms of approximation and not

as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art.

[0392] Also, any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of “1.0 to 10.0” is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including

monovalent non-aromatic condensed heteropolycyclic group is selected from the group consisting of:

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)(Q₁₁), —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), and

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 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, a C₁-C₆₀

alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C₆-C₆₀ aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

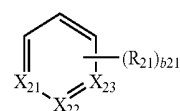
2. The organometallic compound of claim 1, wherein: M₁₁ is selected from Pt, Pd, Cu, Ag, and Au.

3. The organometallic compound of claim 1, wherein:

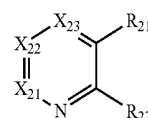
A₁₁ to A₁₆ are each independently selected from a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothio-phenylene group, a dibenzothio-phenylene group, a benzosilole group, a dibenzosilole group, an indeno pyridine group, an indolopyridine group, a benzofuopyridine group, a benzothienopyridine group, a benzosilopyridine group, an indeno pyrimidine group, an indolopyrimidine group, a benzofuopyrimidine group, a benzothienopyrimidine group, a benzosilopyrimidine group, a dihydropyridine group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a 2,3-dihydroimidazole group, a triazole group, a 2,3-dihydrotriazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a 2,3-dihydrobenzimidazole group, an imidazopyridine group, a 2,3-dihydroimidazopyridine group, an imidazopyrimidine group, a 2,3-dihydroimidazopyrimidine group, an imidazopyrazine group, a 2,3-dihydroimidazopyrazine group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group.

4. The organometallic compound of claim 1, wherein:

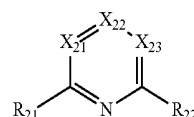
A₁₁ to A₁₃ are each independently represented by one of Formulae 2-1 to 2-43:



2-1

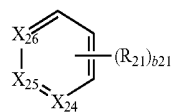


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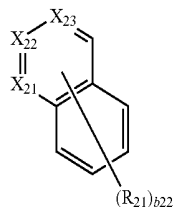


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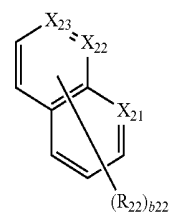
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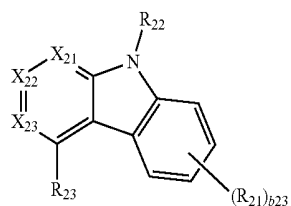
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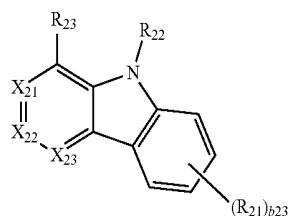
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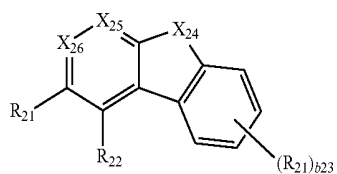
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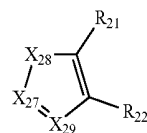
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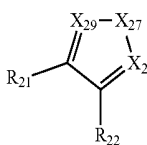
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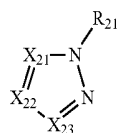
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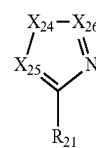


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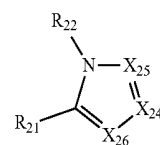


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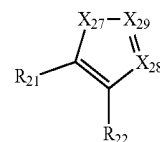
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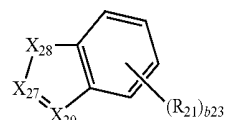
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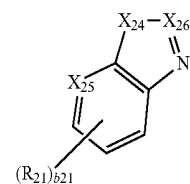
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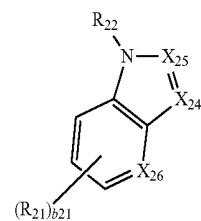
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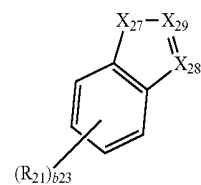
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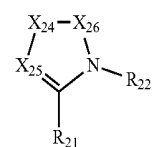
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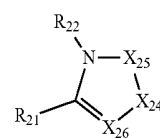
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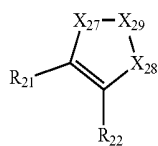


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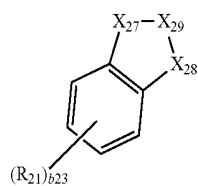


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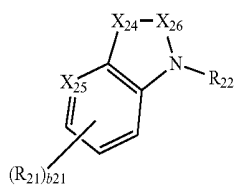
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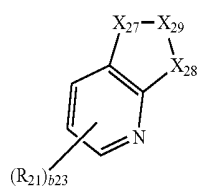
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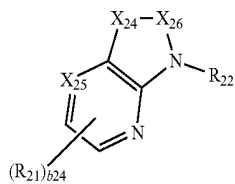
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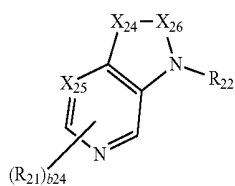
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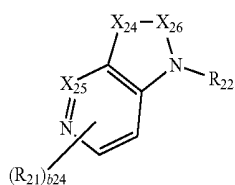
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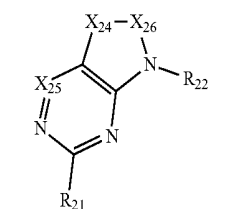
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2-27

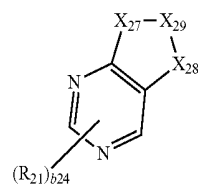


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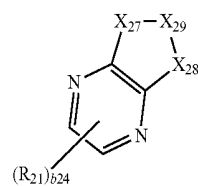


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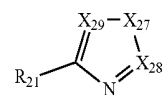
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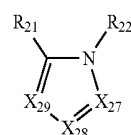
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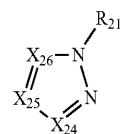
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2-32



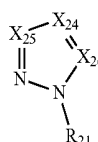
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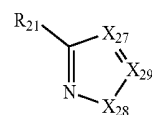
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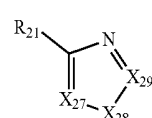
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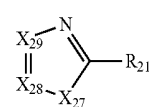
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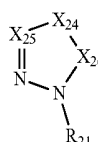
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2-38

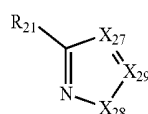


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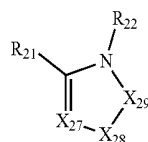


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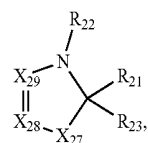
-continued



2-41



2-42



2-43

wherein, in Formulae 2-1 to 2-43,

X₂₁ to X₂₃ are each independently selected from C(R₂₄) and C—*, provided that at least two of X₂₁ to X₂₃ are each C—*,

X₂₄ is N—*, and X₂₅ and X₂₆ are each independently selected from C(R₂₄) and C—*, provided that at least one of X₂₅ and X₂₆ is C—*,

X₂₇ and X₂₈ are each independently selected from N, N(R₂₅), and N—*, and X₂₉ is selected from C(R₂₄) and C—*, wherein i) at least one of X₂₇ and X₂₈ is N—* and X₂₉ is C—*; or ii) X₂₇ and X₂₈ are each N—* and X₂₉ is C(R₂₄),

R₂₁ to R₂₄ are each independently the same as described in connection with R₁₁ in Formula 1,

b21 is selected from 1, 2, and 3,

b22 is selected from 1, 2, 3, 4, and 5,

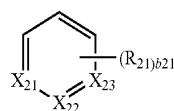
b23 is selected from 1, 2, 3, and 4,

b24 is selected from 1 and 2, and

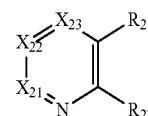
* indicates a binding site to a neighboring atom.

5. The organometallic compound of claim 1, wherein:

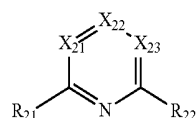
A₁₄ to A₁₆ are each independently represented by one of Formulae 2-1 to 2-4:



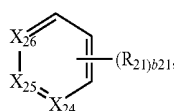
2-1



2-2



2-3



2-4

wherein, in Formulae 2-1 to 2-4,

X₂₁ to X₂₃ are each independently selected from C(R₂₄) and C—*, provided that at least two of X₂₁ to X₂₃ are each C—*,

X₂₄ is N—*, and X₂₅ and X₂₆ are each independently selected from C(R₂₄) and C—*, provided that at least one of X₂₅ and X₂₆ is C—*,

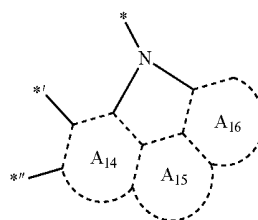
R₂₁ to R₂₂ are each independently the same as described in connection with R₁₁ in Formula 1,

b21 is selected from 1, 2, and 3, and

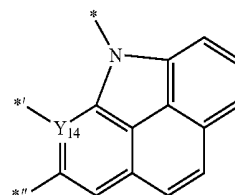
* indicates a binding site to a neighboring atom.

6. The organometallic compound of claim 1, wherein: in Formula 1,

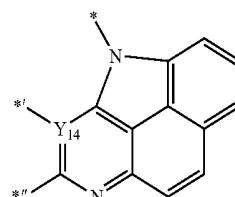
a moiety represented by



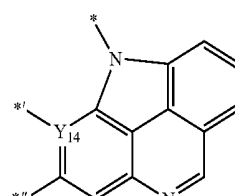
is a moiety represented by one of Formulae 1-1 to 1-64:



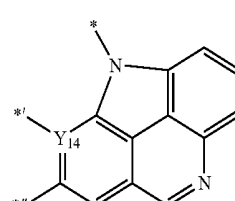
1-1



1-2

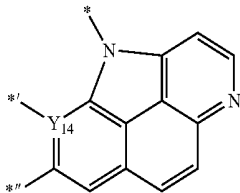


1-3

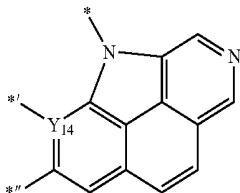


1-4

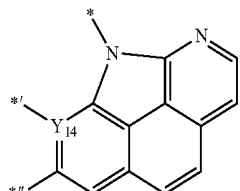
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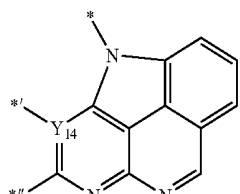
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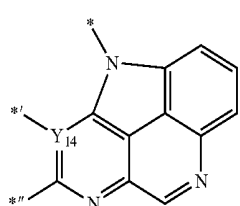
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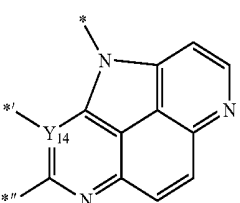
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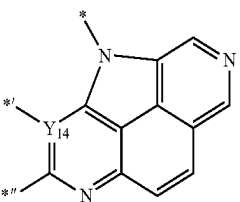
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1-9

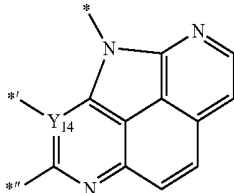


1-10

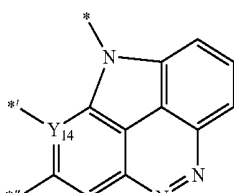


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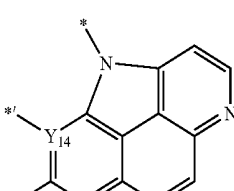
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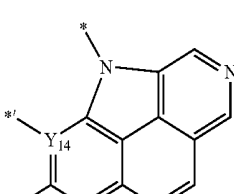
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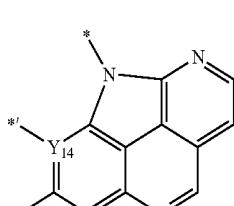
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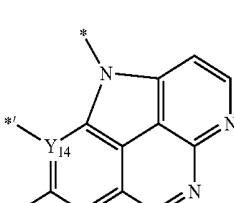
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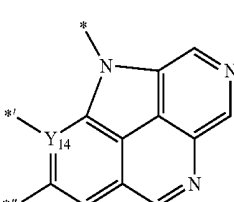
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1-16

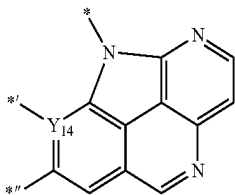


1-17



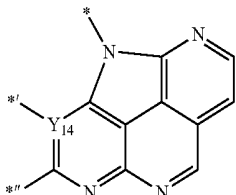
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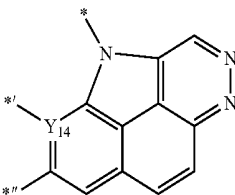


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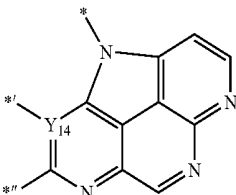
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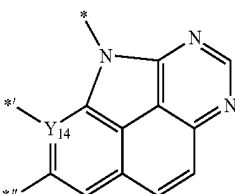
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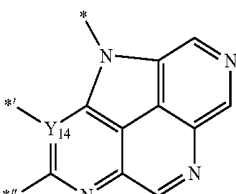
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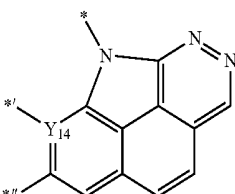
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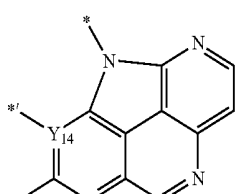
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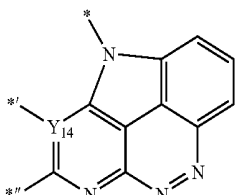
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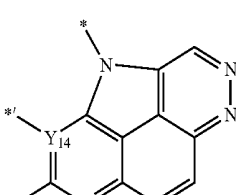
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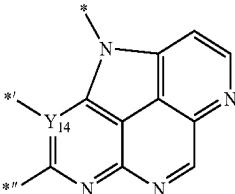
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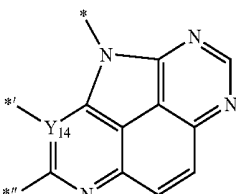
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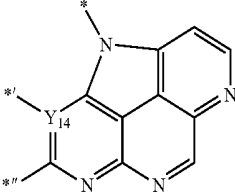
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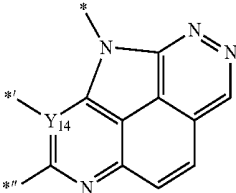
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1-31

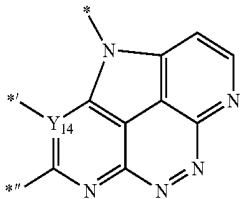


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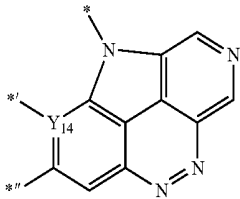


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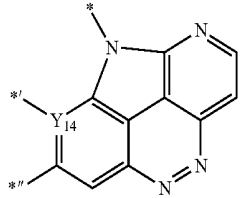
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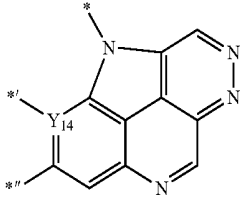
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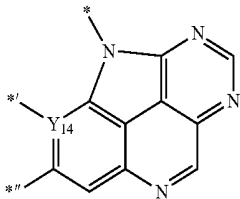
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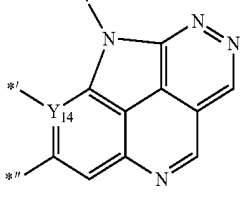
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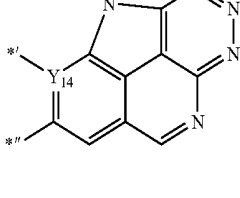
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1-37

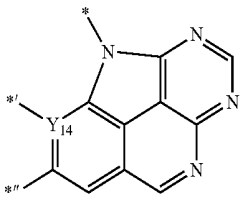


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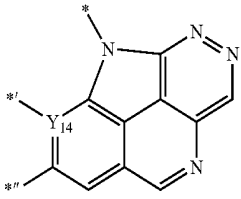


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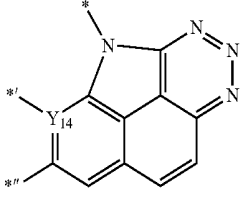
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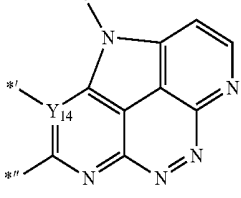
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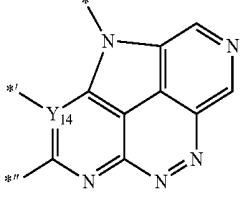
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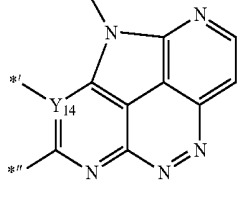
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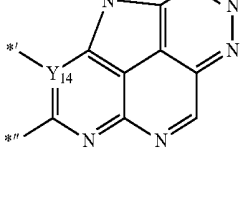
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1-44

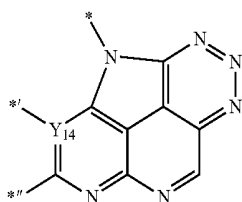


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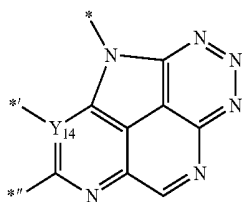


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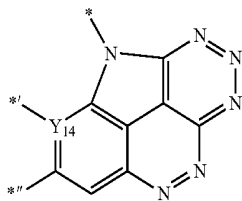
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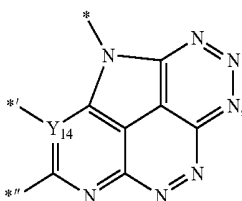
1-61



1-62



1-63



1-64

wherein, in Formulae 1-1 to 1-64,

Y_{14} is the same as described in claim 1, and

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

7. The organometallic compound of claim 1, wherein:

Y_{11} , Y_{12} , and Y_{13} are each C, and Y_{14} is N;

Y_{11} , Y_{12} , and Y_{14} are each C, and Y_{13} is N;

Y_{11} , Y_{13} , and Y_{14} are each C, and Y_{12} is N;

Y_{12} , Y_{13} , and Y_{14} are each C, and Y_{11} is N;

Y_{11} and Y_{14} are each C, and Y_{12} and Y_{13} are each N;

Y_{11} and Y_{14} are each N, and Y_{12} and Y_{13} are each C;

Y_{11} and Y_{12} are each C, and Y_{13} and Y_{14} are each N;

Y_{11} and Y_{12} are each N, and Y_{13} and Y_{14} are each C;

Y_{11} and Y_{13} are each C, and Y_{12} and Y_{14} are each N; or

Y_{11} and Y_{13} are each N, and Y_{12} and Y_{14} are each C.

8. The organometallic compound of claim 1, wherein:

T_{11} to T_{14} are each a single bond;

T_{11} is selected from $*-O-*'$ and $*-S-*'$, and T_{12} to T_{14} are each a single bond;

T_{12} is selected from $*-O-*'$ and $*-S-*'$, and T_{11} , T_{13} , and T_{14} are each a single bond;

T_{13} is selected from $*-O-*'$ and $*-S-*'$, and T_{11} , T_{12} , and T_{14} are each a single bond; or

T_{14} is selected from $*-O-*'$ and $*-S-*'$, and T_{11} , T_{12} , and T_{13} are each a single bond.

9. The organometallic compound of claim 1, wherein:

L_{11} to L_{13} are each independently selected from a single bond, $*-O-*'$, $*-S-*'$, $*-C(R_{17})(R_{18})-*'$, $*-C$

$(R_{17})=*'$, $*-C(R_{17})-*'$, $*-B(R_{17})-*'$, $*-N(R_{17})-*'$, $*-Si(R_{17})(R_{18})-*'$, and $*-P(R_{17})(R_{18})-*'$.

10. The organometallic compound of claim 1, wherein:

L_{11} is $*-N(R_{17})-*'$, $*-C(R_{17})(R_{18})-*'$, or $*-Si(R_{17})(R_{18})-*'$, and R_{17} and R_{12} are linked to form a substituted or unsubstituted C_1 - C_{60} heterocyclic group, or

L_{12} is $*-N(R_{17})-*'$, $*-C(R_{17})(R_{18})-*'$, or $*-Si(R_{17})(R_{18})-*'$, and R_{17} and R_{13} are linked to form a substituted or unsubstituted C_1 - C_{60} heterocyclic group.

11. The organometallic compound of claim 1, wherein:

a_{11} is 0, and a_{12} and a_{13} are each independently selected from 1, 2, and 3;

a_{12} is 0, and a_{11} and a_{13} are each independently selected from 1, 2, and 3; or

a_{13} is 0, and a_{11} and a_{12} are each independently selected from 1, 2, and 3.

12. The organometallic compound of claim 1, wherein: a_{11} is 0.

13. The organometallic compound of claim 1, wherein:

R_{11} to R_{18} are each independently selected from the group consisting of:

hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a cyano group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a cyano group, a phenyl group, and a biphenyl 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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho

silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indeno pyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

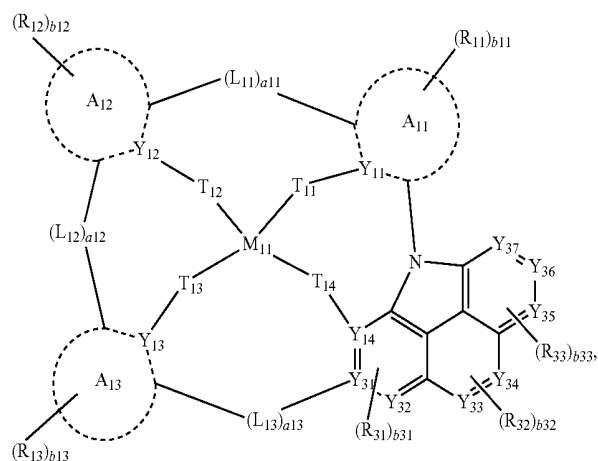
a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indeno pyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano 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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indeno pyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)(Q₃₁), —S(=O)₂(Q₃₁), —P(=O)(Q₃₁)(Q₃₂), and —P(=S)(Q₃₁)(Q₃₂); and

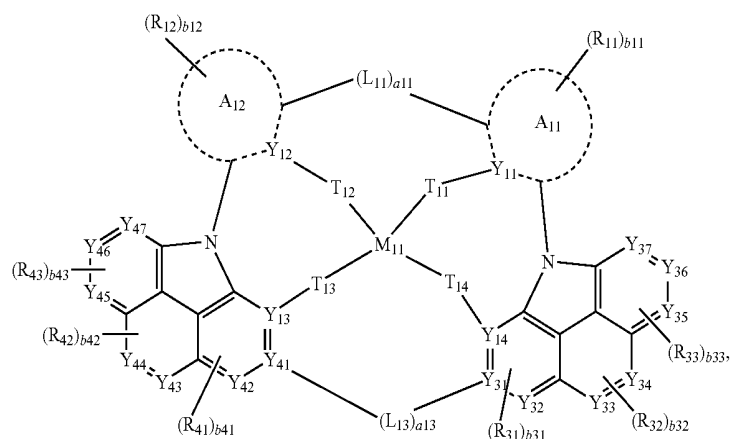
—Si(Q₁)(Q₂)(Q₃), —B(Q₁)(Q₂), —N(Q₁)(Q₂), —P(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)(Q₁), —S(=O)₂(Q₁), —P(=O)(Q₁)(Q₂), and —P(=S)(Q₁)(Q₂), and

Q₁ to Q₃ 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 aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₁-C₆₀ heteroaryloxy group, a C₁-C₆₀ heteroarylthio group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C₁-C₆₀ alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C₆-C₆₀ aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

14. The organometallic compound of claim 1, wherein:
the organometallic compound is represented by Formula 3-1 or 3-2:



Formula 3-1



Formula 3-2

wherein, in Formulae 3-1 and 3-2,

M₁₁, A₁₁ to A₁₃, Y₁₁ to Y₁₄, T₁₁ to T₁₄, L₁₁ to L₁₃, a₁₁ to a₁₃, R₁₁ to R₁₃, and b₁₁ to b₁₃ are the same as described in claim 1,

Y₃₁ to Y₃₇ are each independently N or C,

Y₄₁ to Y₄₇ are each independently N or C,

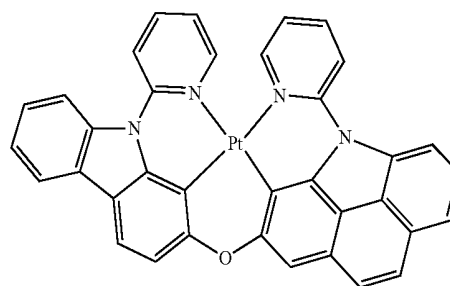
R₃₁ to R₃₃ are each independently the same as described in connection with R₁₄ in claim 1,

R₄₁ to R₄₃ are each independently the same as described in connection with R₁₃ in claim 1,

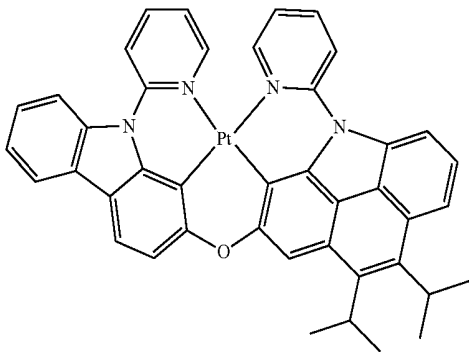
b₃₁, b₃₂, b₄₁, and b₄₂ are each independently 1 or 2, and

b₃₃ and b₄₃ are each independently 1, 2, or 3.

15. The organometallic compound of claim 1, wherein:
the organometallic compound represented by Formula 1 is selected from Compounds 1 to 45:

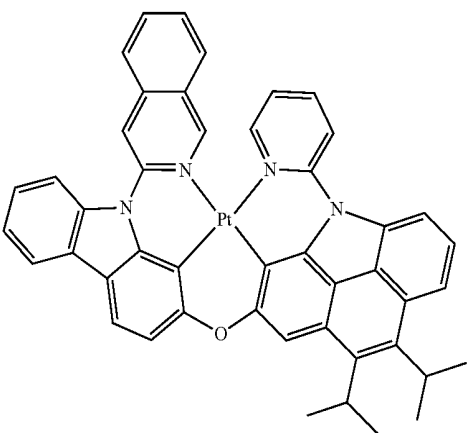


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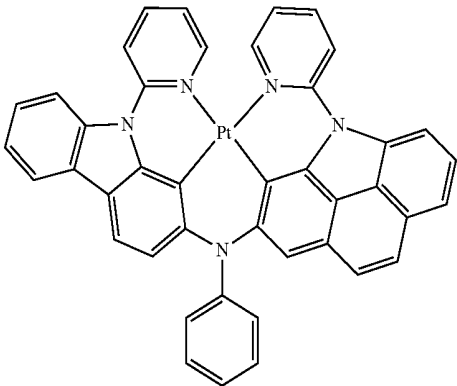
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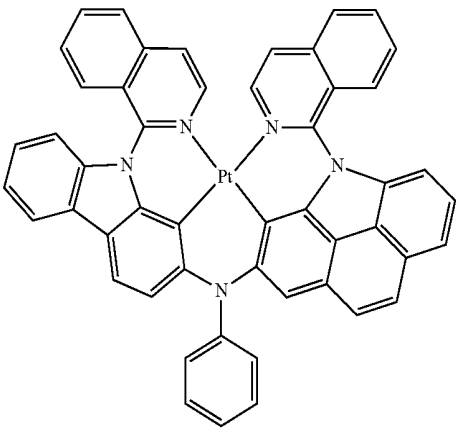


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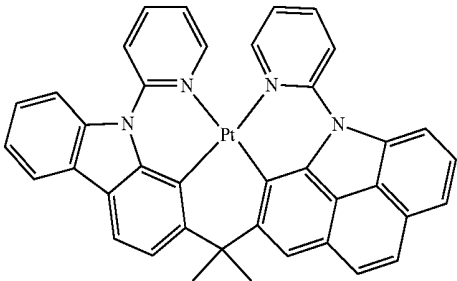
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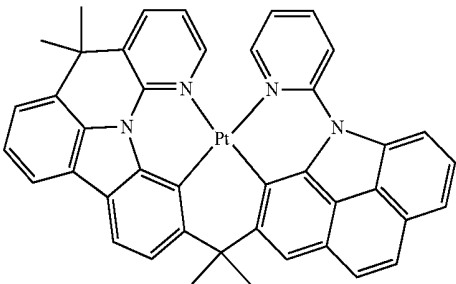
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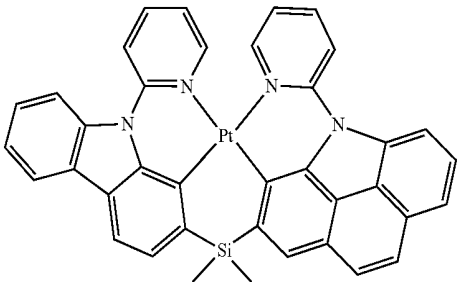
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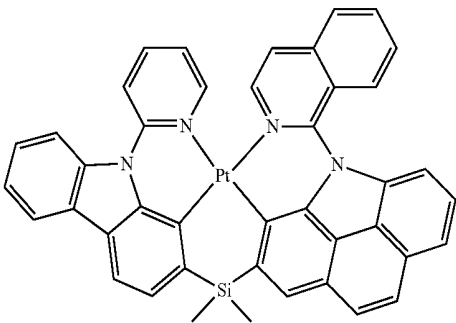
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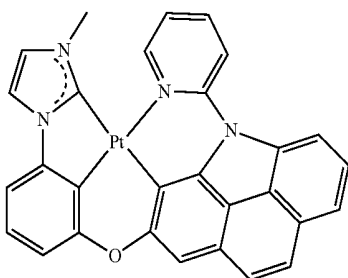


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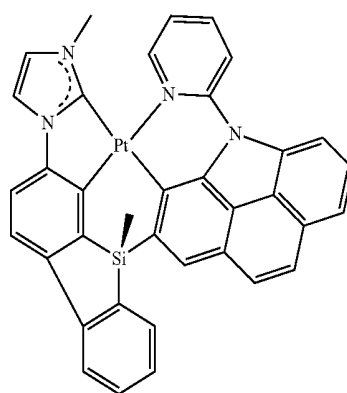
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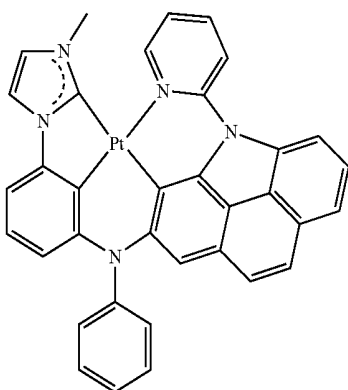


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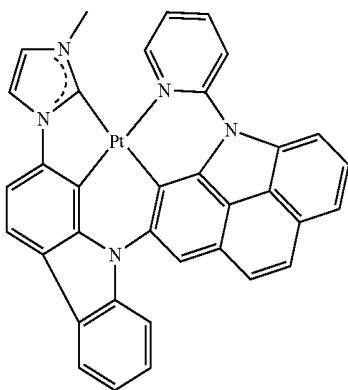
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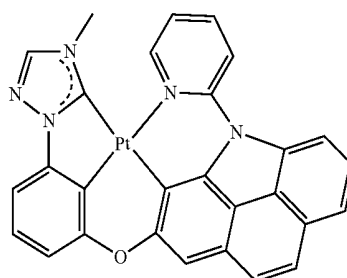
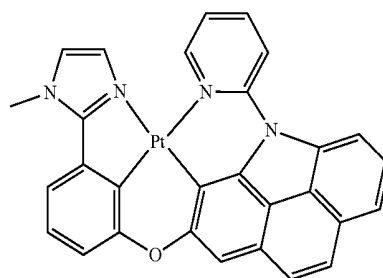
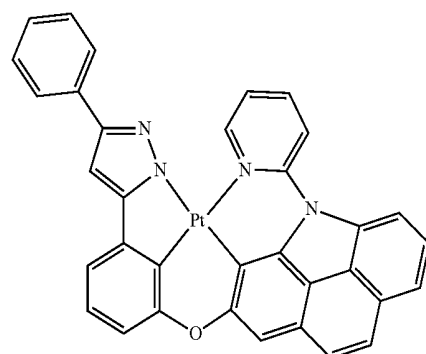
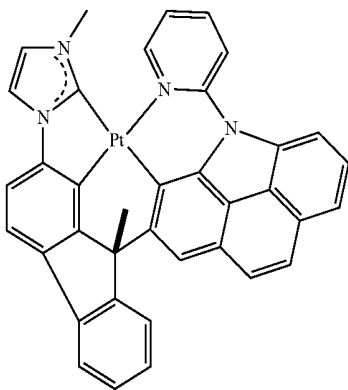
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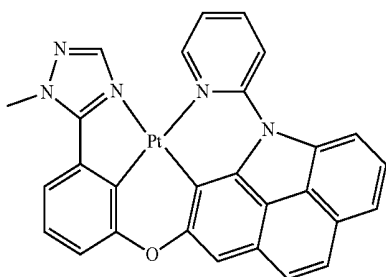
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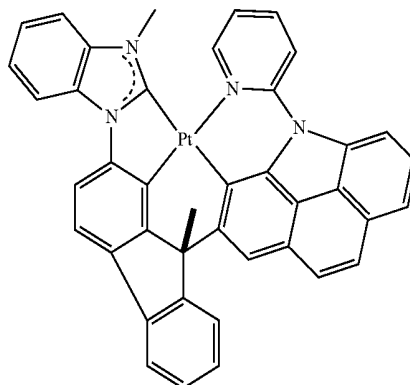
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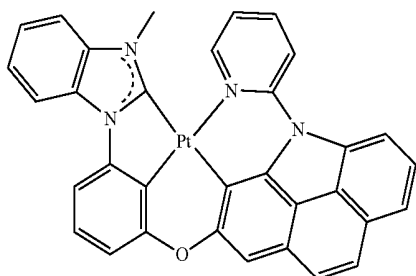


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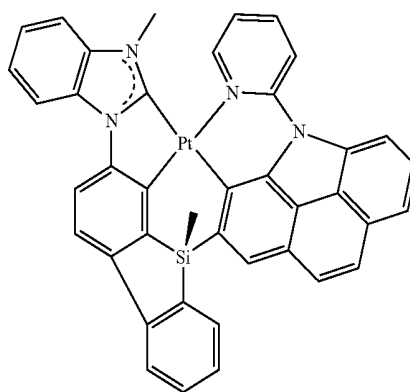
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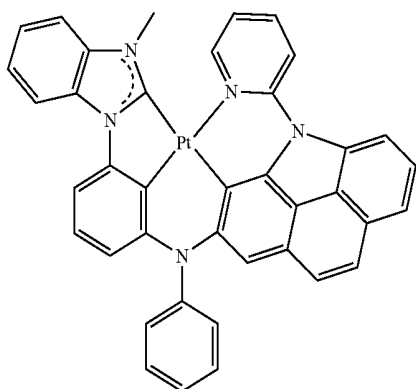
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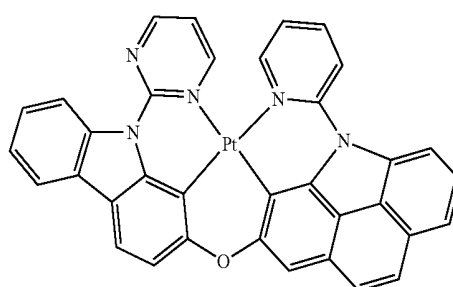
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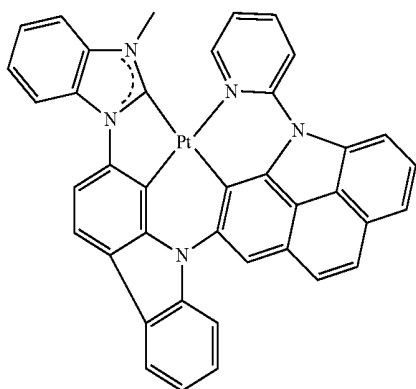
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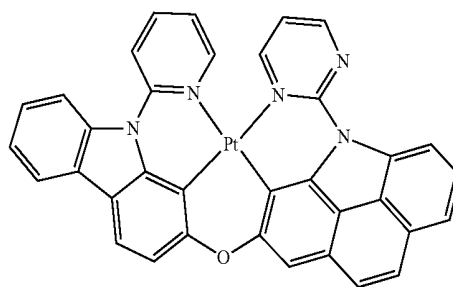
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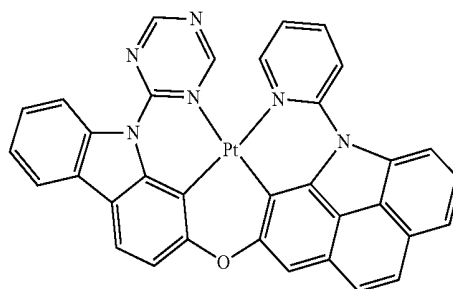
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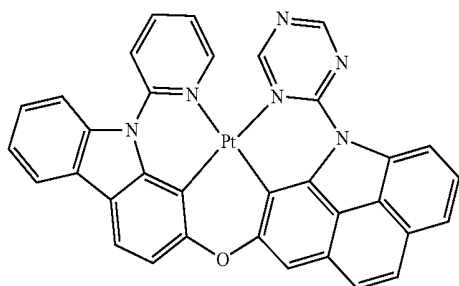


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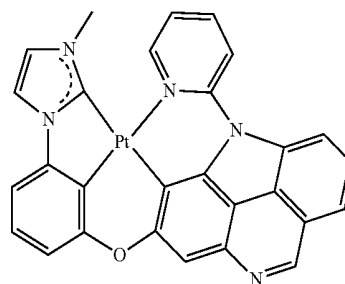
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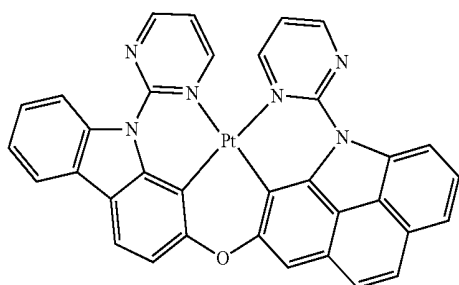


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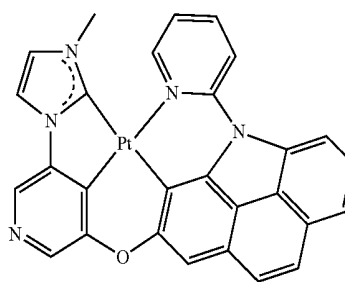
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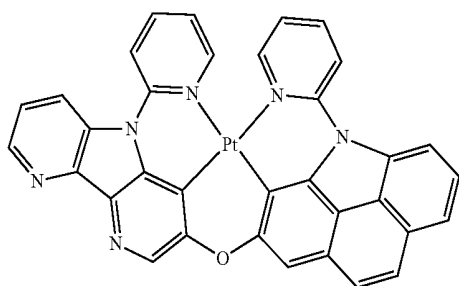
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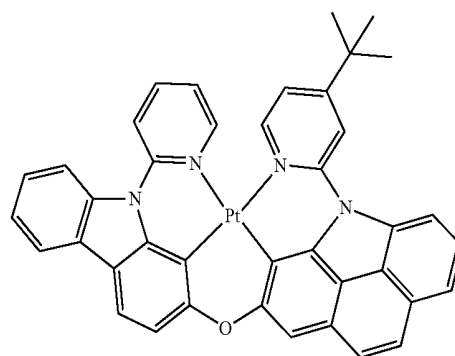
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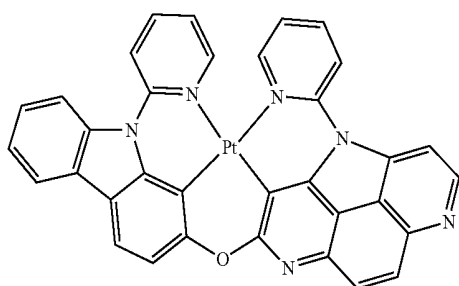
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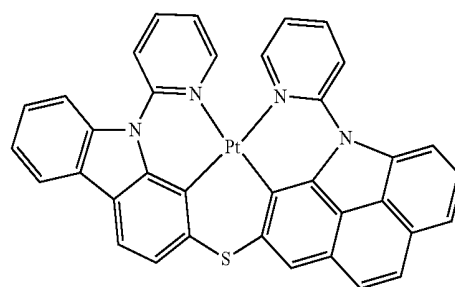
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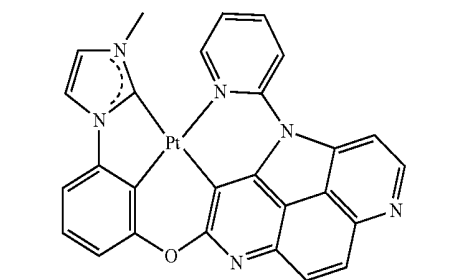
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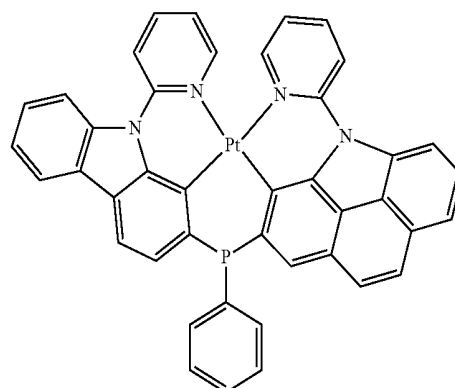
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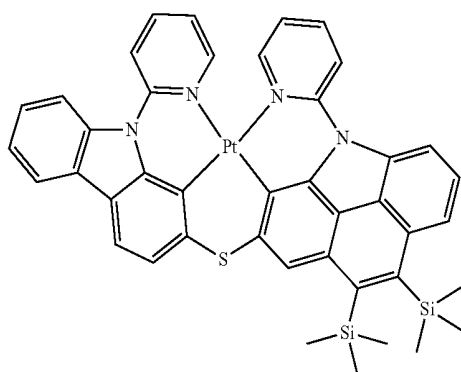


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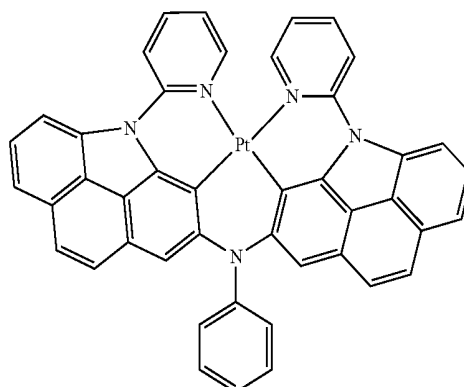
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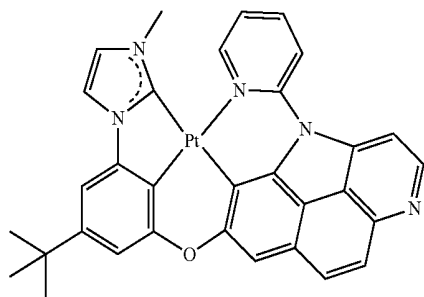


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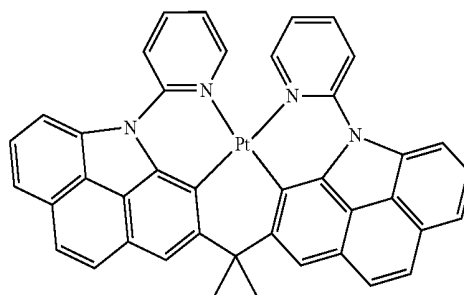
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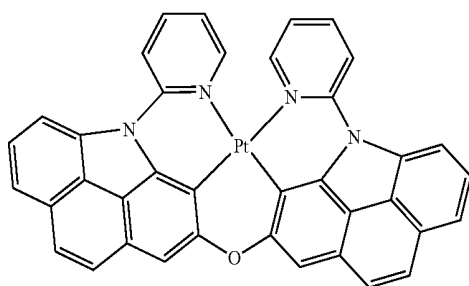
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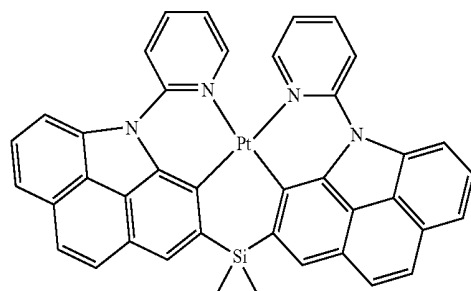
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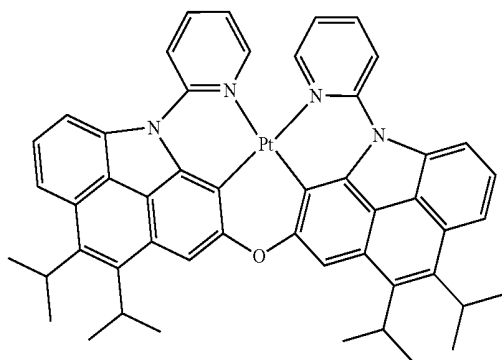
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16. An organic light-emitting device comprising:

a first electrode;

a second electrode; and

an organic layer between the first electrode and the second electrode,

wherein the organic layer comprises an emission layer and the organometallic compound of claim 1.

17. The organic light-emitting device of claim 16, wherein:

the first electrode is an anode,

the second electrode is a cathode,

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,

the hole transport region comprises at least one layer selected from a hole injection layer, a hole transport layer, a buffer layer, an emission auxiliary layer, and an electron blocking layer, and

the electron transport region comprises at least one layer selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

18. The organic light-emitting device of claim 17, wherein: the emission layer comprises the organometallic compound.

19. The organic light-emitting device of claim 18, wherein:

the emission layer further comprises a host, and
the host comprises a carbazole-containing compound.

20. The organic light-emitting device of claim 17, wherein:

the electron transport region comprises the hole blocking
layer, and

the hole blocking layer comprises a phosphine oxide-
containing compound or a silyl-containing compound.

* * * * *

专利名称(译)	有机金属化合物和包括其的有机发光器件		
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申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
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摘要(译)

提供有机金属化合物和包含其的有机发光装置。有机金属化合物可以由式1表示。在式1的化合物中，M 11 可以选自铂 (Pt)，钯 (Pd)，铜 (Cu)，银 (Ag)，金 (Au)，铑 (Rh)，铱 (Ir)，钌 (Ru)，锇 (Os)，钛 (Ti)，锆 (Zr)，铪 (Hf)，钕 (Eu)，铽 (Tb)，和th (Tm)。当应用于有机发光器件时，有机金属化合物的结构特征可以促进能量转移，提高发光效率，并实现高色纯度。

