US 20150228911A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2015/0228911 A1**

(43) **Pub. Date: Aug. 13, 2015**

Kim et al.

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

(71) Applicants: **Samsung Display Co., Ltd.**, Yongin-City (KR); **Pusan National University Industry-University Cooperation Foundation**, Busan (KR)

(72) Inventors: **Jae-Hong Kim**, Yongin-City (KR); **Myeong-Suk Kim**, Yongin-City (KR); **Sung-Wook Kim**, Yongin-City (KR); **Jin-Soo Hwang**, Yongin-City (KR); **Hong-Suk Suh**, Busan (KR)

(21) Appl. No.: **14/338,201**

(22) Filed: **Jul. 22, 2014**

(30) **Foreign Application Priority Data**

Feb. 13, 2014 (KR) 10-2014-0016791

Publication Classification

(51) **Int. Cl.**

H01L 51/00 (2006.01)

H01L 51/50 (2006.01)

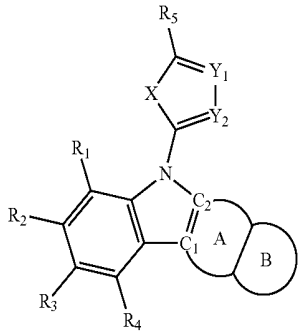
(52) **U.S. Cl.**

CPC ***H01L 51/0072*** (2013.01); ***H01L 51/0069*** (2013.01); ***H01L 51/0067*** (2013.01); ***H01L 51/5072*** (2013.01); ***H01L 51/5056*** (2013.01); ***H01L 51/5096*** (2013.01); ***H01L 51/5092*** (2013.01); ***H01L 51/5088*** (2013.01)

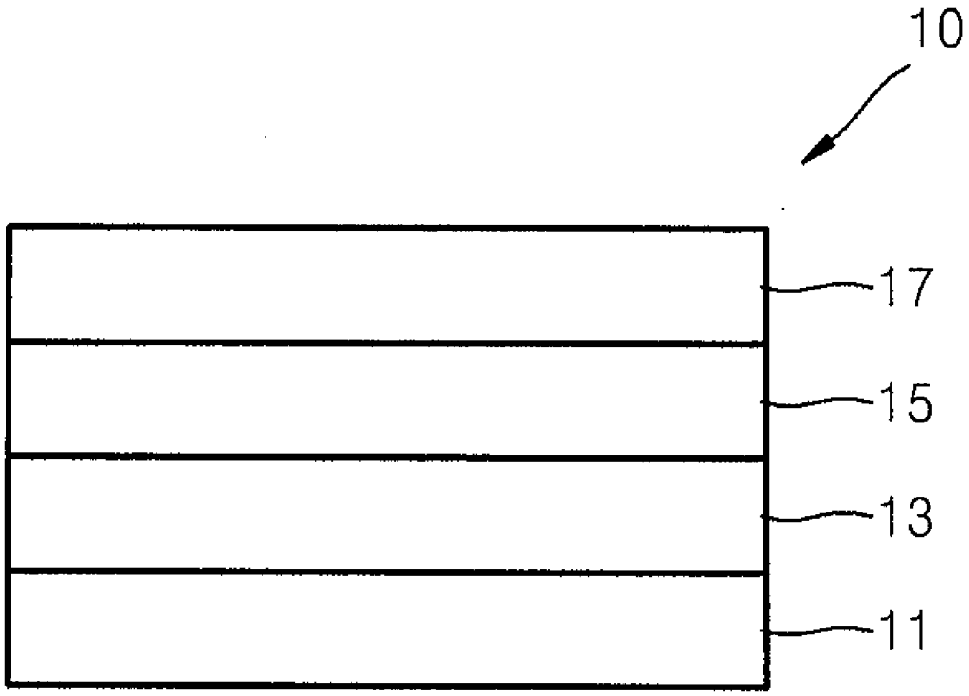
(57) **ABSTRACT**

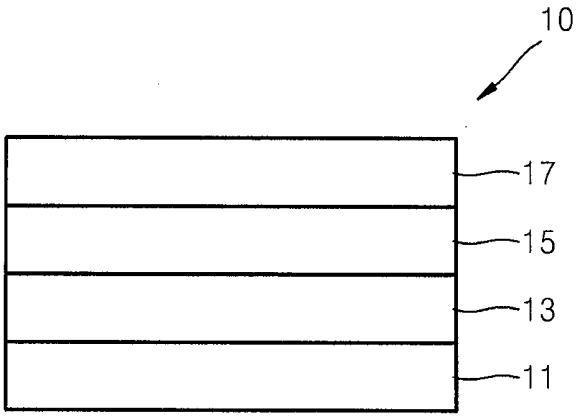
A condensed cyclic compound is represented by Formula 1. An organic light-emitting device includes the condensed cyclic compound represented by Formula 1.

Formula 1



X, Y_1, Y_2, A, B, and R_1 of Formula 1 are described herein. An organic light-emitting device including an organic layer including the condensed cyclic compound may have low driving voltage, high efficiency, high brightness, and long lifespan.




10
17
15
13
11

CONDENSED CYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2014-0016791, filed on Feb. 13, 2014, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

[0002] 1. Field

[0003] Aspects of embodiments of the present disclosure relate to a condensed cyclic compound and an organic light-emitting device including the same.

[0004] 2. Description of the Related Art

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

[0006] An OLED may include a first electrode on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially 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, are recombined in the emission layer to produce excitons. These excitons change (or transition) from an excited state to a ground state, thereby generating light.

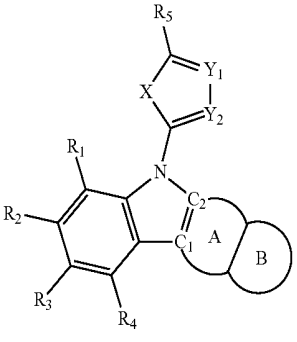
[0007] As a material for a green emission layer and a red emission layer, a compound having a structure in which a **6**-membered hetero ring is connected to a carbazole derivative may be used (utilized).

SUMMARY

[0008] One or more aspects of embodiments of the present disclosure are directed toward a novel condensed cyclic compound and an organic light-emitting device including the same.

[0009] An embodiment of the present disclosure provides a condensed cyclic compound represented by Formula 1:

Formula 1



[0010] where in Formula 1,

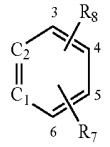
[0011] X is an oxygen atom (O) or a sulfur (S) atom;

[0012] Y_1 and Y_2 are each independently a nitrogen (N) atom or —CR_6;

[0013] C_1 and C_2 are each a carbon (C) atom;

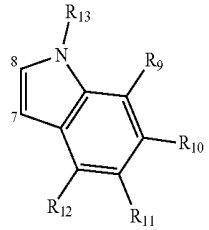
[0014] ring A is a benzene ring represented by Formula 1A, where 3 to 6 in Formula 1A are reference numbers and two of the reference numbers 3 to 6 correspond to respective carbon atoms included in ring B;

Formula 1A



[0015] the ring B is an indole ring represented by Formula 1B, where 7 and 8 in Formula 1B are reference numbers, each of which corresponds to a carbon atom included in ring A;

Formula 1B



[0016] R_1 to R_{13} are each independently selected from a hydrogen atom, a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{10} alkyl group, a substituted or unsubstituted C_2-C_{10} alkenyl group, a substituted or unsubstituted C_2-C_{10} alkynyl group, a substituted or unsubstituted C_1-C_{10} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{30} aryl group, a substituted or unsubstituted C_2-C_{30} heteroaryl group, a substituted or unsubstituted C_6-C_{30} aryloxy group, a substituted or unsubstituted C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, and —$B(Q_4)(Q_5)$,

[0017] at least one substituent of the substituted C_1-C_{10} alkyl group, the substituted C_2-C_{10} alkenyl group, the substituted C_2-C_{10} alkynyl group, the substituted C_1-C_{10} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_3-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} heterocycloalkenyl group, the substituted C_6-C_{30} aryl group, the substituted C_2-C_{30} heteroaryl group, the substituted C_6-C_{30} aryloxy group, and the substituted C_6-C_{30} arylthio group is selected from:

[0018] a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an

amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group;

[0019] a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$;

[0020] a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, and a monovalent C_2-C_{30} non-aromatic condensed polycyclic group;

[0021] a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, and a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

[0022] —$Si(Q_{31})(Q_{32})(Q_{33})$ and —$B(Q_{34})(Q_{35})$, and

[0023] Q_1 to Q_5, Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{35} are each independently selected from a hydrogen atom, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, and a monovalent C_6-C_{30} non-aromatic condensed polycyclic group.

[0024] According to another embodiment of the present disclosure, an organic light-emitting device includes: a first electrode; a second electrode facing the first electrode; and an organic layer between the first and second electrodes and including an emission layer, the organic layer including at least one of the condensed cyclic compound.

BRIEF DESCRIPTION OF THE DRAWINGS

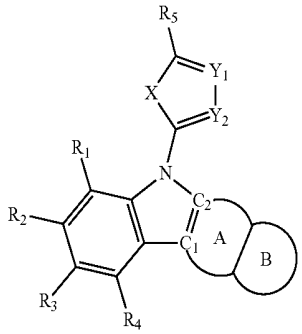
[0025] The above and/or other aspects of the present disclosure will become apparent and more readily appreciated by reference to the following description when considered together with the accompanying drawing, which is a schematic view of an organic light-emitting device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0026] Reference will now be made to certain embodiments of the present disclosure, an example of which is illustrated in the accompanying drawing. As those skilled in the art would recognize, the described embodiments may be modified in many ways and, therefore, should not be construed as limiting. Accordingly, the embodiments are described below, by referring to the figures, merely to explain aspects of the present description. Expressions such as "at least one," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0027] A condensed cyclic compound according to an embodiment of the present disclosure is represented by Formula 1:

Formula 1



[0028] where in Formula 1,

[0029] X is an oxygen atom (O) or a sulfur (S) atom;

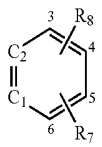
[0030] Y_1 and Y_2 may be each independently a nitrogen (N) atom or —CR_6;

[0031] C_1 and C_2 may be each a carbon (C) atom;

[0032] ring A may be a benzene ring represented by Formula 1A, where 3 to 6 in

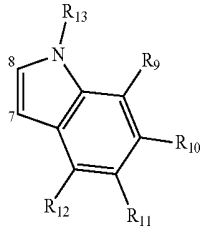
[0033] Formula 1A are reference (or indication) numbers and two of the reference numbers 3 to 6 correspond to respective carbon atoms included in ring B. For example, the reference numbers 3 to 6 may be used (utilized) to distinguish a binding site in Formula 1A.

Formula 1A



[0034] the ring B may be an indole ring represented by Formula 1B, where 7 and 8 in Formula 1B are reference (or indication) numbers, each of which corresponds to a carbon atom included in the ring A. For example, the reference numbers 7 and 8 may be used to distinguish a binding site in Formula 1B, and a binding region between the reference numbers 7 and 8 may be condensed into the ring A.

Formula 1B



[0035] R_1 to R_{13} may be each independently selected from a hydrogen atom, a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{10} alkyl group, a substituted or unsubstituted C_2-C_{10} alkenyl group, a substituted or unsubstituted C_2-C_{10} alkynyl group, a substituted or unsubstituted C_1-C_{10} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{30} aryl group, a substituted or unsubstituted C_2-C_{30} heteroaryl group, a substituted or unsubstituted C_6-C_{30} aryloxy group, a substituted or unsubstituted C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group (non-aromatic condensed polycyclic group), —$Si(Q_1)(Q_2)(Q_3)$, and —$B(Q_4)(Q_5)$.

[0036] Here, at least one substituent of the substituted C_1-C_{10} alkyl group, the substituted C_2-C_{10} alkenyl group, the substituted C_2-C_{10} alkynyl group, the substituted C_1-C_{10} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_3-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} heterocycloalkenyl group, the substituted C_6-C_{30} aryl group, the substituted C_2-C_{30} heteroaryl group, the substituted C_6-C_{30} aryloxy group, and the substituted C_6-C_{30} arylthio group may be selected from:

[0037] a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group;

[0038] a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$;

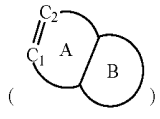
[0039] a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, and a monovalent C_2-C_{30} non-aromatic condensed polycyclic group;

[0040] a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, and a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and —$Si(Q_{31})(Q_{32})(Q_{33})$ and —$B(Q_{34})(Q_{35})$.

[0041] Here, Q_1 to Q_5, Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{35} may be each independently selected from a hydrogen atom, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, and a monovalent C_6-C_{30} non-aromatic condensed polycyclic group.

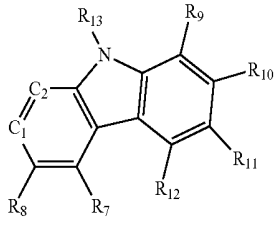
[0042] The ring B may be condensed into one of a binding region between the reference (or indication) numbers 3 and 4 of the ring A, a binding region between the reference (or indication) numbers 4 and 5 of the ring A, and a binding region between the reference (or indication) numbers 5 and 6 of the ring A. For example, the ring B may be condensed to include the carbon atoms corresponding to the reference numbers 3 and 4, the carbon atoms corresponding to the reference numbers 4 and 5, or the carbon atoms corresponding to the references numbers 5 and 6 of the Ring A.

[0043] In some embodiments, the rings A and B



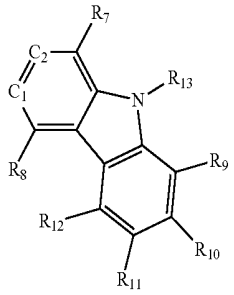
may include a group (e.g., be formed of a compound) represented by any one of Formulae 2A to 2F:

<Formula 2A>

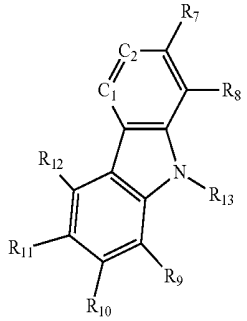


-continued

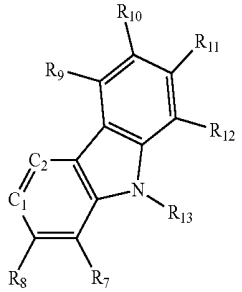
<Formula 2B>



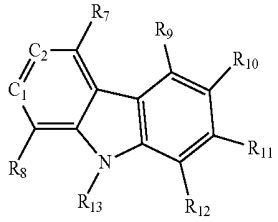
<Formula 2C>



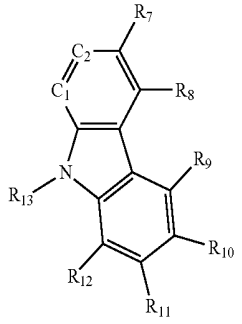
<Formula 2D>



<Formula 2E>



<Formula 2F>



[0044] where in Formulae 2A to 2F,

[0045] R_7 to R_{13} may be each independently selected from a hydrogen atom, a substituted or unsubstituted C_6-C_{30} aryl group, and a substituted or unsubstituted C_2-C_{30} heteroaryl group, and

[0046] at least one substituent of the substituted C_6-C_{30} aryl group and the substituted C_2-C_{30} heteroaryl group may be selected from a C_6-C_{30} aryl group and a C_2-C_{30} heteroaryl group.

[0047] In Formulae 2A to 2F, R_{13} may not be a hydrogen atom. For example, R_{13} may be selected from a substituted or unsubstituted C_6-C_{30} aryl group, and a substituted or unsubstituted C_2-C_{30} heteroaryl group, and at least one substituent of the substituted C_6-C_{30} aryl group and the substituted C_2-C_{30} heteroaryl group may be selected from a C_6-C_{30} aryl group and a C_2-C_{30} heteroaryl group.

[0048] In Formulae 2A to 2F, R_1 to R_{13} may be each independently selected from a hydrogen atom, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a biphenyl group, a heptalenyl group, a phenalenyl group, a fluorenyl group, a phenanthrenyl group, an anthryl function, a fluoranthenyl group, a pyrenyl group, a benzofluorenyl group, a naphthacenyl group, a chrysenyl group, a triphenylenyl group, a terphenyl group, a perylenyl group, a picenyl group, a hexacenyl group, a spirofluorenyl group, a pyrrolyl group, a furyl group, a pyrazolyl group, an imidazolyl group, an oxazolyl group, an isoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a pyridyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a pyranyl group, a thiophenyl group, a thiazolyl group, an isothiazolyl group, a thiopyranyl group, an indolyl group, an isoindolyl group, an indolizinyl group, a benzofuryl group, an isobenzofuryl group, an indazolyl group, a benzimidazolyl group, a benzoxazolyl group, a benzisoxazolyl group, an imidazopyridyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a phthalazinyl group, a quinazolinyl group, a quinoxalinyl group, a naphthyridinyl group, a cinnolinyl group, a benzothiophenyl group, a benzothiazolyl group, a carbazolyl group, a benzocarbazolyl group, a pyridoindolyl group, a dibenzofuryl group, a phenanthridinyl group, a benzoquinolyl group, a phenazinyl group, a dibenzosilolyl group, a dibenzothiophenyl group, and a benzocarbazolyl group;

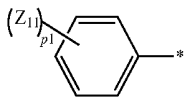
[0049] a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, and a decyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, and an amino group; and

[0050] a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a biphenyl group, a heptalenyl group, a phenalenyl group, a fluorenyl group, a phenanthrenyl group, an anthryl function, a fluoranthenyl group, a pyrenyl group, a benzofluorenyl group, a naphthacenyl group, a chrysenyl group, a triphenylenyl group, a terphenyl group, a perylenyl group, an picenyl group, a hexacenyl group, a spirofluorenyl group, a pyrrolyl group, a furyl group, a pyrazolyl group, an imidazolyl group, an oxazolyl group, an isoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a pyridyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, pyranyl group, a thiophenyl group, a thiazolyl group, an isothiazolyl group, a thiopyranyl group, an indolyl group, an isoindolyl group, an indolizinyl group, a benzofuryl group, an isobenzofuryl group, an indazolyl group, a benzimidazolyl group, a benzox-

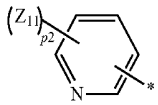
azolyl group, a benzisoxazolyl group, an imidazopyridyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a phthalazinyl group, a quinazolinyl group, a quinoxalinyl group, a naphthyridinyl group, a cinnolinyl group, a benzothiophenyl group, a benzothiazolyl group, a carbazolyl group, a benzocarbazolyl group, a pyridoindolyl group, a dibenzofuryl group, a phenanthridinyl group, a benzoquinolyl group, a phenazinyl group, a dibenzosilolyl group, a dibenzothiophenyl group, and a benzocarbazolyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, a C_1-C_{10} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_4-C_{30} heteroaryl group, a C_5-C_{30} aryloxy group, a C_5-C_{30} arylthio group, and —$Si(Q_{31})(Q_{32})(Q_{33})$ (where, Q_{31} to Q_{33} may be each independently selected from a hydrogen atom, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a C_6-C_{20} aryl group), where R_5 and R_{13} may not be a hydrogen.

[0051] For example, R_1 to R_4 and R_6 to R_{12} may be each independently selected from a hydrogen atom and a compound represented by one of Formulae 3A to 3C, and R_5 and R_{13} may be each independently selected from a compound represented by one of Formulae 3A to 3C:

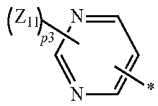
<3A>



<3B>



<3C>



[0052] where in Formulae 3A to 3C,

[0053] Z_{11} may be selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a C_6-C_{30} aryl group, a C_4-C_{30} heteroaryl group, and —$Si(Q_{31})(Q_{32})(Q_{33})$ (where Q_{31} to Q_{33} may be each independently selected from a hydrogen atom, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a C_6-C_{20} aryl group), and

[0054] p1 may be selected from an integer of 1 to 5,

[0055] p2 may be selected from an integer of 1 to 4,

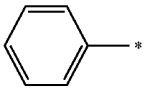
[0056] p3 may be selected from an integer of 1 to 3, and

[0057] * may be (or correspond to) a binding site.

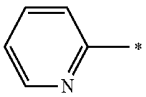
[0058] For example, R_1 to R_4 and R_6 to R_{12} may be each independently selected from a hydrogen and a compound represented by one of Formulae 4A to 4M, and

[0059] R_5 and R_{13} may be each independently selected from a compound represented by one of Formulae 4A to 4M.

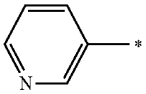
<4A>



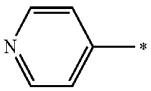
<4B>



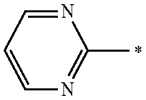
<4C>



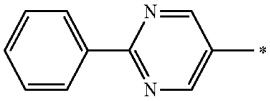
<4D>



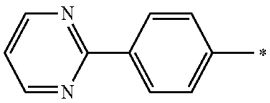
<4E>



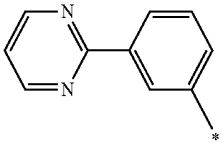
<4F>



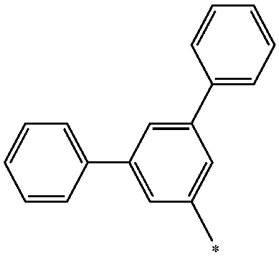
<4G>



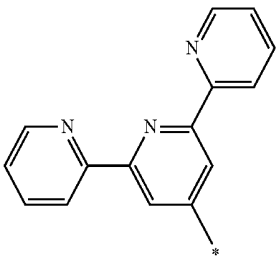
<4H>



<4I>

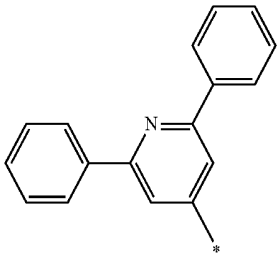


<4J>

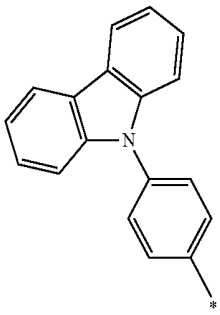


-continued

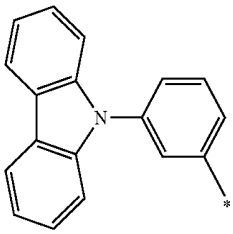
<4K>



<4L>



<4M>



[0060] According to an embodiment, in Formula 1, X may be a sulfur (S) atom, Y_1 may be a nitrogen (N) atom, and Y_2 may be —CR_6.

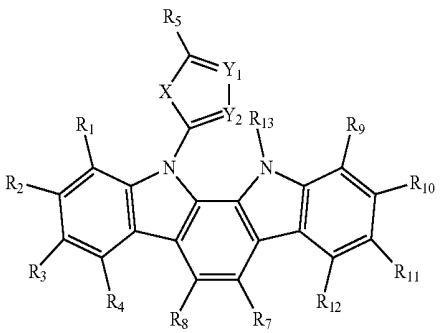
[0061] According to another embodiment of the present disclosure, in Formula 1, X may be a S atom, Y_1 may be —CR_6, and Y_2 may be a N atom.

[0062] According to another embodiment of the present disclosure, in Formula 1, X may be an oxygen (O) atom, Y_1 may be a N atom, and Y_2 may be —CR_6.

[0063] According to another embodiment, in Formula 1, X may be an O atom, Y_1 is —CR_6, and Y_2 may be a N atom.

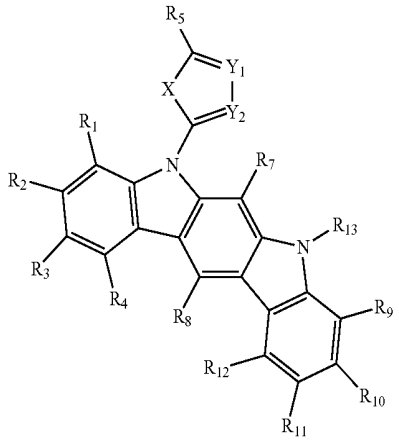
[0064] In some embodiments, the condensed cyclic compound of Formula 1 may be represented by Formulae 1-1 to 1-6:

Formula 1-1

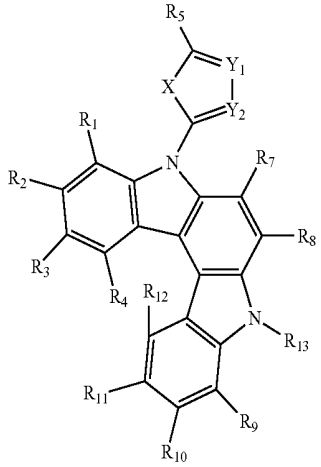


-continued

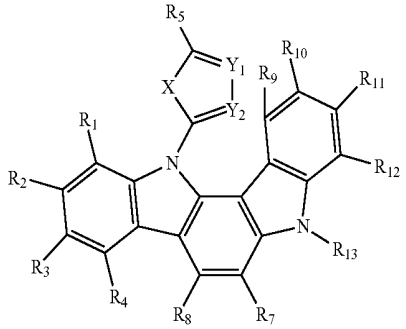
Formula 1-2



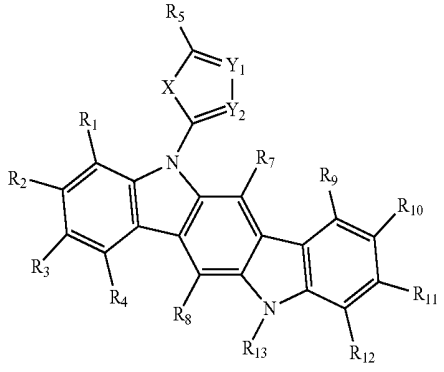
Formula 1-3



Formula 1-4

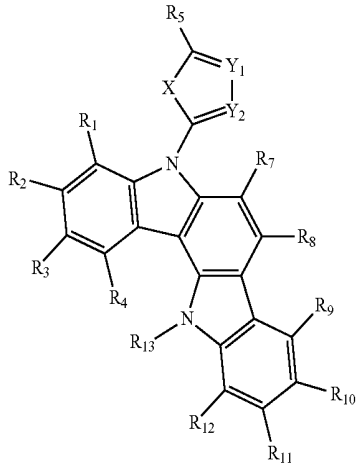


Formula 1-5



-continued

Formula 1-6



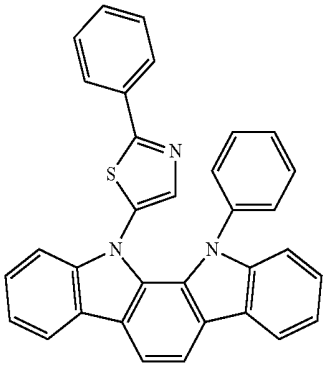
[0065] In Formulae 1-1 to 1-6, X, Y_1, and Y_2 may be understood by referring to the description thereof with respect to Formula 1.

[0066] In Formulae 1-1 to 1-6, R_1 to R_4 and R_6 to R_{12} may be each independently selected from a phenyl group, a pyridyl group, and a pyrimidinyl group, each substituted with at least one selected from a hydrogen atom, a phenyl group, a pyridyl group, and a pyrimidinyl group; and a phenyl group, a pyridyl group, a pyrimidinyl group, and a carbazolyl group.

[0067] R_5 and R_{13} may be each independently selected from a phenyl group, a pyridyl group, and a pyrimidinyl group, each substituted with at least one selected from a phenyl group, a pyridyl group, and a pyrimidinyl group; and a phenyl group, a pyridyl group, a pyrimidinyl group, and a carbazolyl group.

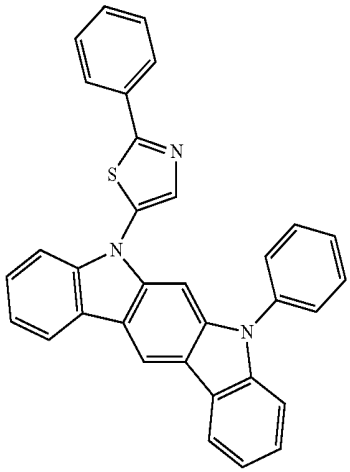
[0068] The condensed cyclic compound of Formula 1 may be any one of Compounds 1 to 159:

1

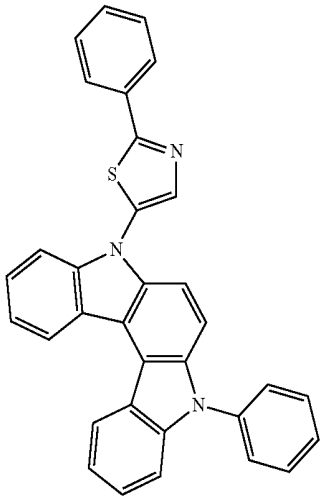


-continued

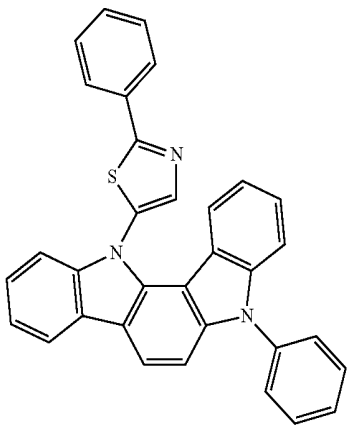
2



3

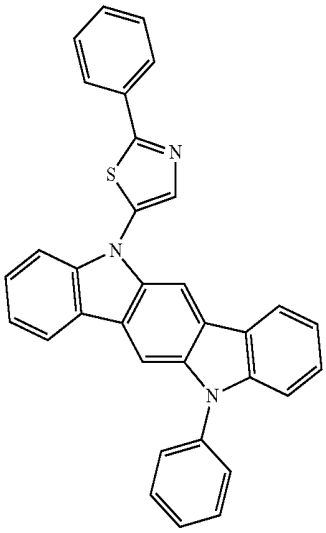


4

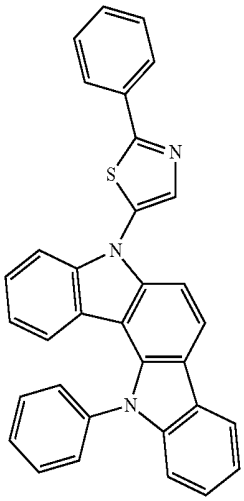


-continued

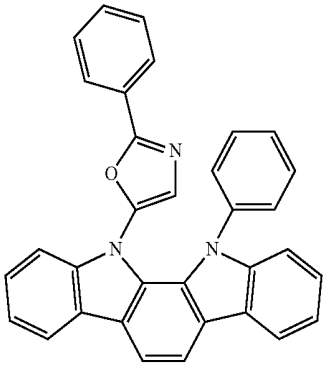
5



6

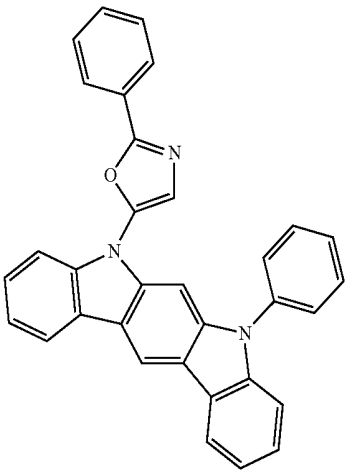


7

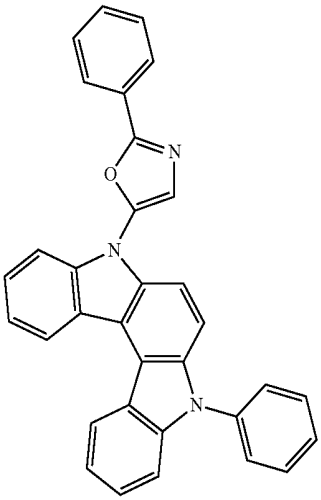


-continued

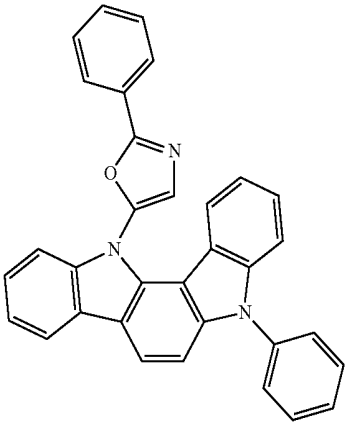
8



9

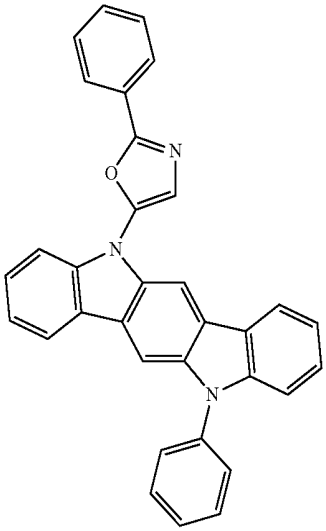


10

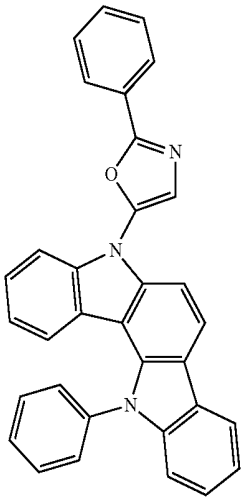


-continued

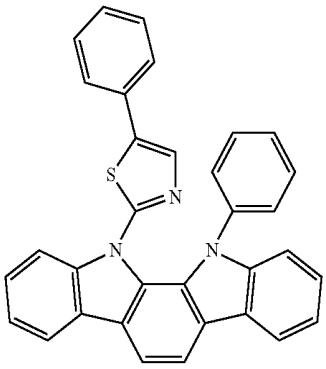
11



12

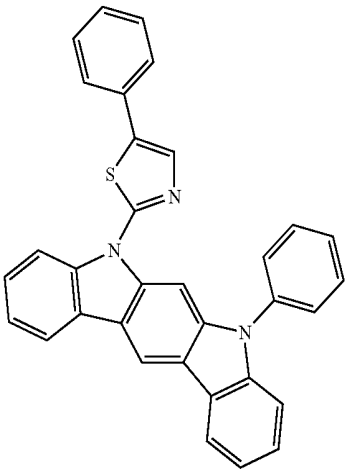


13

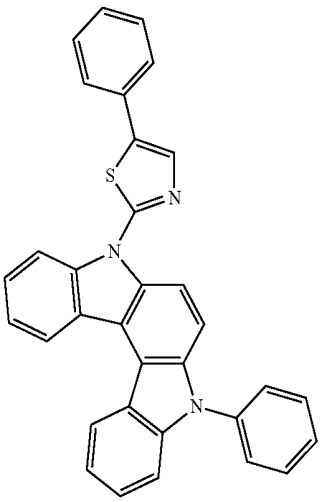


-continued

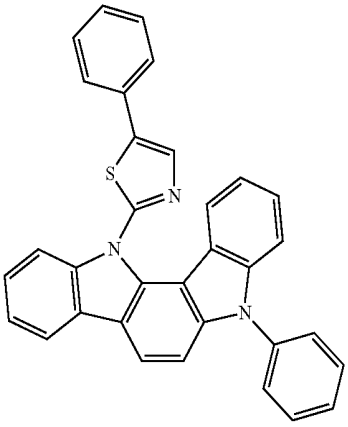
14



15

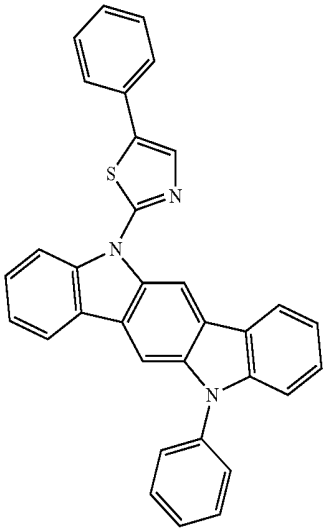


16

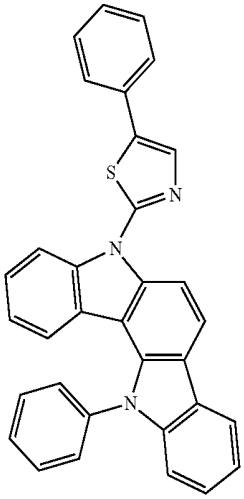


-continued

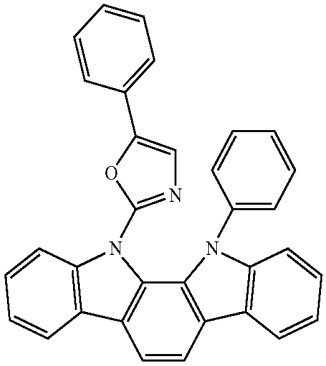
17



18

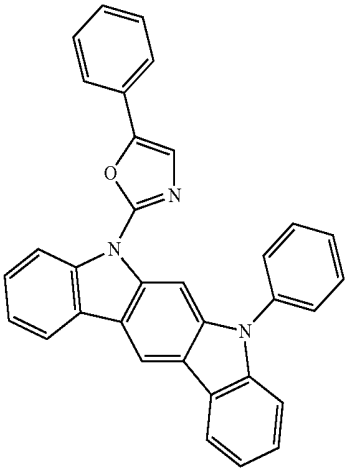


19

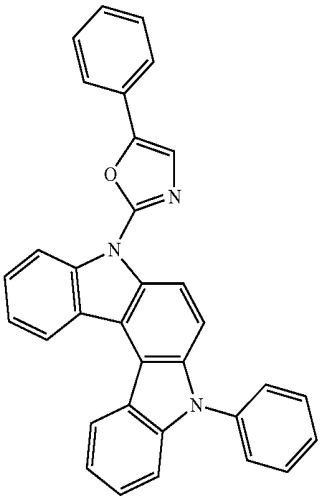


-continued

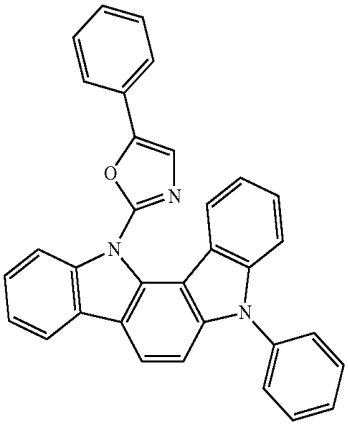
20



21

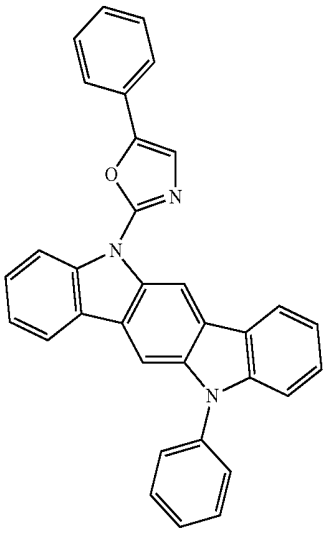


22

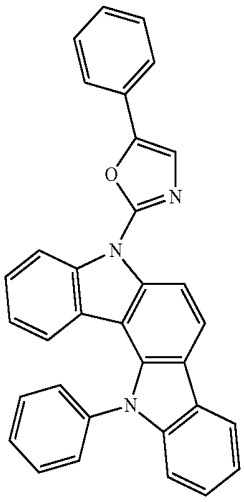


-continued

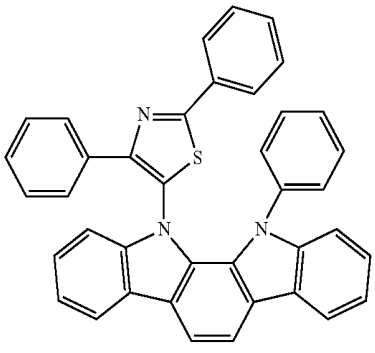
23



24

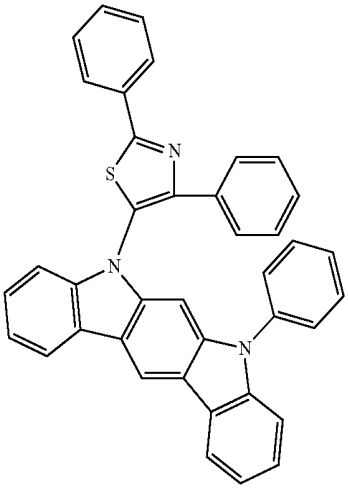


25

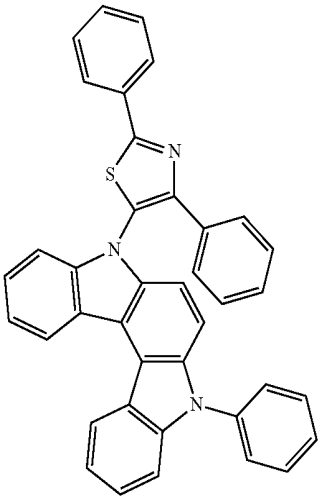


-continued

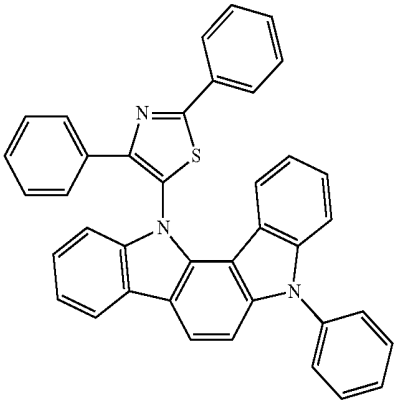
26



27

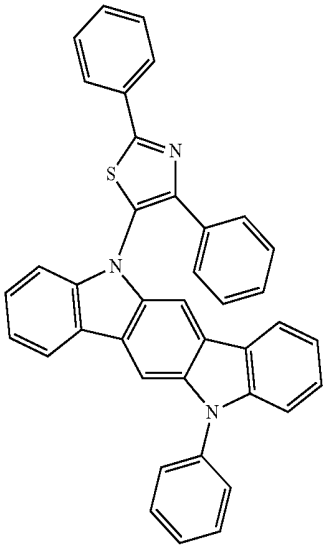


28

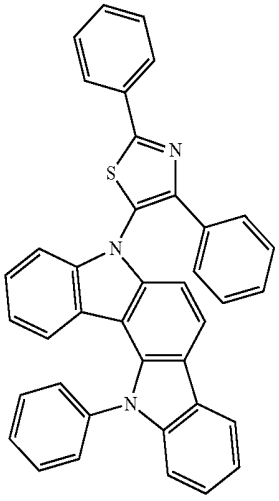


-continued

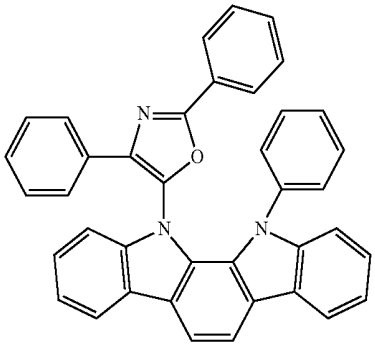
29



30

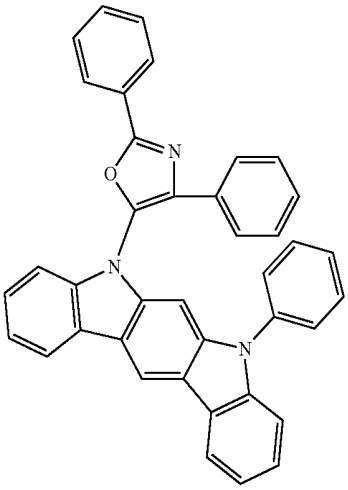


31

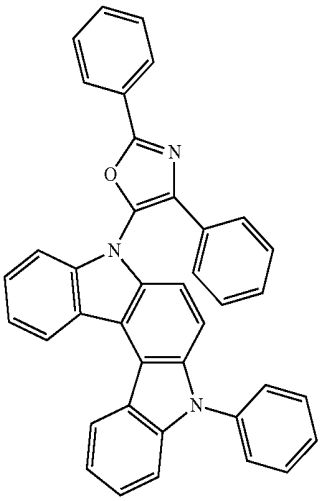


-continued

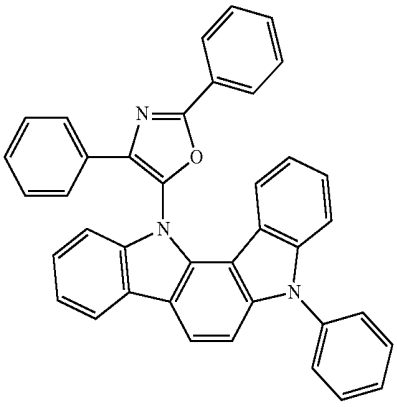
32



33

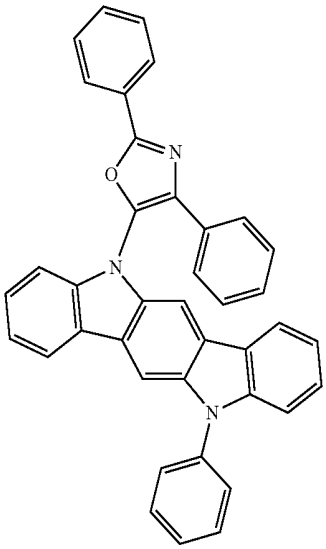


34

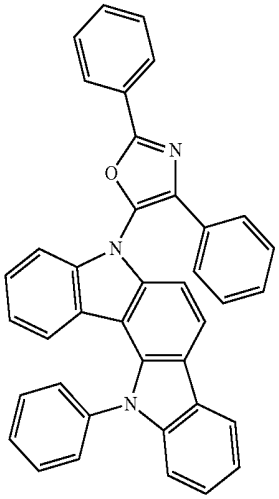


-continued

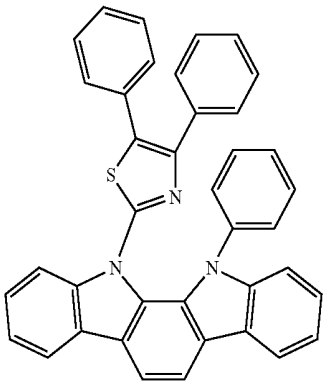
35



36

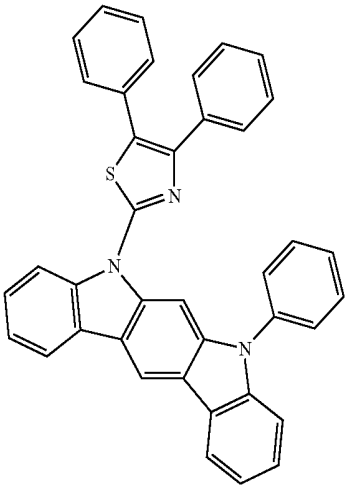


37

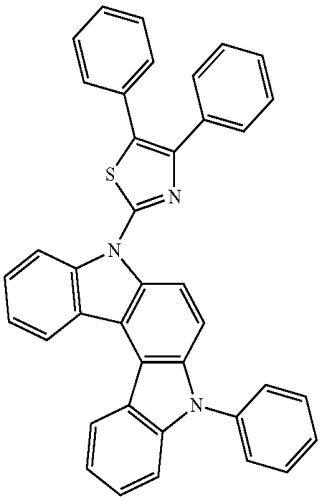


-continued

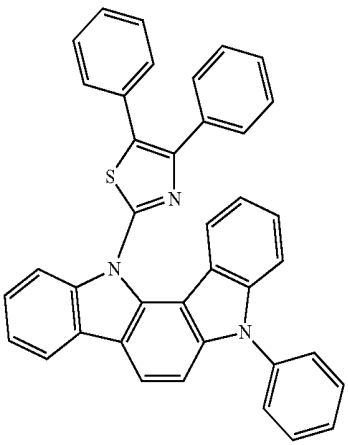
38



39

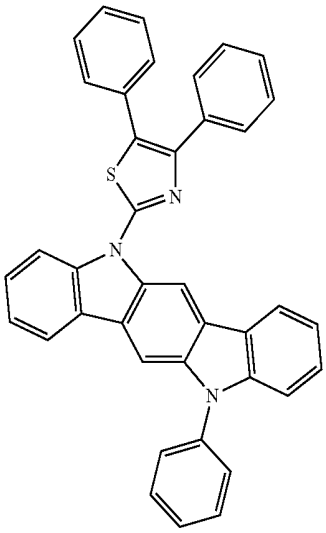


40

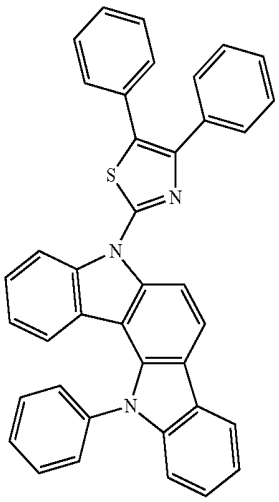


-continued

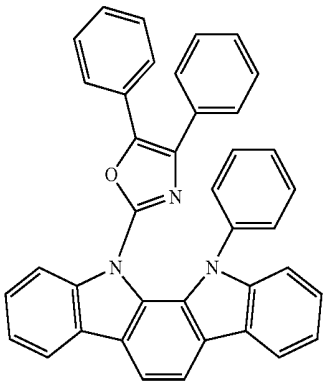
41



42

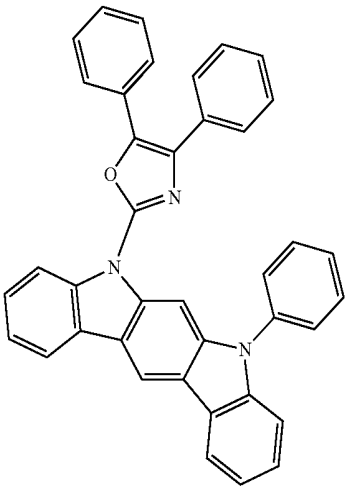


43

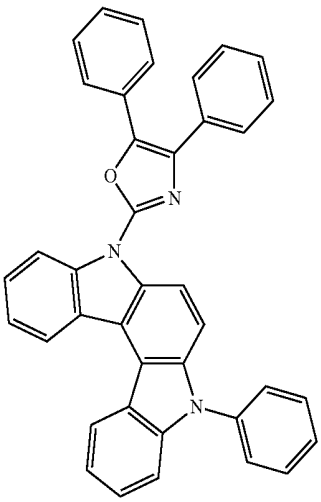


-continued

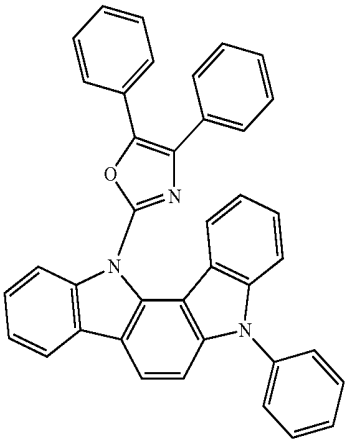
44



45

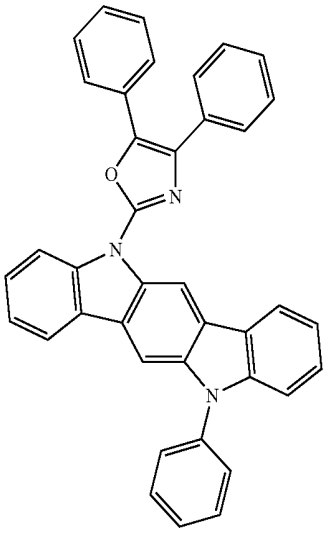


46

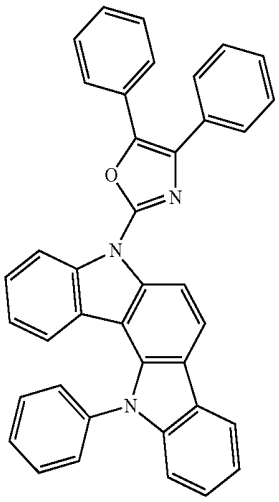


-continued

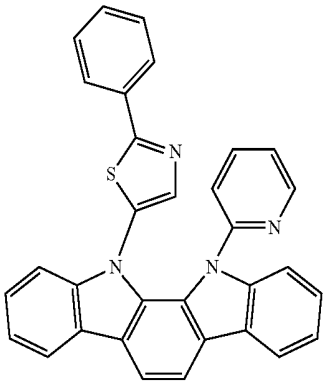
47



48

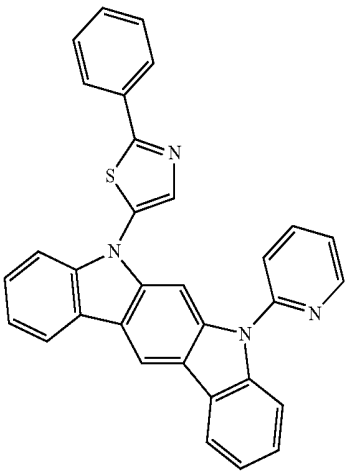


49

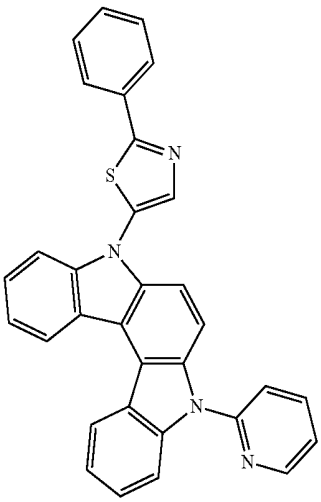


-continued

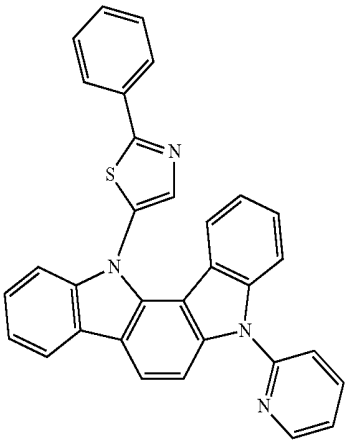
50



51

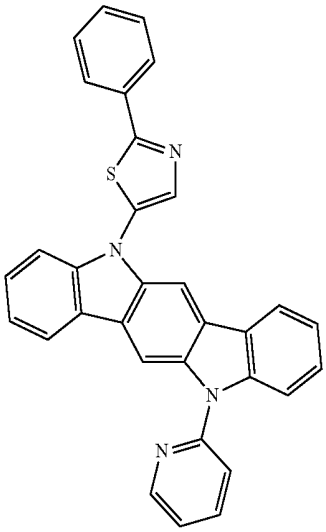


52

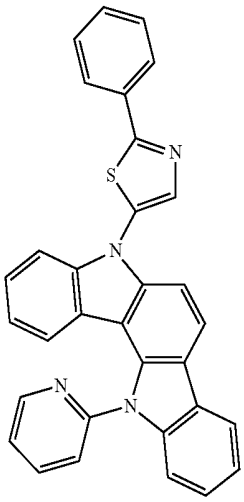


-continued

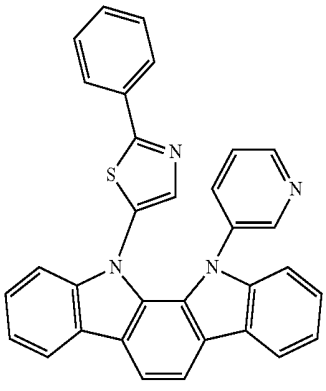
53



54

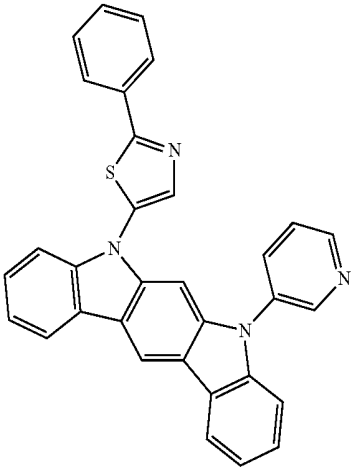


55

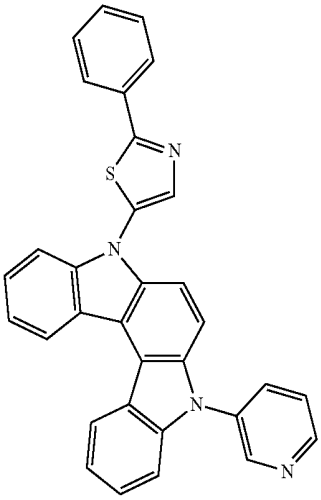


-continued

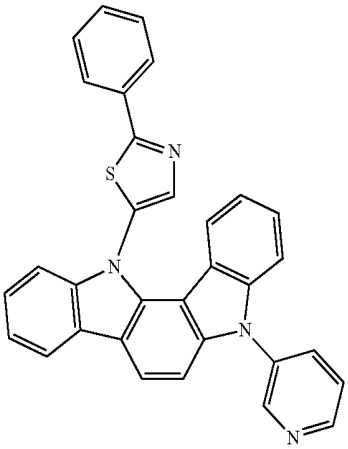
56



57

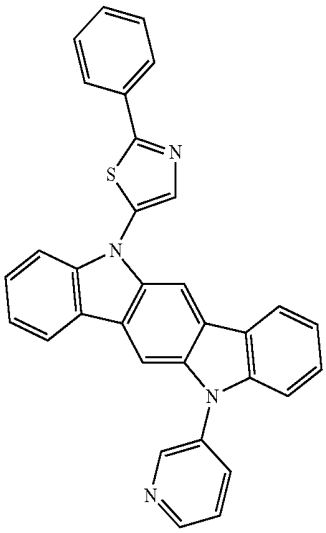


58

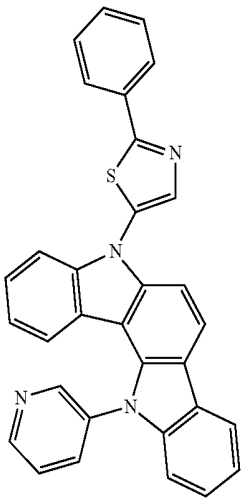


-continued

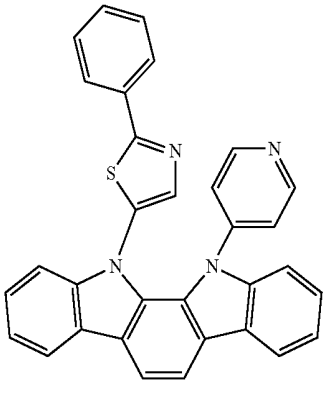
59



60

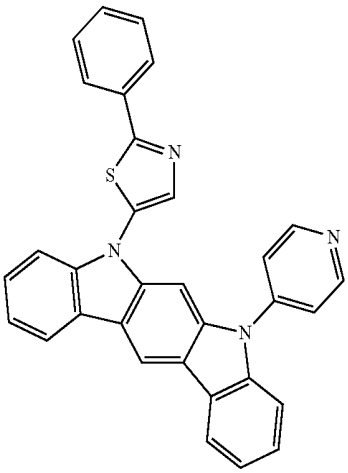


61

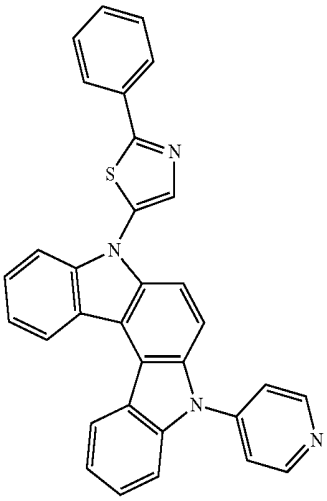


-continued

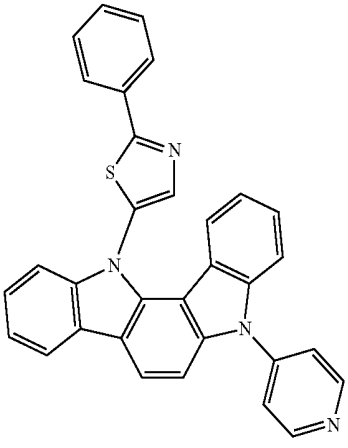
62



63

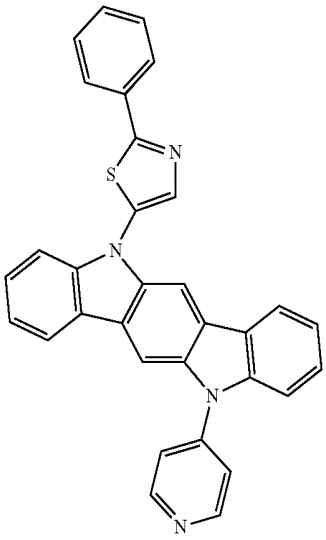


64

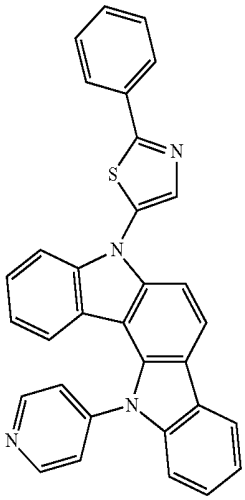


-continued

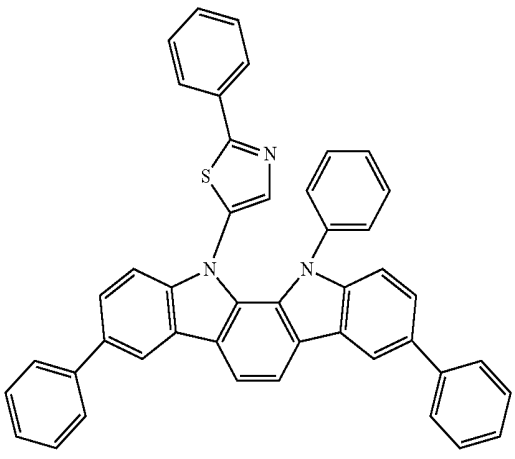
65



66

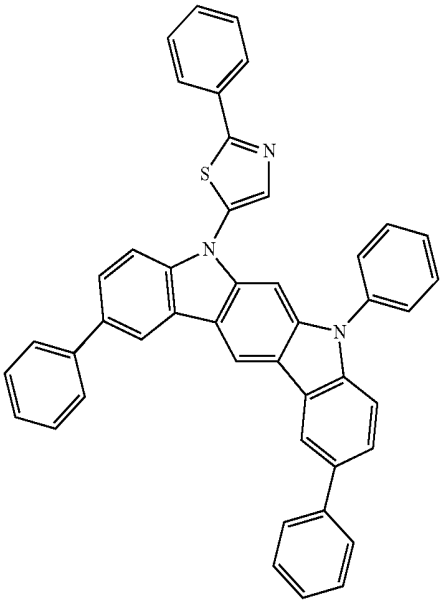


67

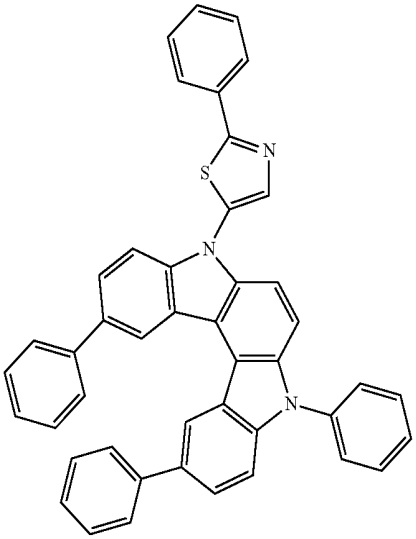


-continued

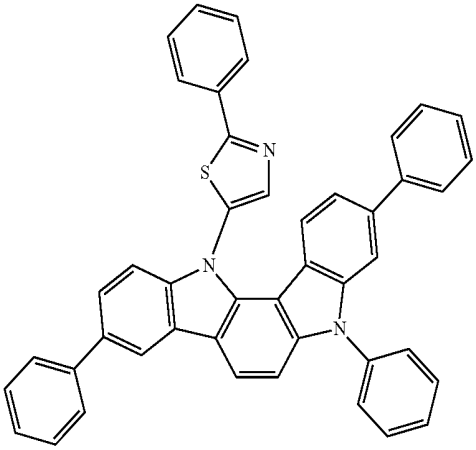
68



69

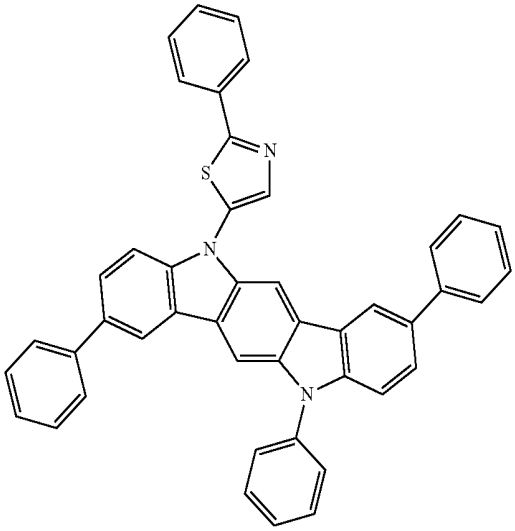


70

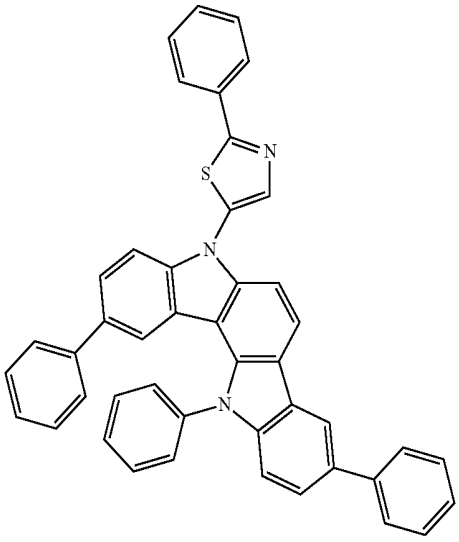


-continued

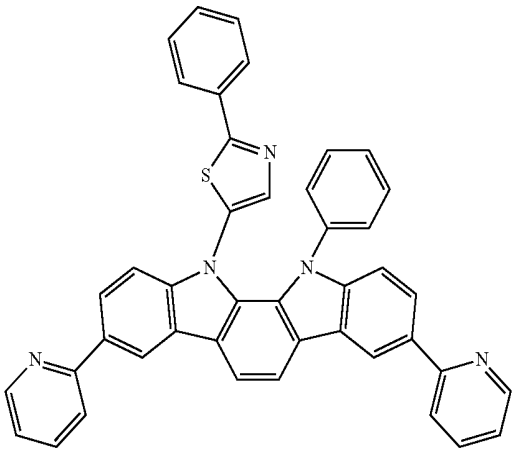
71



72

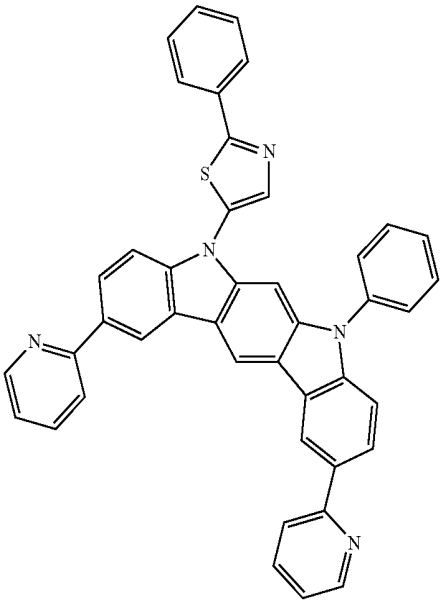


73

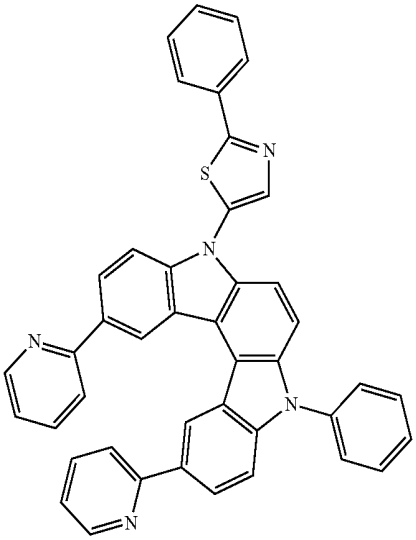


-continued

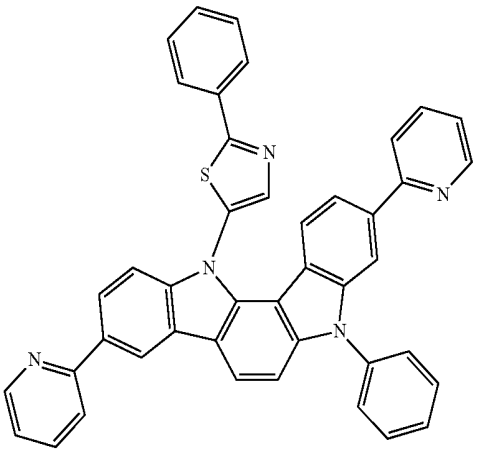
74



75

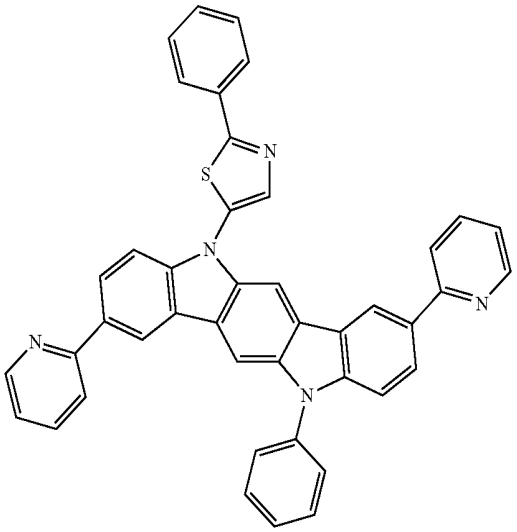


76

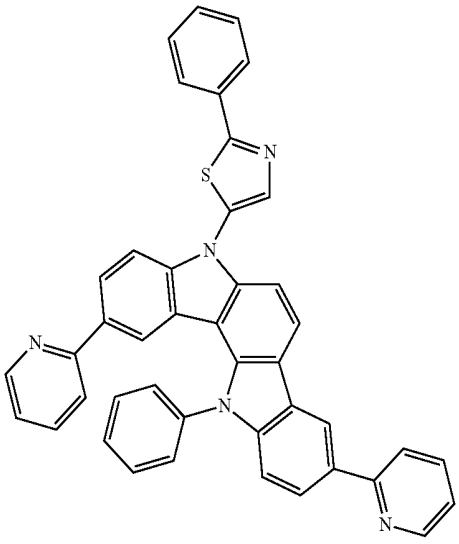


-continued

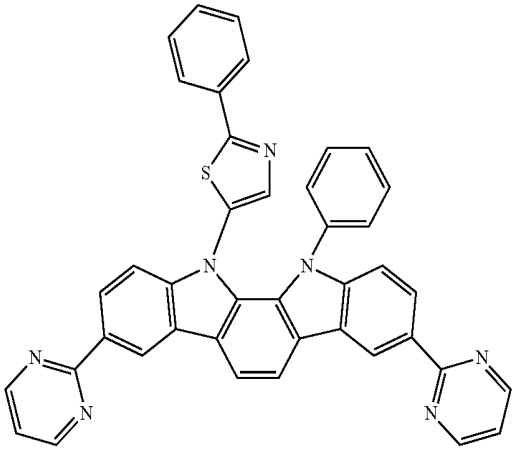
77



78

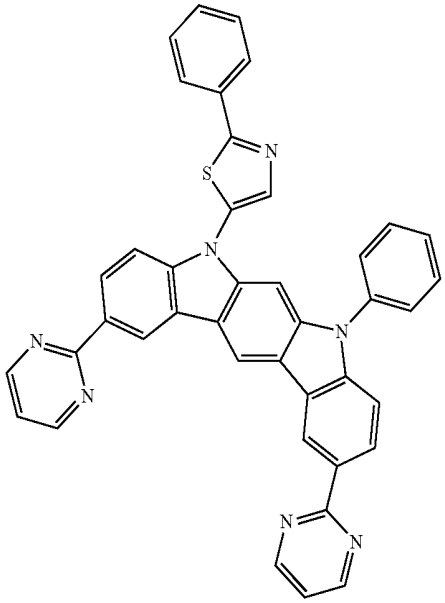


79

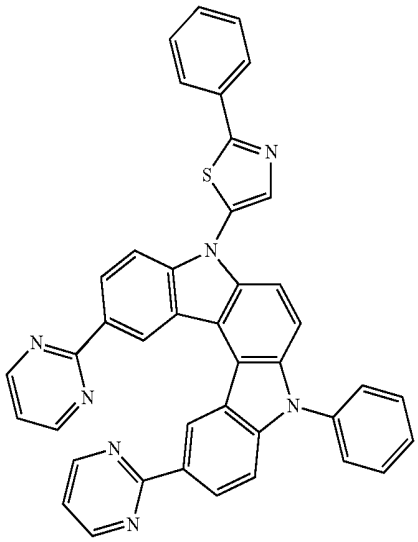


-continued

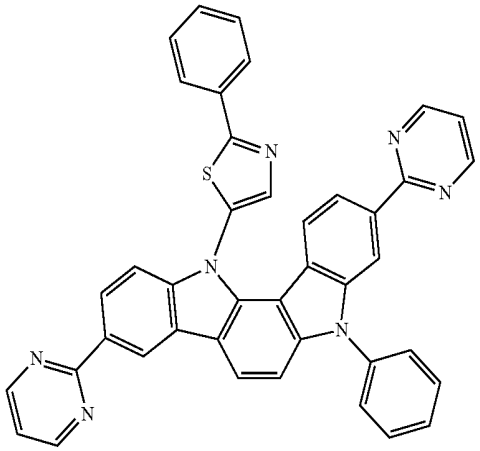
80



81

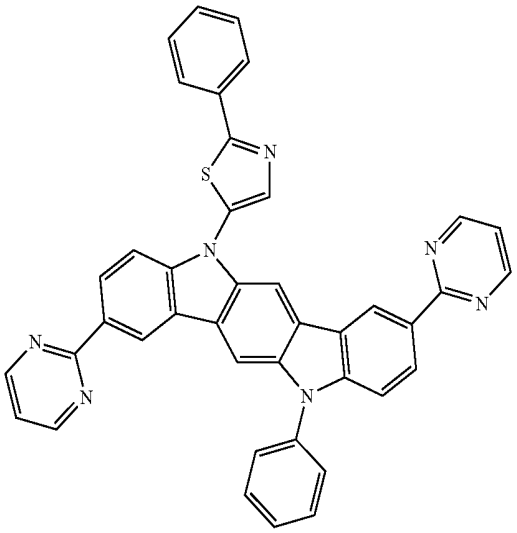


82

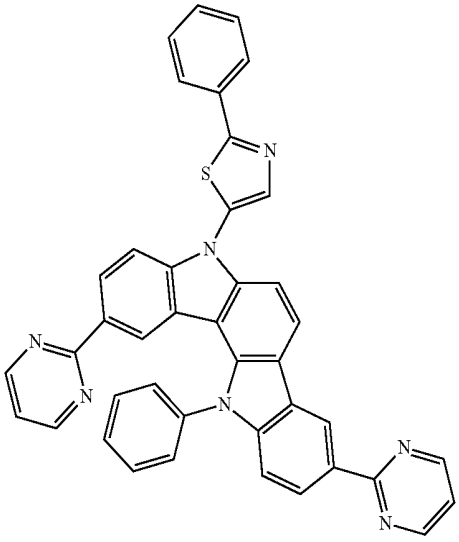


-continued

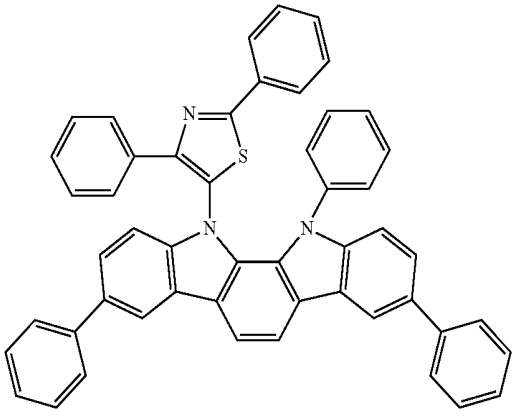
83



84

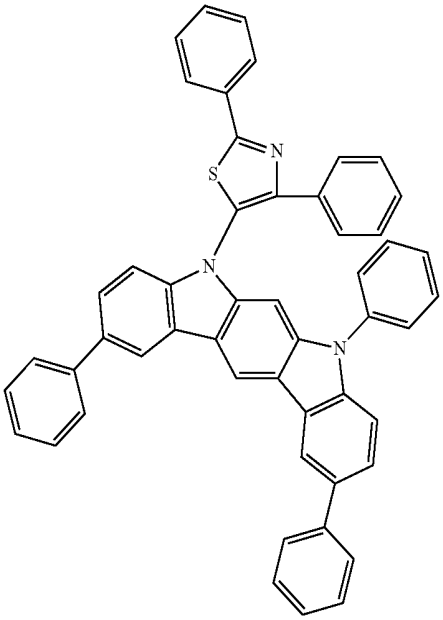


85

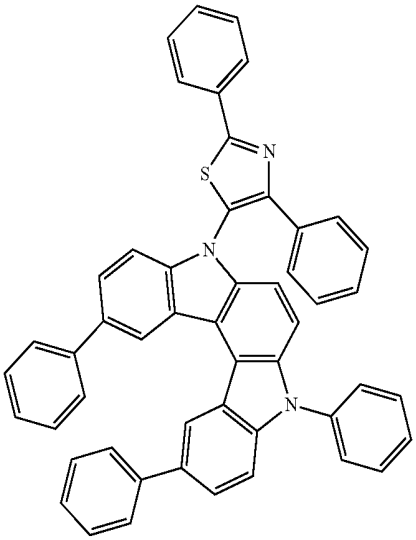


-continued

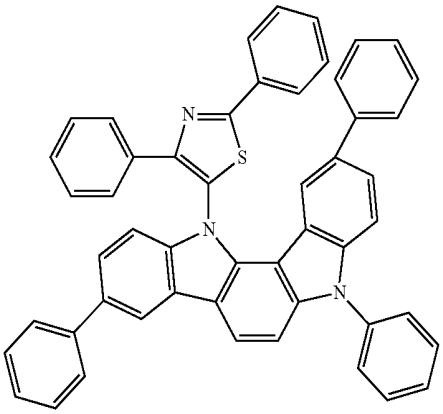
86



87

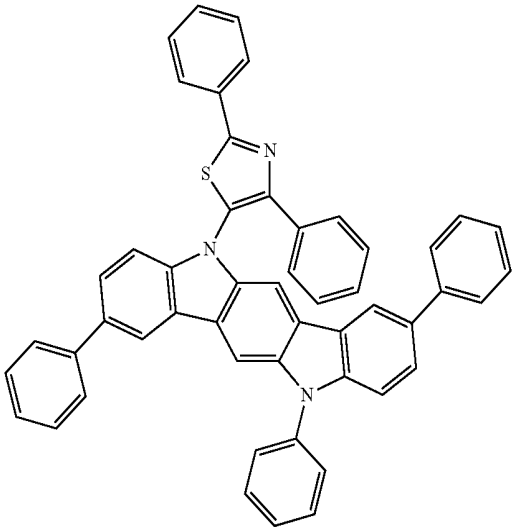


88

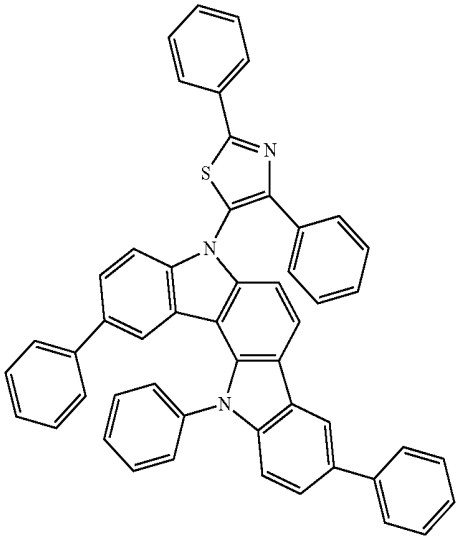


-continued

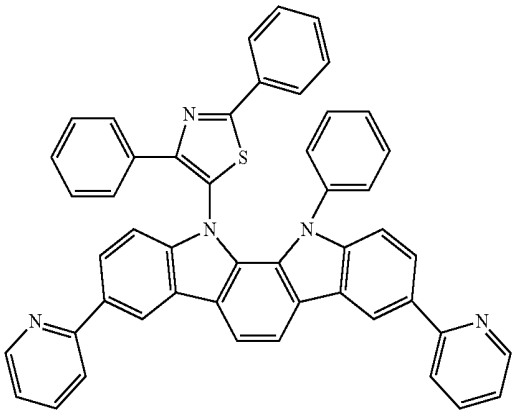
89



90

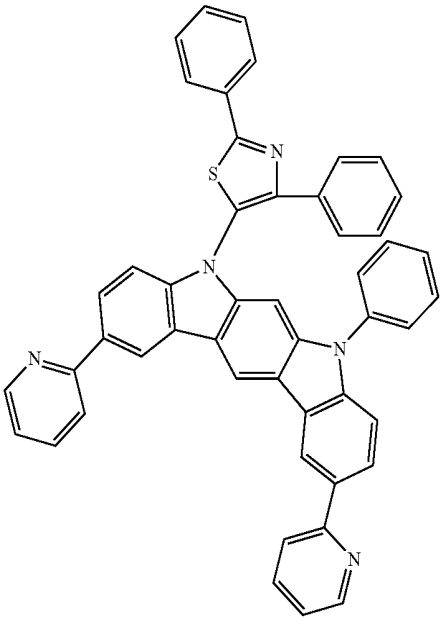


91

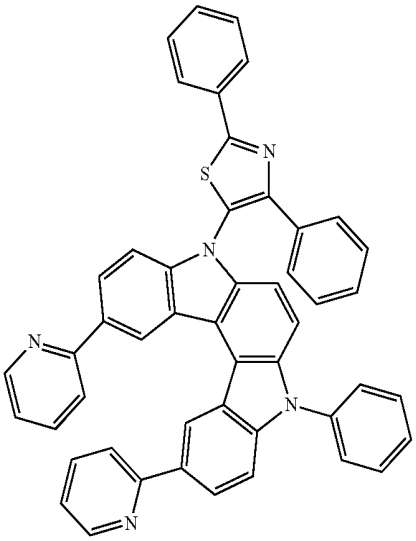


-continued

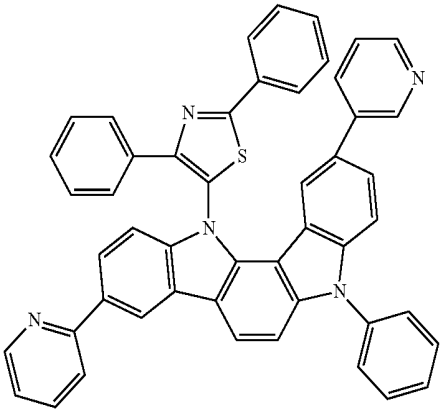
92



93

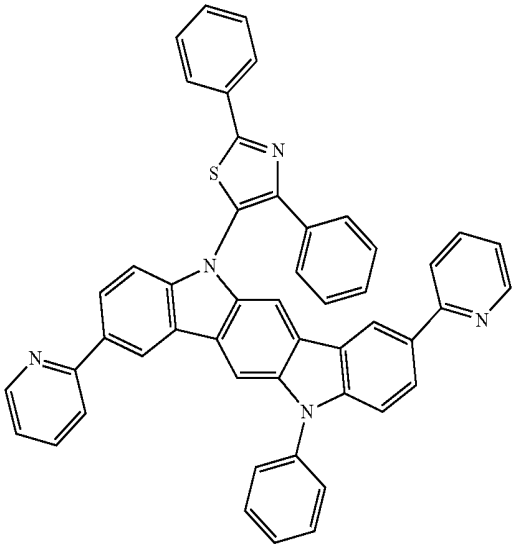


94

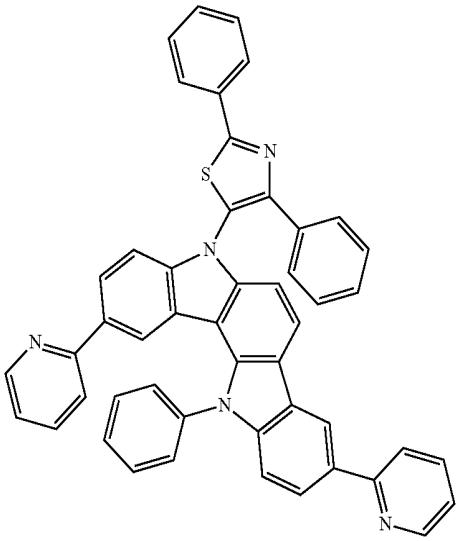


-continued

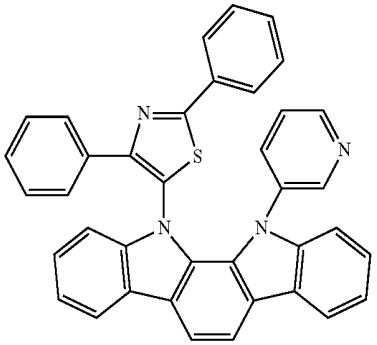
95



96

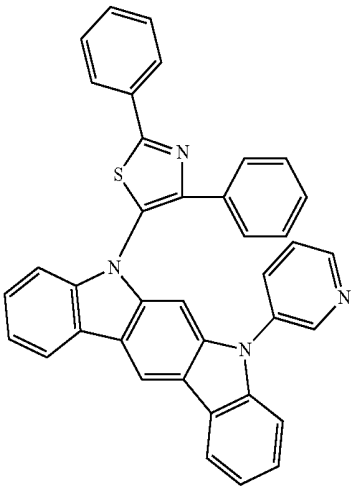


97

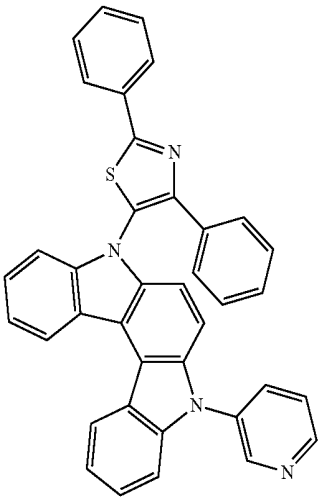


-continued

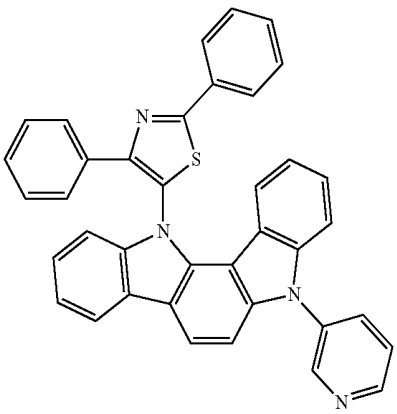
98



99

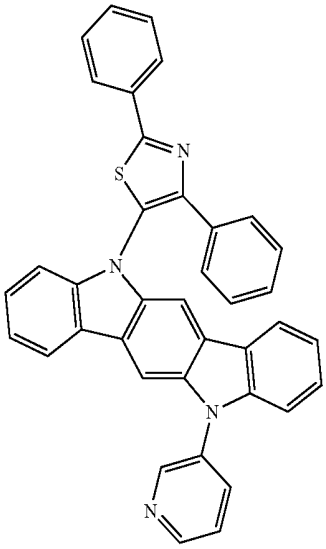


100

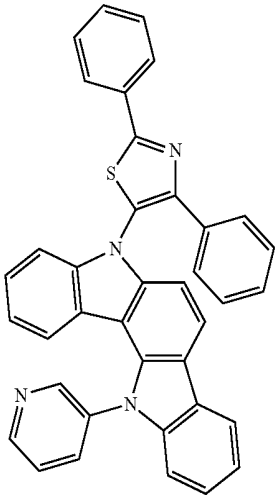


-continued

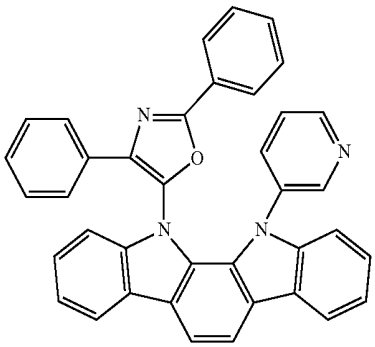
101



102

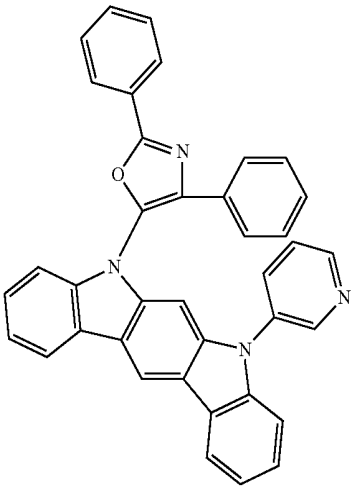


103

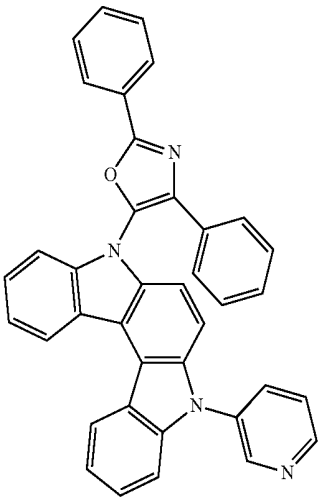


-continued

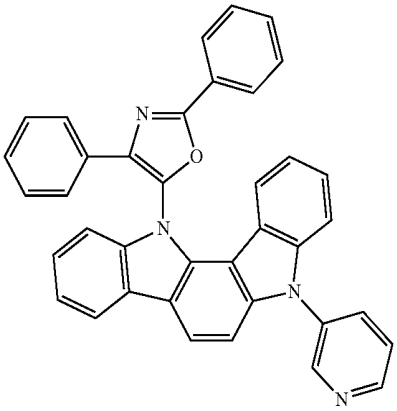
104



105

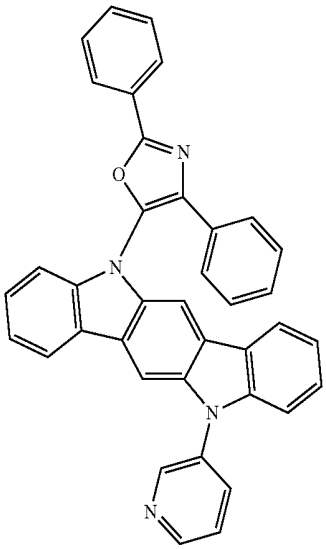


106

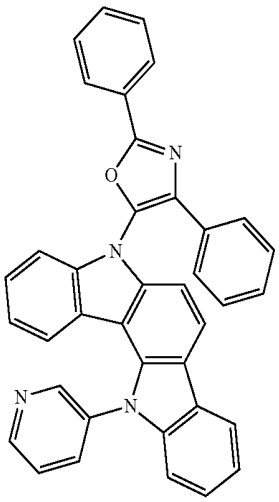


-continued

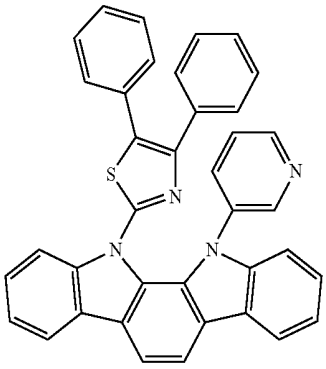
107



108

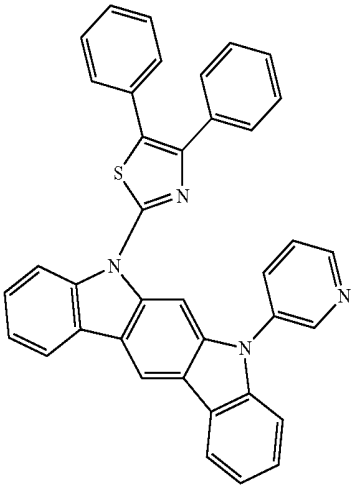


109

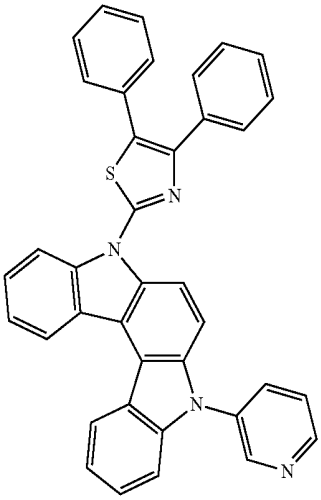


-continued

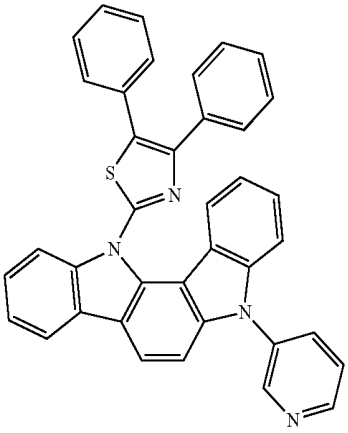
110



111

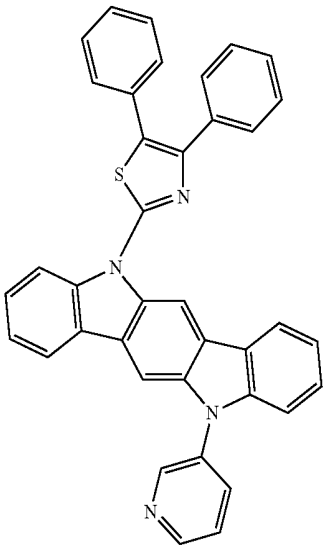


112

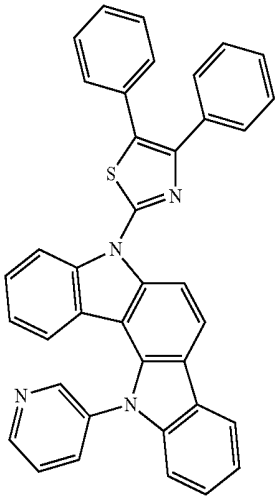


-continued

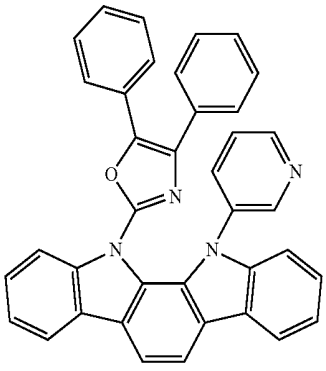
113



114

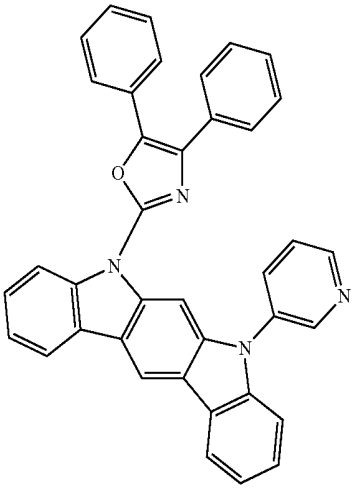


115

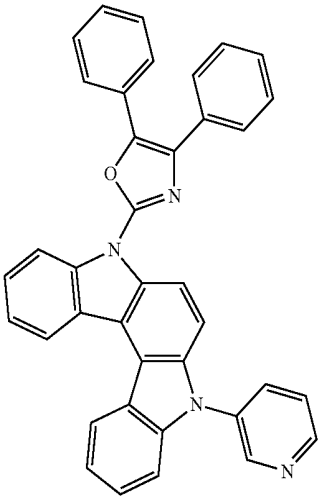


-continued

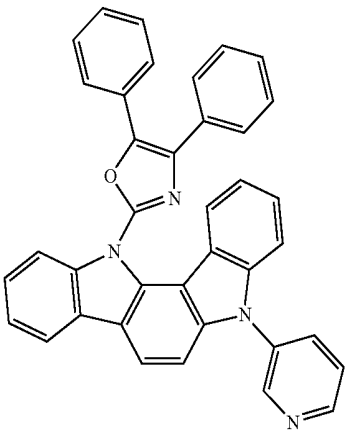
116



117

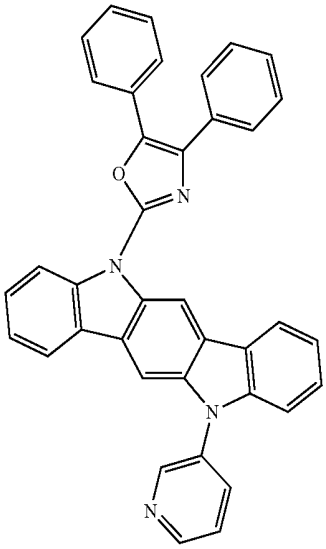


118

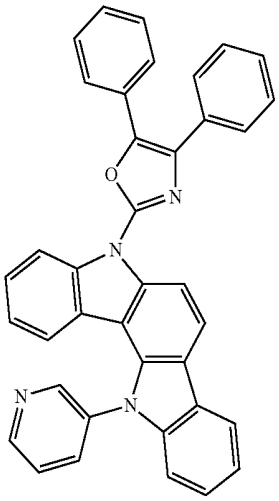


-continued

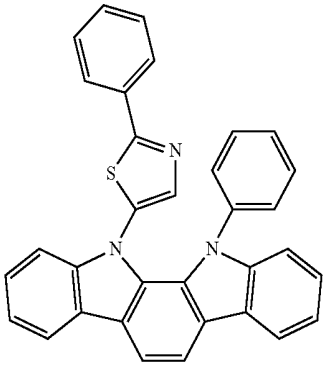
119



120

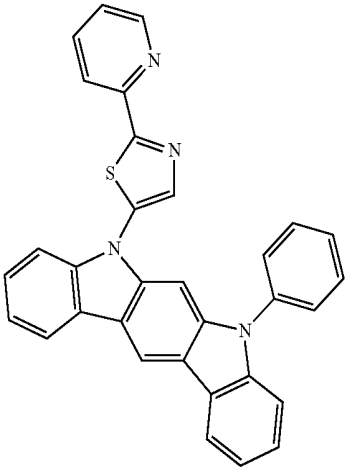


121

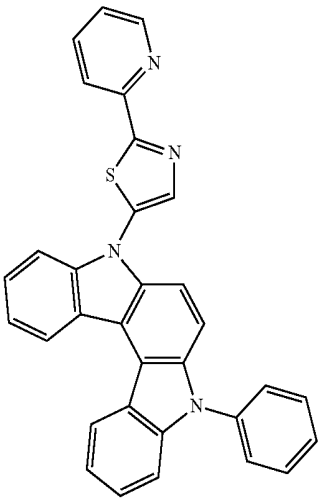


-continued

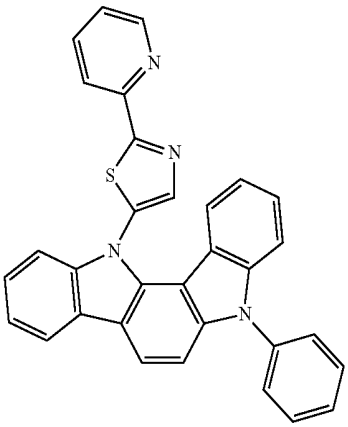
122



123

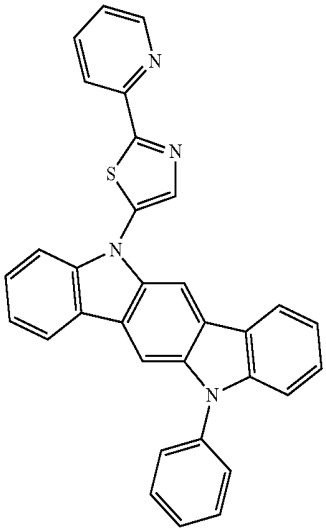


124

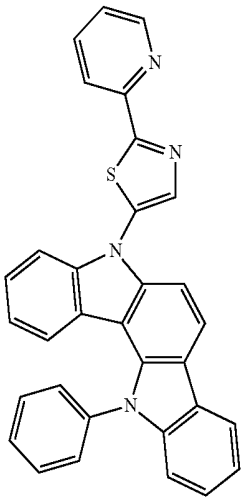


-continued

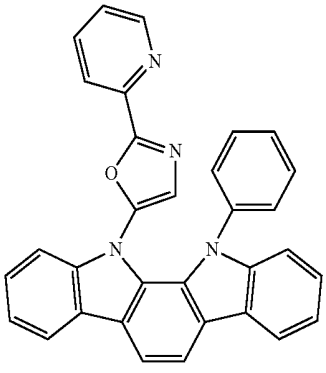
125



126

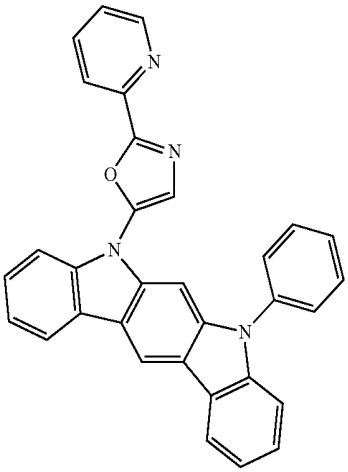


127

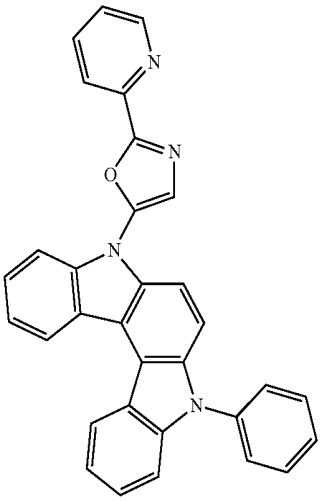


-continued

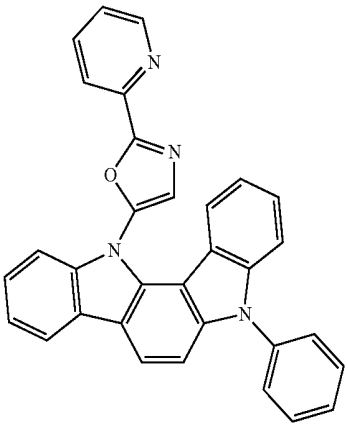
128



129

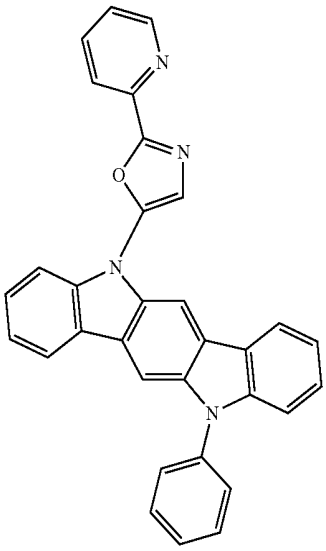


130

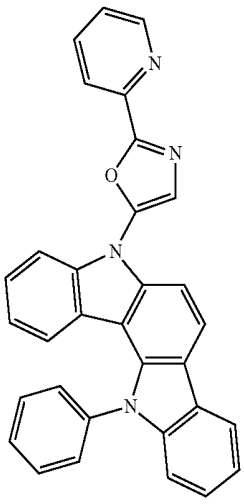


-continued

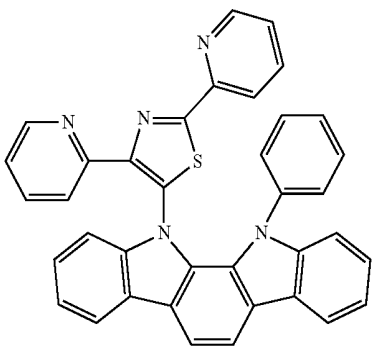
131



132

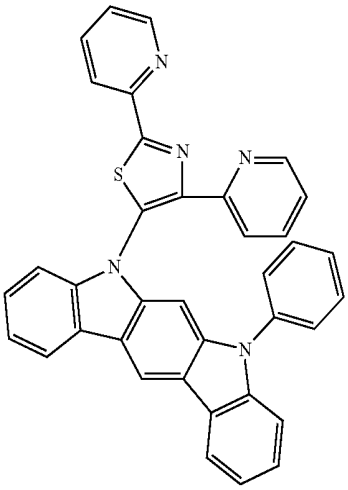


133

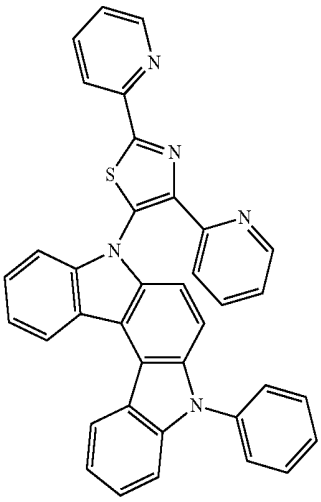


-continued

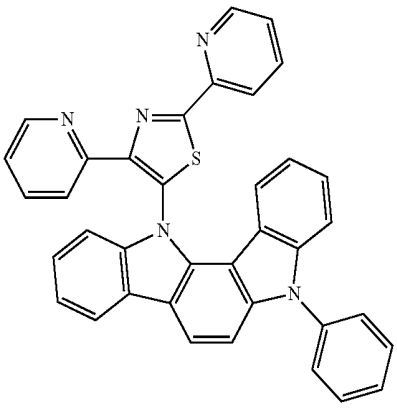
134



135

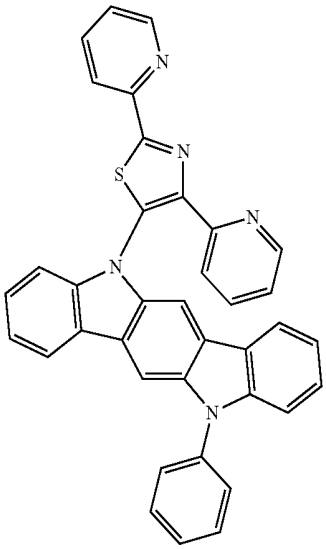


136

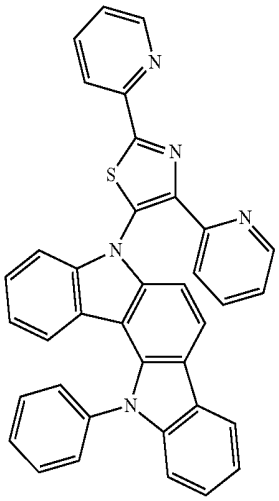


-continued

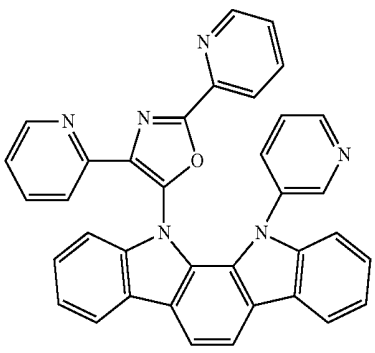
137



138

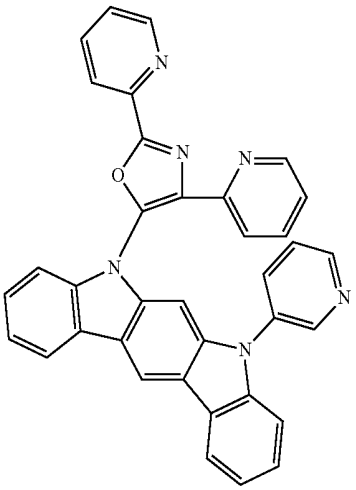


139

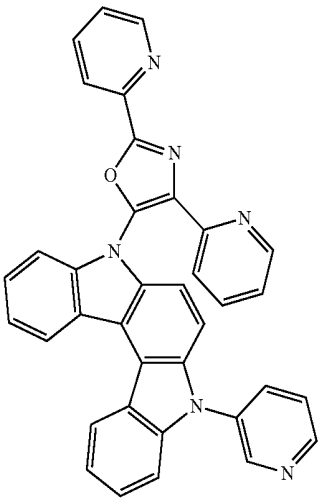


-continued

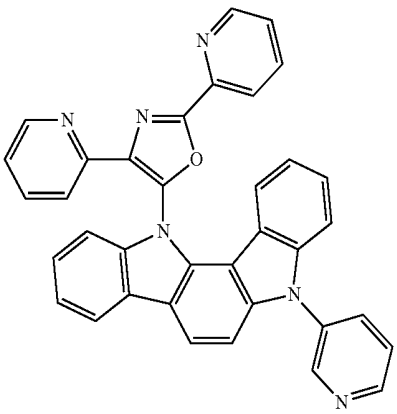
140



141

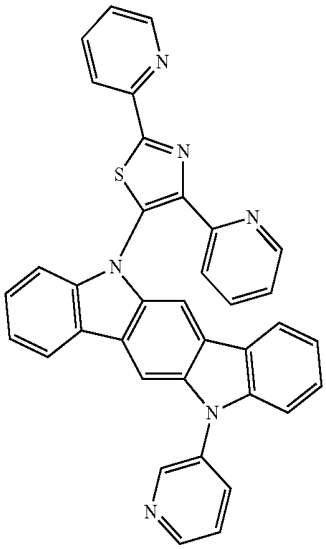


142

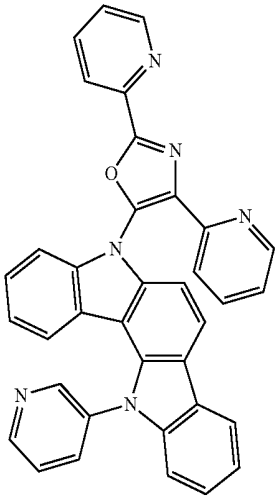


-continued

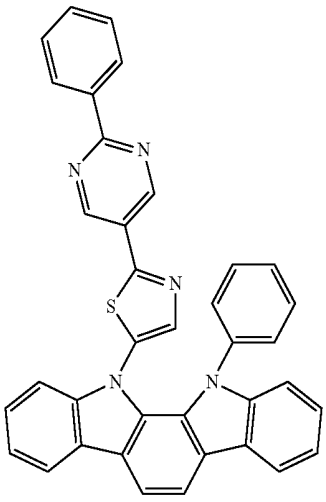
143



144

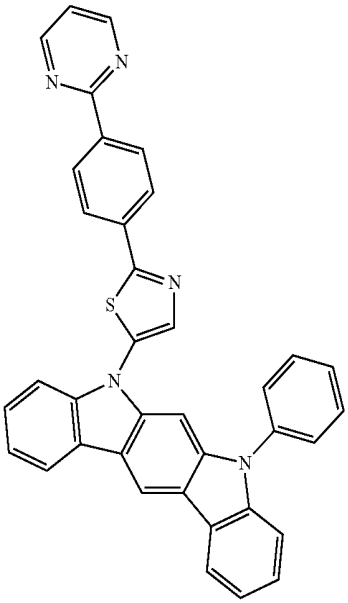


145

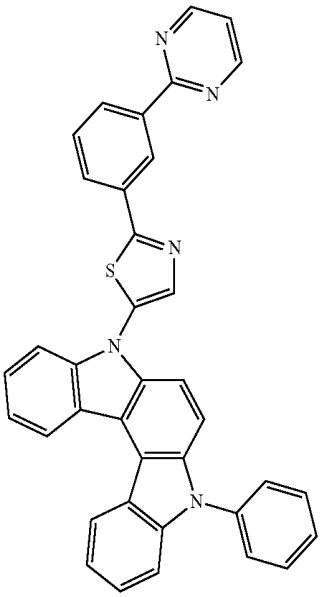


-continued

146

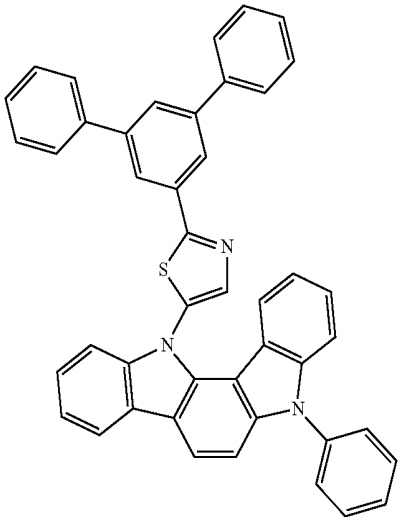


147

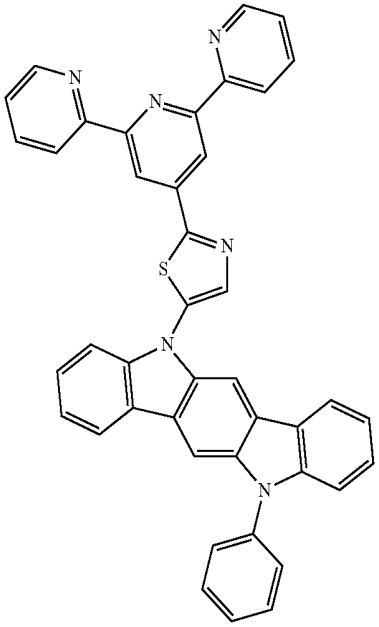


-continued

148

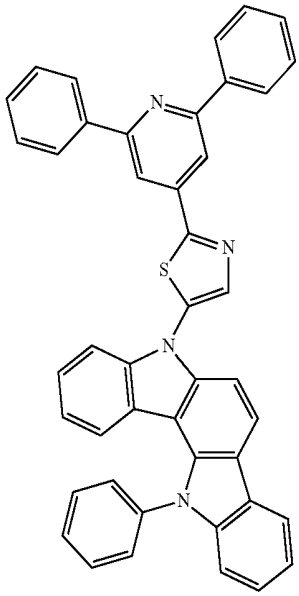


149

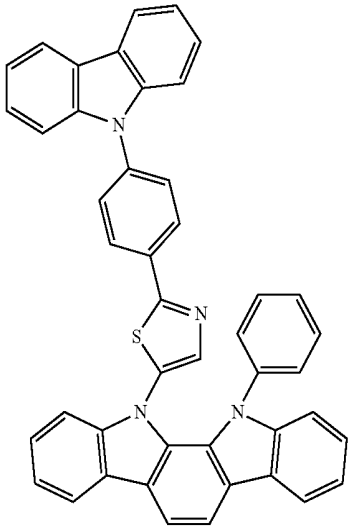


-continued

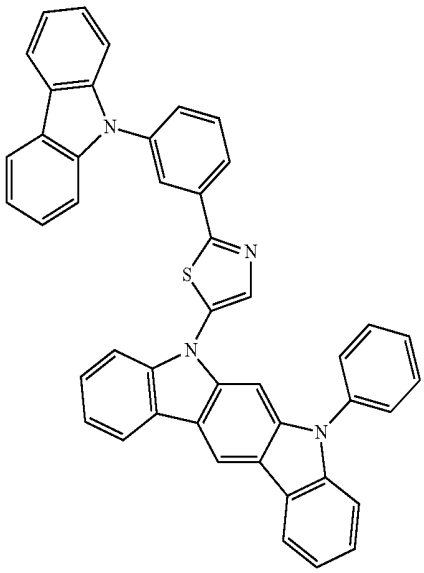
150



151

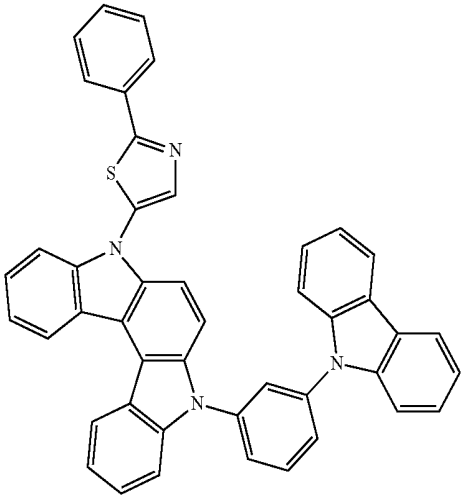


152

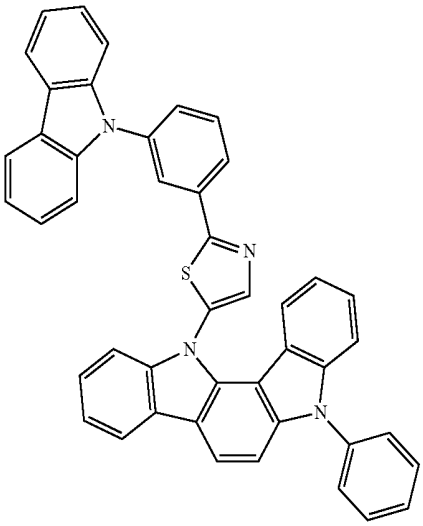


-continued

153

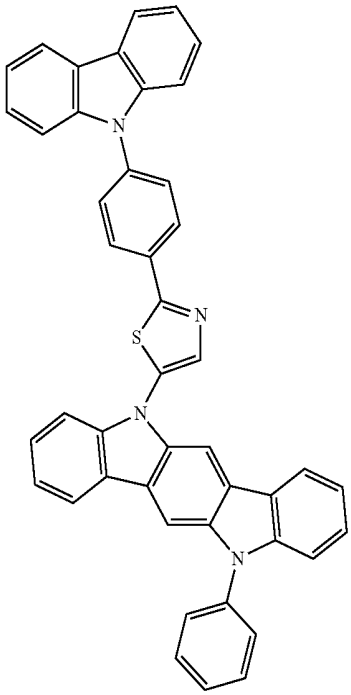


154

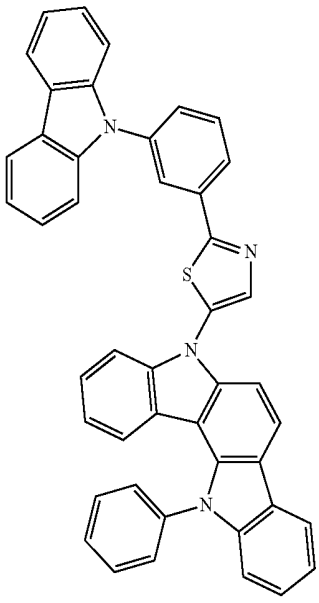


-continued

155

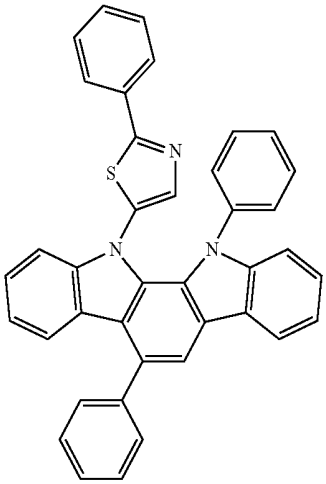


156

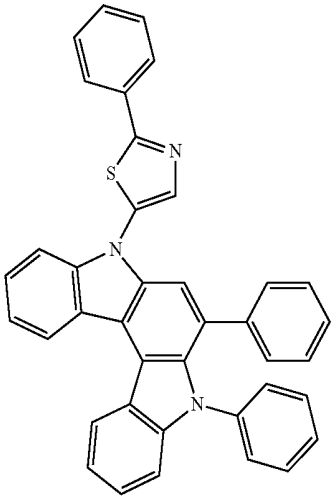


-continued

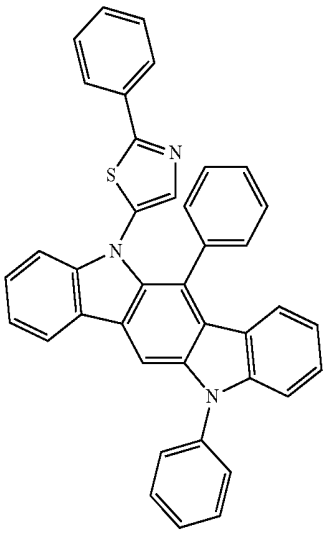
157



158



159



[0069] The condensed cyclic compound of Formula 1 in which an indole group is condensed into (or fused with) a carbazole group and in which a pentagonal hetero ring including a N atom and a S atom or an O atom is introduced to (or bonded to) a N atom of the carbazole group has enhancements (or advantages) in that electrons within the condensed cyclic compound (or organic molecules) may be balanced by maintaining a main skeleton of the condensed cyclic compound (or organic molecules), and accordingly may improve (or optimize) performance of the OLED. Therefore, the OLED including the condensed cyclic compound of Formula 1 may have a low driving voltage, high efficiency, high brightness, and long lifespan.

[0070] The condensed cyclic compound of Formula 1 may be synthesized by using (utilizing) any suitable organic synthesis method used in the art. A synthesis method of the condensed cyclic compound should be apparent to one of ordinary skill in the art in view of the following embodiments.

[0071] The condensed cyclic compound of Formula 1 may be used (utilized) between a pair of electrodes of an OLED. For example, the condensed cyclic compound may be included in a hole transport region, such as, for example, a hole transport layer. Accordingly, an OLED according to an embodiment of the present disclosure includes: a first electrode; a second electrode facing the first electrode; and an organic layer between the first and second electrodes and including an emission layer, the organic layer including at least one of the condensed cyclic compound.

[0072] The expression "(an organic layer) includes (or including) at least one of the condensed cyclic compound" used herein includes a case in which "(an organic layer) includes one condensed cyclic compound of Formula 1 and a case in which (an organic layer) includes two or more different condensed cyclic compounds of Formula 1".

[0073] For example, the organic layer may include only one of the condensed cyclic compound described herein. In this regard, the only one of the condensed cyclic compound may exist in an emission layer of an OLED, an electron transport layer or a hole transport layer of an OLED. In another embodiment of the present disclosure, the organic layer may include, two of the condensed cyclic compounds described herein, the two condensed cyclic compounds having different structures relative to one another. In this regard, the two different condensed cyclic compounds may exist in a same (or an identical) layer (for example, the two different condensed cyclic compounds may both be present in an emission layer), or different layers (for example, one of the two different condensed cyclic compounds may be present in an emission layer and the other of the two different condensed cyclic compounds may be present in an electron transport layer).

[0074] 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. The electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer. The hole transport region may include at least one selected from an electron blocking layer, a hole transport layer, and a hole injection layer.

[0075] The emission layer may include the condensed cyclic compound of Formula 1 above.

[0076] The electron transport region may include the condensed cyclic compound of Formula 1 above. For example, the electron transport region may include the electron transport layer including the condensed cyclic compound of Formula 1.

[0077] The expression "organic layer" used herein refers to a single layer and/or a plurality of layers between the first and second electrodes of an OLED. A material of the "the organic layer" is not limited to an organic material. For example, the

organic layer may include inorganic materials or compounds in addition to organic materials or compounds.

[0078] The accompanying drawing is a schematic view of an OLED **10** according to an embodiment of the present disclosure. The OLED **10** includes a substrate **11**, a first electrode **13**, an organic layer **15**, and a second electrode **17**.

[0079] Hereinafter, the structure of an OLED according to an embodiment of the present disclosure and a method of manufacturing an OLED, according to an embodiment of the present disclosure, will be described in connection with the accompanying drawing.

[0080] The substrate **11** may be a glass substrate or a transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water repellency.

[0081] The first electrode **13** may be formed by depositing or sputtering a material for forming the first electrode **13** on the substrate **11**. When the first electrode **13** is an anode, the material for the first electrode **13** may be selected from materials with a high work function to allow holes to be easily injected. The first electrode **13** may be a reflective electrode or a transmissive electrode. The material for the first electrode may be a transparent and highly conductive material, and examples of such a material include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). When the first electrode **13** is a semi-transmissive electrode or a reflective electrode, a material for forming the first electrode **13** may include at least one selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag).

[0082] The first electrode **13** may have a single-layer structure, or a multi-layer structure including two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode **120** is not limited thereto.

[0083] The organic layer **15** is on the first electrode **13**. The organic layer **15** may include an emission layer.

[0084] The organic layer **15** may further include a hole transport region between the first electrode **13** and the emission layer, and an electron transport region between the emission layer and the second electrode **17**.

[0085] The hole transport region may include at least one selected from a hole injection layer (HIL), a hole transport layer (HTL), a buffer layer, and an electron blocking layer (EBL), and the electron transport region may include at least one selected from a hole blocking layer (HBL), an electron transport layer (ETL), and an electron injection layer (EIL), but the hole transport region and the electron transport region are not limited thereto.

[0086] The hole transport region may have a single-layered structure formed of a single material, a single-layered structure formed of different materials, or a multi-layered structure having a plurality of layers formed of different materials.

[0087] For example, the hole transport region may have a single-layered structure formed of different materials, or a structure of HIL/HTL, a structure of HIL/HTL/buffer layer, a structure of HIL/buffer layer, a structure of HTL/buffer layer, or a structure of HIL/HTL/EBL, but the structures are not limited thereto.

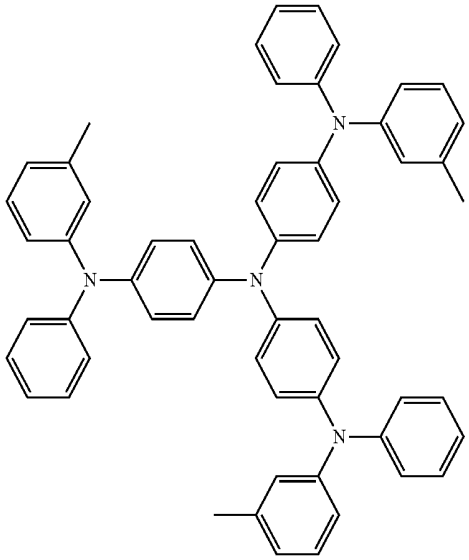
[0088] When the hole transport region includes a HIL, the HIL may be formed on the first electrode **13** by using (utilizing) various suitable methods, such as vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, or laser-induced thermal imaging (LITI)

[0089] When a HIL is formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01 to about 100 Å/sec in consideration of a composition of the compound to be deposited for the HIL, and the structure of the HIL to be formed.

[0090] When a HIL is formed by spin coating, the spin coating may be performed at a coating rate of about 2,000 rpm to about 5,000 rpm, and at a temperature of about 80° C. to 200° C. in consideration of a composition of the compound to be deposited for the HIL, and the structure of the HIL to be formed.

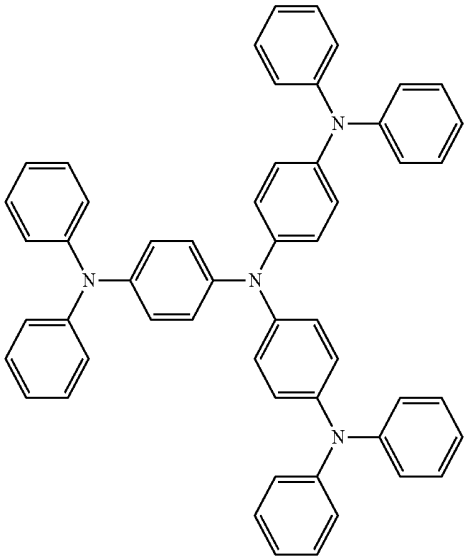
[0091] When the hole transport region includes a HTL, the HTL may be formed on the first electrode **13** or the HIL by using (utilizing) various methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, or LITI. When the HTL is formed by vacuum deposition or spin coating, deposition and coating conditions for the HTL may be determined by referring to the deposition and coating conditions for the HIL.

[0092] The hole transport region may include at least one selected from the condensed cyclic compound of Formula 1, m-MTDATA, TDATA, 2-TNATA, NPB, 13-NPB, TPD, Spiro-TPD, Spiro-NPB, α-NPD, 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 sulfonicacid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

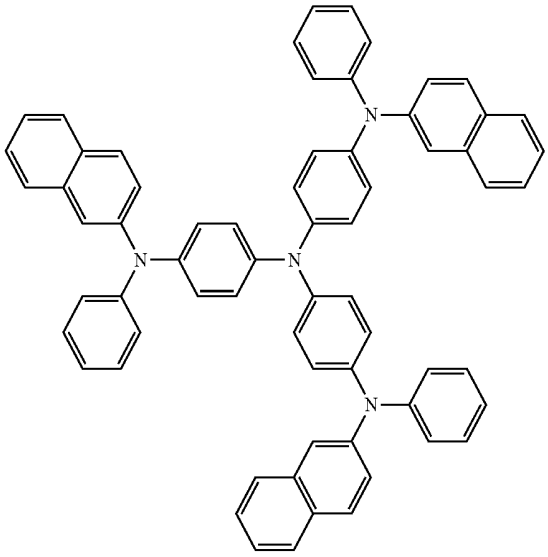


m-MTDATA

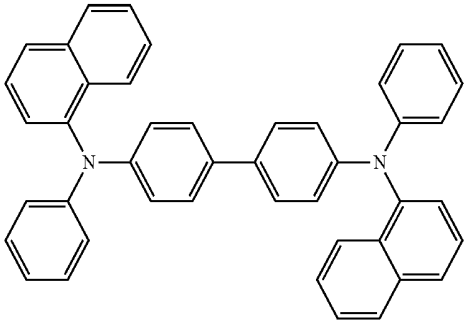
-continued



TDATA

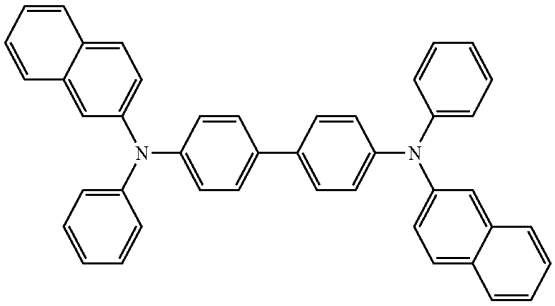


2-TNATA

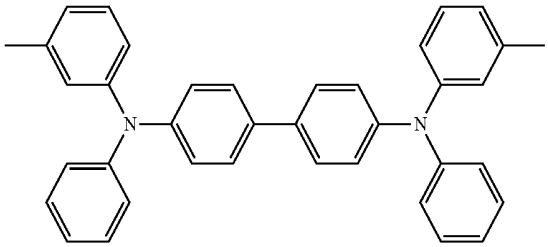


NPB

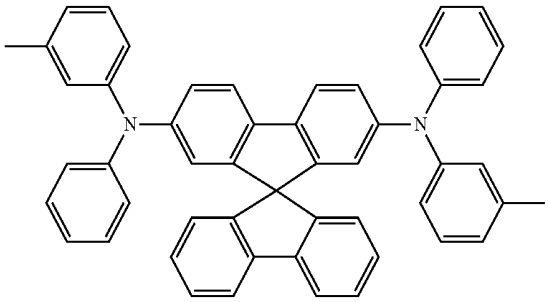
-continued



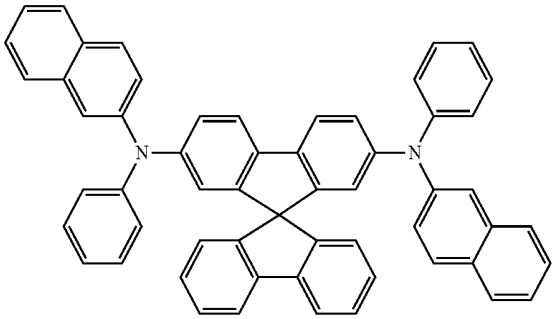
β-NPB



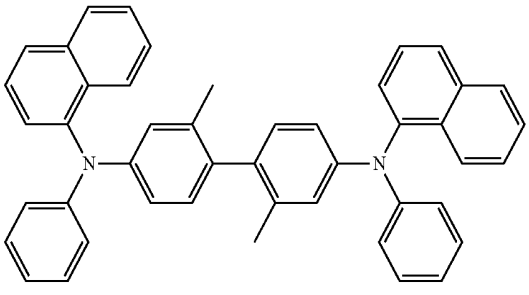
TPD



spiro-TBD

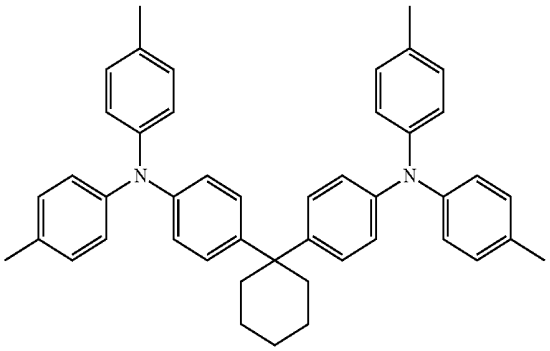


spiro-NPB

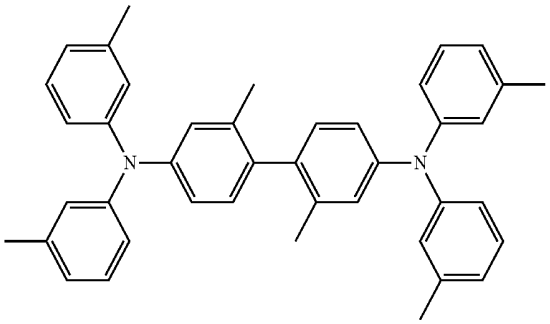


α-NPD

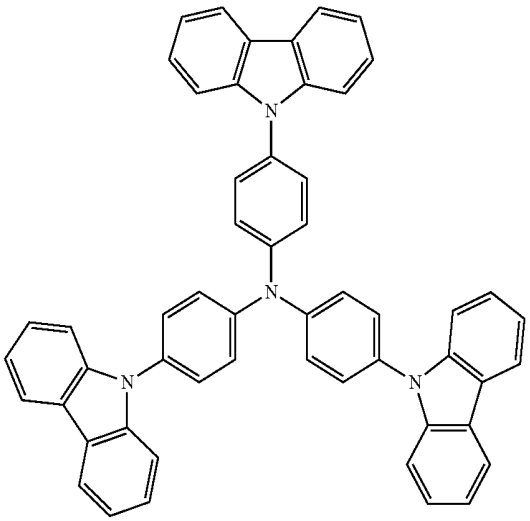
-continued



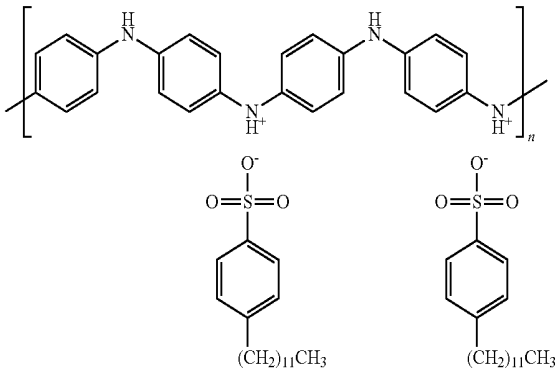
TAPC



HMTPD

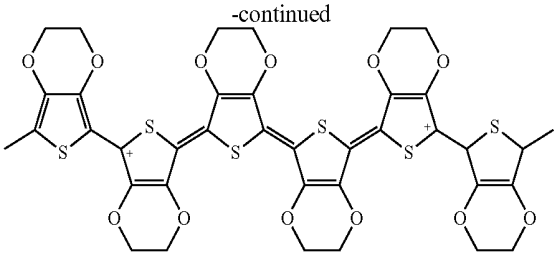


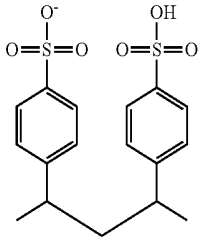
TCTA



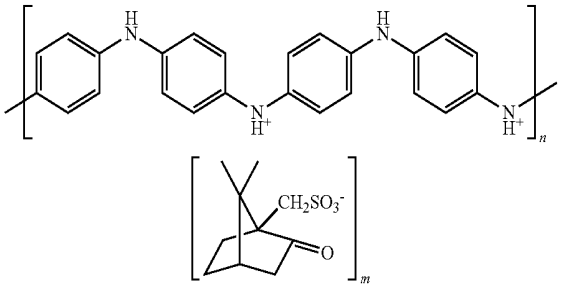
PANI/DBSA

-continued

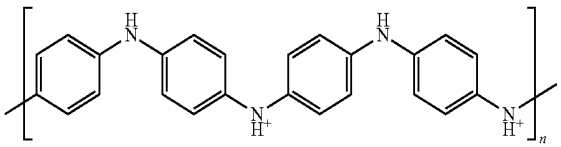


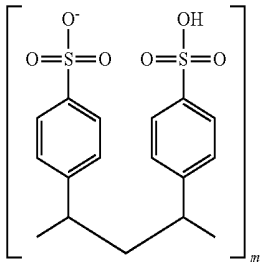


PEDOT/PSS



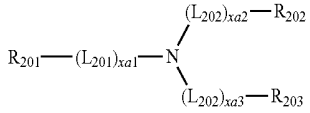
PANI/CSA



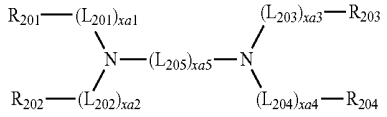


PANI/PSS

Formula 201



Formula 202



[0093] where in Formulae 201 and 202,

[0094] L_{201} to L_{205} may be each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_3-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalk-

enylene group, a substituted or unsubstituted C_3-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_2-C_{60} heteroarylene group, and a substituted or unsubstituted divalent C_6-C_{60} non-aromatic condensed polycyclic group;

[0095] xa1 to xa4 may be each independently selected from 0, 1, 2, and 3;

[0096] xa5 may be selected from 1, 2, 3, 4, and 5; and

[0097] R_{201} to R_{204} may be each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_2-C_{60} heteroaryl group, and a substituted or unsubstituted a monovalent C_6-C_{30} non-aromatic condensed polycyclic group.

[0098] For example, in Formulae 201 and 202, L_{201} to L_{205} may be each independently selected from:

[0099] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0100] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0101] xa1 to xa4 may be each independently 0, 1, or 2;

[0102] xa5 may be 1, 2, or 3;

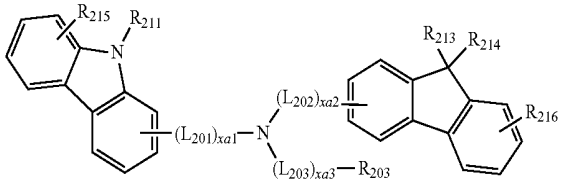
[0103] R_{201} to R_{204} may be each independently selected from:

[0104] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0105] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group.

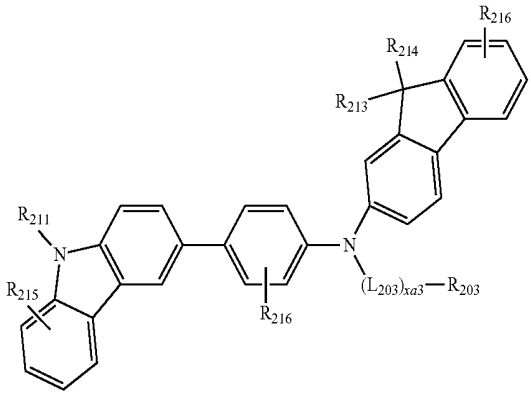
[0106] For example, the compound of Formula 201 may be represented by Formula 201A.

Formula 201A



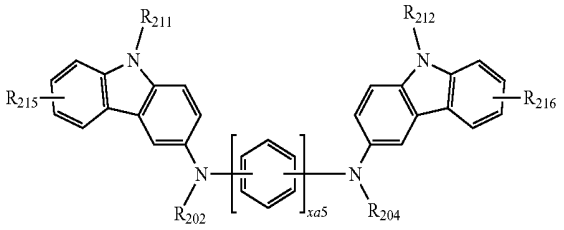
[0107] For example, the compound of Formula 201 may be represented by Formula 201A-1, but the present disclosure is not limited thereto:

Formula 201A-1



[0108] For example, the compound of Formula 202 may be represented by Formula 202A, but the present disclosure is not limited thereto:

Formula 202A



[0109] where in Formulae 201A, 201A-1, and 202A, L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} may be understood by referring to the description thereof provided herein with respect to Formulae 201 and 202, and R_{211} may be understood by referring to the description provided herein for R_{203} with respect to Formulae 201 and 202, and where R_{213} to R_{216} may be each independently selected from a hydrogen atom, a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, and a C_6-C_{60} non-aromatic condensed polycyclic group.

[0110] For example, in Formulae 201A, 201A-1, and 202A,

[0111] L_{201} to L_{203} may be each independently selected from:

[0112] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0113] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0114] xa1 to xa3 may be each independently 0 or 1;

[0115] R_{203}, R_{211}, and R_{212} may be each independently selected from:

[0116] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0117] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0118] R_{213} and R_{214} may be each independently selected from:

[0119] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group;

[0120] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0121] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0122] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl

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

[0123] R_{215} and R_{216} may be each independently selected from:

[0124] a hydrogen atom, a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

[0125] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group;

[0126] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0127] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, and a triazinyl group; and

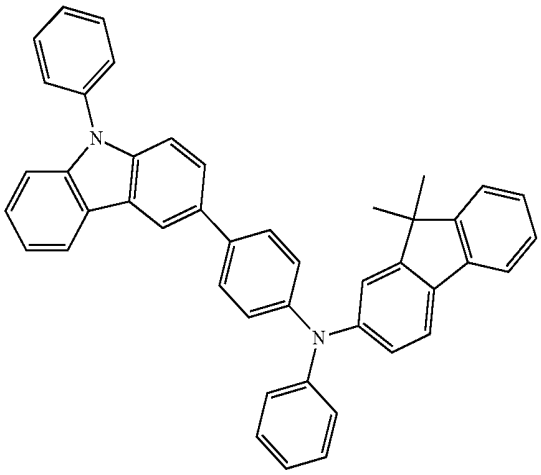
[0128] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0129] xa5 may 1 or 2.

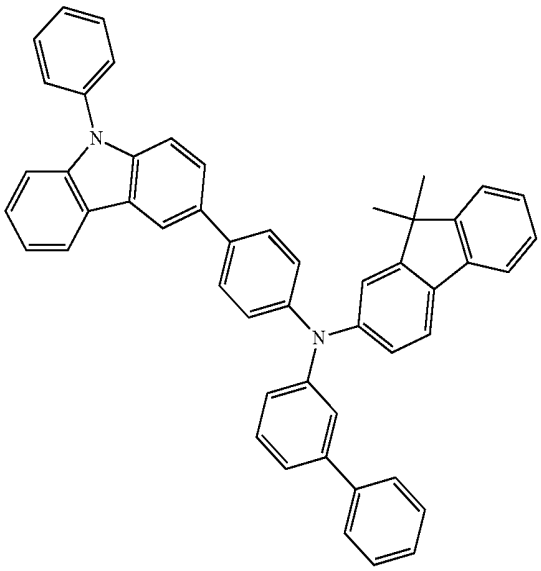
[0130] In Formulae 201A and 201A-1, R_{213} and R_{214} may, optionally, bind to each other (e.g., combine) to form a saturated or unsaturated ring.

[0131] The compound of 201 and the compound of 202 may include Compounds HT1 to HT20, but the present disclosure is not limited thereto.

HT1

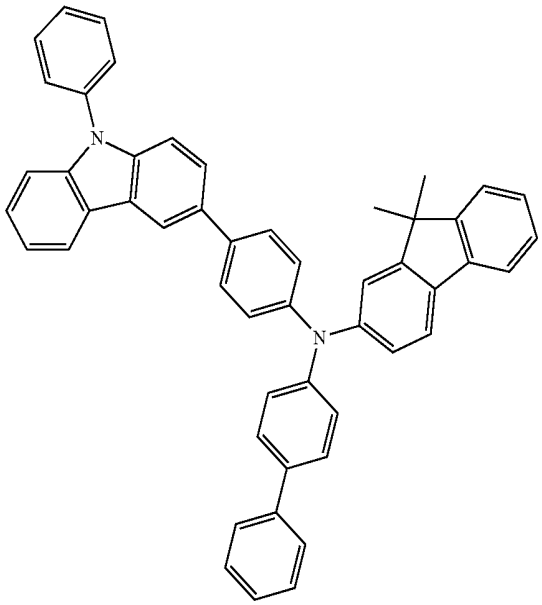


HT2

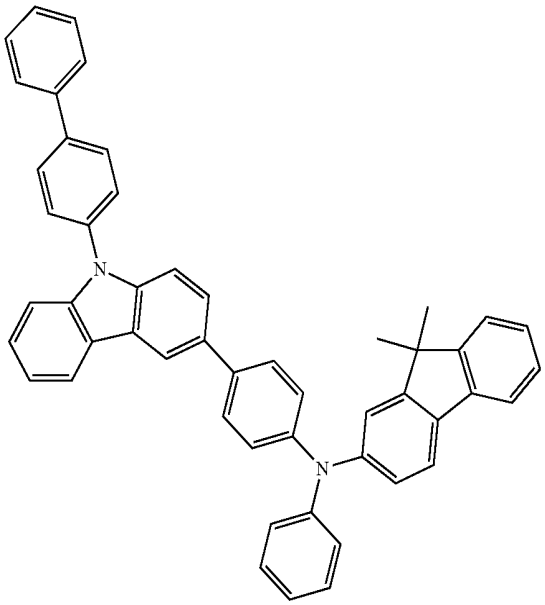


-continued

HT3

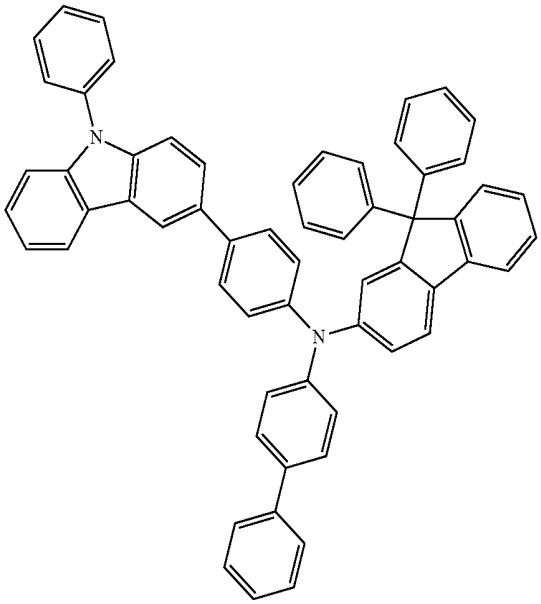


HT4

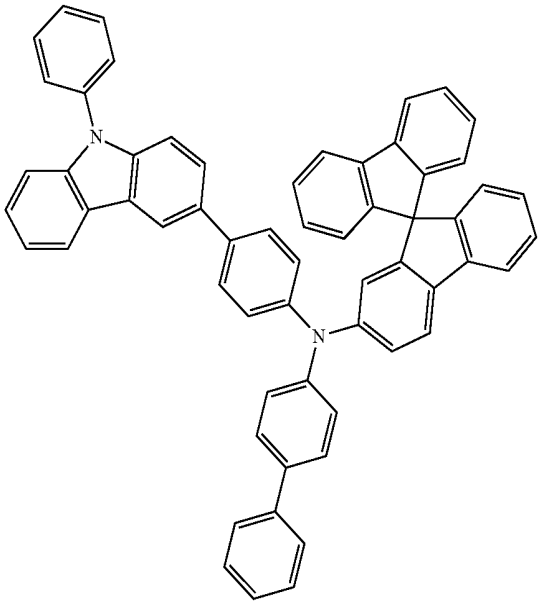


-continued

HT5

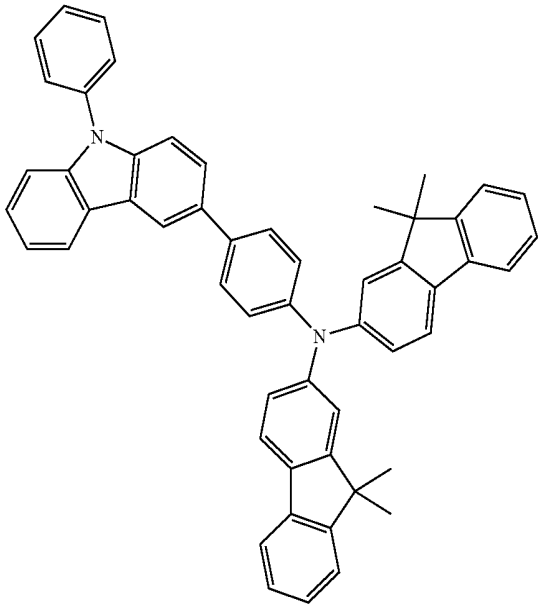


HT6

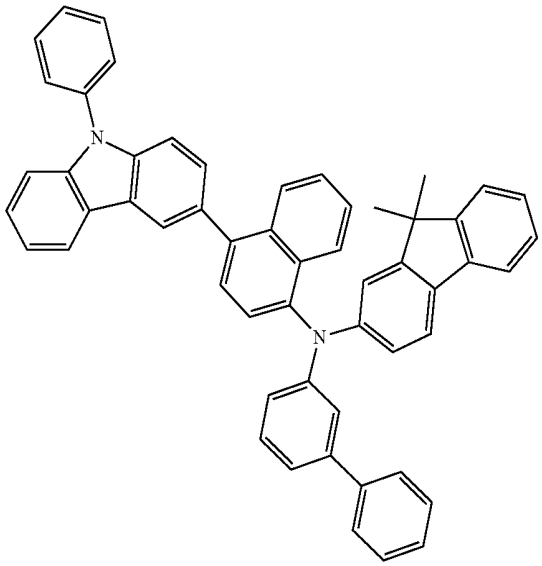


-continued

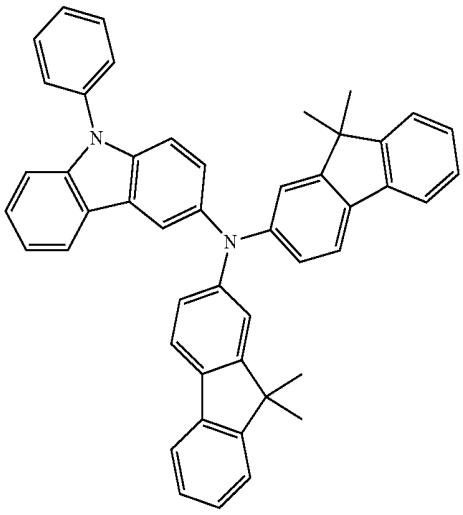
HT7



HT8

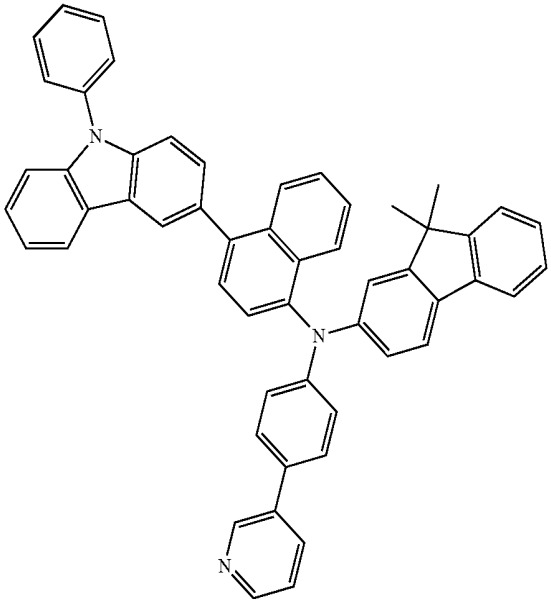


HT9

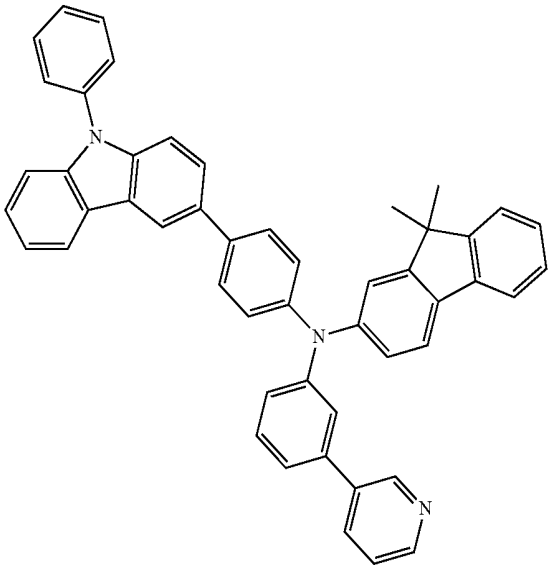


-continued

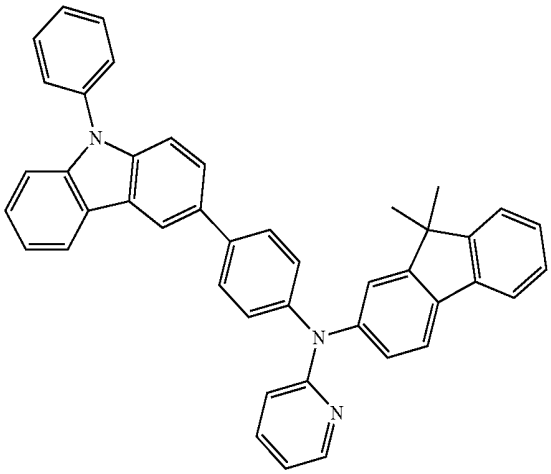
HT10



HT11

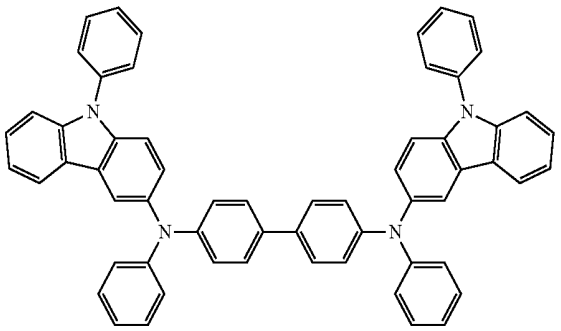


HT12

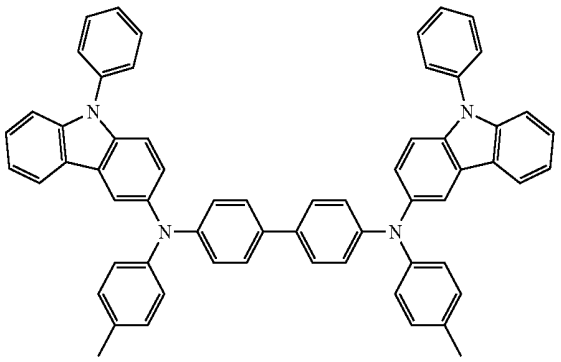


-continued

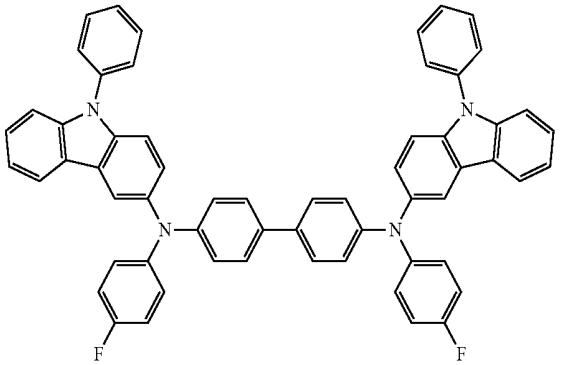
HT13



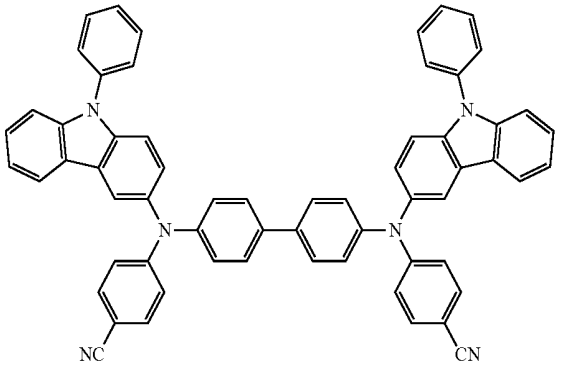
HT14



HT15

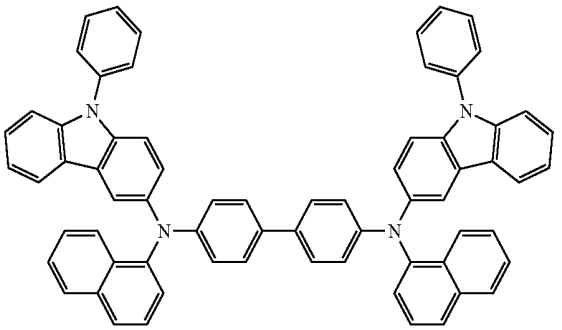


HT16

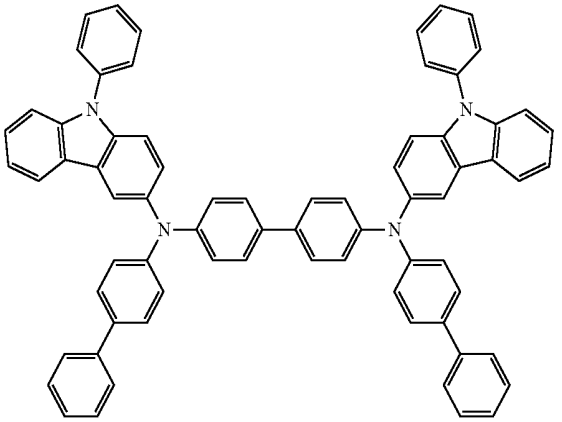


-continued

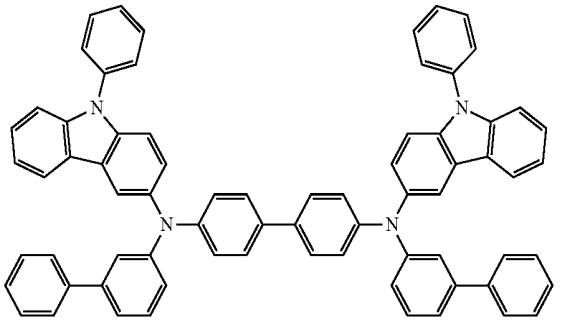
HT17



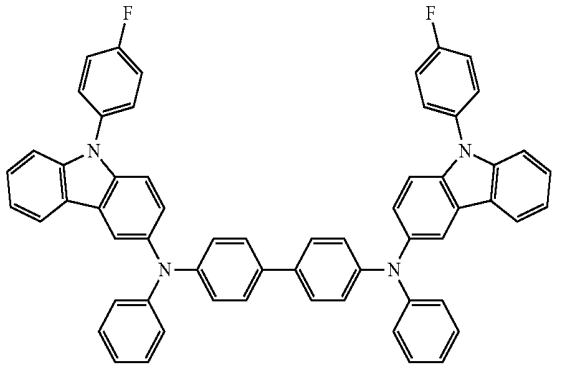
HT18



HT19



HT20

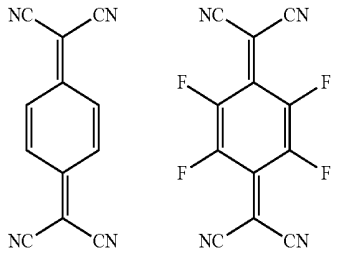


[0132] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes a HIL and a HTL, a thickness of the HIL may be in a range of about 100 Å to about 10,000 Å, for example, about

100 Å to about 1,000 Å, and a thickness of the HTL may be in a range of about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the HIL, and the HTL are within any of the foregoing ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

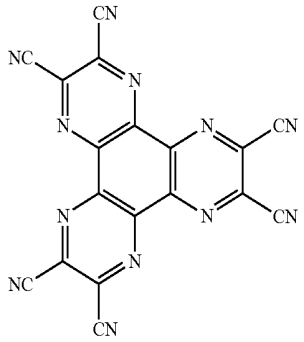
[0133] The hole transport region may further include, in addition to the foregoing materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

[0134] The charge-generation material may be, for example, a p-dopant. The p-dopant may be one of a quinone derivative, a metal oxide, and a cyano group-containing compound, but is not limited thereto. For example, non-limiting examples of the p-dopant include a quinone derivative, such as tetracyanoquinonedimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenum oxide, and HATCN, but are not limited thereto.



TCNQ

F4TCNQ



HATCN

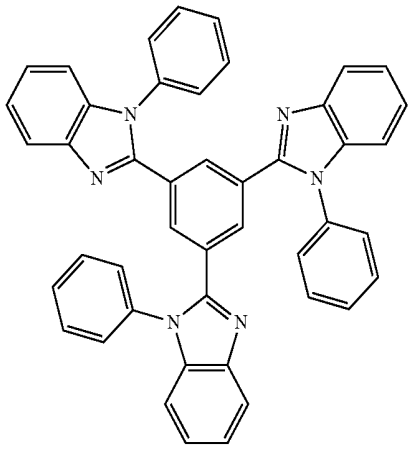
[0135] The hole transport region may further include, in addition to the HIL and the HTL, at least one selected from a buffer layer and an EBL. The buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer, and thus, a light-emission efficiency of a formed OLED may be improved. For use as a material of the buffer layer, materials of the hole transport region may be used (utilized). The EBL prevents (or reduces) injection of electrons from the electron transport region.

[0136] An emission layer is formed on the first electrode **13** or the hole transport region by using (utilizing) various suitable methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, or LITI. When the emission layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the emission layer may be determined by referring to the deposition and coating conditions described herein for the HIL.

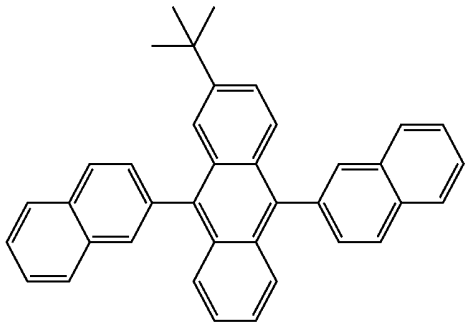
[0137] When the OLED **10** is a full color OLED, the emission layer may be patterned into a red emission layer, a green emission layer, and a blue emission layer, according to a sub-pixel. In some embodiments, the emission layer may have a stacked structure of a red emission layer, a green emission layer, and a blue emission layer, or may include a red-light emission material, a green-light emission material, and a blue-light emission material, which are mixed with each other in a single layer, to emit white light.

[0138] The emission layer may include a host and a dopant.

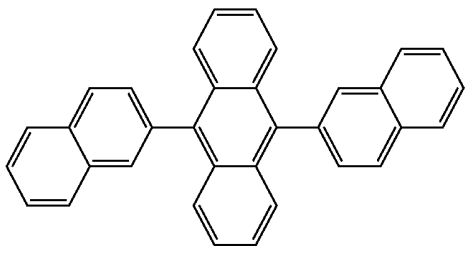
[0139] The host may include at least one selected from the compound of Formula 1, TPBi, TBADN, ADN, CBP, CDBP, and TCP illustrated:



TPBI

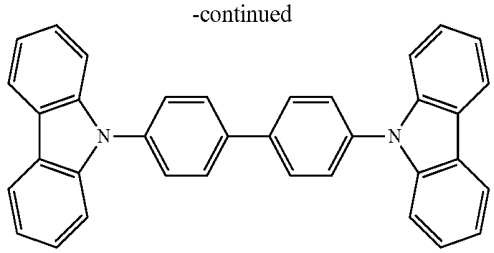


TBADN

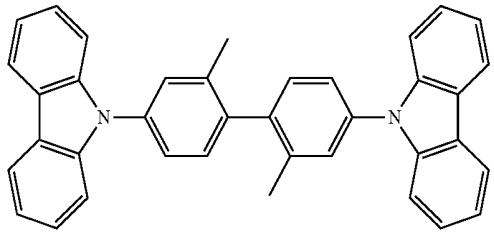


ADN

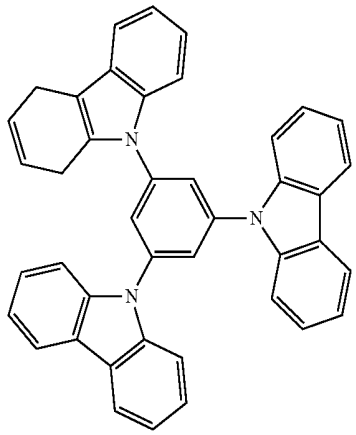
-continued



CBP



CDBP



TCP

[0140] According to another embodiment of the present disclosure, the host may include a compound represented by Formula 301.

$$Ar_{301}\text{-}[(L_{301})_{xb1}\text{-}R_{301}]_{xb2} \qquad \text{Formula 301}$$

[0141] where in Formula 301, Ar_{301} may be:

[0142] a naphthalene, a heptalene, a fluorenene, a spiro-fluorene, a benzofluorenene, a dibenzofluorenene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene;

[0143] a naphthalene, a heptalene, a fluorenene, a spiro-fluorene, a benzofluorenene, a dibenzofluorenene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent C_2-C_{60} non-aromatic condensed polycyclic group, and —$Si(Q_{301})(Q_{302})(Q_{303})$ (where Q_{301} to Q_{303} may be each independently selected from a hydrogen atom, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_2-C_{60} heteroaryl group);

[0144] L_{301} may be understood by referring to the description provided herein for L_{201} with respect to Formulae 201 and 202;

[0145] R_{301} may be selected from:

[0146] a C_1-C_{20} alkyl group and a C_1-C_{20}alkoxy group;

[0147] a C_1-C_{20} alkyl group and a C_1-C_{20}alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0148] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbozoyl group, and a triazinyl group; and

[0149] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbozoyl group, and a triazinyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20}alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0150] xb1 may be selected from 0, 1, 2, and 3; and

[0151] xb2 may be selected from 1, 2, 3, and 4.

[0152] For example, in Formula 301

[0153] L_{301} may be selected from:

[0154] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group and a chrysenylene group; and

[0155] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenylene group, an anthracenylene

group, a pyrenylene group and a chrysenylene group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group; and

[0156] R_{301} may be selected from:

[0157] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group;

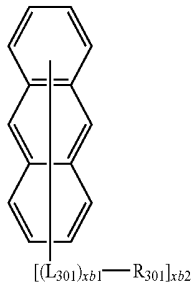
[0158] a C_1-C_{20} alkyl group and a C_1-C_{20}alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group;

[0159] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group; and

[0160] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group, but they are not limited thereto.

[0161] For example, the host may include a compound represented by Formula 301A:

Formula 301A

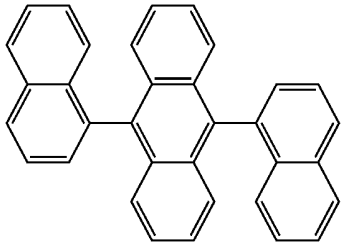


$[(L_{301})_{xb1}—R_{301}]_{xb2}$

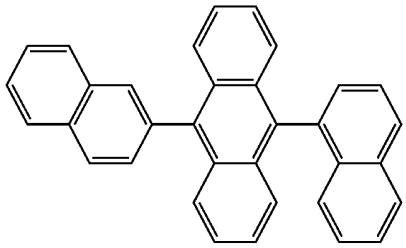
[0162] Substituents of Formula 301A are as those described above with respect to Formula 301.

[0163] The compound of Formula 301 may include at least one selected from Compounds H1 to H42, but the present disclosure is not limited thereto:

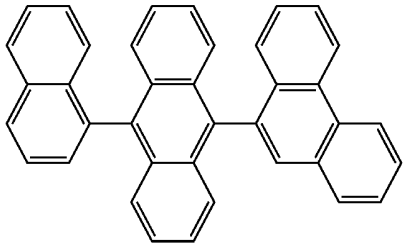
H1



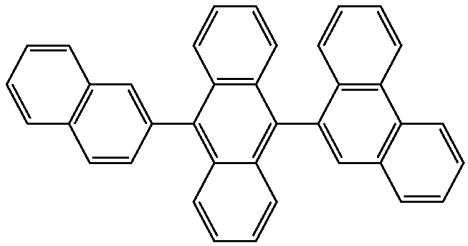
H2



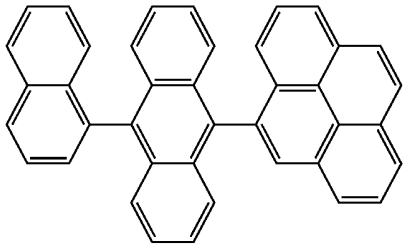
H3



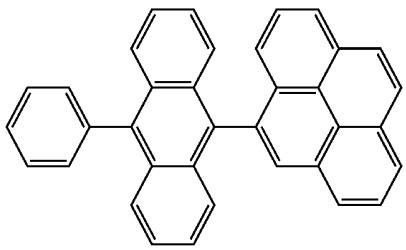
H4



H5

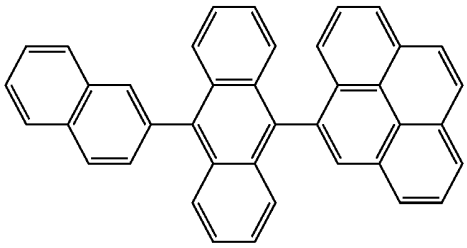


H6

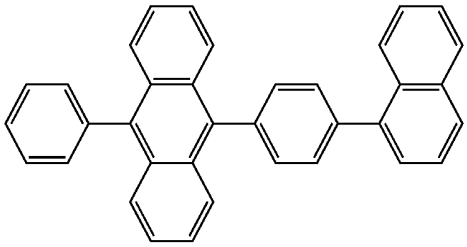


-continued

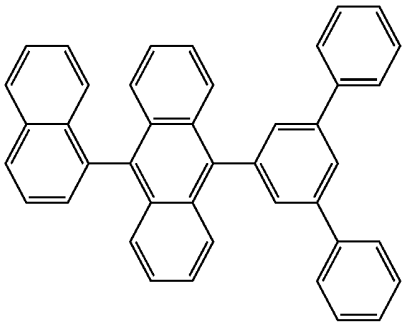
H7



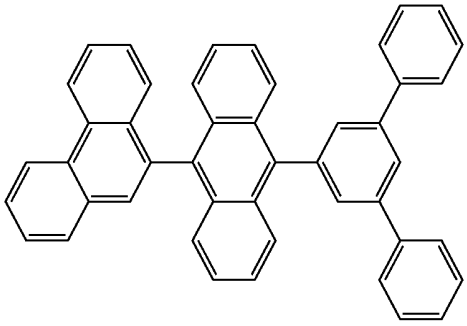
H8



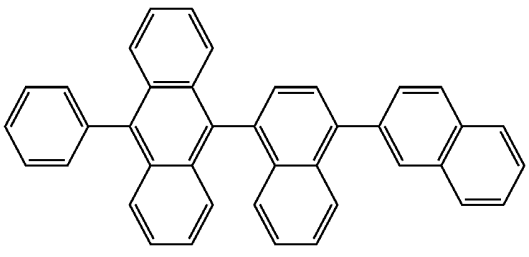
H9



H10

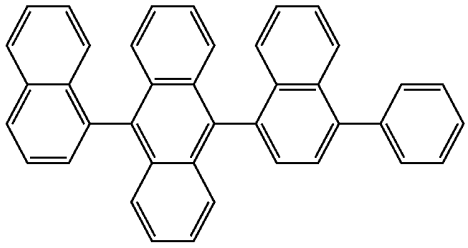


H11

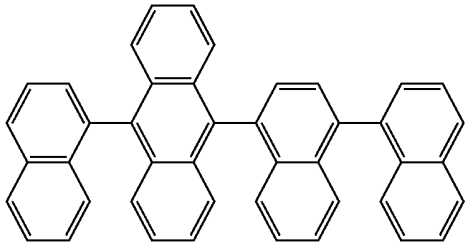


-continued

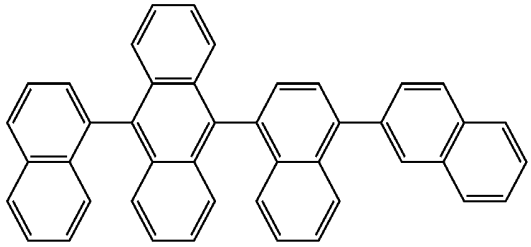
H12



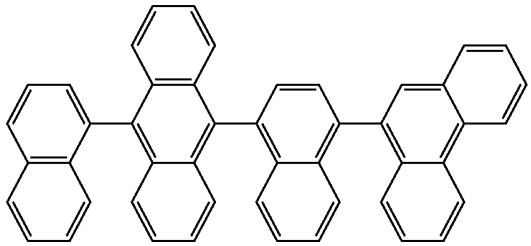
H13



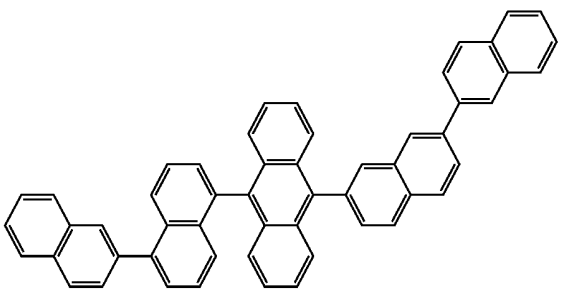
H14



H15

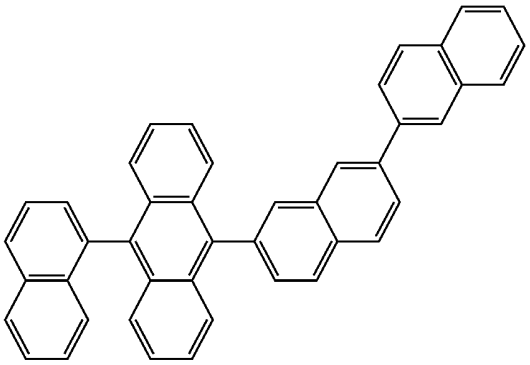


H16

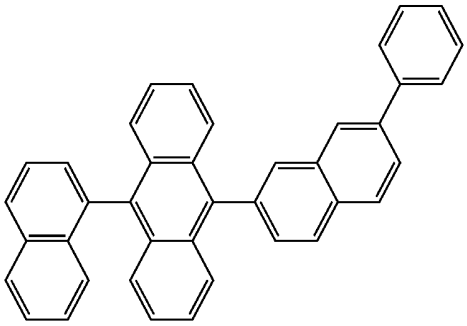


-continued

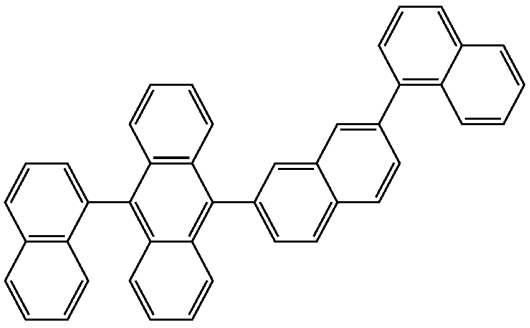
H17



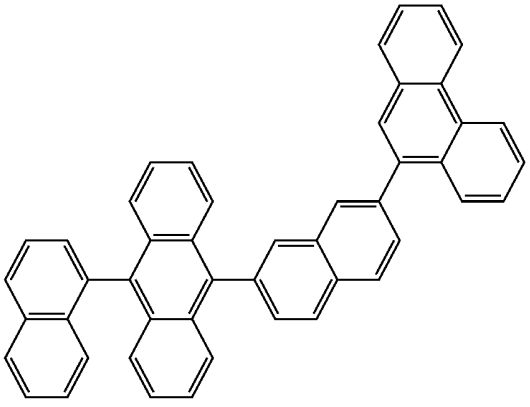
H18



H19

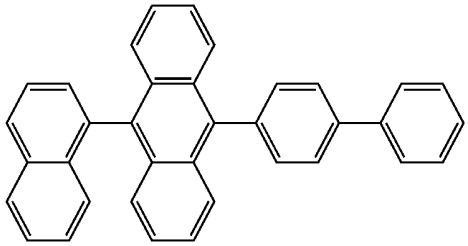


H20

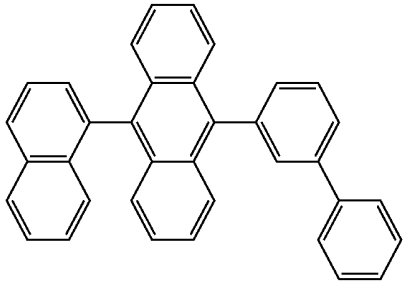


-continued

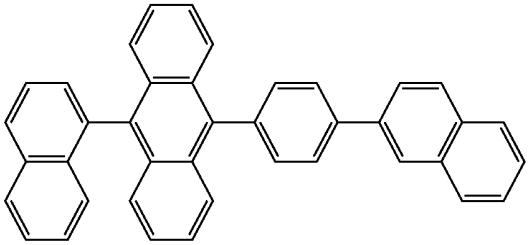
H21



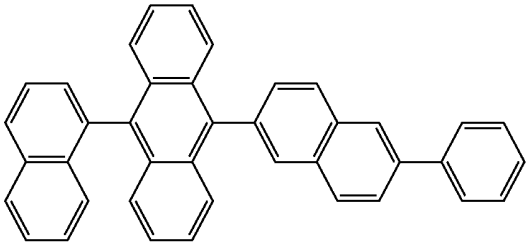
H22



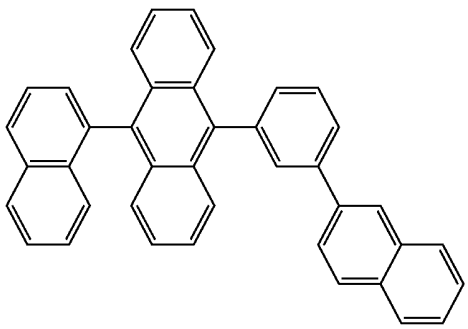
H23



H24

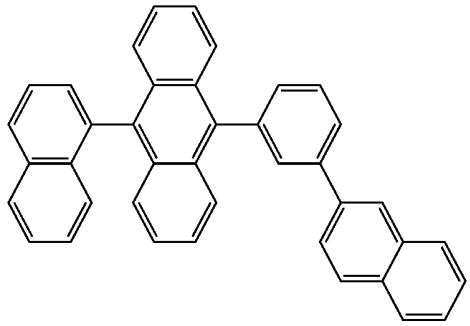


H25

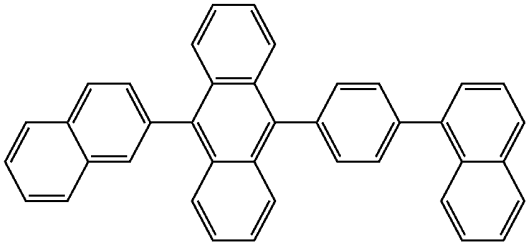


-continued

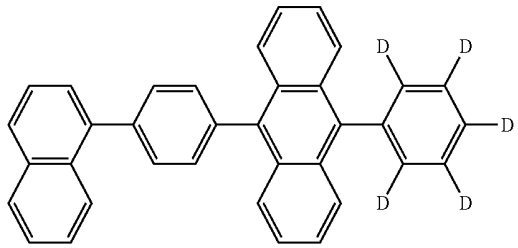
H26



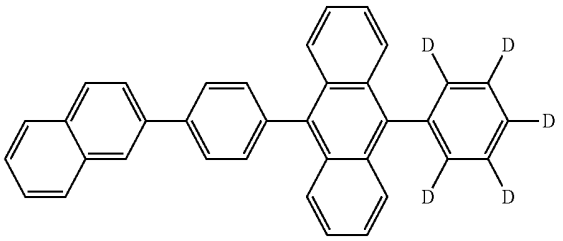
H27



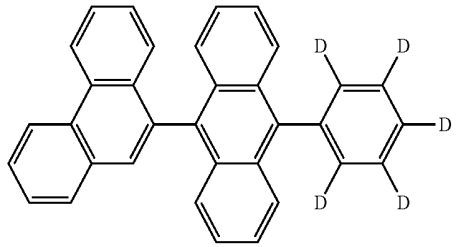
H28



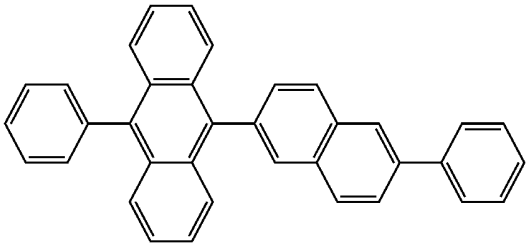
H29



H30

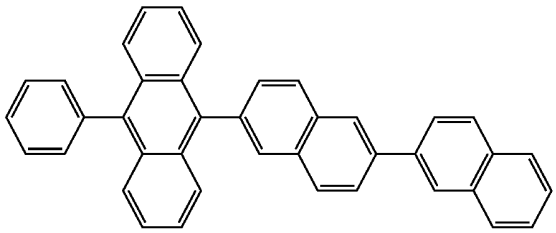


H31

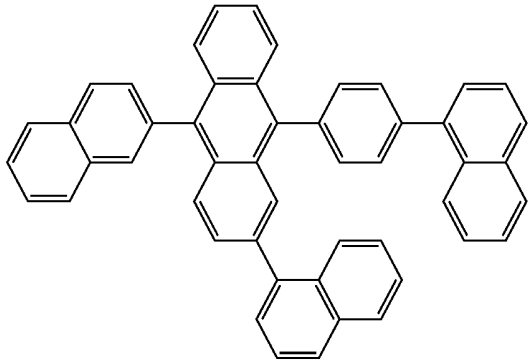


-continued

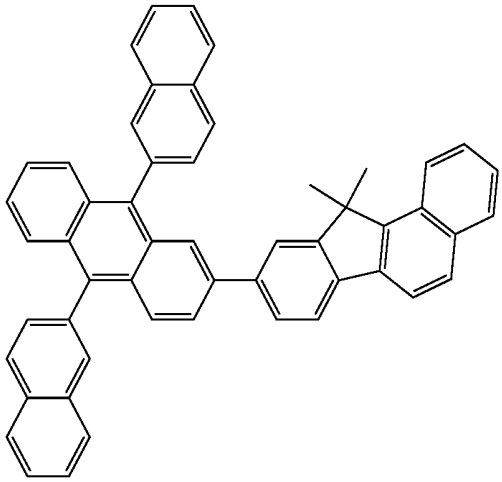
H32



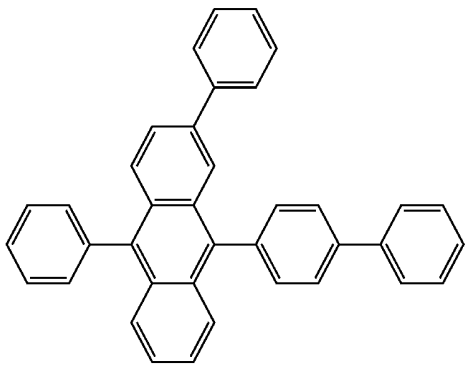
H33



H34

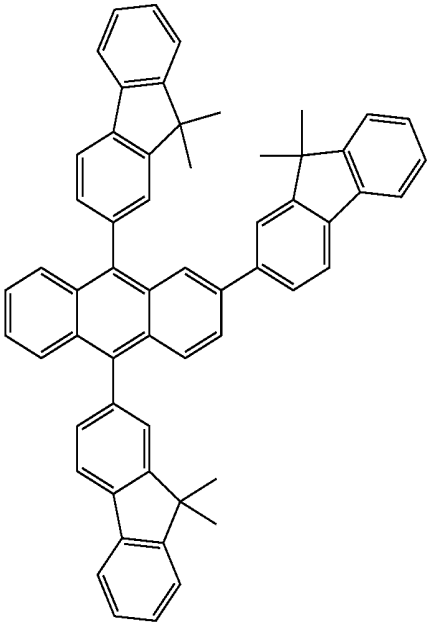


H35

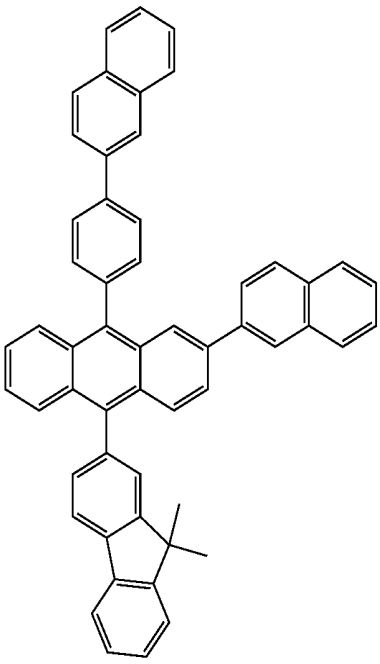


-continued

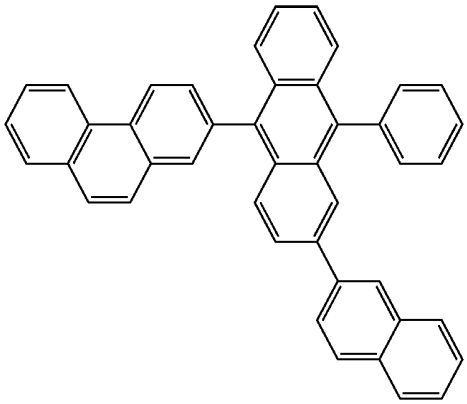
H36



H37

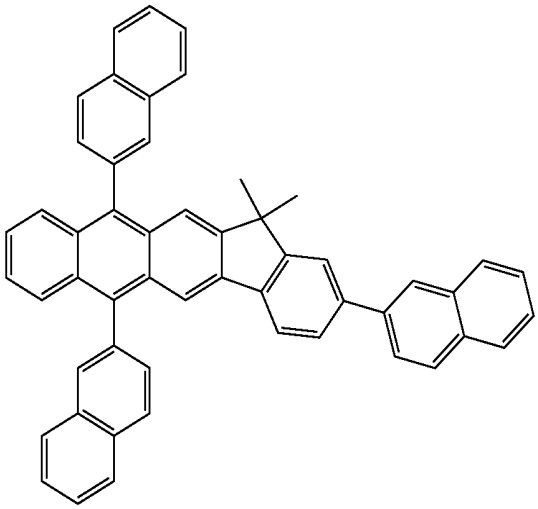


H38

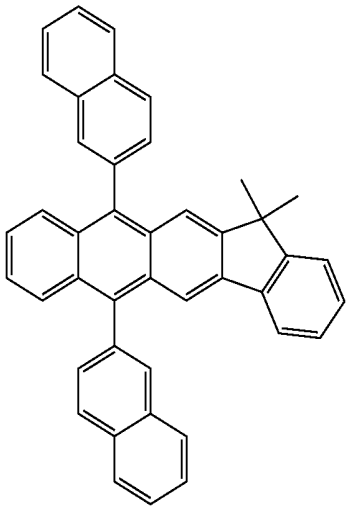


-continued

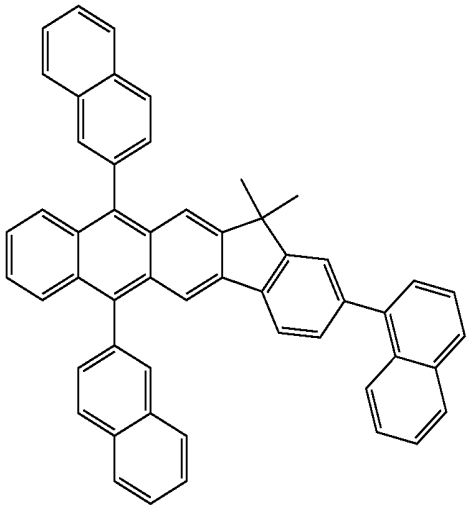
H39



H40

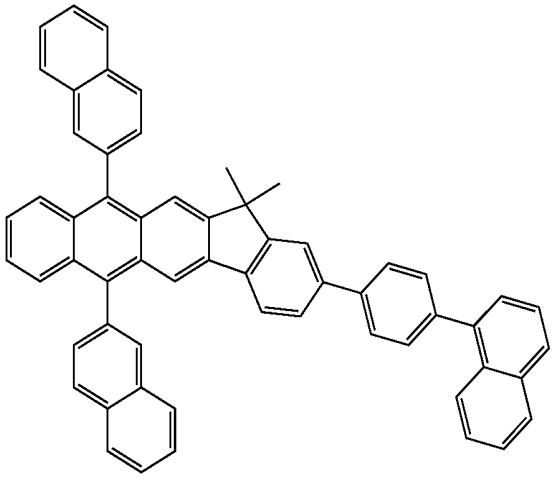


H41



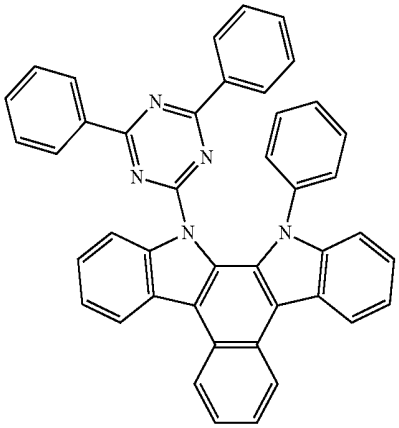
-continued

H42

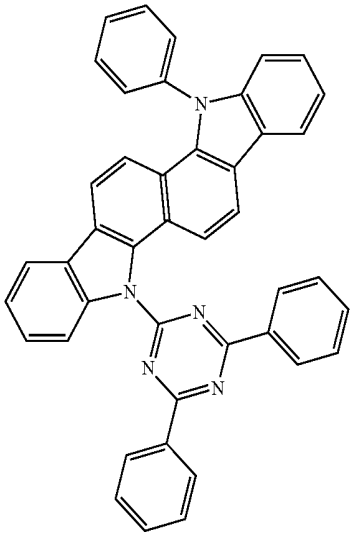


[0164] According to another embodiment of the present disclosure, the host may include at least one selected from Compounds H43 to H49, but the host is not limited thereto:

H43

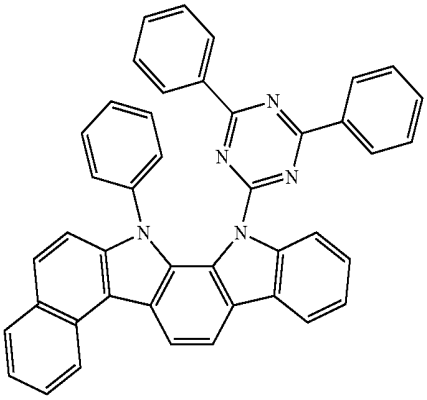


H44

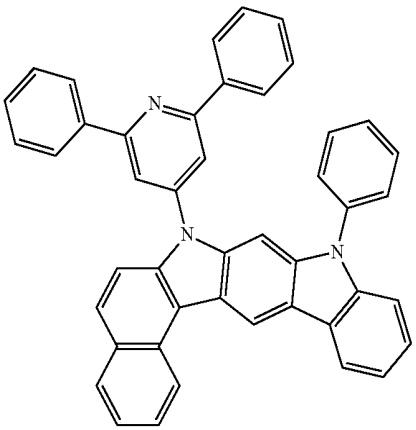


-continued

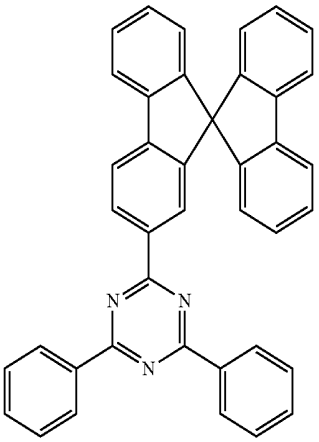
H45



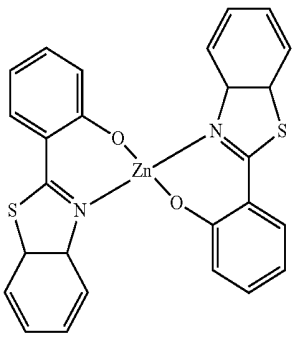
H46



H47

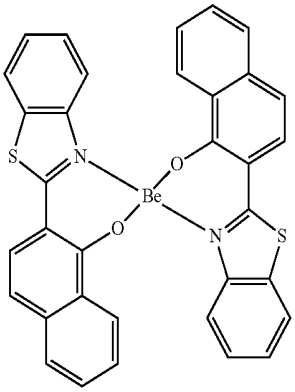


H48



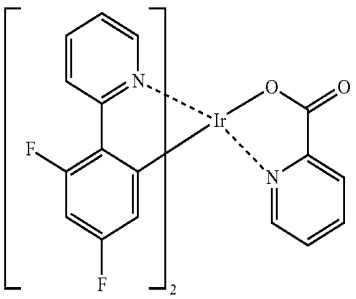
-continued

H49

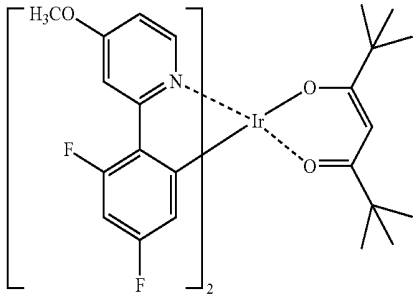


[0165] The dopant may be any suitable dopant generally used in the art. The dopant may include at least one selected from a fluorescent dopant and a phosphorescent dopant. The phosphorescent dopant may include an organometallic complex containing a combination of two or more of iridium (Ir), platinum (Pt), osmium (Os), rhenium (Re), titanium (Ti), zirconium (Zr), and hafnium (Hf), but the present disclosure is not limited thereto.

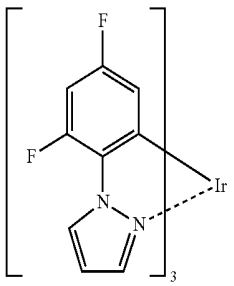
[0166] Meanwhile, as a suitable blue dopant, the following compounds, such as F_2Irpic bis[3,5-difluoro-2-(2-pyridyl) phenyl](picolinato)iridium (III), $(F_2ppy)_2Ir(tmd)$, $Ir(dfppz)_3$, 4,4'-bis(2,2'-diphenylethen-1-yl)biphenyl (DPVBi), and 4,4'-bis[4-(diphenylamino)styryl]biphenyl (DPAVBi), or 2,5,8,11-tetra-tert-butyl perylene (TBPe) may be used, but the blue dopant is not limited thereto.



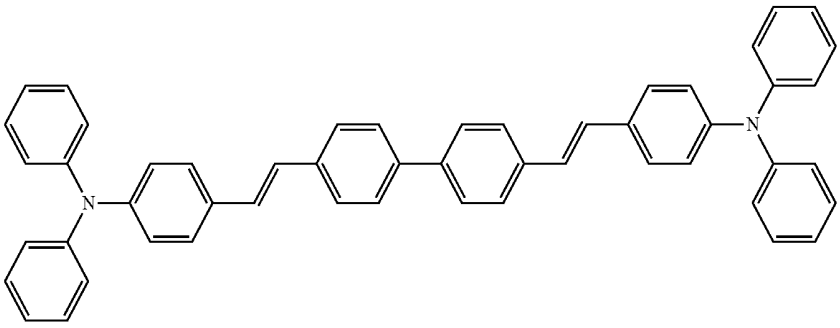
F_2Irpic



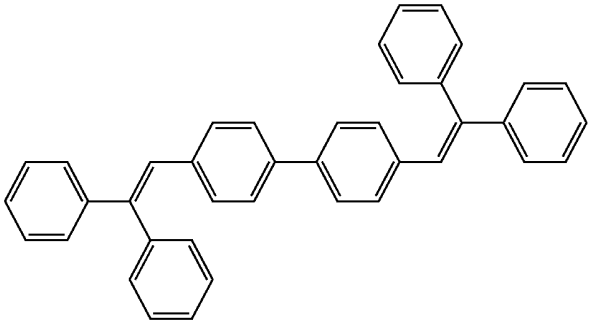
$(F_2ppy)_2Ir(tmd)$



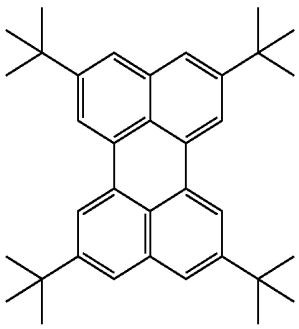
$Ir(dfppz)_3$



DPAVBi

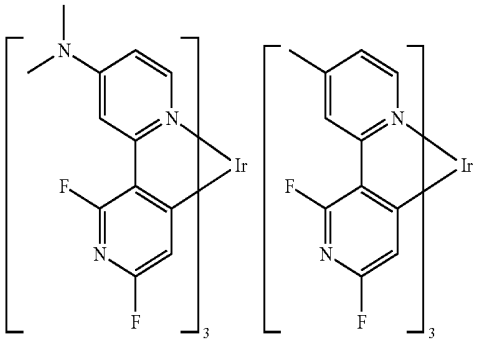


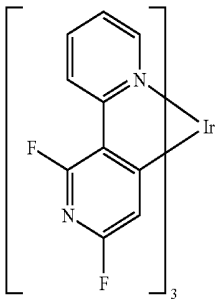
DPABi

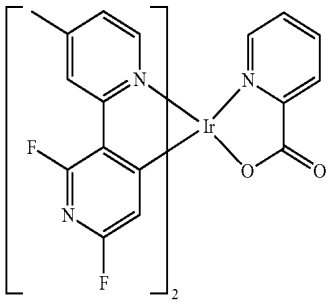


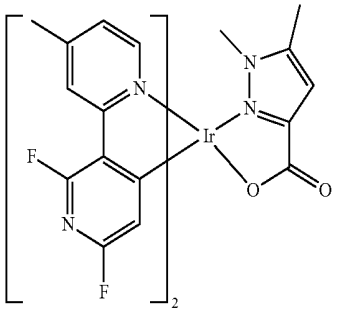
TPBe

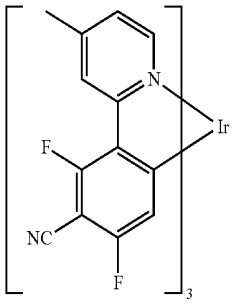
[0167] In some embodiments, as a suitable blue dopant, any of the following compounds may be used, but the blue dopant is not limited thereto.



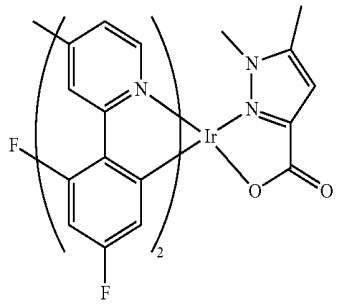


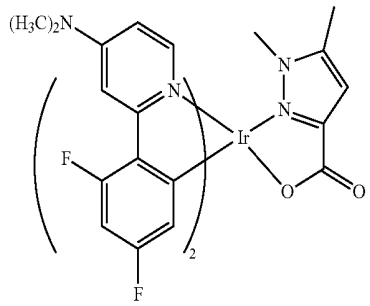


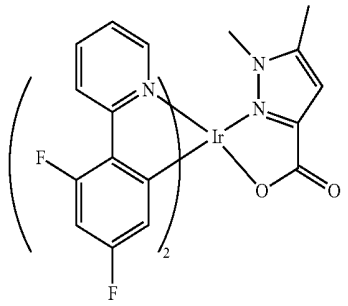




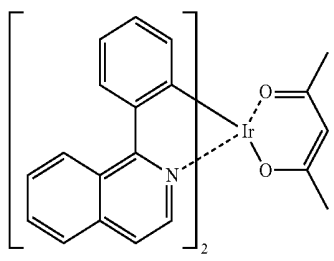
-continued





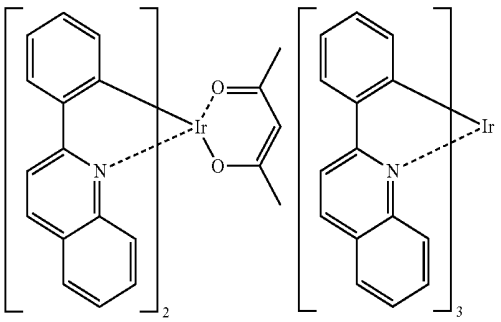


[0168] Meanwhile, as a suitable red dopant, the following compounds, such as Pt(II) octaethylporphine (PtOEP), tris(2-phenylisoquinoline)iridium ($Ir(piq)_3$), bis(2-(2'-benzothienyl)-pyridinato-N,C3')iridium (acetylacetonate) (Btp_2Ir(acac), 4-(dicyanomethylene)-2-methyl-6-[p-(dimethylamino)styryl]-4H-pyran (DCM), or 4-(dicyanomethylene)-2-tert-butyl-6-(1,1,7,7,-tetramethyl-julolidyl-9-enyl)-4H-pyran (DCJTB), may be used, but the red dopant is not limited thereto.

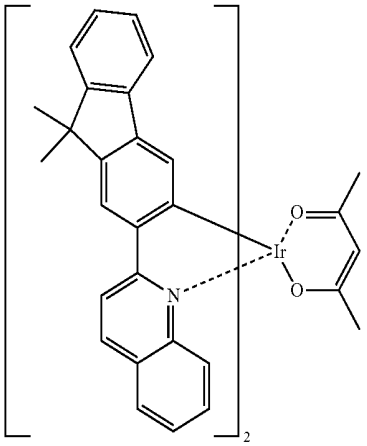


$Ir(piq)_2(acac)$

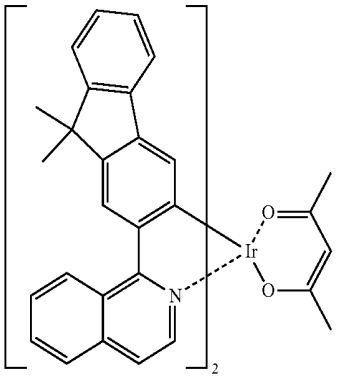
-continued



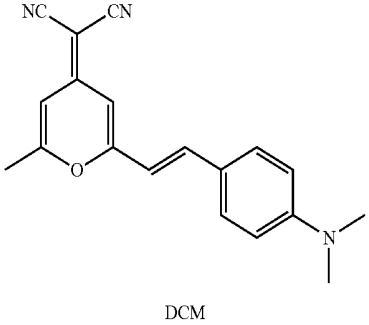
$Ir(2\text{-}phq)_2(acac)$ $Ir(2\text{-}phq)_3$



$Ir(flq)_2(acac)$

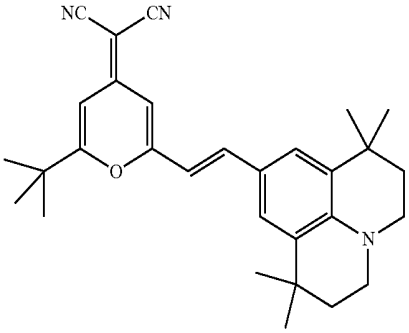


$Ir(fliq)_2(acac)$

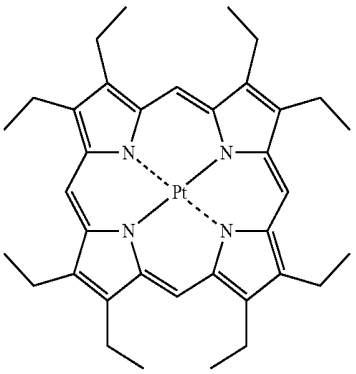


DCM

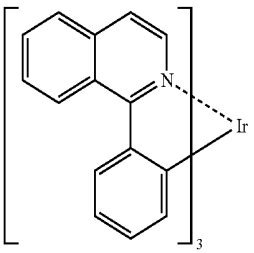
-continued



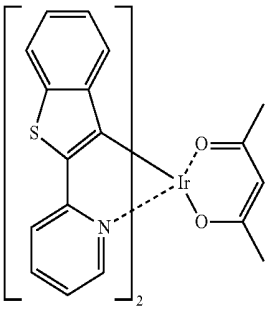
DCJTB



PtOEP

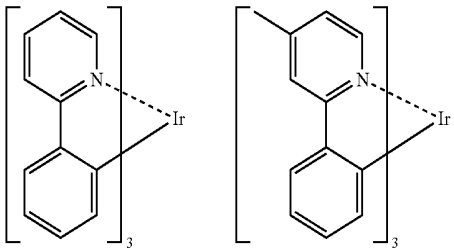


Ir(piq)3

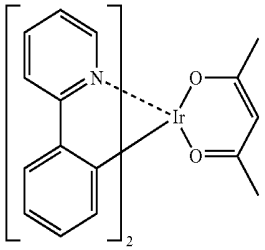


Btp2Ir(acac)

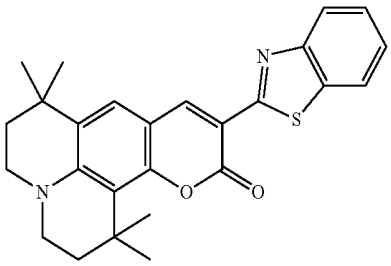
[0169] In some embodiments, as a suitable green dopant, the following compounds, such as tris(2-phenylpyridine) iridium ($Ir(ppy)_3$), bis(2-phenylpyridine)(acetylacetonato)iridium (III) ($Ir(ppy)_2(acac)$), tris(2-(4-tolyl)phenylpiridine)iridium ($Ir(mppy)_3$), or 10-(2-benzothiazolyl)-1,1,7,7-tetramethyl-2,3,6,7-tetrahydro-1H,5H,11H-[1]benzopyrano [6,7,81]-quinolizin-11-one (C545T), may be used, but the green dopant is not limited thereto.



$Ir(ppy)_3$ $Ir(mppy)_3$



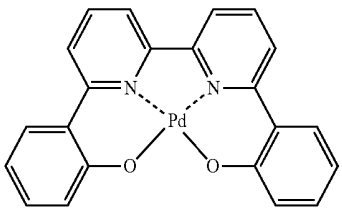
$Ir(ppy)_2(acac)$



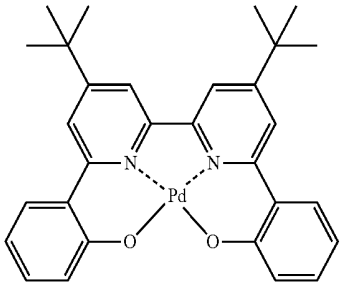
C545T

[0170] In some other embodiments, the dopant included in the emission layer may be any one of Pt-complexes D1-D50, but the dopant is not limited thereto:

D1

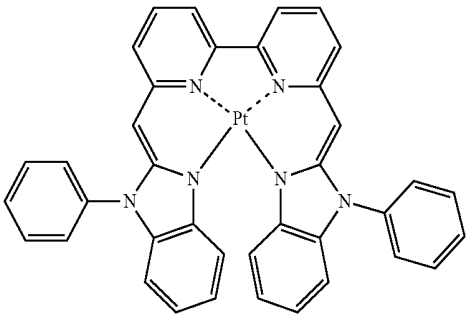


D2

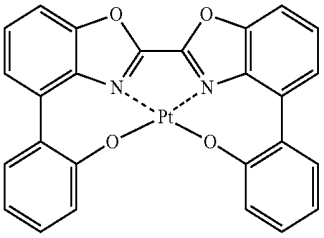


-continued

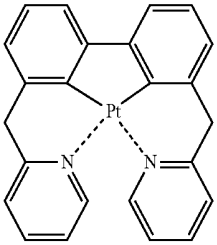
D3



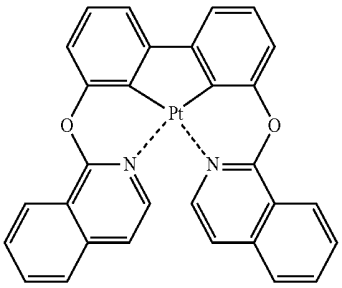
D4



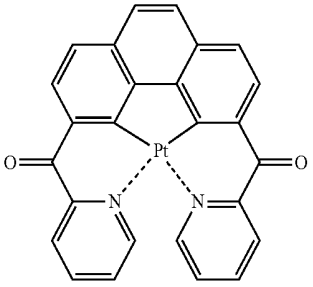
D5



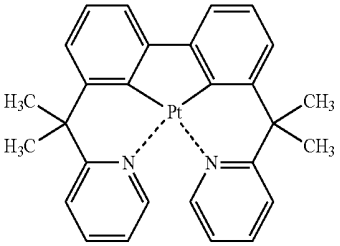
D6



D7

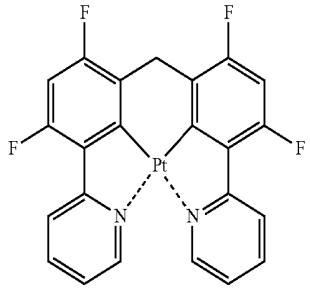


D8

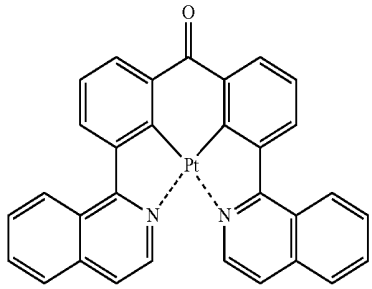


-continued

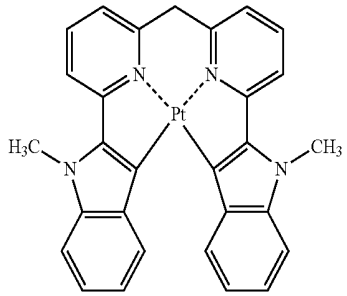
D9



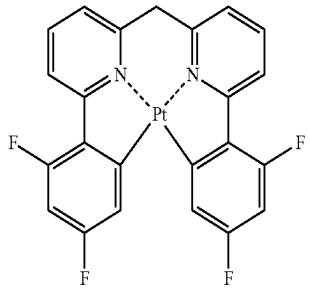
D10



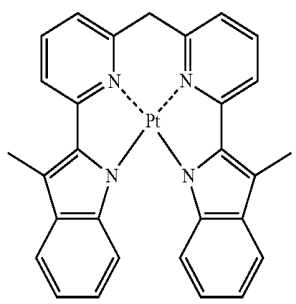
D11



D12

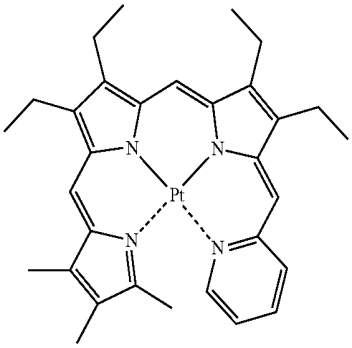


D13

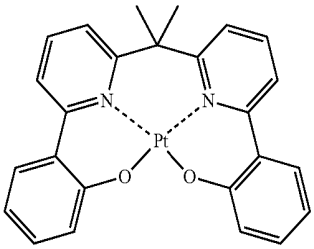


-continued

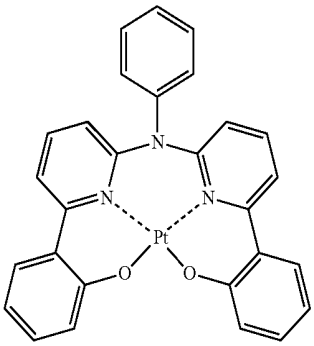
D14



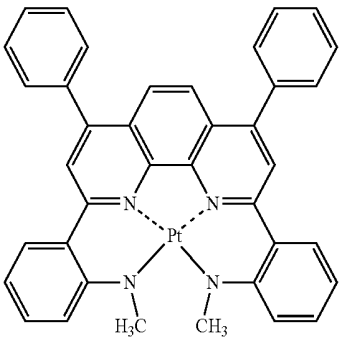
D15



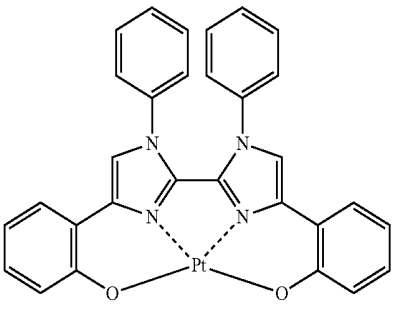
D16



D17

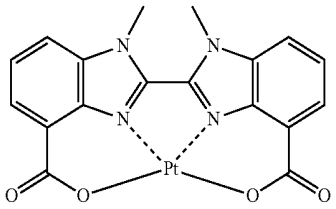


D18

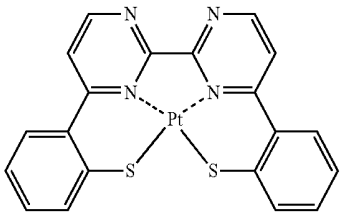


-continued

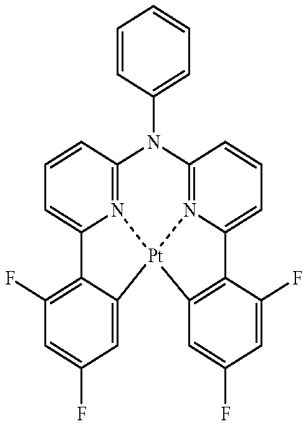
D19



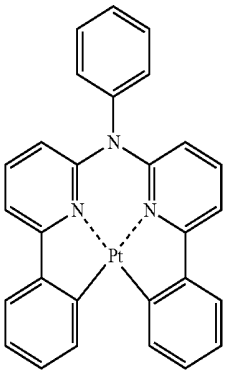
D20



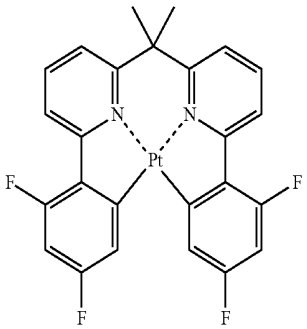
D21



D22

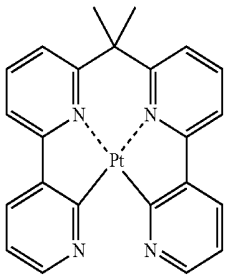


D23

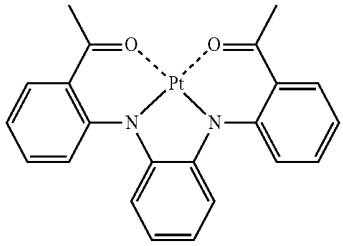


-continued

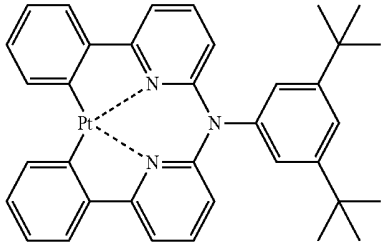
D24



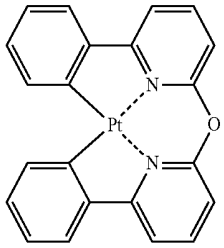
D25



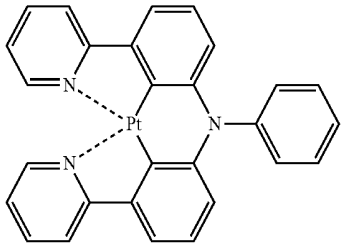
D26



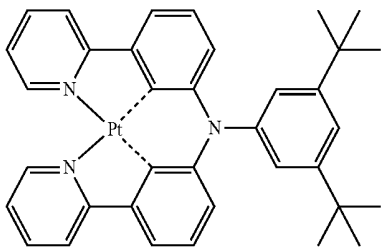
D27



D28

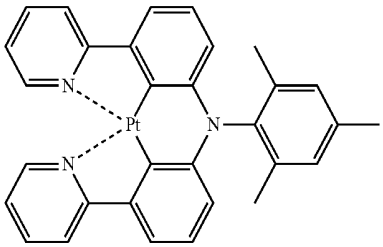


D29

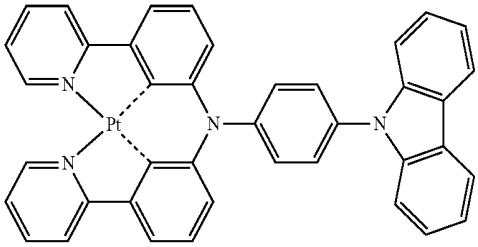


-continued

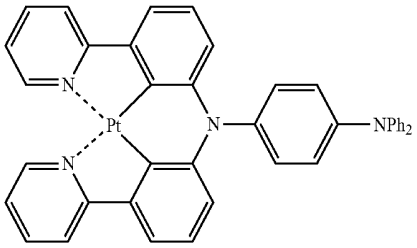
D30



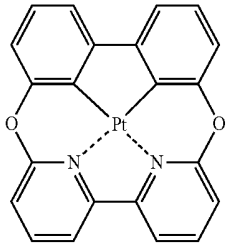
D31



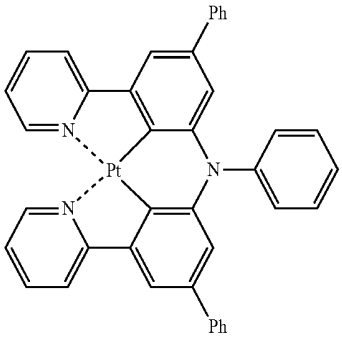
D32



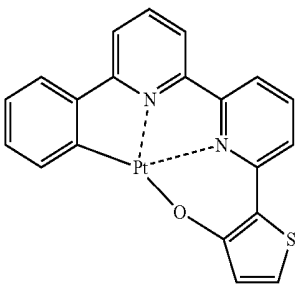
D33



D34

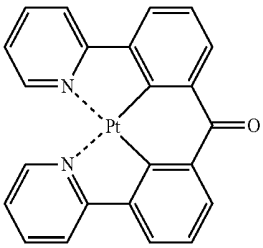


D35

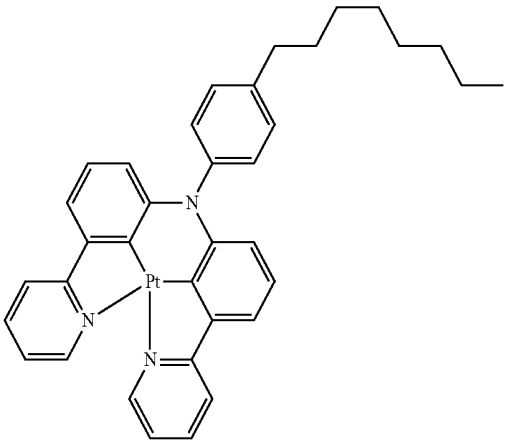


-continued

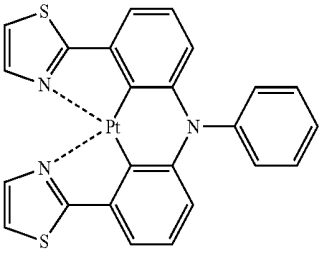
D36



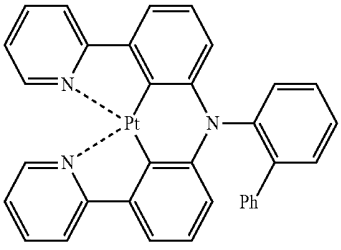
D37



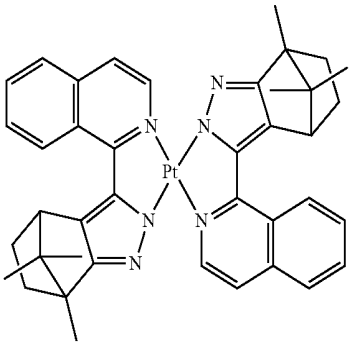
D38



D39

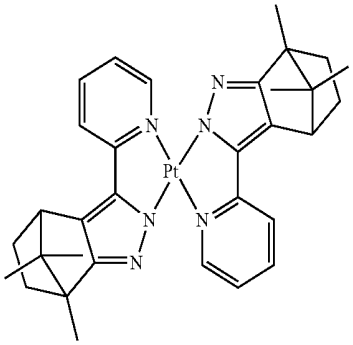


D40

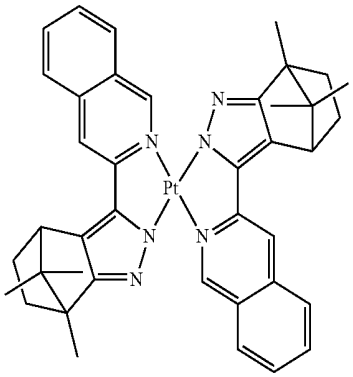


-continued

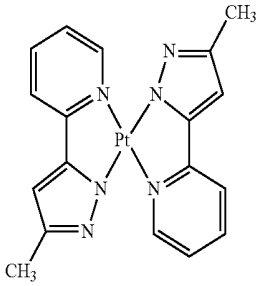
D41



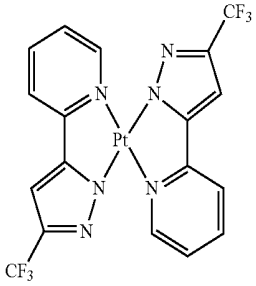
D42



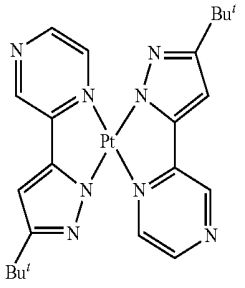
D43



D44

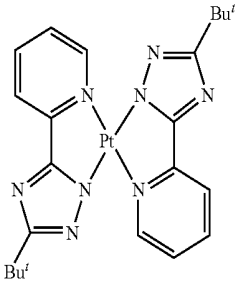


D45

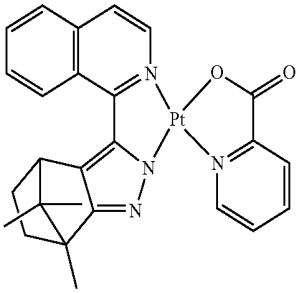


-continued

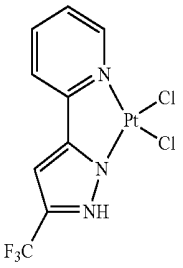
D46



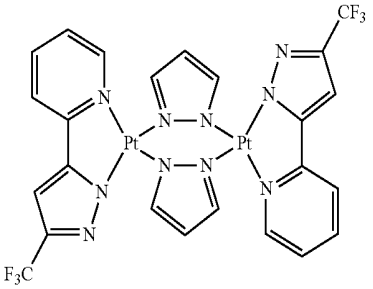
D47



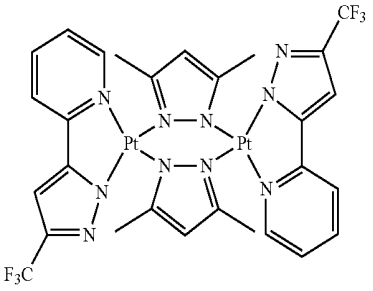
D48



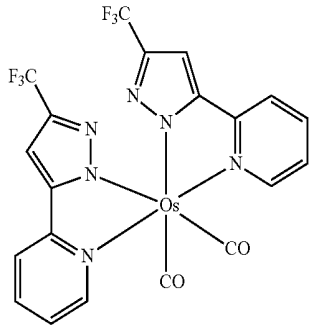
D49



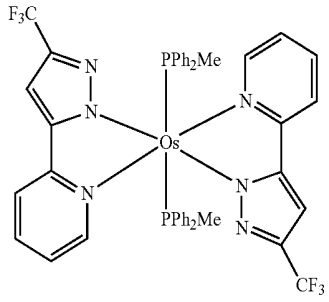
D50



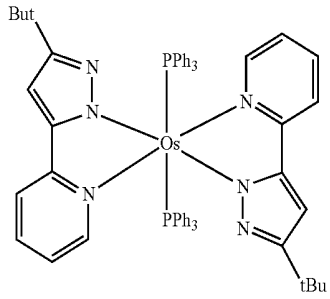
[0171] In addition, the dopant included in the emission layer may be any one of Os-complexes shown below, but the dopant is not limited thereto:



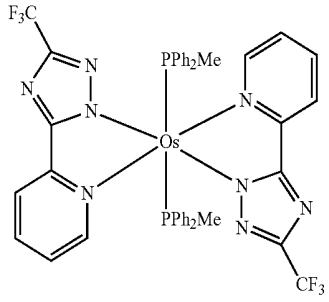
$Os(fppz)_2(CO)_2$



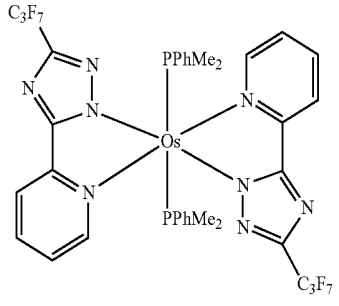
$Os(fppz)_2(PPh_2Me)_2$



$Os(bppz)_2(PPh_3)_2$



$Os(fptz)_2(PPh_2Me)_2$



$Os(hptz)_2(PPhMe_2)_2$

[0172] An amount of the dopant in the emission layer may be, in general, in a range of about 0.01 to about 15 parts by weight based on 100 parts by weight of the host, but the dopant is not limited thereto.

[0173] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within any of the foregoing ranges, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0174] Then, an electron transport region may be on the emission layer.

[0175] The electron transport region may include at least one selected from a HBL, an electron transport layer (ETL), and an EIL, but the electron transport region is not limited thereto.

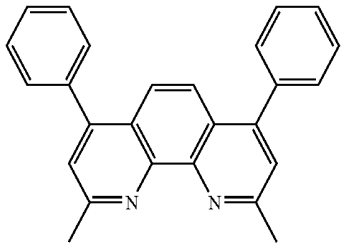
[0176] For example, the electron transport region may have a structure of ETL/EIL or a structure of HBL/ETL/EIL, where layers of each structure are sequentially stacked from the emission layer in the stated order, but the electron transport region is not limited thereto.

[0177] According to an embodiment of the present disclosure, the organic layer **15** of the OLED includes an electron transport region between the emission layer and the second electrode **17**, where the electron transport region includes the condensed cyclic compound of Formula 1.

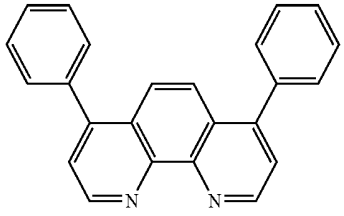
[0178] The electron transport region may include a HBL. The HBL may be formed, when the emission layer includes a phosphorescent dopant, to prevent (or reduce) diffusion of excitons or holes into an electron transport layer.

[0179] When the electron transport region may include a HBL, the HBL may be formed on the emission layer by using various methods, such as vacuum deposition, spin coating casting, an LB method, ink-jet printing, laser-printing, or LITI. When the hole blocking layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the HBL may be determined by referring to the deposition and coating conditions described herein with respect to the HIL.

[0180] The HBL may include, for example, at least one selected from BCP and Bphen, but the HBL is not limited thereto.



BCP

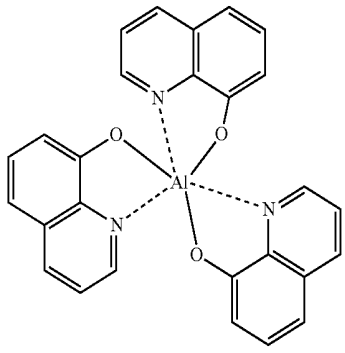


Bphen

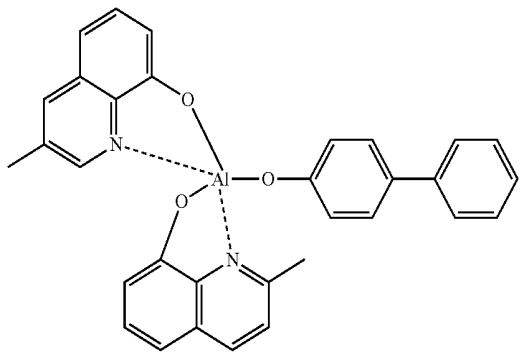
[0181] A thickness of the HBL may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thickness of the HBL is within any of the foregoing ranges, the HBL may have excellent hole blocking characteristics without a substantial increase in driving voltage.

[0182] The electron transport region may include an ETL. The ETL may be formed on the emission layer or the HBL by using various methods, such as vacuum deposition, spin coating casting, an LB method, ink-jet printing, laser-printing, or LITI. When an ETL is formed by vacuum deposition or spin coating, deposition and coating conditions for the ETL may be determined by referring to the deposition and coating conditions described herein with respect to the HIL.

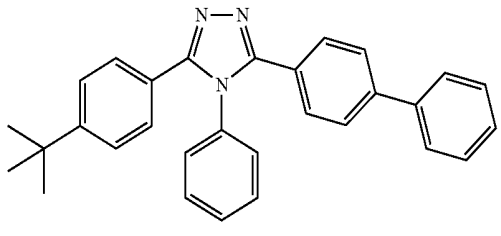
[0183] The ETL may further include, in addition to the condensed cyclic compound of Formula 1, at least one selected from BCP, Bphen, and Alq_3, Balq, TAZ, and NTAZ, which are illustrated below.



Alq3

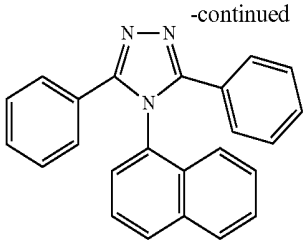


BAlq



TAZ

-continued



NTAZ

[0184] In some embodiments, the ETL may include at least one selected from compounds represented by Formula 601:

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

[0185] where in Formula 601,

[0186] Ar_{601} may be may be understood by referring to the description provided herein for Ar_{301} with respect to Formula 301;

[0187] L_{601} may be may be understood by referring to the description provided herein for L_{201} with respect to Formulae 201 and 202; and

[0188] E_{601} may be selected from a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

[0189] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20}alkoxy group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an

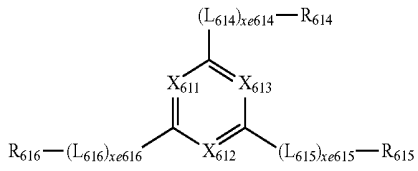
acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, an picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group; a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

[0190] xe1 may be selected from 0, 1, 2, and 3;

[0191] xe2 may be selected from 1, 2, 3, and 4.

[0192] In some other embodiments, the ETL may include at least one compound represented by Formula 602:

Formula 602



[0193] where in Formula 602,

[0194] X_{611} may be N or C-$(L_{611})_{xe611}$-R_{611}, X_{612} may be N or C-$(L_{612})_{xe612}$-R_{612}, X_{613} may be N or C-$(L_{613})_{xe613}$-R_{613}, at least one of X_{611} to X_{613} may be N; and

[0195] L_{611} to L_{616} may be each understood by referring to a detailed description thereof provided herein for L_{201} with respect to Formulae 201 and 202;

[0196] R_{611} to R_{616} may be each independently selected from:

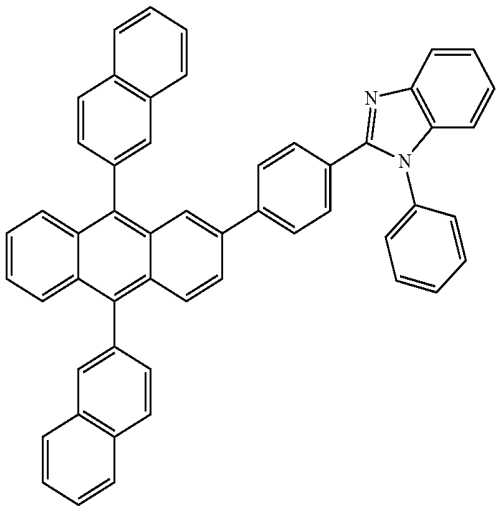
[0197] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0198] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20}alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

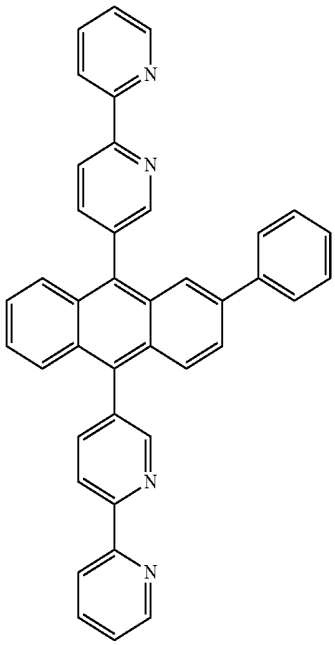
[0199] xe611 to xe616 may be each independently selected from 0, 1, 2, and 3.

[0200] The compound of Formula 601 and the compound of Formula 602 may include at least one selected from Compounds ET1 to ET15.

ET1

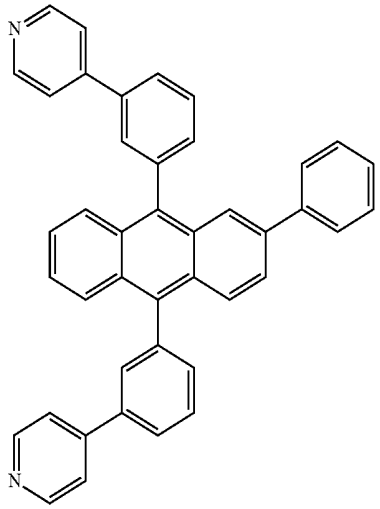


ET2

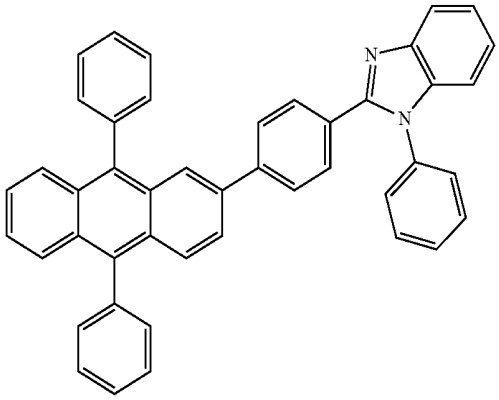


-continued

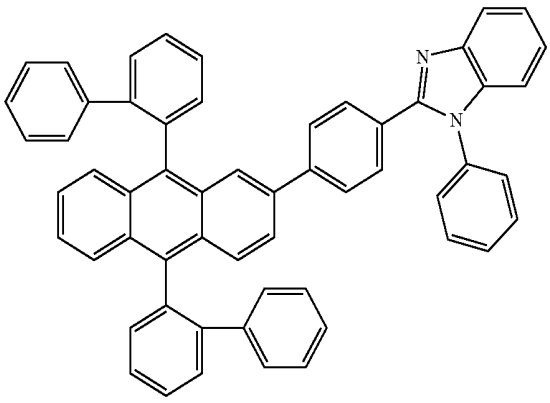
ET3



ET4

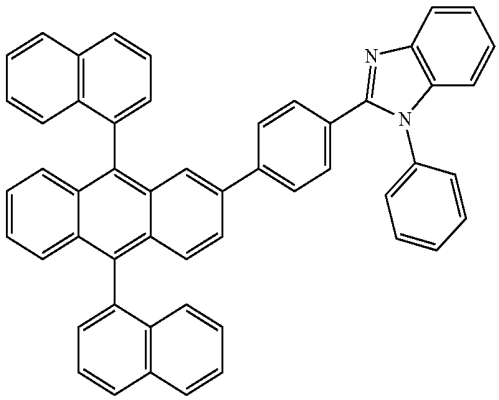


ET5

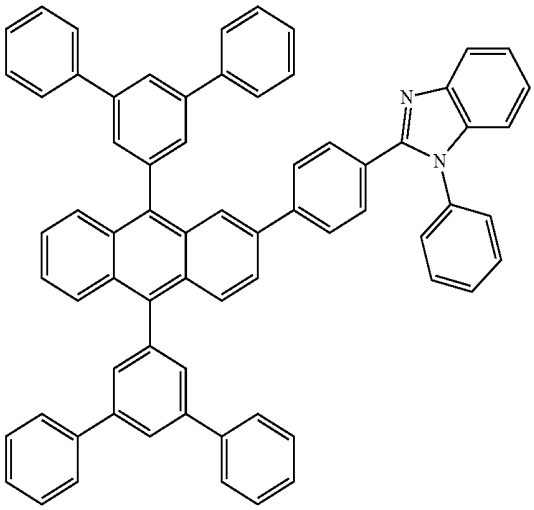


-continued

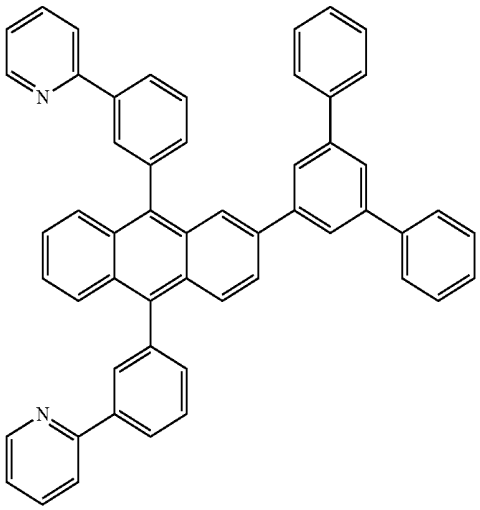
ET6



ET7

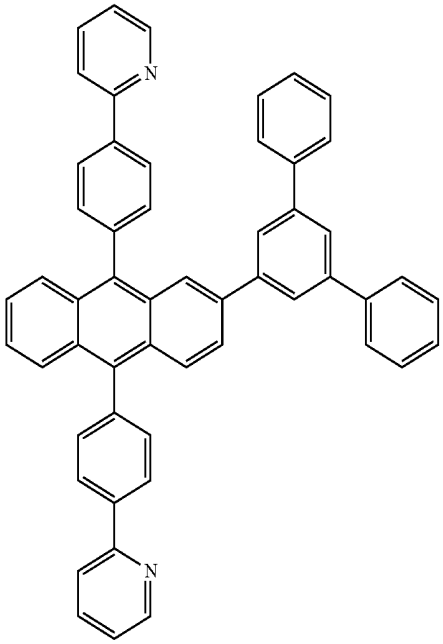


ET8

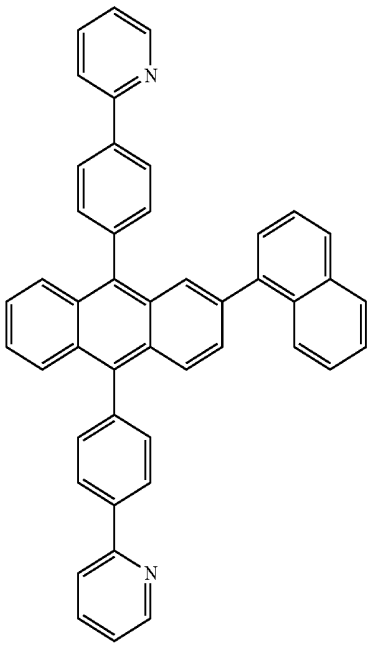


-continued

ET9

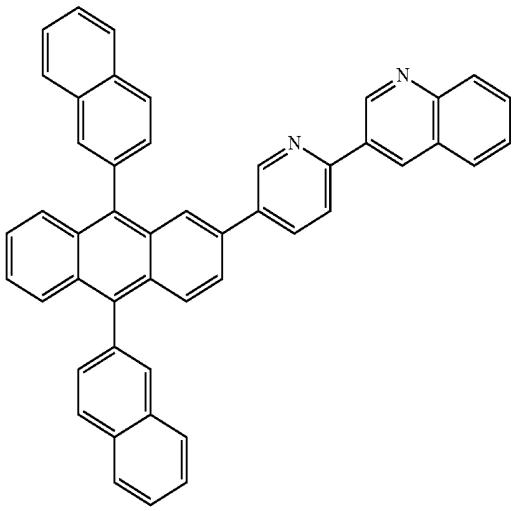


ET10

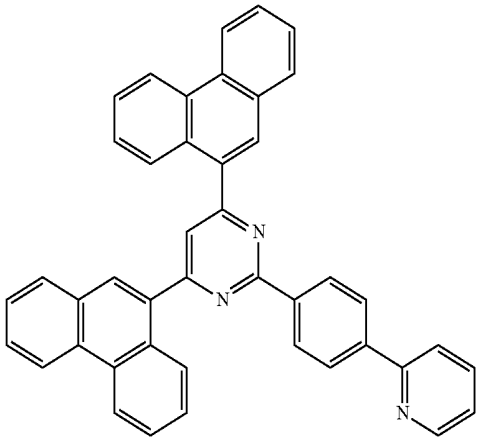


-continued

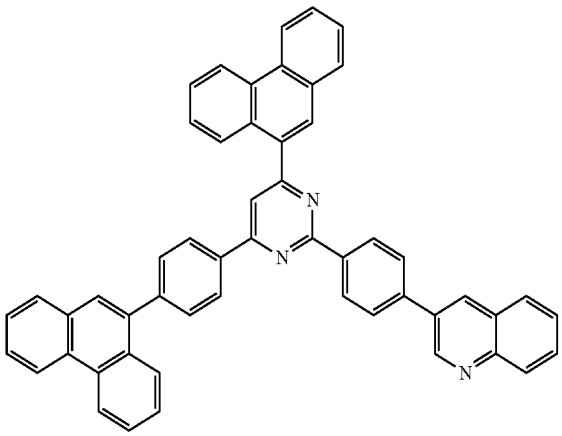
ET11



ET12

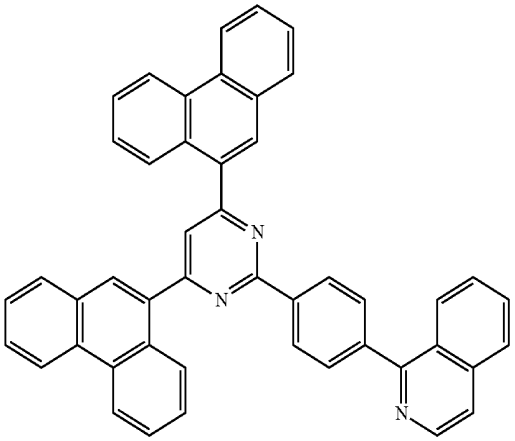


ET13

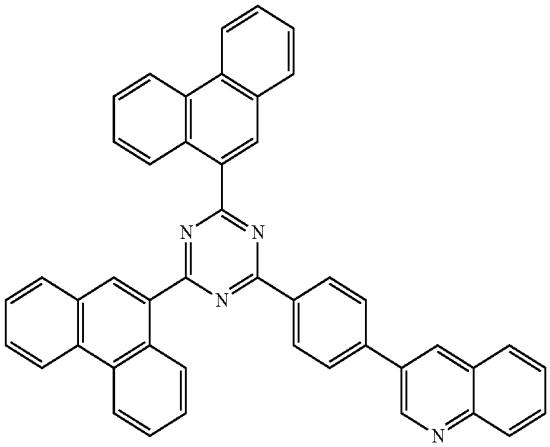


-continued

ET14



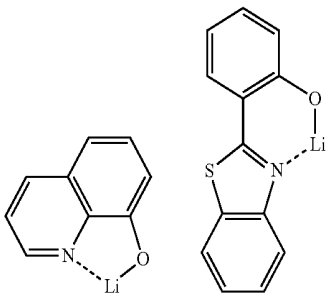
ET15



[0201] A thickness of the ETL may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the ETL is within any of the foregoing ranges, the ETL may have satisfactory electron transportation characteristics without a substantial increase in driving voltage.

[0202] The ETL may further include, in addition to the materials described above, a metal-containing material.

[0203] The metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2.



ET-D1

ET-D2

[0204] The electron transport region may include an EIL that allows electrons to be easily provided from the second electrode **17**.

[0205] The EIL may be formed on the ETL by using (utilizing) various suitable methods, such as vacuum deposition, spin coating casting, an LB method, ink-jet printing, laser-printing, or LITI. When an EIL is formed by vacuum deposition or spin coating, deposition and coating conditions for the EIL may be determined by referring to the deposition and coating conditions described herein with respect to the HIL.

[0206] The EIL may include at least one selected from, LiF, NaCl, CsF, Li_2O, BaO, and LiQ.

[0207] A thickness of the EIL may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the EIL is within any of the foregoing ranges, the EIL may have satisfactory electron transportation characteristics without a substantial increase in driving voltage.

[0208] The second electrode **17** is on the organic layer **15** having such a structure. The second electrode **17** may be a cathode that is an electron injection electrode, and in this regard, a material for forming the second electrode **17** may be a material having a low work function, and such a material may be a metal, an alloy, an electrically conductive compound, or a mixture thereof. Examples of the second electrode **17** include lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag). According to another embodiment of the present disclosure, the material for forming the second electrode **190** may be ITO or IZO. The second electrode **17** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode.

[0209] The OLED has been described with reference to the accompanying drawing, but the OLED is not limited thereto. For example, the OLED of the accompanying drawing includes the substrate **11** that is disposed at the bottom of the first electrode **13**, but optionally, the substrate **11** may be disposed on top of the second electrode **17**.

[0210] The term "alkyl group" as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group, and examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-a butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term "alkylene group" as used herein refers to a divalent group having substantially the same structure as the alkyl group except that the alkylene group is a divalent group instead of a monovalent group.

[0211] The term "alkoxy group" as used herein refers to a monovalent group represented by OA_{101} (where A_{101} is the C_1-C_{30} alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0212] The term "alkenyl group" as used herein refers to a hydrocarbon group formed by substituting at least one carbon double bond in the main chain (e.g., middle) or terminal end of the alkyl group, and examples thereof include an ethenyl group, a propenyl group and a butenyl group. The term "alkenylene group" as used herein refers to a divalent group having substantially the same structure as the alkenyl group except that the alkenylene group is a divalent group instead of a monovalent group.

[0213] The term "alkynyl group" as used herein refers to a hydrocarbon group formed by substituting at least one carbon triple bond in the main chain (e.g., middle) or terminal end of the alkyl group, and examples thereof include an ethynyl group and a propynyl group. The term "alkynylene group" as

used herein refers to a divalent group having substantially the same structure as the alkynyl group except that the alkynylene group is a divalent group instead of a monovalent group.

[0214] The term "cycloalkyl group" as used herein refers to a monovalent saturated hydrocarbon monocyclic group, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term "cycloalkylene group" as used herein refers to a divalent group having substantially the same structure as the cycloalkyl group except that the cycloalkylene group is a divalent group instead of a monovalent group.

[0215] The term "heterocycloalkyl group" as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and examples thereof include a tetrahydrofuranyl group and a tetrahydrothiophenyl group. The term "heterocycloalkylene group" as used herein refers to a divalent group having substantially the same structure as the heterocycloalkyl group except that the heterocycloalkylene group is a divalent group instead of a monovalent group.

[0216] The term "cycloalkenyl group" as used herein refers to a monovalent monocyclic group that has at least one double bond in the ring thereof and does not have aromaticity (e.g., is not aromatic), and examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "cycloalkenylene group" as used herein refers to a divalent group having substantially the same structure as the cycloalkenyl group except that the cycloalkenylene group is a divalent group instead of a monovalent group.

[0217] The term "heterocycloalkenyl group" as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and at least one double bond in its ring. Examples of the heterocycloalkenyl group include a 2,3-hydrofuranyl group and a 2,3-hydrothiophenyl group. The term "heterocycloalkenylene group" as used herein refers to a divalent group having substantially the same structure as the heterocycloalkenyl group except that the heterocycloalkenylene group is a divalent group instead of a monovalent group.

[0218] The term "aryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system, and the term "arylene group" as used herein refers to a divalent group having a carbocyclic aromatic system. Examples of the aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the aryl group and the arylene group each include two or more rings, the rings may be fused to each other.

[0219] The term "heteroaryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom. The term "heteroarylene group" as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom. Examples of the heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the heteroaryl group and the heteroarylene group each include two or more rings, the rings may be fused to each other.

[0220] The term "aryloxy group" as used herein refers to OA_{102} (where, A_{102} is the aryl group), and the term "arylthio group" as used herein refers to $-SA_{103}$ (where, A_{103} is the aryl group).

[0221] A monovalent non-aromatic condensed polycyclic group used herein refers to a monovalent group that has two or more rings condensed to each other, and non-aromaticity in the entire molecular structure. The monovalent non-aromatic condensed polycyclic group includes i) only carbon atoms as a ring-forming atom, or ii) a heteroatom selected from N, O, P, and S, other than carbon atoms, as a ring forming atom. Examples of the monovalent non-aromatic condensed polycyclic group include a heptalenyl group and a triquinacenyl group. The term "divalent non-aromatic condensed polycyclic group" as used herein refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group except that the divalent non-aromatic condensed polycyclic group is a divalent group instead of a monovalent group.

[0222] Regarding the expression C_m-C_n (m<n) as used herein, m and n indicate the number of carbon atoms. For example, a C_1-C_{10} alkyl group refers to an alkyl group having 1 to 10 carbon atoms, and a C_6-C_{30} aryl group refers to an aryl group having 6 to 30 carbon atoms.

[0223] The term "Ph" as used herein refers to a phenyl group, the term "Me" as used herein refers to a methyl group, the term "Et" as used herein refers to an ethyl group, and the term "ter-Bu" or "Bu^t" as used herein refers to tert-butyl.

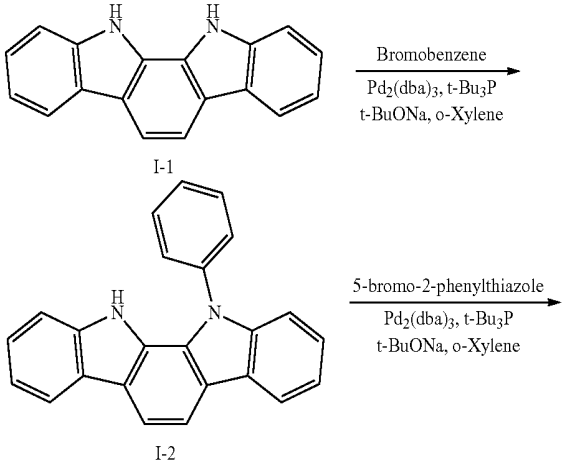
[0224] Hereinafter, an organic light-emitting diode according to an embodiment of the present disclosure will be described with reference to Synthesis Examples and Examples. The wording "B was used instead of A" as used in describing the Synthesis Examples means that a molar equivalent of A was identical (or substantially identical) to a molar equivalent of B.

SYNTHESIS EXAMPLE

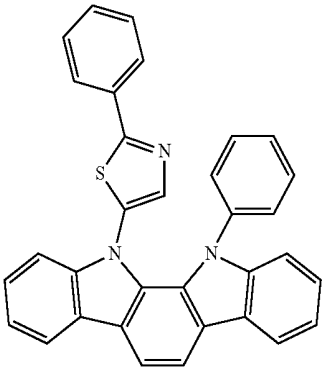
Synthesis Example 1

Synthesis of Compound 1

[0225]



-continued



1

Synthesis of Intermediate I-2

[0226] 178.6 mg (0.20 mmol) of $Pd_2(dba)_3$ and 78.9 mg (0.39 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. 5 g (19.51 mmol) of 11,12-dihydroindolo [2,3-a]carbazole (Intermediate I-1), 3.37 g (21.46 mmol) of bromobenzene, and 1.12 g (11.71 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.35 g (yield: 83%) of Intermediate I-2 (11-pheny-11,12-dihydroindolo[2,3-a]carbazol).

[0227] EI-MS, m/e, 332.13 (calculated value), 332.19 (measured value).

Synthesis of Compound 1

[0228] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) of Intermediate I-2, 3.97 g (16.54 mmol) of 5-bromo-2-phenyl phenyithiazole, and 0.867 mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.84 g (yield: 79%) of Compound 1 (2-phenyl-5-(12-phenylindolo[2,3-a]carbazole-11(12H)-yl)thiazole).

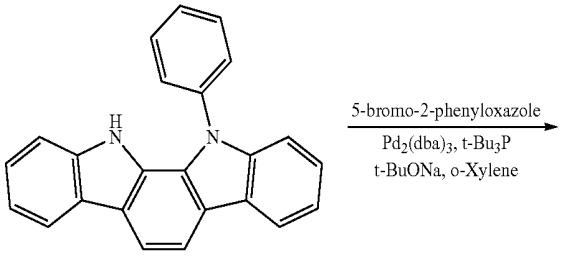
[0229] 1H NMR (300 MHz, CDCl3), d (ppm): 8.02-7.95 (1H, s), 7.74-7.58 (7H, m), 7.57-7.50 (2H, m), 7.43-7.34 (5H, m), 7.34-7.27 (1H, m), 7.26-7.14 (3H, m), 7.13-7.06 (2H, m).

[0230] EI-MS, m/e, 491.15 (calculated value), 491.17 (measured value).

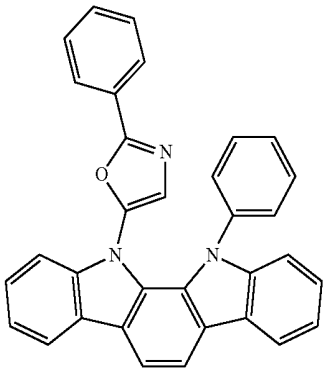
Synthesis Example 2

Synthesis of Compound 7

[0231]



I-2



7

Synthesis of Compound 7

[0232] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) of Intermediate I-2, 3.71 g (16.55 mmol) of 5-bromo-2-phenyloxazole, and 0.867 mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 6.12 g (yield 86%) of Compound 7 (2-phenyl-5-(12-phenylindolo[2,3-a]carbazole-11(12H)-yl)oxazole).

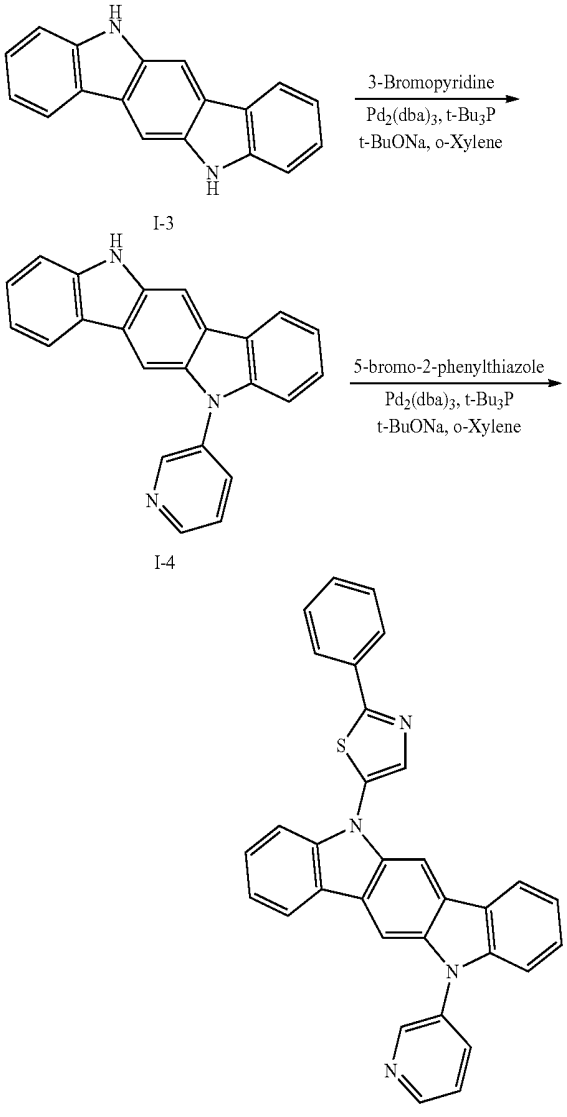
[0233] 1H NMR (300 MHz, CDCl3), d (ppm): 7.72-7.68 (1H, d), 7.68-7.64 (2H, m), 7.63-7.58 (3H, m), 7.54-7.48 (2H, m), 7.46-7.37 (4H, m), 7.37-7.29 (3H, m), 7.21-7.04 (6H, m).

[0234] EI-MS, m/e, 475.17 (calculated value), 475.21 (measured value)

Synthesis Example 3

Synthesis of Compound 59

[0235]



Synthesis of Intermediate I-4

[0236] 178.6 mg (0.20 mmol) of $Pd_2(dba)_3$ and 78.9 mg (0.39 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (19.51 mmol) of 5,11-dihydroindolo[3,2-b]carbazole (Intermediate I-3), 3.39 g (21.46 mmol) of 3-bromopyridine, and 1.12 g (11.71 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.10 g (yield: 78%) of Intermediate I-4 (5-(pyridine-3-yl)-5,11-dihydroindolo[3,2-b]carbazol).

[0237] EI-MS, m/e, 332.13 (calculated value), 332.15 (measured value).

Synthesis of Compound 59

[0238] 137.3 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.7 mg (0.30 mmol) of t-Bu3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.00 mmol) of Intermediate I-4, 3.96 g (16.50 mmol) of 5-bromo-2-phenylthiazole, and 0.864 mg (9.00 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 6.02 g (yield: 81%) of Compound 59 (2-phenyl-5-(11-(pyridine-3-yl)indolo[3,2-b]carbazole-5(11H)-yl) thiazole).

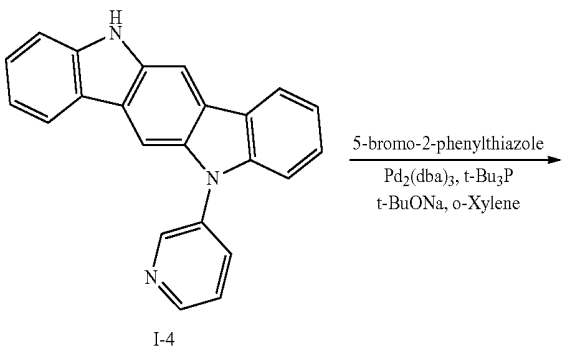
[0239] 1H NMR (300 MHz, CDCl3), d (ppm): 9.28-9.17 (1H, s), 8.63-8.53 (1H, m), 8.36-8.27 (1H, s), 8.03-7.92 (2H, m), 7.85-7.79 (1H, s), 7.75-7.69 (2H, m), 7.68-7.60 (3H, m), 7.58-7.51 (1H, m), 7.51-7.44 (1H, t), 7.44-7.37 (2H, t), 7.37-7.28 (1H, m), 7.22-7.14 (2H, m), 7.14-7.05 (2H, m).

[0240] EI-MS, m/e, 492.14 (calculated value), 492.19 (measured value).

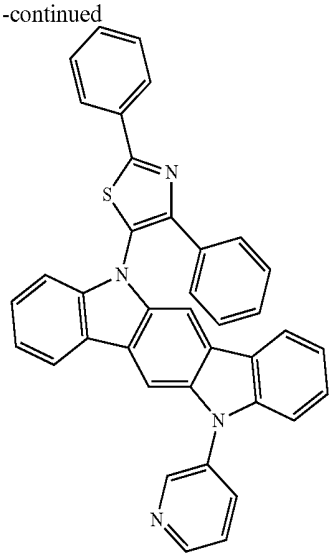
Synthesis Example 4

Synthesis of Compound 101

[0241]



-continued



101

Synthesis of Compound 101

[0242] 137.3 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.7 mg (0.30 mmol) of t-Bu3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.00 mmol) of Intermediate I-4, 5.22 g (16.50 mmol) of 5-bromo-2,4-diphenylthiazole, and 0.864 mg (9.00 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 6.77 g (yield: 79%) of Compound 101 (2,4-diphenyl-5-(11-(pyridine-3-yl)indolo[3,2-b]carbazole-5 (11H)-yl)thiazole).

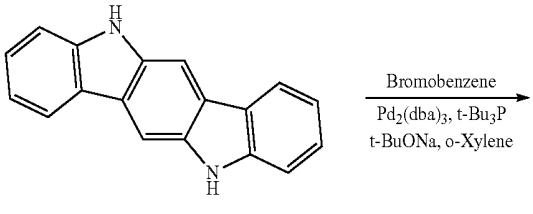
[0243] 1H NMR (300 MHz, CDCl3), d (ppm): 9.13-9.05 (1H, m), 8.58-8.49 (1H, m), 8.21-8.10 (1H, s), 8.00-7.90 (2H, m), 7.84-7.70 (7H, m), 7.66-7.58 (1H, m), 7.52-7.36 (6H, m), 7.35-7.15 (5H, m).

[0244] EI-MS, m/e, 568.17 (calculated value), 568.20 (measured value).

Synthesis Example 5

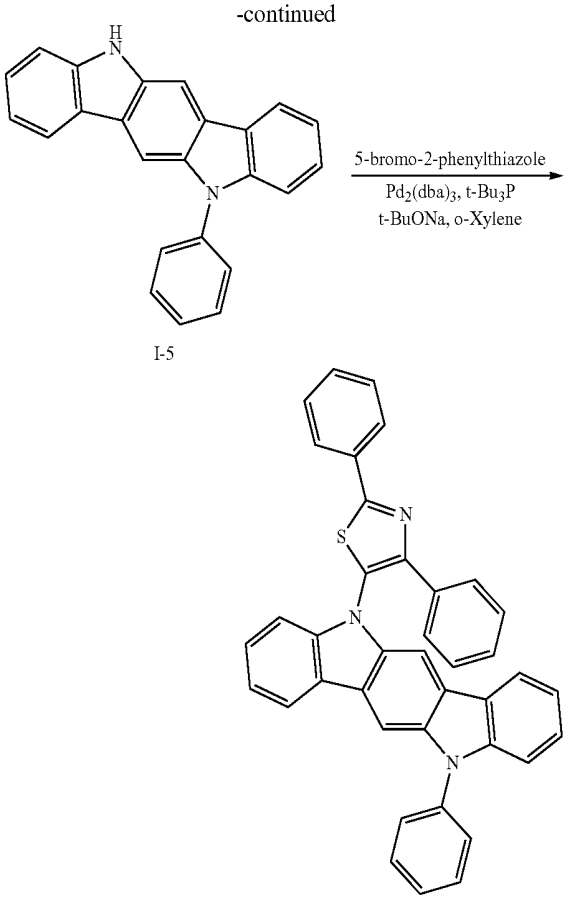
Synthesis Compound 29

[0245]



I-3

-continued



I-5

29

Synthesis of Intermediate I-5

[0246] 178.6 mg (0.20 mmol) of $Pd_2(dba)_3$ and 78.9 mg (0.39 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (19.51 mmol) of 5,11-dihydroindolo[3,2-b]carbazole (Intermediate I-3), 3.37 g (21.46 mmol) of bromobenzene, and 1.12 g (11.71 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.62 g (yield: 87%) of Intermediate I-5 (5-phenyl-5,11-dihydroindolo[3,2-b]carbazol).

[0247] EI-MS, m/e, 332.13 (calculated value), 332.18 (measured value).

Synthesis of Compound 29

[0248] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of t-Bu_3P were dissolved 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) of Intermediate I-5, 5.23 g (16.55 mmol) of 5-bromo-2,4-diphenylthiazole, and 0.867

mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 7.32 g (yield: 86%) of Compound 29 (2,4-diphenyl-5-(11-phenylindolo[3,2-b]carbazole-5(11H)-yl)thiazole).

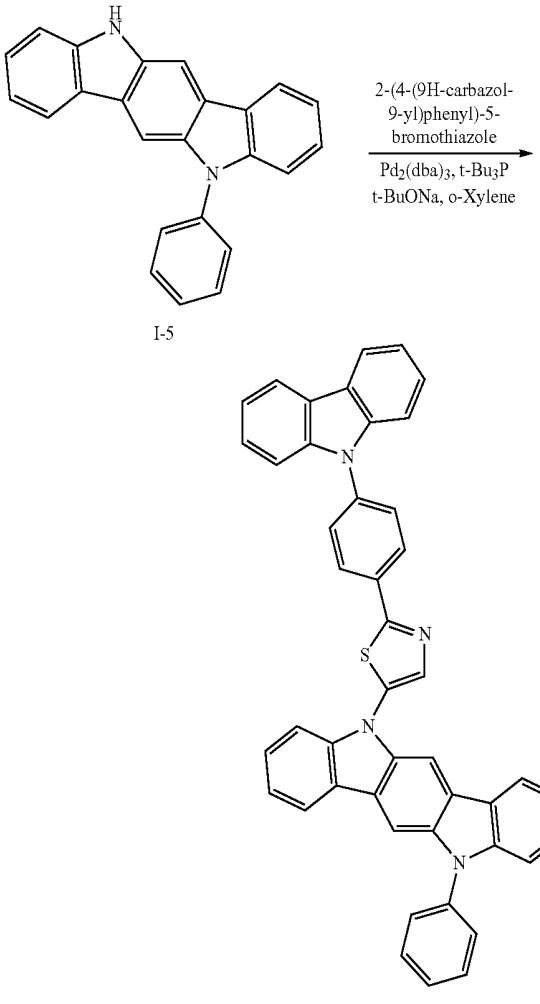
[0249] 1H NMR (300 MHz, CDCl3), d (ppm): 8.09-8.05 (1H, s), 7.83-7.78 (1H, s), 7.77-7.73 (2H, s), 7.73-7.68 (2H, m), 7.64-7.53 (6H, m), 7.50-7.41 (6H, m), 7.40-7.34 (1H, m), 7.31-7.11 (6H, m).

[0250] EI-MS, m/e, 567.18 (calculated value), 567.21 (measured value).

Synthesis Example 6

Synthesis of Compound 155

[0251]



Synthesis of Compound 155

[0252] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of $t\text{-}Bu_3P$ were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.00 mmol) of Intermediate I-5, 6.71 g (16.55 mmol) of 2-(4-(9H-carbazol-9-yl)phenyl)-5-bromotiazole, and 0.867 mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 7.58 g (yield: 77%) of Compound 155 (2-(4-(9H-carbazol-9-yl)phenyl)-5-(11-phenylindolo[3,2-b]carbazole-5(11H)-yl)thiazole).

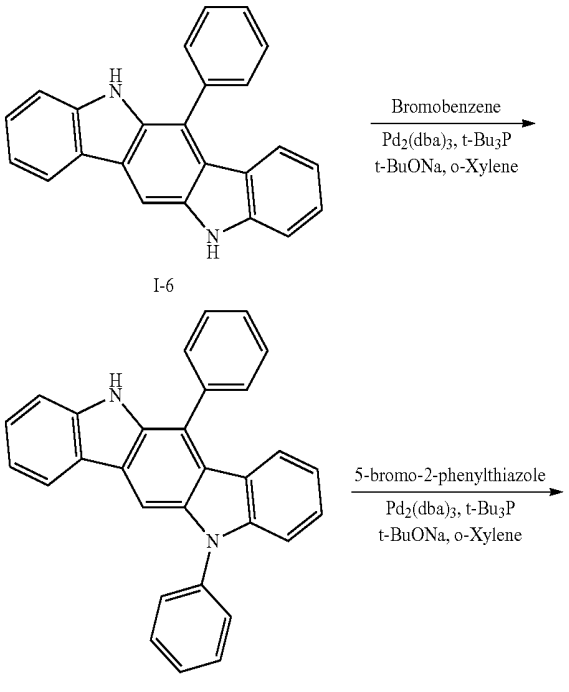
[0253] 1H NMR (300 MHz, CDCl3), d (ppm): 8.32-8.27 (1H, s), 8.03-7.99 (1H, s), 7.86-7.83 (1H, s), 7.82-7.72 (7H, m), 7.70-7.64 (3H, m), 7.64-7.59 (2H, m), 7.56-7.50 (2H, m), 7.49-7.42 (2H, t), 7.31-7.14 (9H, m).

[0254] EI-MS, m/e, 656.20 (calculated value), 656.25 (measured value).

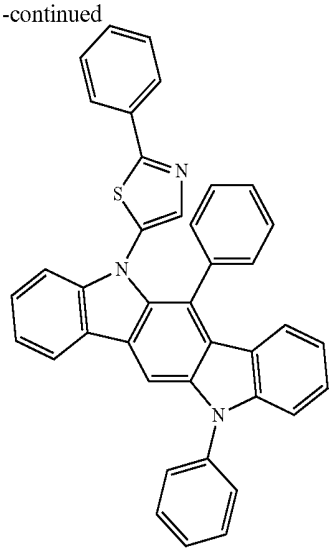
Synthesis Example 7

Synthesis of Compound 159

[0255]



-continued



159

Synthesis of Intermediate I-7

[0256] 178.6 mg (0.20 mmol) of $Pd_2(dba)_3$ and 78.9 mg (0.39 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) of 6-phenyl-5,11-dihydroindolo[3,2-b]carbazole (Intermediate I-6), 2.60 g (16.55 mmol) of bromobenzene, and 867 mg (9.03 mmol) of t-BuONa were added thereto, the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.14 g (yield: 84%) of Intermediate I-7 (5,12-diphenyl-5,11-dihydroindolo[3,2-b]carbazol).

[0257] EI-MS, m/e, 408.16 (calculated value), 408.21 (measured value).

Synthesis of Compound 159

[0258] 112.1 mg (0.12 mmol) of $Pd_2(dba)_3$ and 49.5 mg (0.24 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (12.24 mmol) of Intermediate I-7, 3.23 g (13.46 mmol) of 5-bromo-2-phenylthiazole, and 0.706 mg (7.34 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.25 g (yield: 76%) of Compound 159 (5-(6,11-diphenylindolo[3,2-b]carbazole-5(11H)-yl)-2-phenylthiazole).

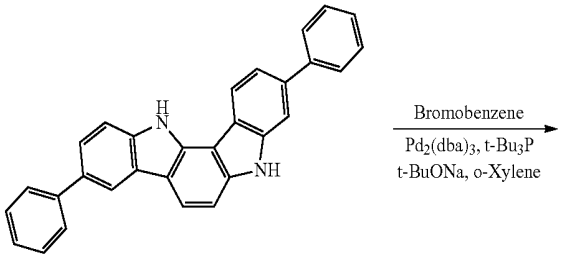
[0259] 1H NMR (300 MHz, CDCl3), d (ppm): 8.08-8.03 (1H, s), 7.95-7.90 (1H, s), 7.82-7.75 (3H, m), 7.14-7.08 (1H, m), 7.64-7.59 (3H, m), 7.69-7.64 (3H, m), 7.58-7.43 (7H, m), 7.33-7.21 (3H, m), 7.42-7.34 (2H, m), 7.21-7.15 (1H, m).

[0260] EI-MS, m/e, 567.18 (calculated value), 567.23 (measured value)

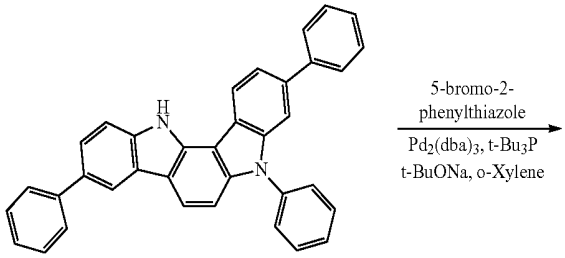
Synthesis Example 8

Synthesis of Compound 70

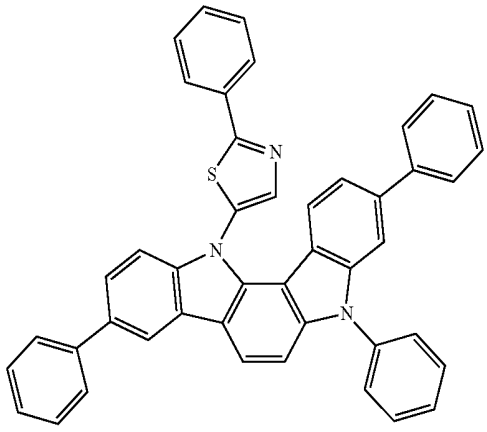
[0261]



I-8



I-9



70

Synthesis of Intermediate I-9

[0262] 112.0 mg (0.12 mmol) of $Pd_2(dba)_3$ and 49.5 mg (0.24 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (12.24 mmol) of 3,9-diphenyl-5,12-dihydroindolo[3,2-a]carbazole (Intermediate I-8), 2.11 g (13.46 mmol) of bromobenzene, and 706 mg (7.34 mmol) of t-BuONa were added thereto, and the resultant solution

was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 2.87 g (yield: 48%) of Intermediate I-9 (3,5,9-triphenyl-5,12-dihydroindolo[3,2-a]carbazol).

[0263] EI-MS, m/e, 484.19 (calculated value), 484.23 (measured value).

Synthesis of Compound 70

[0264] 94.5 mg (0.10 mmol) of $Pd_2(dba)_3$ and 41.7 mg (0.21 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (10.32 mmol) of Intermediate I-9, 2.73 g (11.35 mmol) of 5-bromo-2-phenylthiazole, and 0.595 mg (6.19 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.42 g (yield: 82%) of Compound 70 (2-phenyl-5-(3,5,9-triphenylindolo[3,2-a]carbazole-12(5H)-yl)thiazole).

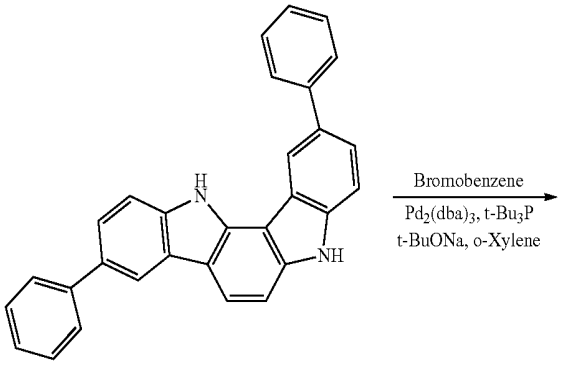
[0265] 1H NMR (300 MHz, CDCl3), d (ppm): 8.28-8.23 (1H, m), 8.16-8.10 (2H, m), 8.04-7.99 (1H, d), 7.97-7.94 (1H, s), 7.93-7.88 (1H, d), 7.74-7.65 (6H, m), 7.65-7.60 (3H, m), 7.56-7.51 (2H, m), 7.51-7.43 (8H, m), 7.42-7.33 (3H, m), 7.33-7.26 (1H, m).

[0266] EI-MS, m/e, 643.21 (calculated value), 643.25 (measured value).

Synthesis Example 9

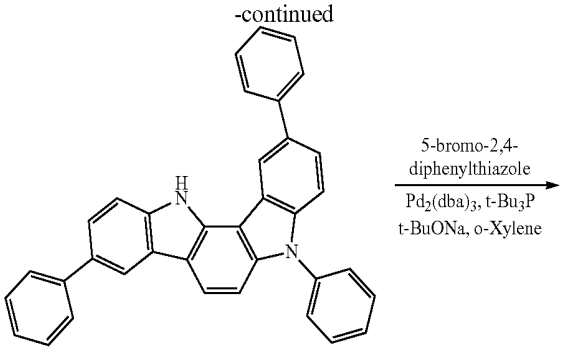
Synthesis of Compound 88

[0267]

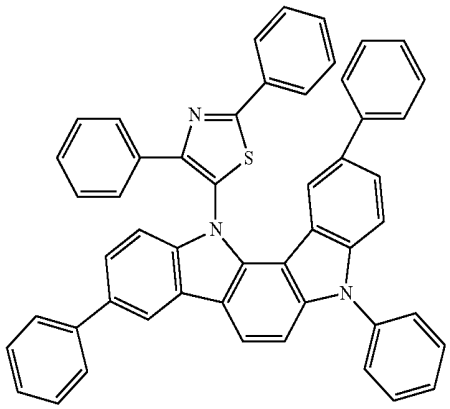


I-10

-continued



I-11



88

Synthesis of Intermediate I-11

[0268] 112.0 mg (0.12 mmol) of $Pd_2(dba)_3$ and 49.5 mg (0.24 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (12.24 mmol) of 2,9-diphenyl-5,12-dihydroindolo[3,2-a]carbazole (Intermediate I-10), 2.11 g (13.46 mmol) of bromobenzene, and 706 mg (7.34 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 3.14 g (yield: 53%) of Intermediate I-11 (2,5,9-triphenyl-5,12-dihydroindolo[3,2-a]carbazol).

[0269] EI-MS, m/e, 484.19 (calculated value), 484.22 (measured value).

Synthesis of Compound 88

[0270] 94.5 mg (0.10 mmol) of $Pd_2(dba)_3$ and 41.7 mg (0.21 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (10.32 mmol) of Intermediate I-11, 3.59 g (11.35 mmol) of 5-bromo-2,4-diphenylthiazole, and 0.595 mg (6.19 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or sub-

stantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.14 g (yield: 69%) of Compound 88 (2,4-diphenyl-5-(2,5,9-triphenylindolo[3,2-a]carbazole-12(5H)-yl)thiazole).

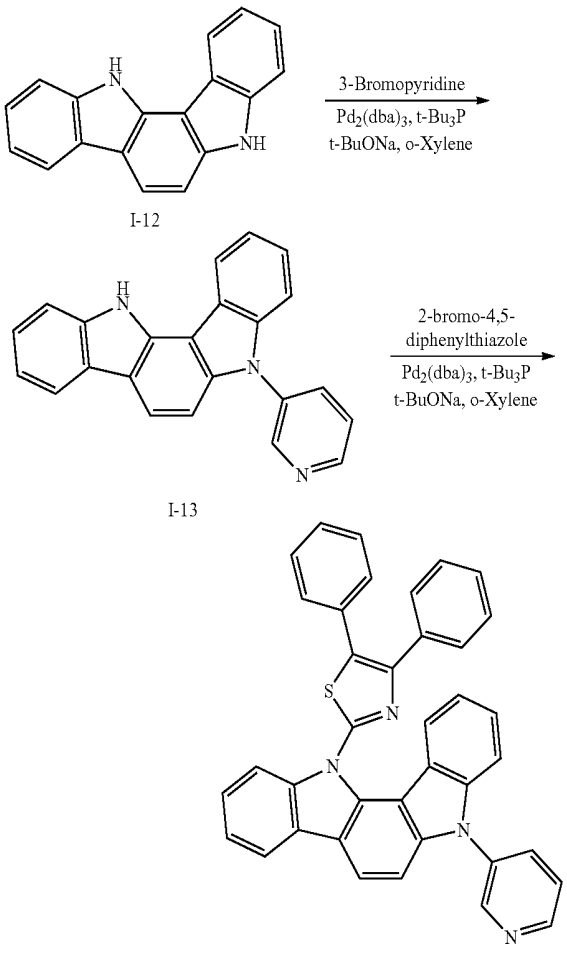
[0271] 1H NMR (300 MHz, CDCl3), d (ppm): 8.74-8.65 (1H, m), 8.27-8.21 (1H, m), 7.94-7.87 (2H, m), 7.87-7.81 (3H, m), 7.78-7.70 (4H, m), 7.69-7.58 (5H, m), 7.56-7.51 (1H, m), 7.51-7.43 (11H, m), 7.42-7.34 (4H, m), 7.33-7.26 (1H, m).

[0272] EI-MS, m/e, 719.24 (calculated value), 719.28 (measured value)

Synthesis Example 10

Synthesis of Compound 112

[0273]



Synthesis of Intermediate I-13

[0274] 178.6 mg (0.20 mmol) of $Pd_2(dba)_3$ and 78.9 mg (0.39 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (19.51 mmol) of 5,12-dihydroindolo[3,2-a]carbazole (Intermediate I-12), 3.39 g (21.46 mmol) of 3-bromopyridine, and 1.12 g (11.71 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing)magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 3.43 g (yield: 53%) of Intermediate I-13 (5-(pyridine-3-yl)-5,12-dihydroindolo[3,2-a]carbazol).

[0275] EI-MS, m/e, 333.13 (calculated value), 333.14 (measured value).

Synthesis of Compound 112

[0276] 137.3 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.7 mg (0.30 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.00 mmol) of Intermediate I-13, 5.22 g (16.50 mmol) of 2-bromo-4,5-diphenylthiazole, and 0.864 mg (9.00 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 6.23 g (yield: 73%) of Compound 112 (4,5-diphenyl-2-(5-(pyridine-3-yl)indolo[3,2-a]carbazole-12 (5H)-yl)thiazole).

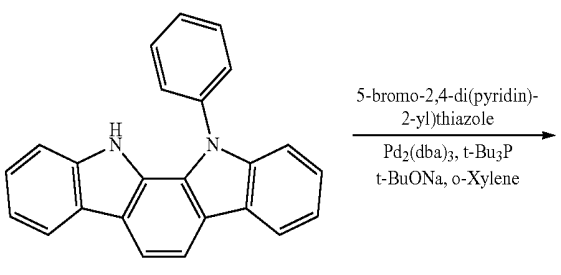
[0277] 1H NMR (300 MHz, CDCl3), d (ppm): 9.15-9.07 (1H, m), 8.59-8.51 (1H, m), 8.02-7.94 (1H, m), 7.92-7.86 (1H, m), 7.86-7.82 (1H, d), 7.82-7.74 (2H, m), 7.71-7.66 (2H, m), 7.66-7.61 (2H, m), 7.61-7.56 (1H, m), 7.51-7.33 (8H, m), 7.31-7.23 (1H, m), 7.22-7.14 (2H, m), 7.13-7.04 (1H, m).

[0278] EI-MS, m/e, 568.17 (calculated value), 568.20 (measured value).

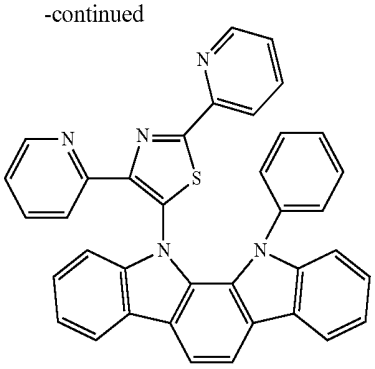
Synthesis Example 11

Synthesis of Compound 133

[0279]



-continued



133

Synthesis of Compound 133

[0280] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of t-Bu_3P dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) Intermediate I-2, 5.26 g (16.54 mmol) of 5-bromo-2,4-di(pyridine-2-yl)thiazole, and 0.867 mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 6.48 g (yield: 76%) of Compound 133 (5-(12-phenylindolo[2,3-a]carbazole-11(12H)-yl)-2,4-di(pyridine-2-yl)thiazole).

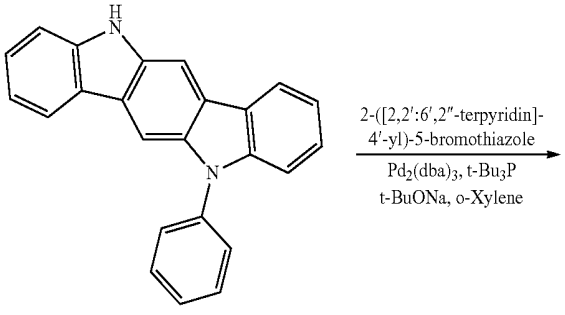
[0281] 1H NMR (300 MHz, CDCl3), d (ppm): 8.78-8.71 (2H, m), 7.97-7.88 (2H, m), 7.86-7.76 (5H, m), 7.75-7.69 (1H, m), 7.69-7.63 (2H, m), 7.59-7.53 (1H, m), 7.52-7.39 (5H, m), 7.30-7.13 (5H, m).

[0282] EI-MS, m/e, 569.17 (calculated value), 569.22 (measured value).

Synthesis Example 12

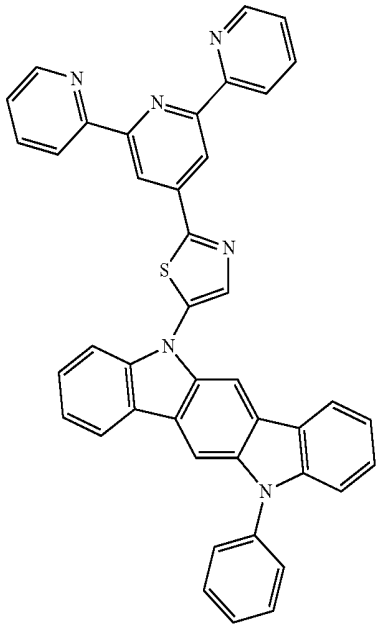
Synthesis of Compound 149

[0283]



I-5

-continued



149

Synthesis of Compound 149

[0284] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of t-Bu_3P were dissolved in 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) of Intermediate I-5, 6.54 g (16.55 mmol) of 2-([2,2':6',2"-terpyridine]-4'-yl)-5-bromothiazole, and 0.867 mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 8.19 g (yield: 84%) of Compound 149 (2-([2,2':6',2"-terpyridine]-4'-yl)-5-(11-phenylindolo[3,2-b]carbazole-5(11H)-yl)thiazole).

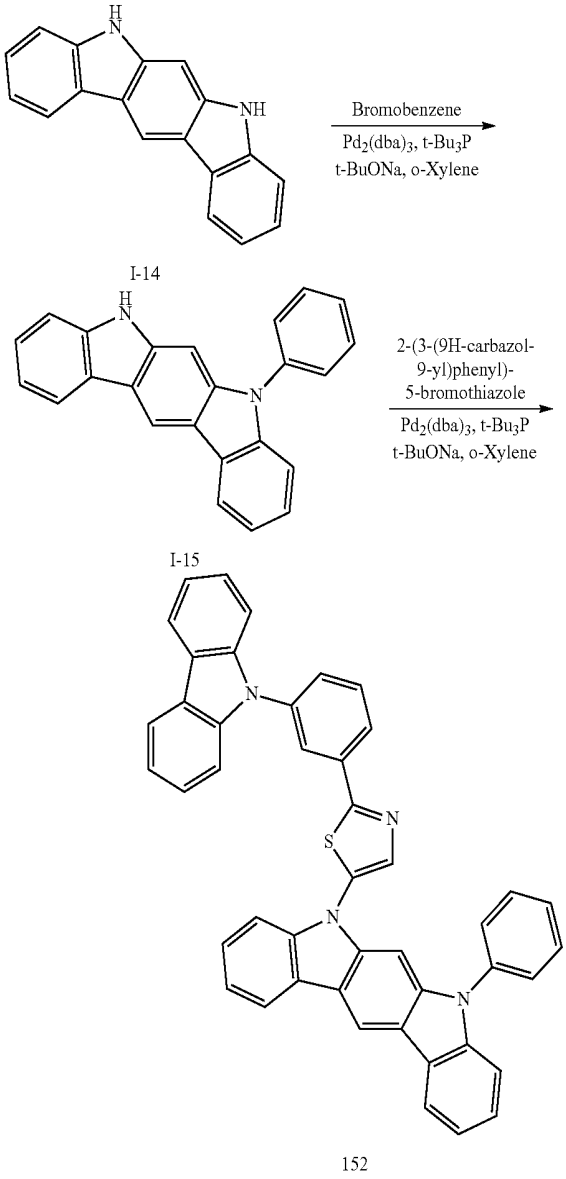
[0285] 1H NMR (300 MHz, CDCl3), d (ppm): 8.74-8.69 (2H, s), 8.67-8.61 (3H, m), 8.47-8.40 (2H, m), 8.08-8.03 (1H, s), 7.91-7.87 (1H, s), 7.86-7.76 (3H, m), 7.74-7.65 (3H, m), 7.65-7.60 (2H, m), 7.50-7.43 (2H, t), 7.33-7.25 (3H, m), 7.24-7.16 (4H, m).

[0286] EI-MS, m/e, 646.19 (calculated value), 646.25 (measured value).

Synthesis Example 13

Synthesis of Compound 152

[0287]



Synthesis of Intermediate I-15

[0288] 178.6 mg (0.20 mmol) of $Pd_2(dba)_3$ and 78.9 mg (0.39 mmol) of t-Bu_3P were dissolved 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (19.51 mmol) of 5,7-dihydroindolo[2,3-b]carbazole (Intermediate I-14), 3.37 g (21.46 mmol) of bromobenzene, and 1.12 g (11.71 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 5.72 g (yield: 88%) of Intermediate I-15 (5-phenyl-5,7-dihydroindolo[2,3-b]carbazol).

[0289] EI-MS, m/e, 332.13 (calculated value), 332.17 (measured value).

Synthesis of Compound 152

[0290] 137.7 mg (0.15 mmol) of $Pd_2(dba)_3$ and 60.8 mg (0.30 mmol) of t-Bu_3P were dissolved 50 mL of o-xylene, and then, the resultant mixture was stirred at room temperature for 10 minutes. Here, 5 g (15.04 mmol) of Intermediate I-15, 6.71 g (16.55 mmol) of 2-(3-(9H-carbazol-9-yl)phenyl)-5-bromothiazole, and 0.867 mg (9.03 mmol) of t-BuONa were added thereto, and the resultant solution was stirred under reflux at a temperature of 160° C. for 48 hours. After completing (or substantially completing) the reaction, 20 mL of cold distilled water was added to the reaction solution, and then an extraction was performed thereon by using (utilizing) ethyl acetate. An organic layer obtained therefrom was dried by using (utilizing) magnesium sulfate, and then, was dried and filtered to remove a solvent therefrom, and the obtained residual was separation-purified by using (utilizing) column chromatography to obtain 8.12 g (yield: 82%) of Compound 152 (2-(3-(9H-carbazol-9-yl)phenyl)-5-(7-phenylindolo[2,3-b]carbazole-5(7H)-yl)thiazole).

[0291] 1H NMR (300 MHz, CDCl3), d (ppm): 8.38-8.32 (1H, s), 8.10-8.05 (1H, m), 7.98-7.94 (1H, s), 7.90-7.83 (3H, m), 7.82-7.75 (3H, m), 7.71-7.65 (4H, m), 7.65-7.58 (4H, m), 7.50-7.43 (2H, t), 7.36-7.13 (9H, m).

[0292] EI-MS, m/e, 656.20 (calculated value), 656.25 (measured value).

[0293] Additional compounds were synthesized according to synthesis pathways and synthesis methods substantially the same as those described above by using (utilizing) appropriate intermediates. The additional synthesized compounds were identified by ^1H NMR and MS/FAB as shown in Table 1.

[0294] Synthesis methods for compounds other than the compounds shown in Table 1 should be apparent to one of ordinary skill in the art by referring to the synthesis methods and source materials of the Synthesis Examples above.

TABLE 1

Compound	^1H NMR ($CDCl_3$, 300 MHz)	MS/FAB measured value	MS/FAB calculated value
2	8.23-8.17 (1H, s), 7.90-7.86 (1H, s), 7.81-7.76 (1H, s), 7.70-7.59 (5H, m), 7.57-7.49 (3H, m), 7.44-7.36 (4H, m), 7.34-7.27 (1H, m), 7.26-7.21 (1H, m), 7.20-7.13 (2H, m), 7.12-7.04 (2H, m).	491.18	491.15

TABLE 1-continued

Compound	^{1}H NMR ($CDCl_3$, 300 MHz)	MS/FAB measured value	MS/FAB calculated value
8	7.91-7.86 (1H, s), 7.81-7.77 (1H, s), 7.70-7.64 (3H, m), 7.63-7.58 (2H, m), 7.57-7.49 (3H, m), 7.44-7.37 (4H, m), 7.33-7.28 (1H, m), 7.26-7.13 (4H, m), 7.13-7.05 (2H, m).	475.22	475.17
17	8.25-8.20 (1H, s), 7.99-7.94 (1H, s), 7.76-7.73 (1H, s), 7.73-7.70 (1H, m), 7.70-7.65 (2H, d), 7.65-7.59 (2H, m), 7.56-7.49 (3H, m), 7.43-7.36 (4H, m), 7.32-7.26 (1H, m), 7.26-7.14 (3H, m), 7.12-7.05 (2H, m).	491.17	491.15
23	7.95-7.91 (1H, s), 7.76-7.72 (1H, s), 7.72-7.68 (1H, m), 7.68-7.58 (4H, m), 7.56-7.50 (3H, m), 7.44-7.36 (4H, m), 7.33-7.27 (1H, m), 7.25-7.14 (4H, m), 7.12-7.06 (2H, m).	475.21	475.17
33	8.06-8.00 (2H, m), 7.85-7.81 (1H, d), 7.75-7.67 (4H, m), 7.65-7.62 (1H, m), 7.62-7.57 (3H, m), 7.56-7.51 (1H, d), 7.49-7.42 (6H, m), 7.41-7.33 (2H, m), 7.32-7.18 (5H, m).	551.25	551.20
39	8.06-7.99 (2H, m), 7.99-7.95 (1H, d), 7.83-7.78 (1H, m), 7.74-7.66 (4H, m), 7.65-7.57 (3H, m), 7.55-7.51 (1H, d), 7.50-7.42 (6H, m), 7.41-7.34 (2H, m), 7.32-7.18 (5H, m).	567.19	567.18
53	8.74-8.67 (1H, m), 8.23-8.16 (1H, s), 7.94-7.86 (2H, m), 7.82-7.77 (1H, s), 7.73-7.60 (6H, m), 7.60-7.54 (1H, m), 7.44-7.38 (2H, t), 7.38-7.27 (2H, m), 7.23-7.14 (2H, m), 7.13-7.04 (2H, m).	492.19	492.14
63	8.74-8.67 (2H, d), 8.10-8.05 (1H, s), 7.93-7.87 (2H, m), 7.72-7.67 (1H, d), 7.66-7.56 (5H, m), 7.53-7.48 (1H, m), 7.43-7.36 (3H, t), 7.34-7.28 (1H, m), 7.23-7.08 (4H, m).	492.19	492.14
123	8.73-8.67 (1H, m), 8.12-8.06 (1H, s), 7.94-7.86 (3H, m), 7.79-7.73 (1H, m), 7.72-7.67 (1H, d), 7.66-7.61 (1H, m), 7.56-7.48 (3H, m), 7.48-7.36 (4H, m), 7.26-7.07 (5H, m).	492.16	492.14
132	8.73-8.66 (1H, m), 7.95-7.88 (1H, m), 7.81-7.70 (4H, m), 7.65-7.59 (3H, m), 7.58-7.52 (1H, d), 7.51-7.41 (4H, m), 7.35-7.28 (1H, m), 7.28-7.21 (3H, m), 7.21-7.14 (1H, m), 7.11-7.04 (1H, m).	476.21	476.16
148	8.28-8.23 (2H, m), 8.21-8.17 (1H, m), 8.03-7.98 (1H, s), 7.86-7.81 (2H, d), 7.78-7.74 (2H, m), 7.72-7.65 (4H, m), 7.63-7.57 (3H, m), 7.50-7.42 (7H, m), 7.41-7.35 (2H, m), 7.32-7.26 (2H, m), 7.26-7.14 (3H, m).	643.22	643.21

EXAMPLE

Example 1

[0295] An ITO glass substrate (a product of Corning Co., Ltd) including an ITO layer having a sheet resistance of 15 Ω/cm^2 (thickness of 1,200 Å) was cut to a size of 50 mm×50 mm×0.7 mm, sonicated by using (utilizing) isopropyl alcohol and pure water each for 5 minutes, and cleaned by exposure to ultraviolet rays for 30 minutes and then ozone. Then, the ITO glass substrate was mounted on a vacuum deposition apparatus.

[0296] 2-TNATA was deposited on the ITO anode to form a HIL having a thickness of 600 Å, NPB was deposited on the HIL to form a HTL having a thickness of 300 Å, and then, Compound 1 (host) and $Ir(piq)_2(acac)$ (dopant) were co-deposited at a weight ratio of 87:13 on the HTL to form an emission layer having a thickness of 300 Å.

[0297] Thereafter, Alq_3 was deposited on the emission layer to form an ETL having a thickness of 300 Å, LiF was deposited on the ETL to form an EIL having a thickness of 10 Å, and Al was deposited on the ETL to form a cathode having a thickness of 3,000 Å, thereby completing the manufacture of an OLED.

Example 2

[0298] An OLED was manufactured as in Example 1, except that in forming the emission layer, Compound 7 was used instead of Compound 1.

Example 3

[0299] An OLED was manufactured as in Example 1, except that in forming the emission layer, Compound 88 was used instead of Compound 1.

Example 4

[0300] An OLED was manufactured as in Example 1, except that in forming the emission layer, Compound 112 was used instead of Compound 1.

Example 5

[0301] An OLED was manufactured as in Example 1, except that in forming the emission layer, Compound 29 was used instead of Compound 1, and $Ir(ppy)_3$ was used instead of $Ir(piq)_2(acac)$.

Example 6

[0302] An OLED was manufactured as in Example 5, except that in forming the emission layer, Compound 59 was used instead of Compound 29.

Example 7

[0303] An OLED was manufactured as in Example 5, except that in forming the emission layer, Compound 70 was used instead of Compound 29.

Example 8

[0304] An OLED was manufactured as in Example 5, except that in forming the emission layer, Compound 101 was used instead of Compound 29.

Example 9

[0305] An OLED was manufactured as in Example 1, except that in forming the emission layer, ADN and DPVBi were co-deposited at a weight ratio of 98:2 instead of Compound 1 and $Ir(piq)_2(acac)$ that were co-deposited at a weight ratio of 87:13, and in forming the ETL, Compound 133 was used instead of Alq_3.

Example 10

[0306] An OLED was manufactured as in Example 9, except that in forming the ETL, Compound 149 was used instead of Compound 133.

Example 11

[0307] An OLED was manufactured as in Example 9, except that in forming the ETL, Alq_3 was as used instead of Compound 133, and in forming a HTL, Compound 152 was used instead of NPB.

Example 12

[0308] An OLED was manufactured as in Example 9, except that in forming the HTL, Compound 155 was used instead of Compound 152.

Comparative Example 1

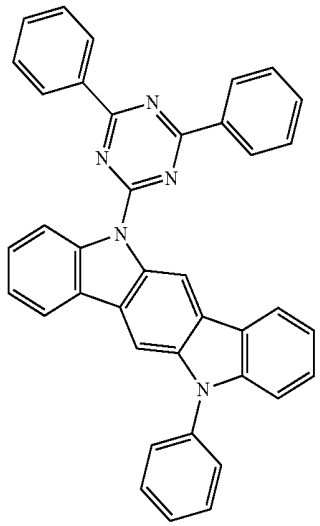
[0309] An OLED was manufactured as in Example 1, except that in forming the emission layer, CBP was used instead of Compound 1.

Comparative Example 2

[0310] An OLED was manufactured as in Example 5, except that in forming the emission layer, Compound 401 was used instead of Compound 59.

Compound 401

401



Comparative Example 3

[0311] An OLED was manufactured as in Example 9, except that in forming the ETL, Alq_3 was used instead of Compound 133.

Comparative Example 4

[0312] An OLED was manufactured as in Example 11, except that in forming the ETL, NPB was used instead of Compound 152.

Evaluation Example

[0313] The driving voltage and emission efficiency of the OLEDs of Examples 1 to 8 and Comparative Examples 1 and 2 were measured by using (utilizing) a Keithley SMU 236 and a brightness photometer PR650 with respect to a brightness of 1,000 cd/m^2, and results thereof are shown in Table 2.

TABLE 2

	Host	Dopant	ETL	HTL	Driving voltage (V)	Emission efficiency (cd/A)	Emission color	Brightness (cd/m^2)
Example 1	Compound 1	$Ir(piq)_2(acac)$	Alq_3	NPB	5.7	16.8	Red	1,000
Example 2	Compound 7	$Ir(piq)_2(acac)$	Alq_3	NPB	6.0	17.5	Red	1,000
Example 3	Compound 88	$Ir(piq)_2(acac)$	Alq_3	NPB	5.9	18.1	Red	1,000
Example 4	Compound 112	$Ir(piq)_2(acac)$	Alq_3	NPB	6.1	17.8	Red	1,000
Example 5	Compound 29	$Ir(ppy)_3$	Alq_3	NPB	5.1	24.3	Green	1,000
Example 6	Compound 59	$Ir(ppy)_3$	Alq_3	NPB	5.2	23.8	Green	1,000

TABLE 2-continued

	Host	Dopant	ETL	HTL	Driving voltage (V)	Emission efficiency (cd/A)	Emission color	Brightness (cd/m^2)
Example 7	Compound 70	$Ir(ppy)_3$	Alq_3	NPB	5.4	25.4	Green	1,000
Example 8	Compound 101	$Ir(ppy)_3$	Alq_3	NPB	5.5	23.7	Green	1,000
Comparative Example 1	CBP	$Ir(piq)_2(acac)$	Alq_3	NPB	7.8	11.1	Red	1,000
Comparative Example 2	Compound 401	$Ir(ppy)_3$	Alq_3	NPB	7.4	19.4	Green	1,000

[0314] The driving voltage, brightness, emission efficiency of the OLEDs of Examples 9 to 12 and Comparative Examples 3 and 4 were measured with respect to a current density of 50 mA/cm^2, and results thereof are shown in Table 3 with the half-lifespan of the same OLEDs. Here, the half-lifespan of the OLEDs was measured as the time taken for the OLEDs to arrive at a brightness that is 50% of the initial value of the brightness of the OLED while being operated at current density of 100 mA/cm^2. The measurements were made using (utilizing) a Keithley SMU 236 and a brightness photometer PR650.

TABLE 3

	Host	Dopant	ETL	HTL	Driving voltage (V)	Brightness (cd/m^2)	Emission efficiency (cd/A)	Current density (mA/cm^2)	Emission color	Half-lifespan (Hr)
Example 9	ADN	DPVBi	Compound 133	NPB	6.5	2472	4.9	50	Blue	265
Example 10	ADN	DPVBi	Compound 149	NPB	6.2	2380	4.7	50	Blue	248
Example 11	ADN	DPVBi	Alq_3	Compound 152	6.4	2375	4.6	50	Blue	268
Example 12	ADN	DPVBi	Alq_3	Compound 155	6.5	2432	4.7	50	Blue	254
Comparative Example 3	ADN	DPVBi	Alq_3	NPB	7.8	1664	3.4	50	Blue	132
Comparative Example 4	ADN	DPVBi	Alq_3	NPB	7.8	1640	3.3	50	Blue	142

[0315] Referring to Table 2 above, it can be seen that the driving voltage and emission efficiency of the OLEDs of Examples 1 to 8 are improved relative to those of Comparative Examples 1 and 2. Referring to Table 3, it can be seen that the driving voltage, current density, brightness, emission efficiency and half-lifespan of the OLEDs of Examples 9 to 12 are improved relative to the driving voltage, current density, brightness, emission efficiency, and half-lifespan of the OLEDs of Comparative Examples 3 and 4.

[0316] As described above, according to aspects of one or more embodiments of the present disclosure, an organic light-emitting device including a condensed cyclic compound may have a low driving voltage, high efficiency, high brightness, and long lifespan

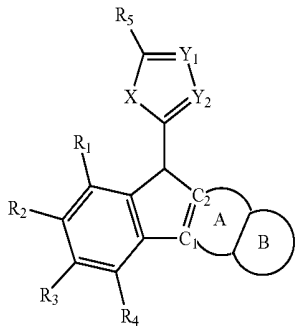
[0317] It should be understood that the embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

[0318] While one or more embodiments of the present disclosure have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims, and equivalents thereof.

What is claimed is:

1. A condensed cyclic compound for an organic light-emitting device represented by Formula 1:

Formula 1



wherein in Formula 1,

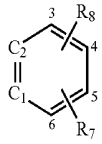
X is an oxygen atom (O) or a sulfur (S) atom;

Y_1 and Y_2 are each independently a nitrogen (N) atom or —CR_6;

C_1 and C_2 are each a carbon (C) atom;

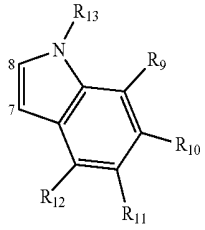
ring A is a benzene ring represented by Formula 1A, wherein 3 to 6 in Formula 1A are reference numbers and two of the reference numbers 3 to 6 correspond to respective carbon atoms included in ring B;

Formula 1A



the ring B is an indole ring represented by Formula 1B, wherein 7 and 8 in Formula 1B are reference numbers, each of which corresponds to a carbon atom included the ring A;

Formula 1B



R_1 to R_{13} are each independently selected from a hydrogen atom, a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{10} alkyl group, a substituted or unsubstituted C_2-C_{10} alkenyl group, a substituted or unsubstituted C_2-C_{10} alkynyl group, a substituted or unsubstituted C_1-C_{10} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{30} aryl group, a substituted or unsubstituted C_2-C_{30} heteroaryl group, a substituted or unsubstituted C_6-C_{30} aryloxy group, a substituted or unsubstituted C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, and —$B(Q_4)(Q_5)$,

at least one substituent of the C_1-C_{10} substituted alkyl group, the substituted C_2-C_{10} alkenyl group, the substituted C_2-C_{10} alkynyl group, the substituted C_1-C_{10} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_3-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} heterocycloalkenyl group, the substituted C_6-C_{30} aryl group, the substituted C_2-C_{30} heteroaryl group, the substituted C_6-C_{30} aryloxy group, and the substituted C_6-C_{30} arylthio group is selected from:

a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group;

a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, and a C_1-C_{30} alkoxy group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$;

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, and a monovalent C_2-C_{30} non-aromatic condensed polycyclic group;

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, and a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, a C_6-C_{30} aryloxy group, a C_6-C_{30} arylthio group, a monovalent C_6-C_{30} non-aromatic condensed polycyclic group, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

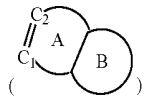
$Si(Q_{31})(Q_{32})(Q_{33})$ and —$B(Q_{34})(Q_{35})$, and

Q_1 to Q_5, Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{35} are each independently selected from a hydrogen atom, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_2-C_{30} heteroaryl group, and a monovalent C_6-C_{30} non-aromatic condensed polycyclic group.

2. The condensed cyclic compound of claim **1**, wherein the ring B comprises the carbon atoms corresponding to the reference numbers 3 and 4 of the ring A, the carbon atoms corresponding to the reference numbers 4 and 5 of the ring A,

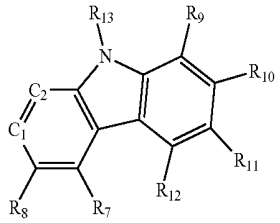
or the carbon atoms corresponding to the reference numbers 5 and 6 of the ring A.

3. The condensed cyclic compound of claim **1**, wherein the rings A and B

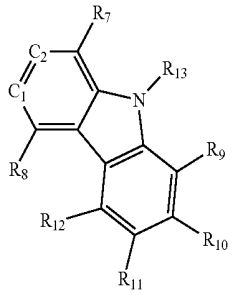


comprise a group represented by any one of Formulae 2A to 2F:

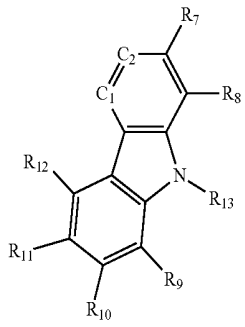
<Formula 2A>



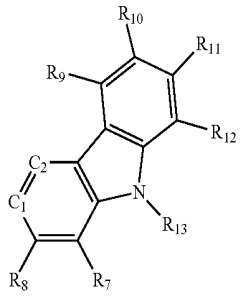
<Formula 2B>



<Formula 2C>

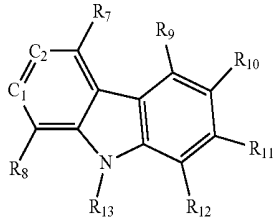


<Formula 2D>

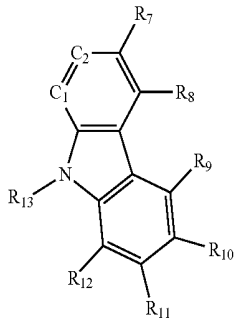


-continued

<Formula 2E>



<Formula 2F>



wherein in Formulae 2A to 2F,

R_7 to R_{13} are each independently selected from a hydrogen atom, a substituted or unsubstituted C_6-C_{30} aryl group, and a substituted or unsubstituted C_2-C_{30} heteroaryl group,

at least one substituent of the substituted C_6-C_{30} aryl group and the substituted C_2-C_{30} heteroaryl group is selected from a C_6-C_{30} aryl group and a C_2-C_{30} heteroaryl group, and

R_{13} is not a hydrogen atom.

4. The condensed cyclic compound of claim **1**, wherein

R_1 to R_{13} are each independently selected from:

a hydrogen atom, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a biphenyl group, a heptalenyl group, a phenalenyl group, a fluorenyl group, a phenanthrenyl group, an anthryl function, a fluoranthenyl group, a pyrenyl group, a benzofluorenyl group, a naphthacenyl group, a chrysenyl group, a triphenylenyl group, a terphenyl group, a perylenyl group, a picenyl group, a hexacenyl group, a spiro-fluorenyl group, a pyrrolyl group, a furyl group, a pyrazolyl group, an imidazolyl group, an oxazolyl group, an isoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a pyridyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a pyranyl group, a thiophenyl group, a thiazolyl group, an isothiazolyl group, a thiopyranyl group, an indolyl group, an isoindolyl group, an indolizinyl group, a benzofuryl group, an isobenzofuryl group, an indazolyl group, a benzimidazolyl group, a benzoxazolyl group, a benzisoxazolyl group, an imidazopyridyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a phthalazinyl group, a quinazolinyl group, a quinoxalinyl group, a naphthyridinyl group, a cinnolinyl group, a benzothiophenyl group, a benzothiazolyl group, a carbazolyl group, a benzocarbazolyl group, a pyridoindolyl group, a dibenzofuryl group, a phenanthridinyl group, a

benzoquinolyl group, a phenazinyl group, a dibenzosilolyl group, a dibenzothiophenyl group, and a benzocarbazolyl group;

a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, and a decyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, and an amino group; and

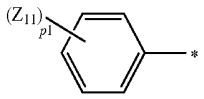
a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a biphenyl group, a heptalenyl group, a phenalenyl group, a fluorenyl group, a phenanthrenyl group, an anthryl function, a fluoranthenyl group, a pyrenyl group, a benzofluorenyl group, a naphthacenyl group, a chrysenyl group, a triphenylenyl group, a terphenyl group, a perylenyl group, an picenyl group, a hexacenyl group, a spiro-fluorenyl group, a pyrrolyl group, a furyl group, a pyrazolyl group, an imidazolyl group, an oxazolyl group, an isoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a pyridyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, pyranyl group, a thiophenyl group, a thiazolyl group, an isothiazolyl group, a thiopyranyl group, an indolyl group, an isoindolyl group, an indolizinyl group, a benzofuryl group, an isobenzofuryl group, an indazolyl group, a benzimidazolyl group, a benzoxazolyl group, a benzisoxazolyl group, an imidazopyridyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a phthalazinyl group, a quinazolinyl group, a quinoxalinyl group, a naphthyridinyl group, a cinnolinyl group, a benzothiophenyl group, a benzothiazolyl group, a carbazolyl group, a benzocarbazolyl group, a pyridoindolyl group, a dibenzofuryl group, a phenanthridinyl group, a benzoquinolyl group, a phenazinyl group, a dibenzosilolyl group, a dibenzothiophenyl group, and a benzocarbazolyl group, each substituted with at least one selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, a C_1-C_{10} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, C_3-C_{10} heterocycloalkenyl group, a C_6-C_{30} aryl group, a C_4-C_{30} heteroaryl group, a C_5-C_{30} aryloxy group, a C_5-C_{30} arylthio group, and —$Si(Q_{31})(Q_{32})(Q_{33})$ (wherein, Q_{31} to Q_{33} are each independently selected from a hydrogen atom, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a C_6-C_{20} aryl group), wherein R_5 and R_{13} are not hydrogen.

5. The condensed cyclic compound of claim **1**, wherein

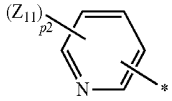
R_1 to R_4 and R_6 to R_{12} are each independently a hydrogen atom or a compound represented by one of Formulae 3A to 3C, and

R_5 and R_{13} are each independently selected from a compound represented by one of Formulae 3A to 3C:

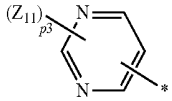
<3A>



<3B>



<3C>



wherein in Formulae 3A to 3C,

Z_{11} is selected from a deuterium atom, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a C_6-C_{30} aryl group, a C_4-C_{30} heteroaryl group, and —$Si(Q_{31})(Q_{32})(Q_{33})$ (wherein Q_{31} to Q_{33} are each independently selected from a hydrogen atom, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a C_6-C_{20} aryl group),

p1 is selected from an integer of 1 to 5,

p2 is selected from an integer of 1 to 4,

p3 is selected from an integer of 1 to 3, and

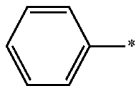
* is a binding site.

6. The condensed cyclic compound of claim **1**, wherein:

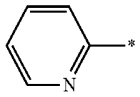
R_1 to R_4 and R_6 to R_{12} are each independently a hydrogen atom or a compound represented by one of Formulae 4A to 4M, and

R_5 and R_{13} are each independently a compound represented by one of Formulae 4A to 4M:

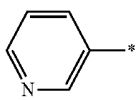
<4A>



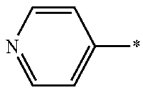
<4B>



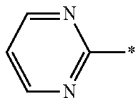
<4C>



<4D>

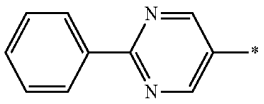


<4E>

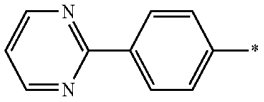


-continued

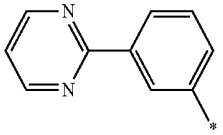
<4F>



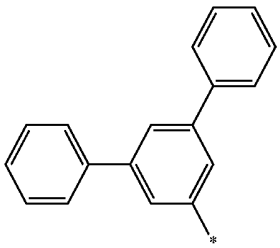
<4G>



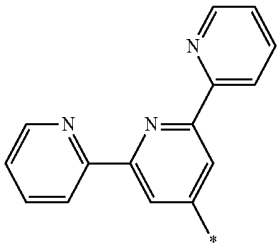
<4H>



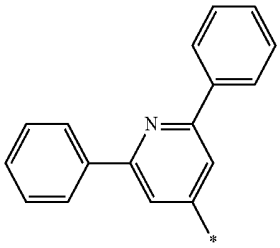
<4I>



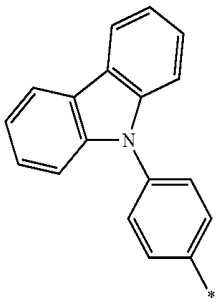
<4J>



<4K>

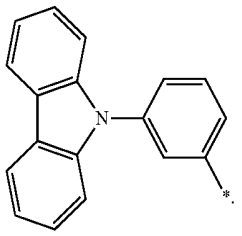


<4L>



-continued

<4M>



7. The condensed cyclic compound of claim **1**, wherein X is a sulfur (S) atom, Y_1 is a nitrogen (N) atom, and Y_2 is —CR_6.

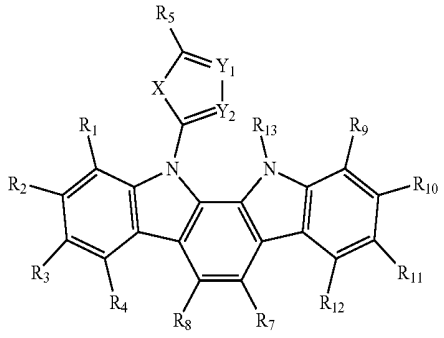
8. The condensed cyclic compound of claim **1**, wherein X is a S atom, Y_1 is —CR_6, and Y_2 is a N atom.

9. The condensed cyclic compound of claim **1**, wherein X is an oxygen (O) atom, Y_1 is a N atom, and Y_2 is —CR_6.

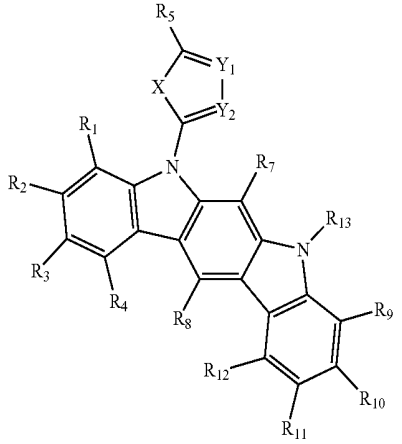
10. The condensed cyclic compound of claim **1**, wherein X is an O atom, Y_1 is CR_6, and Y_2 is a N atom.

11. The condensed cyclic compound of claim **1**, wherein the condensed cyclic compound of Formula 1 is represented by Formulae 1-1 to 1-6:

Formula 1-1

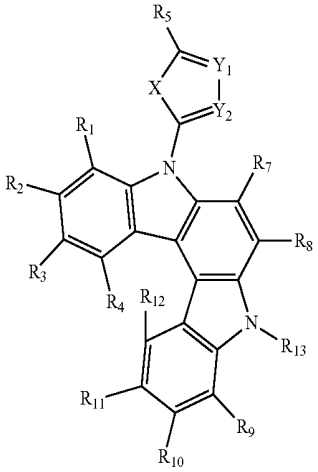


Formula 1-2

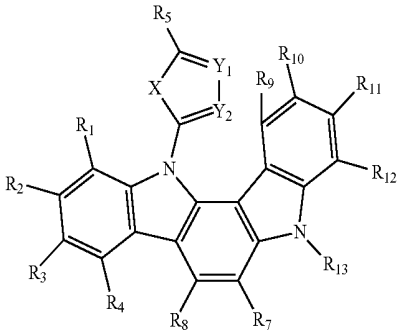


-continued

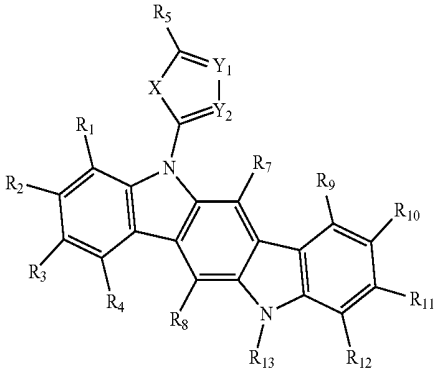
Formula 1-3



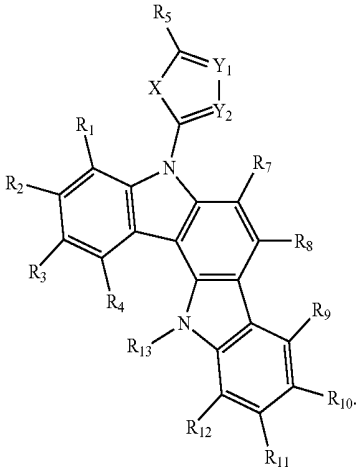
Formula 1-4



Formula 1-5



Formula 1-6



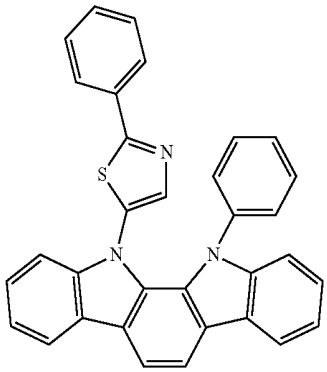
12. The condensed cyclic compound of claim **11**, wherein:

R_1 to R_4 and R_6 to R_{12} are each independently selected from a hydrogen atom, a phenyl group, a pyridyl group, and a pyrimidinyl group; a phenyl group, a pyridyl group, and a pyrimidinyl group, each substituted with at least one selected from a phenyl group, a pyridyl group, a pyrimidinyl group, and a carbazolyl group, and

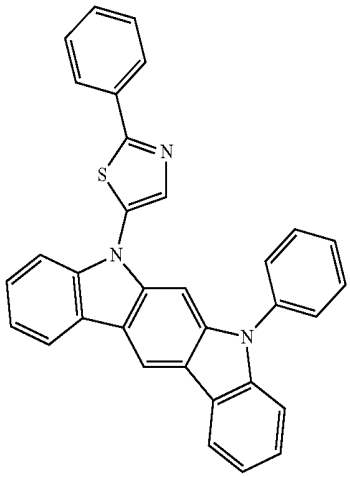
R_5 and R_{13} are each independently selected from a phenyl group, a pyridyl group, and a pyrimidinyl group; a phenyl group, a pyridyl group, and a pyrimidinyl group, each substituted with at least one selected from a phenyl group, a pyridyl group, a pyrimidinyl group, and a carbazolyl group.

13. The condensed cyclic compound of claim **1**, wherein the condensed cyclic compound is any one of Compounds 1 to 159:

1

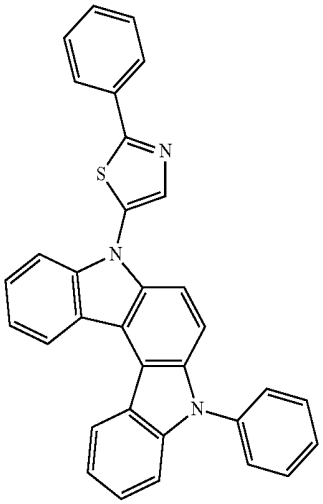


2

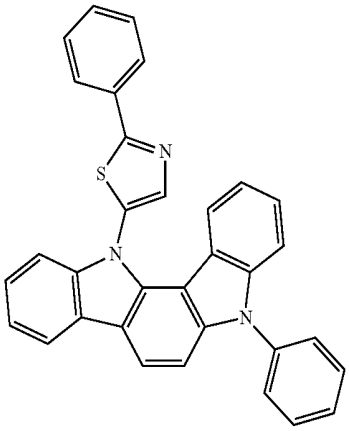


-continued

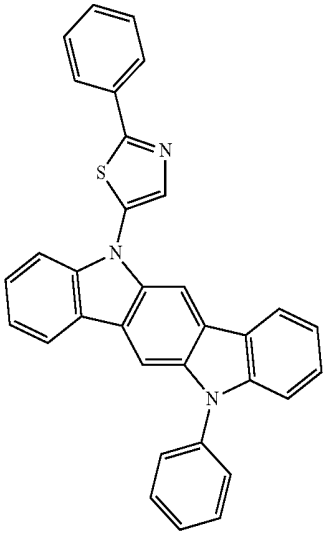
3



4

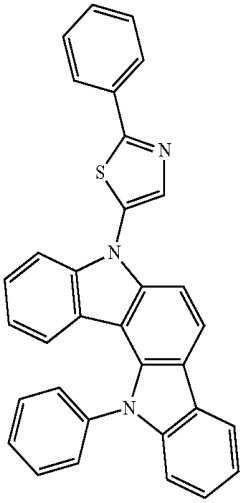


5

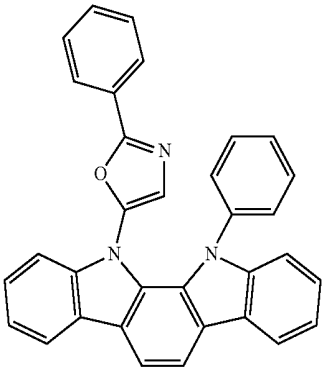


-continued

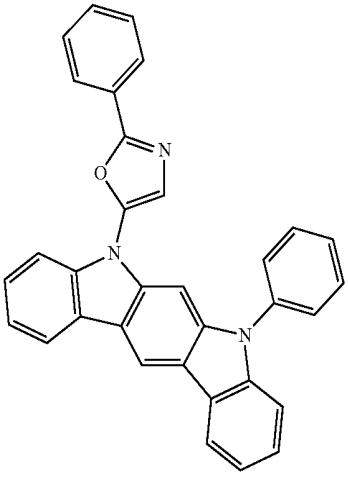
6



7

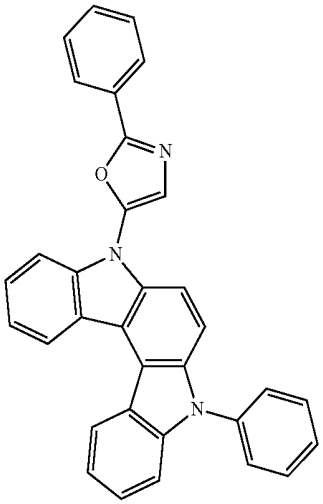


8

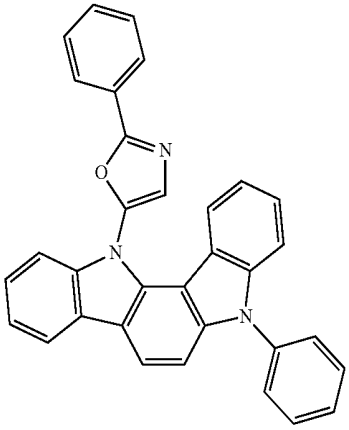


-continued

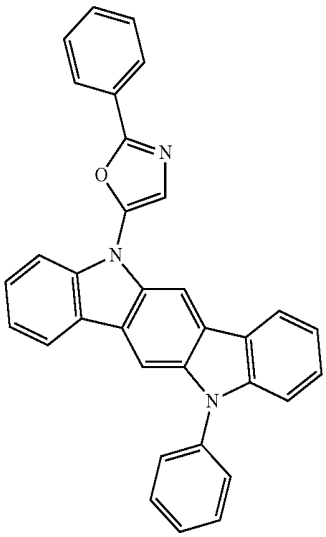
9



10

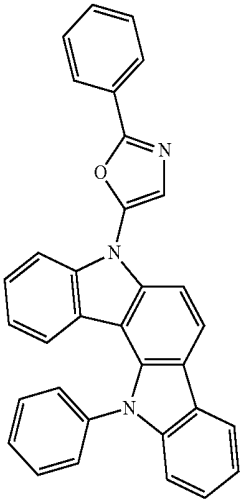


11

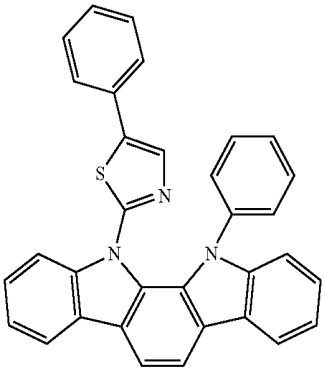


-continued

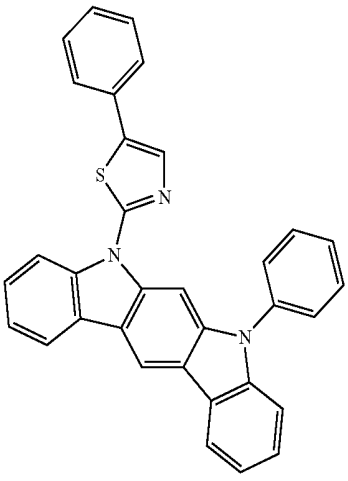
12



13

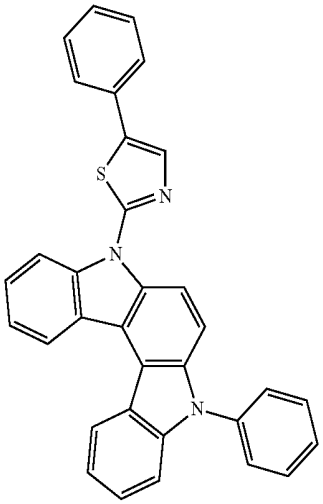


14

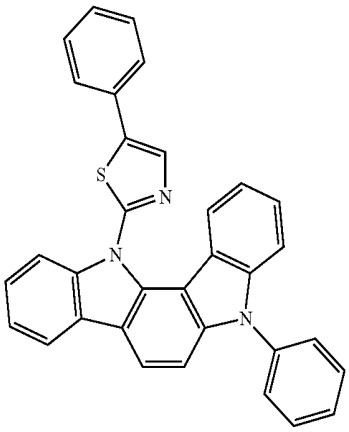


-continued

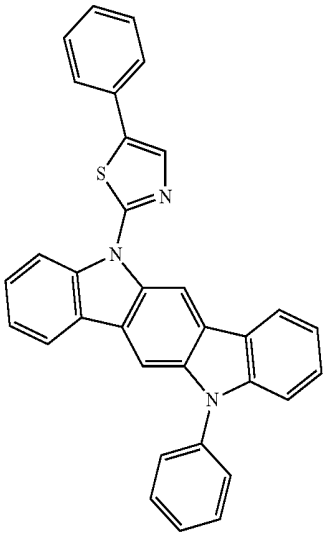
15



16

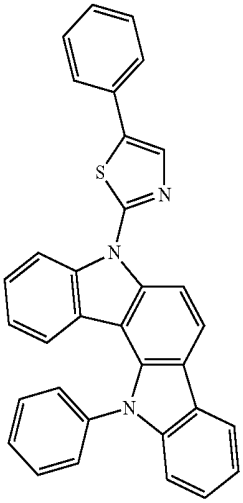


17

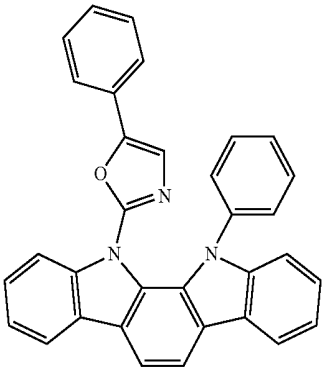


-continued

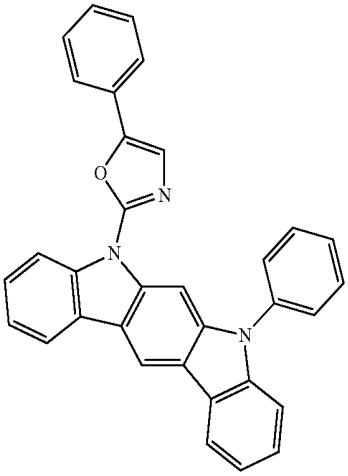
18



19

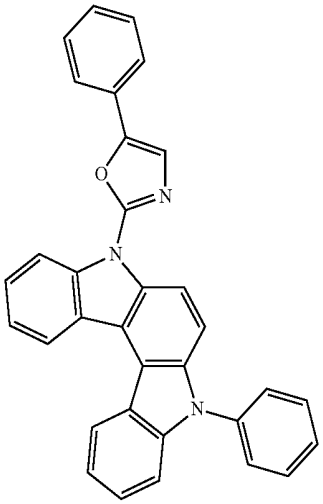


20

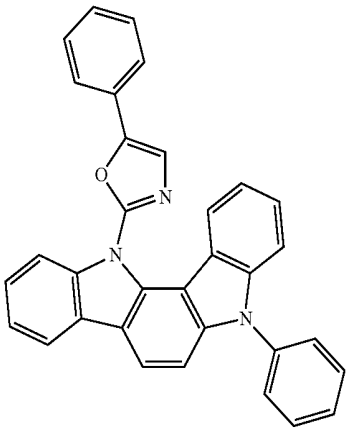


-continued

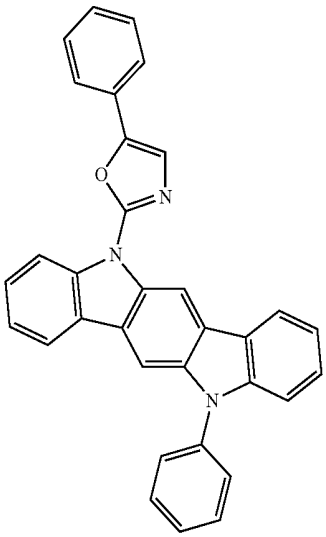
21



22

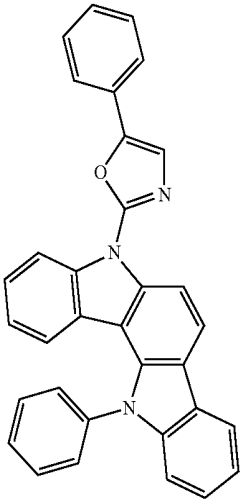


23

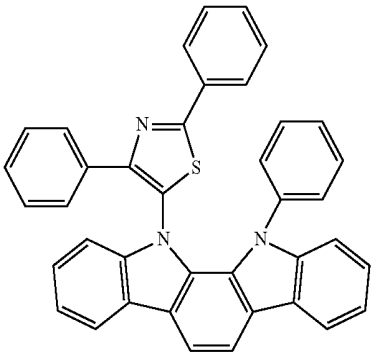


-continued

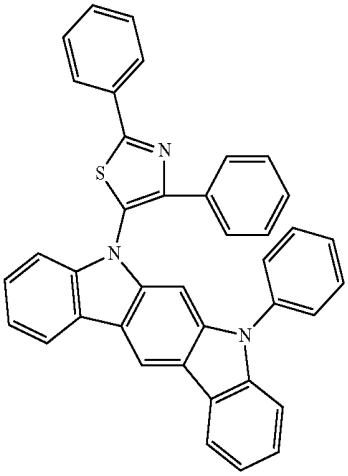
24



25

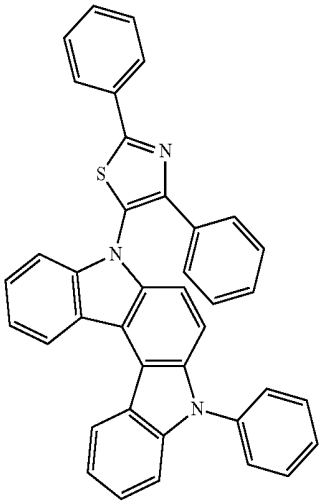


26

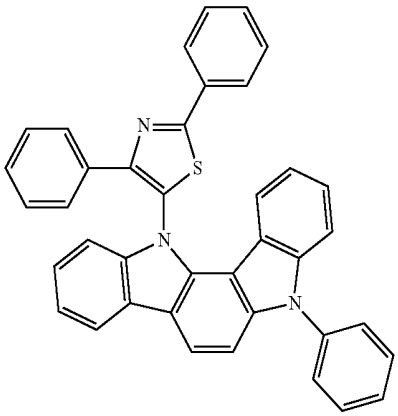


-continued

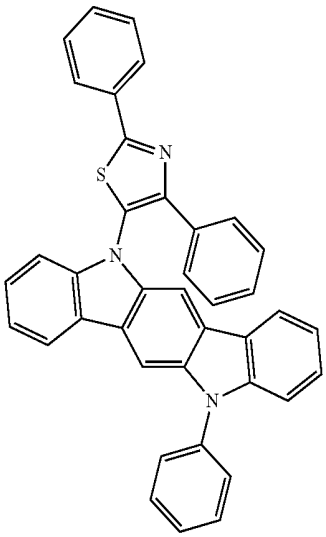
27



28

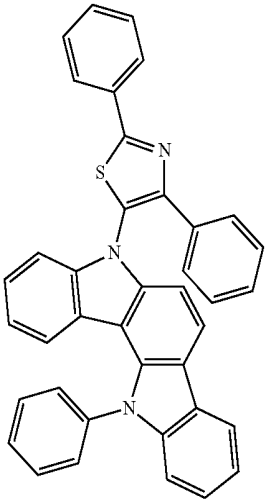


29

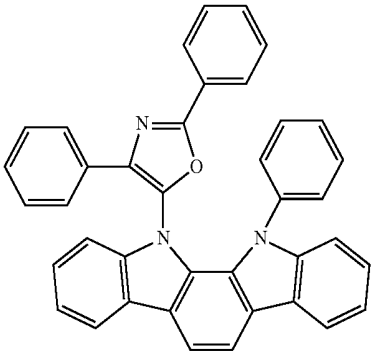


-continued

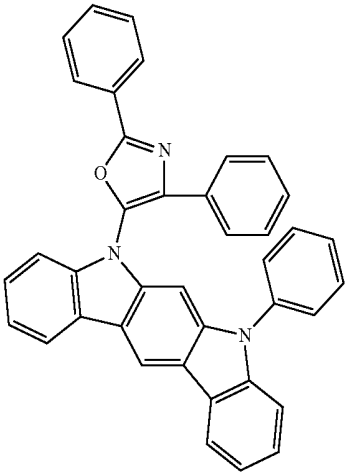
30



31

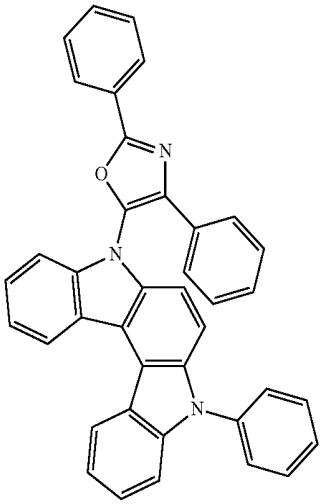


32

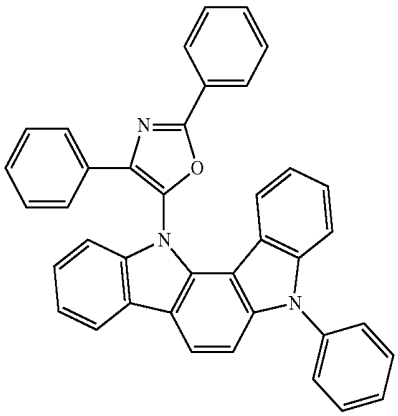


-continued

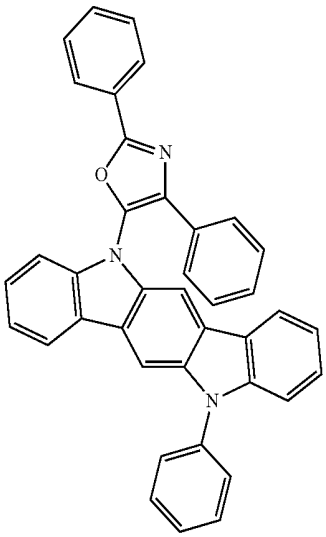
33



34

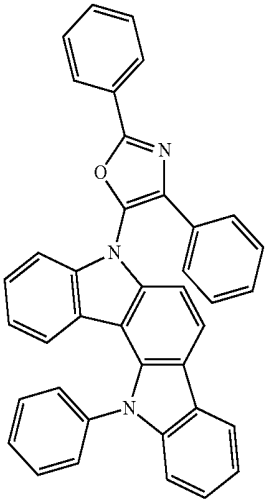


35

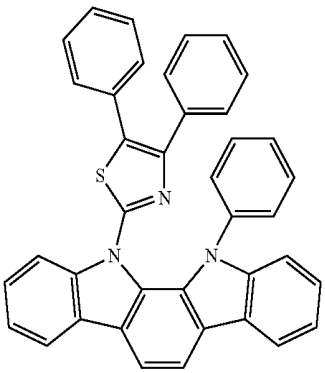


-continued

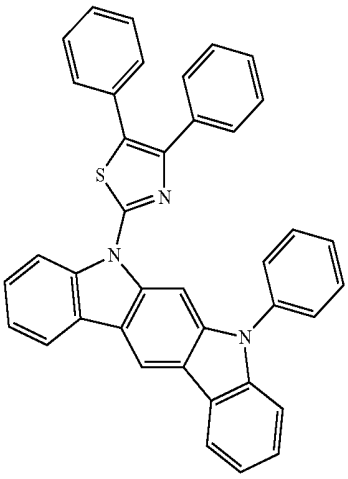
36



37

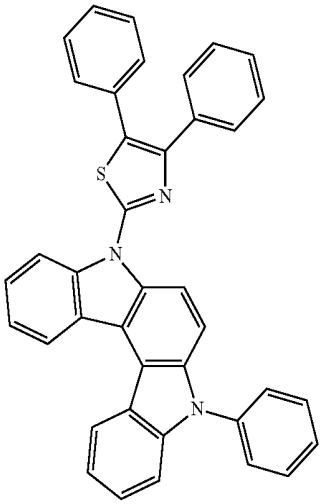


38

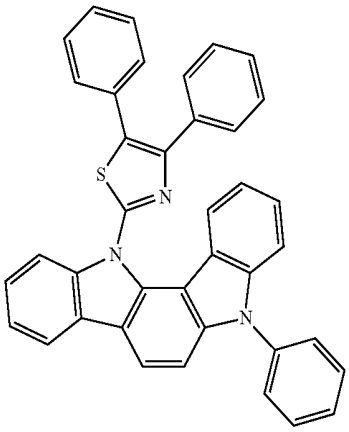


-continued

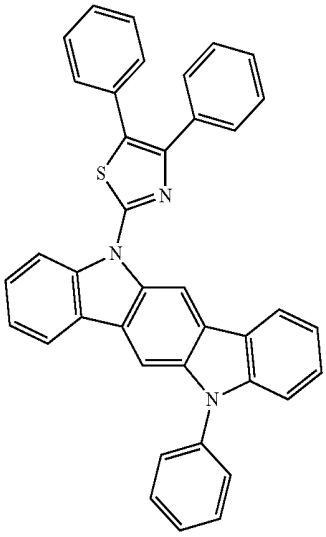
39



40

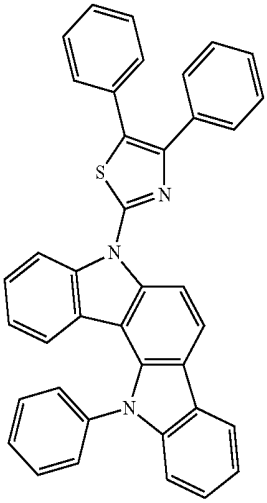


41

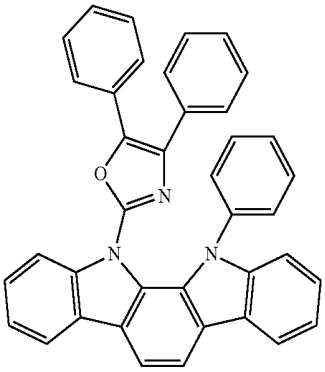


-continued

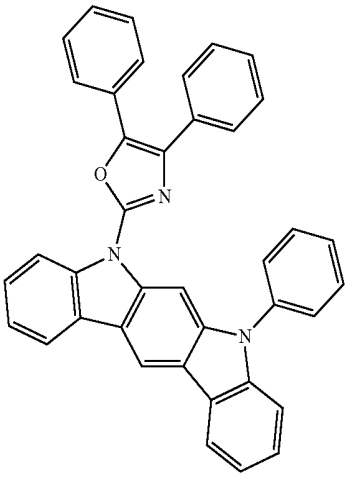
42



43

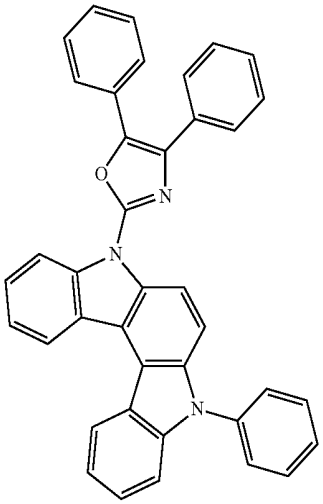


44

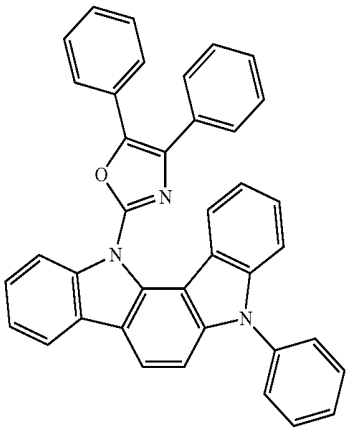


-continued

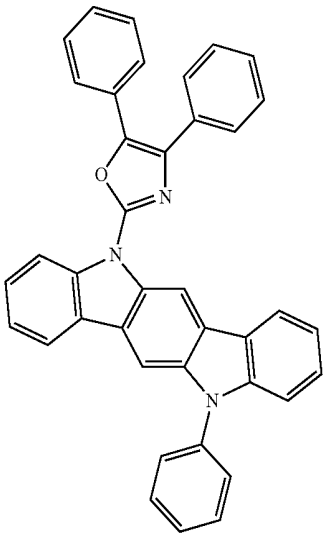
45



46

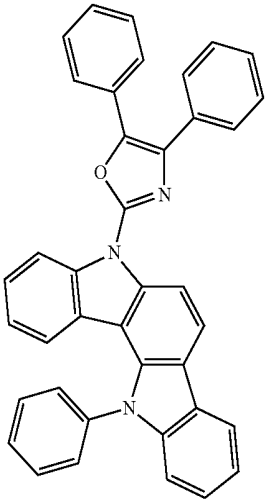


47

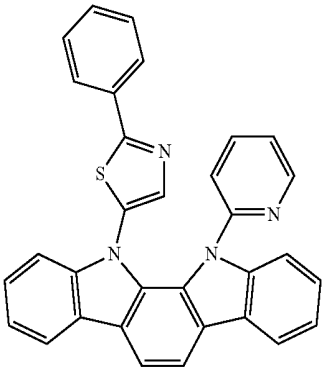


-continued

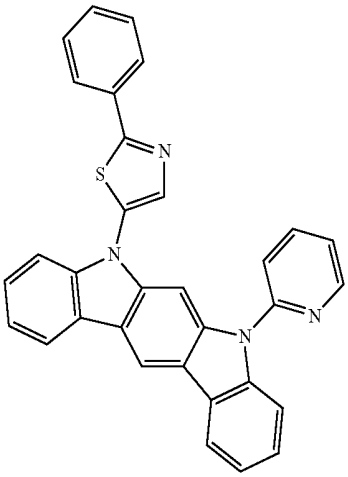
48



49

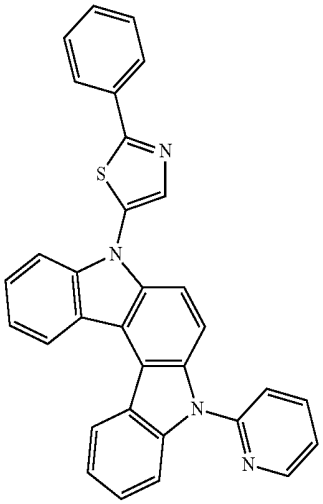


50

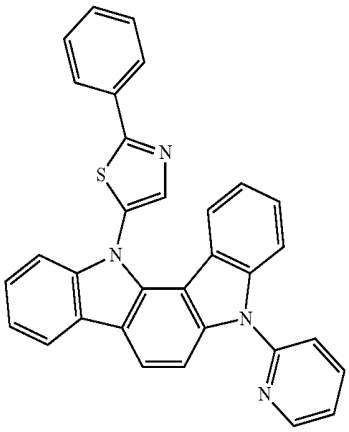


-continued

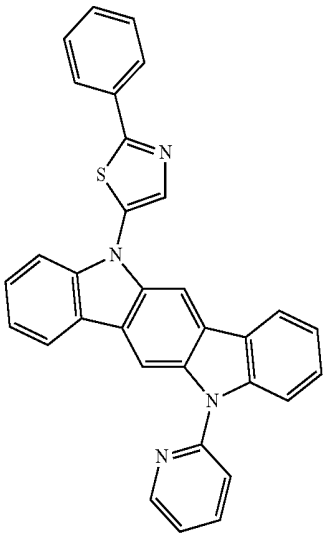
51



52

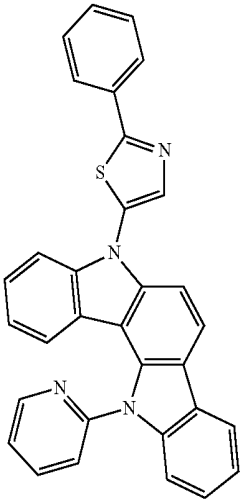


53

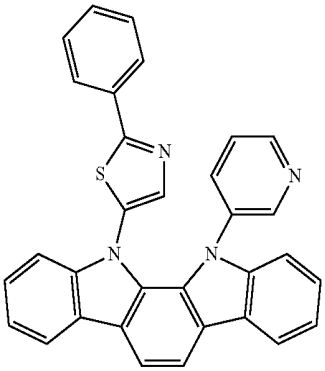


-continued

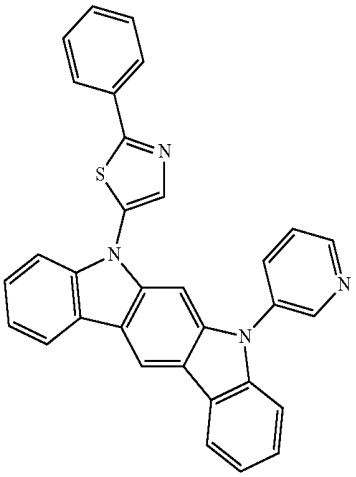
54



55

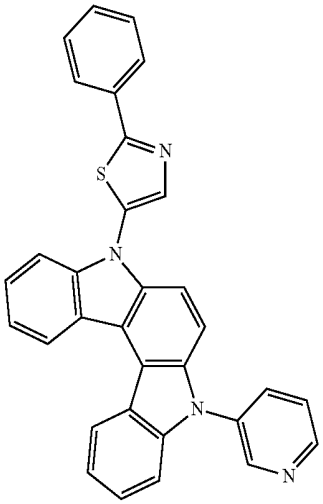


56

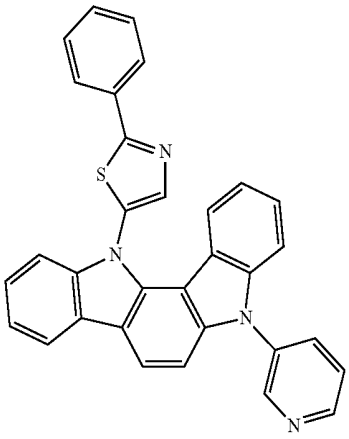


-continued

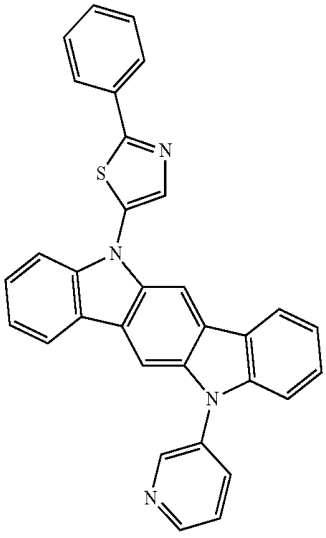
57



58

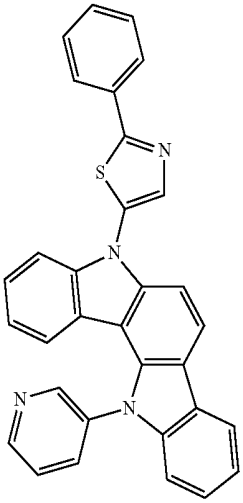


59

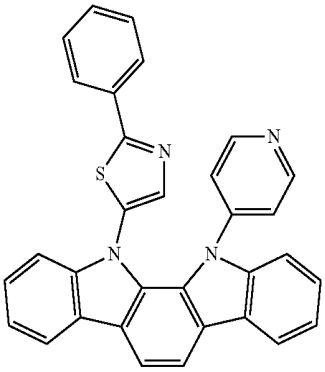


-continued

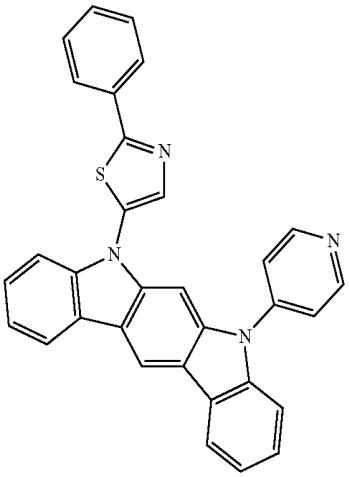
60



61

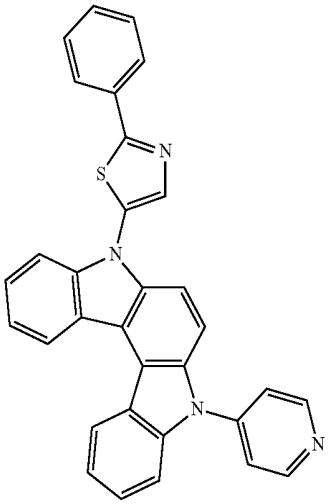


62

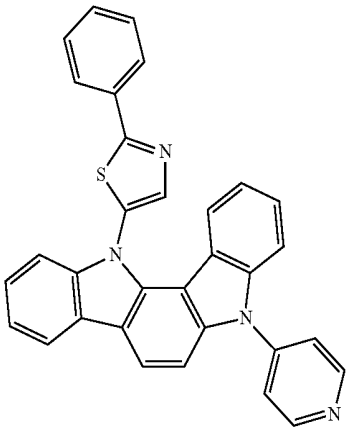


-continued

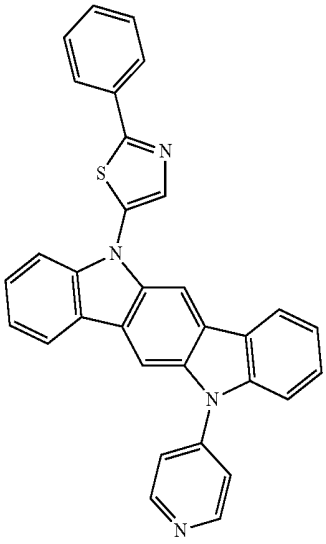
63



64

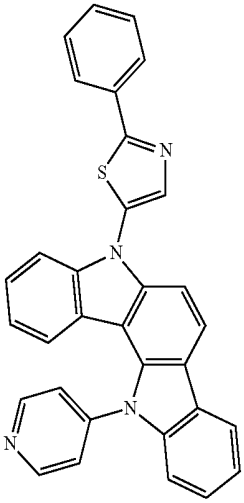


65

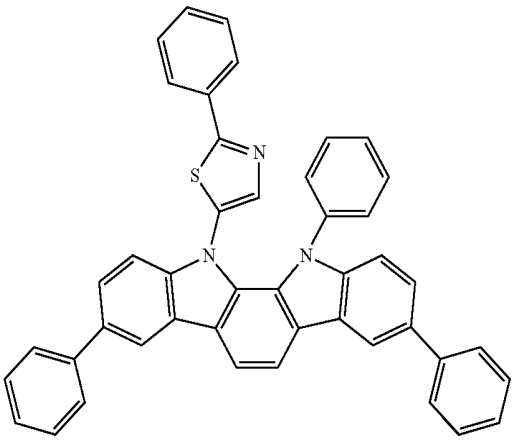


-continued

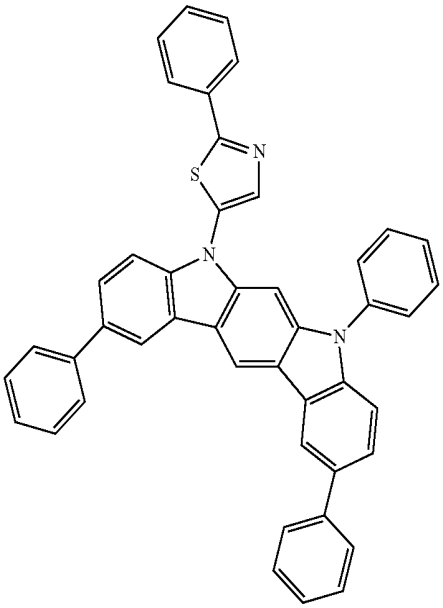
66



67

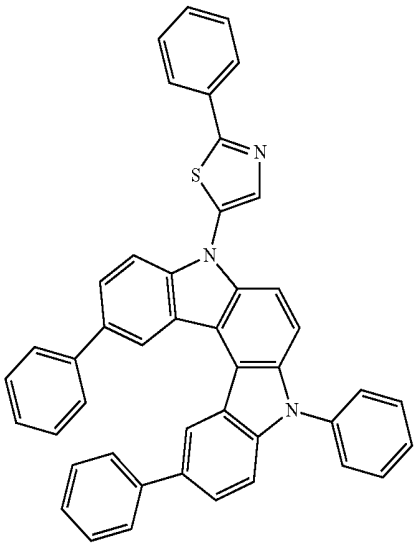


68

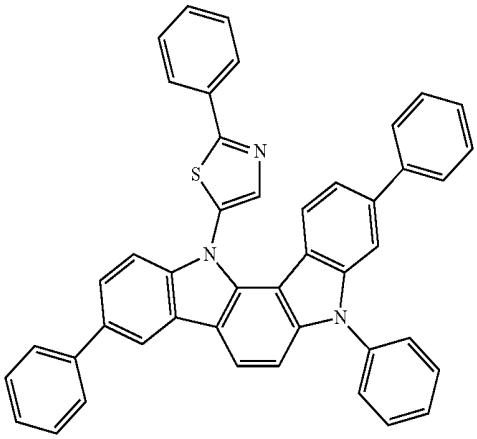


-continued

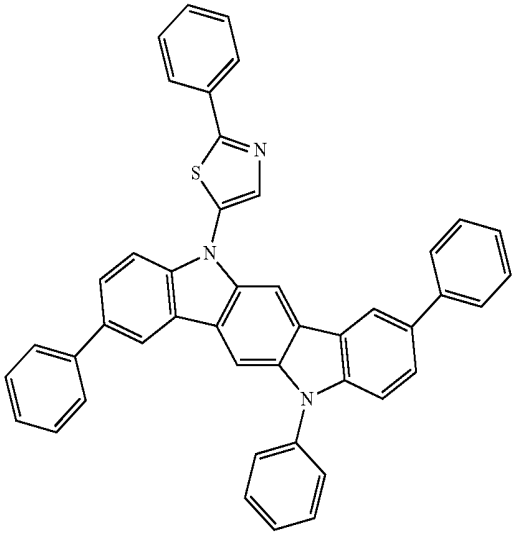
69



70

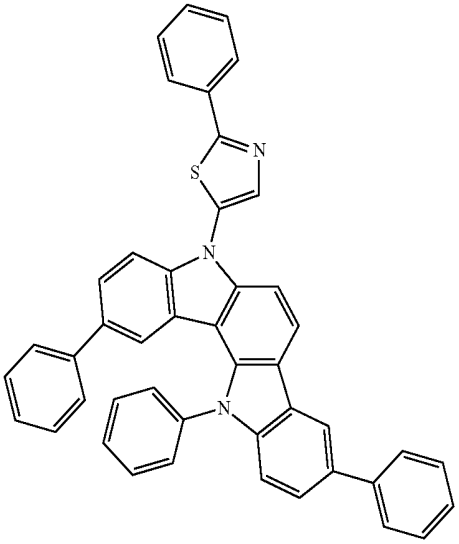


71

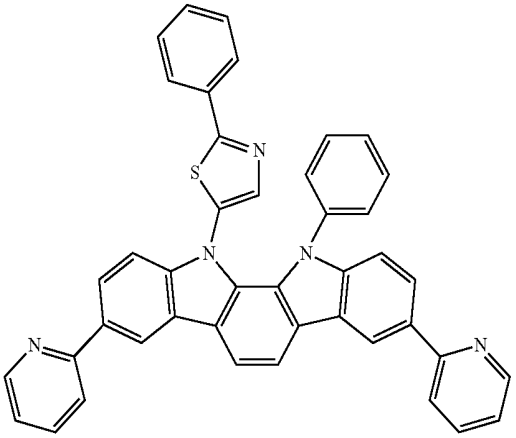


-continued

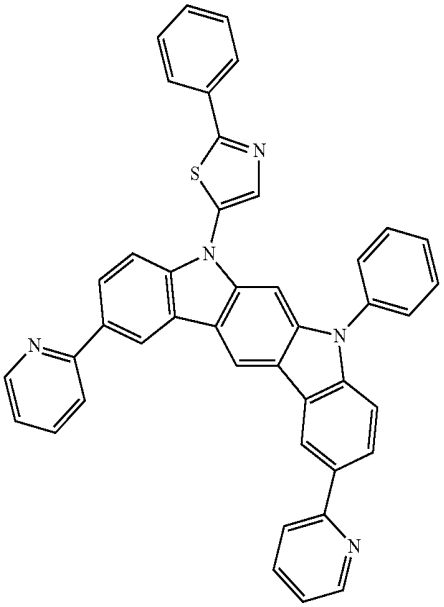
72



73

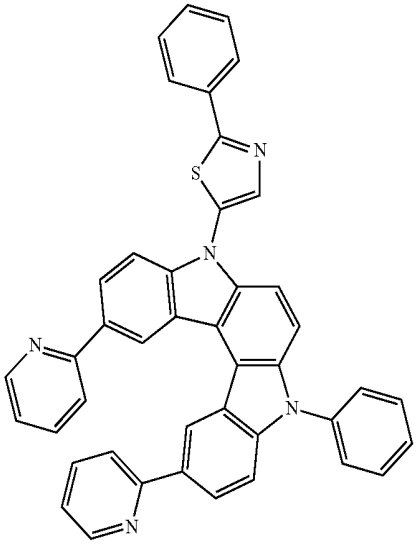


74

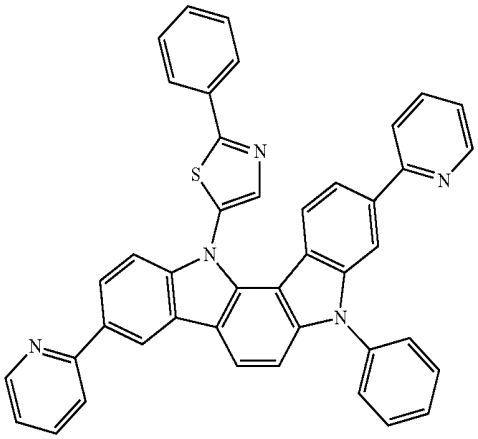


-continued

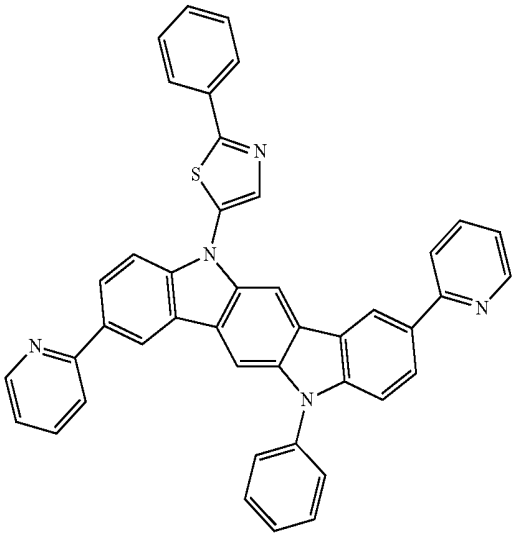
75



76

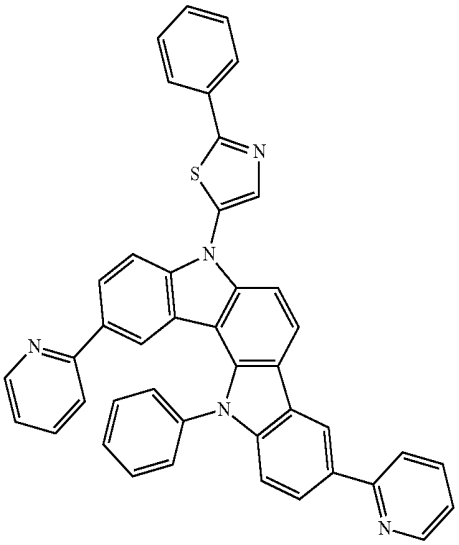


77

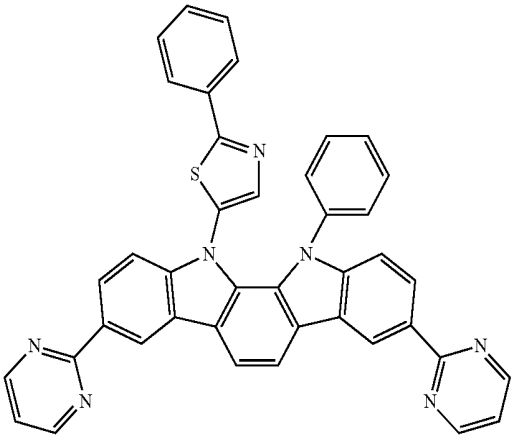


-continued

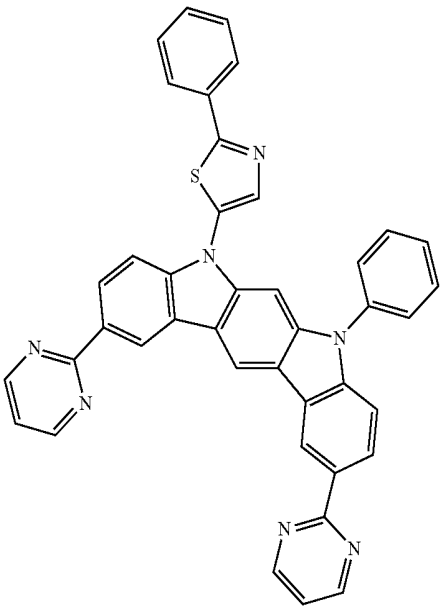
78



79

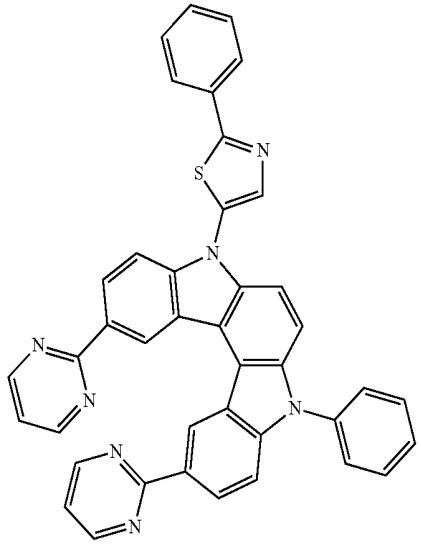


80

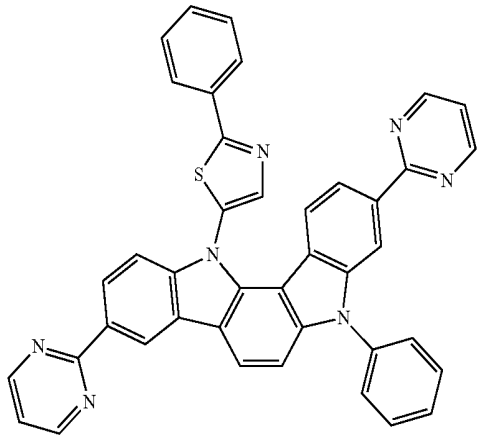


-continued

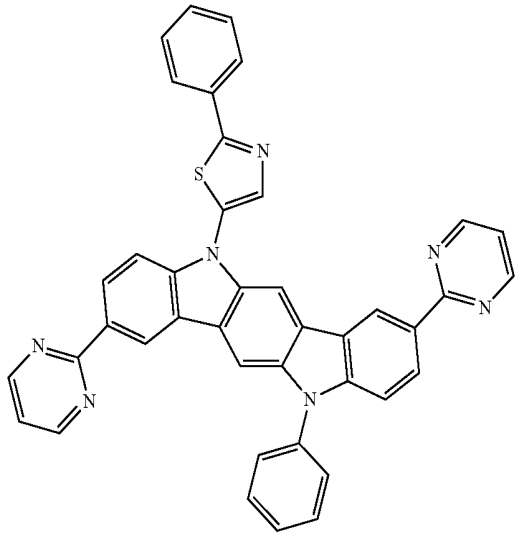
81



82

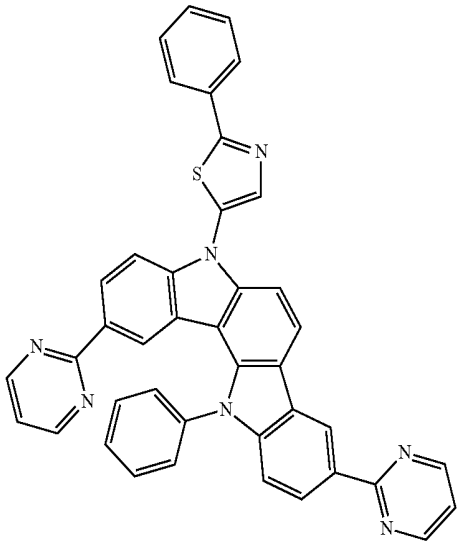


83

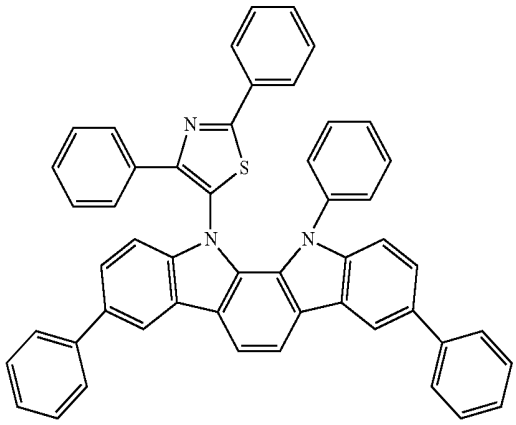


-continued

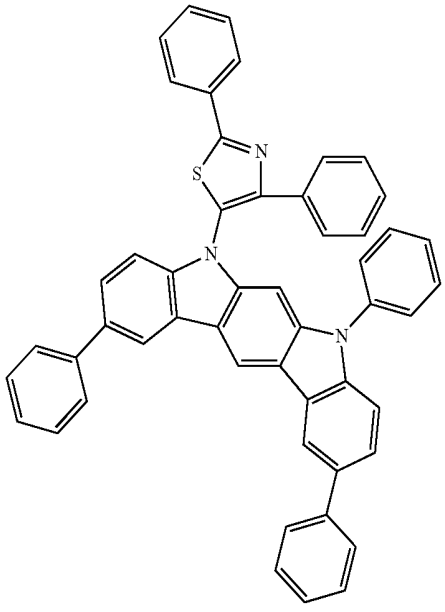
84



85

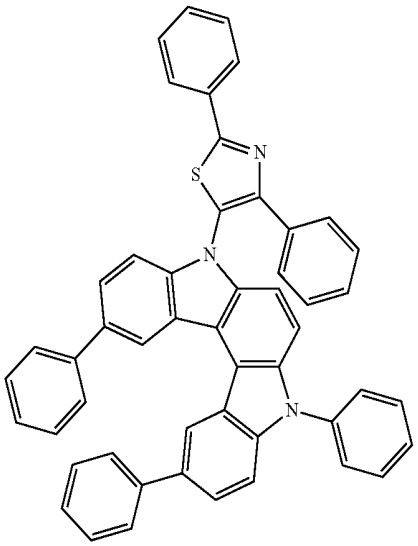


86

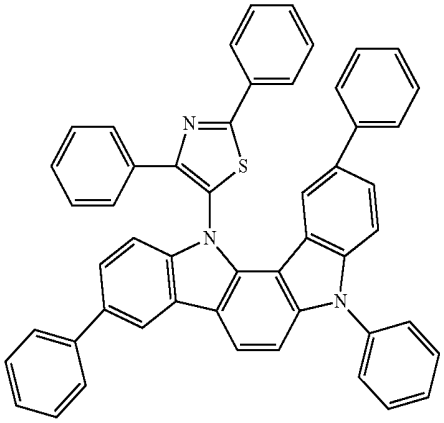


-continued

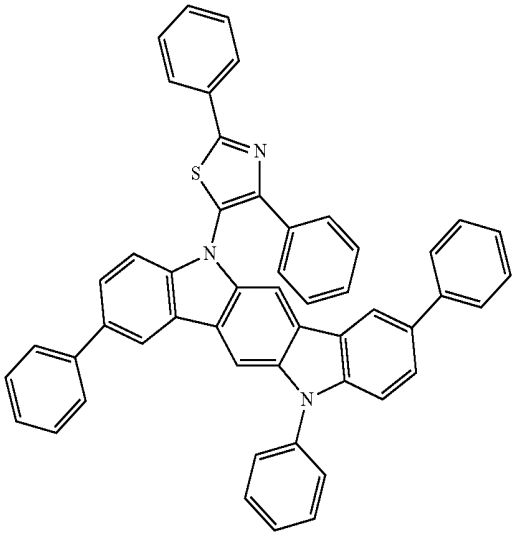
87



88

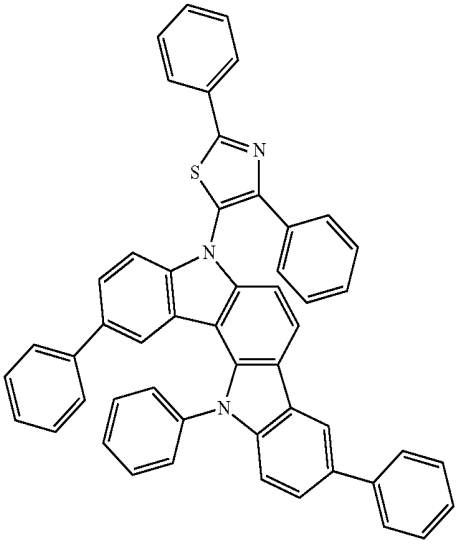


89

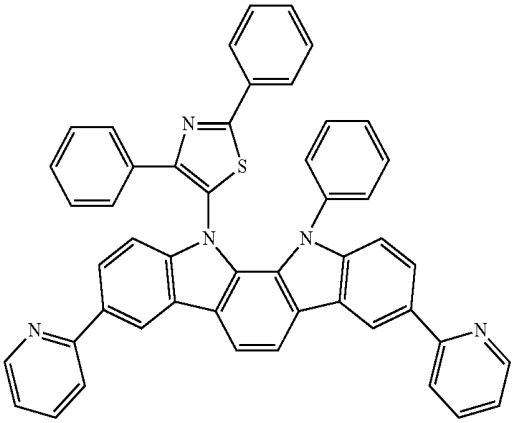


-continued

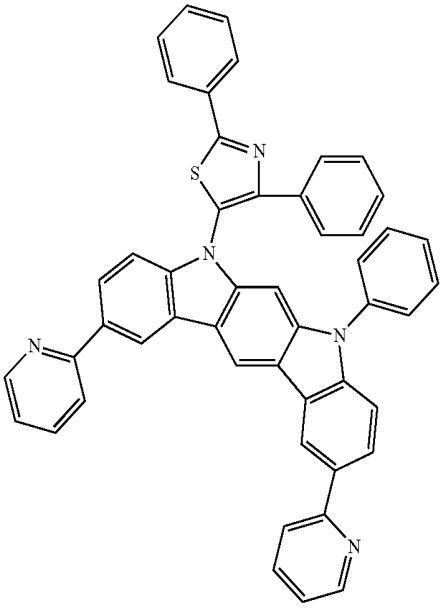
90



91

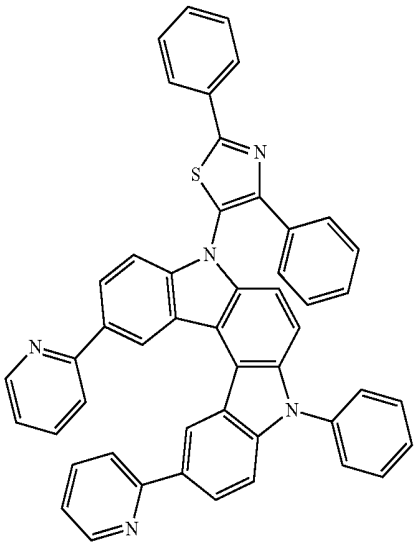


92

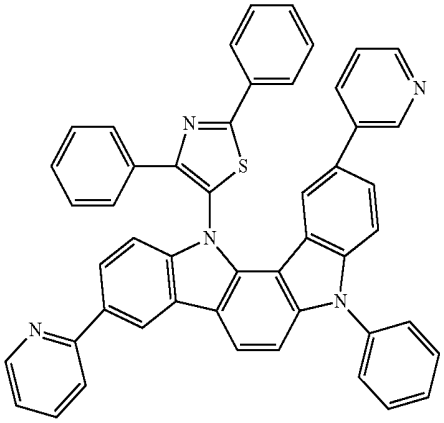


-continued

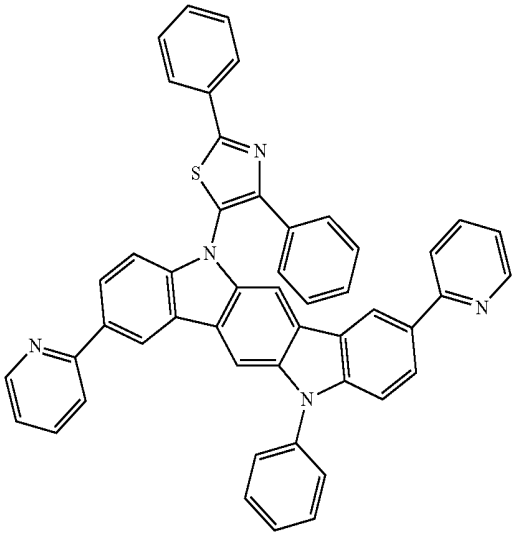
93



94

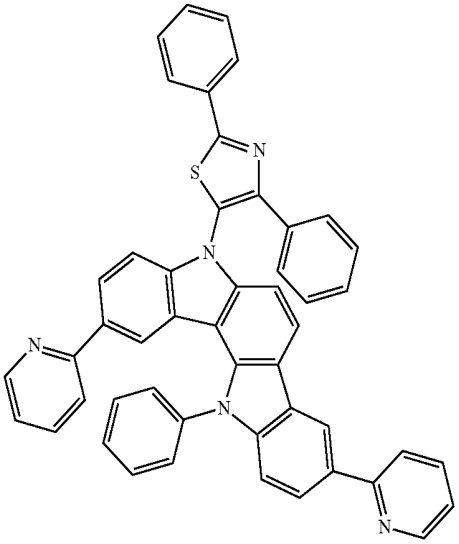


95

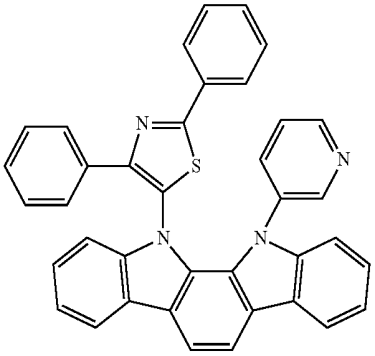


-continued

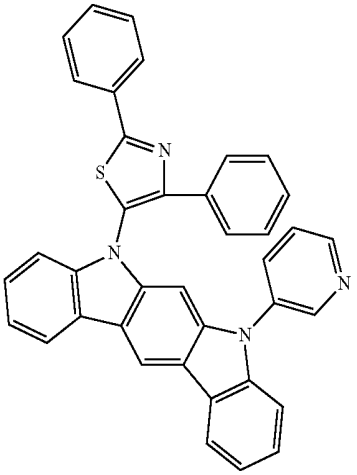
96



97

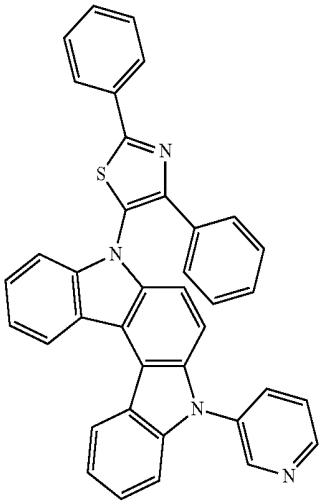


98

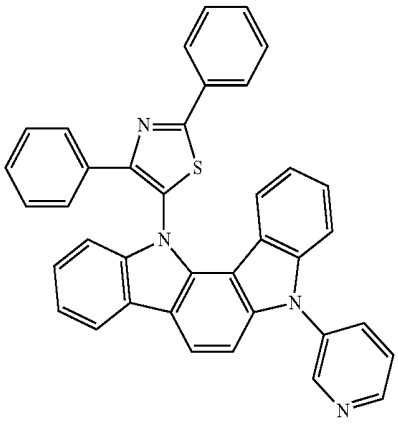


-continued

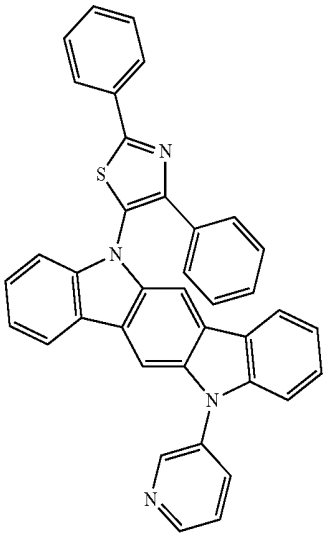
99



100

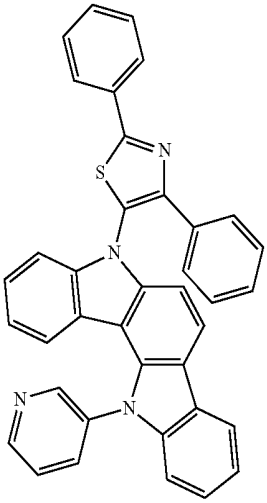


101

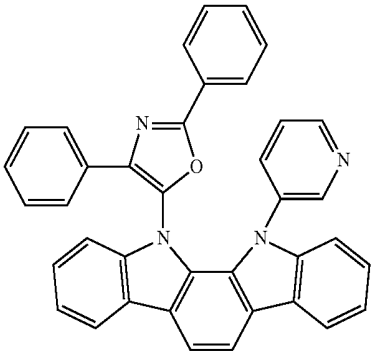


-continued

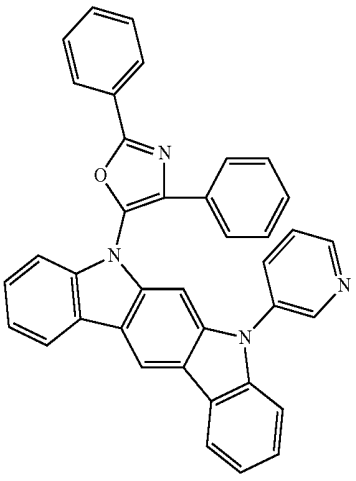
102



103

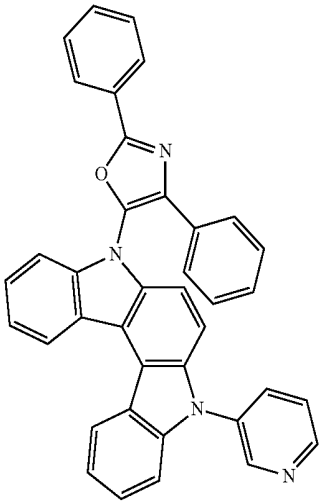


104

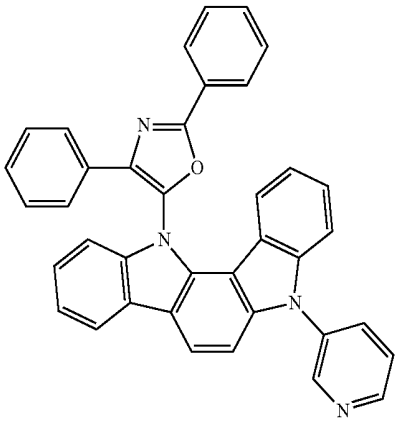


-continued

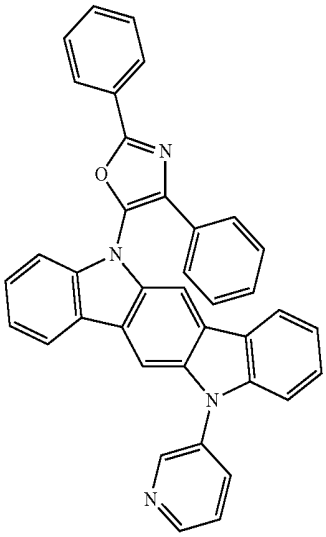
105



106

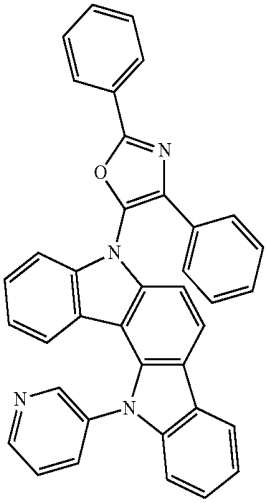


107

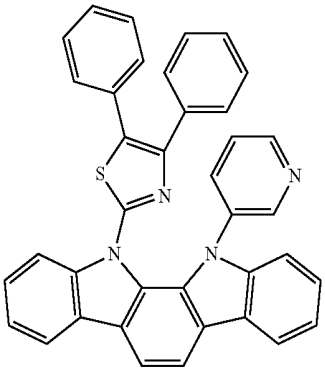


-continued

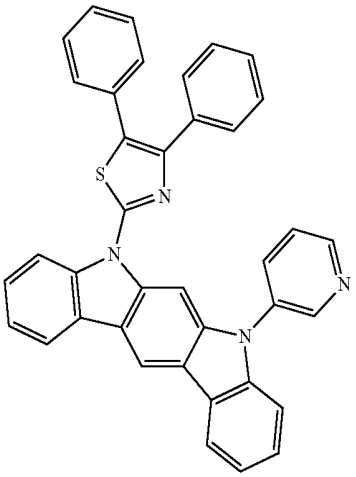
108



109

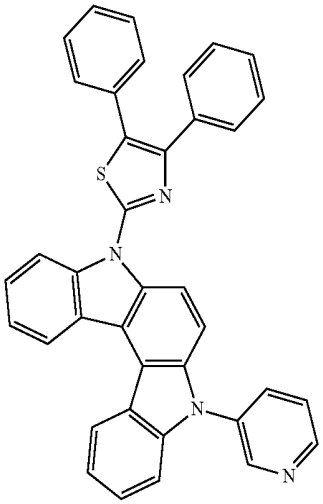


110

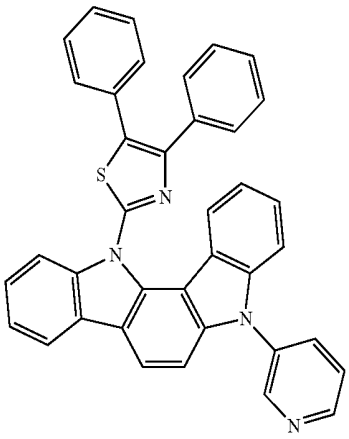


-continued

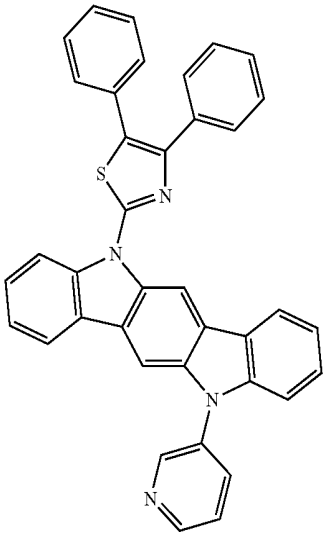
111



112

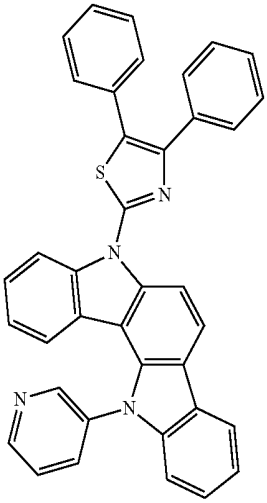


113

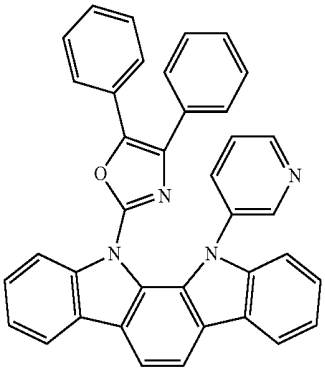


-continued

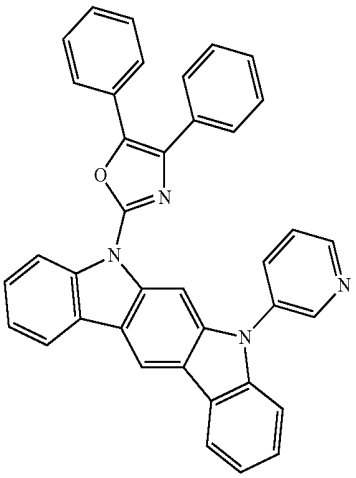
114



115

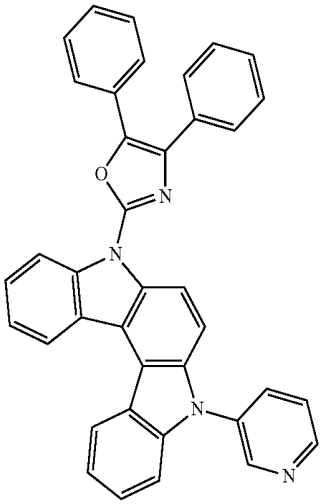


116

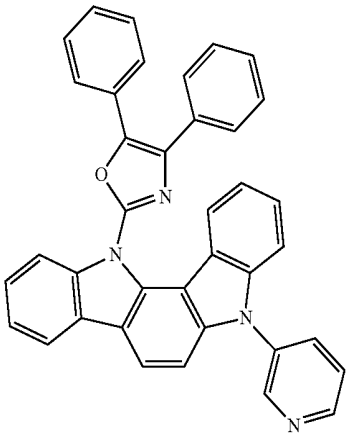


-continued

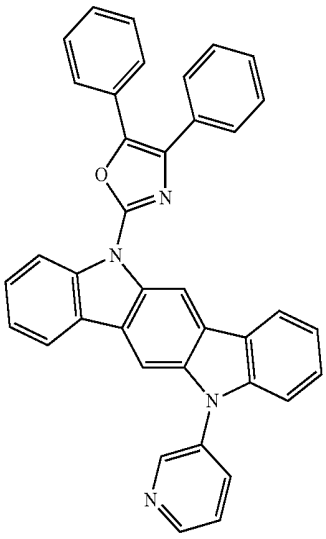
117



118

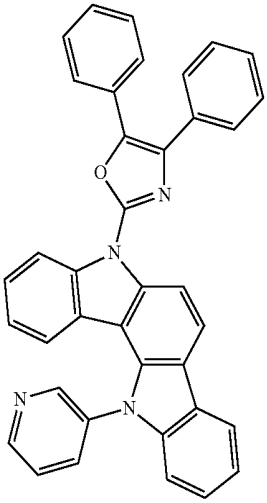


119

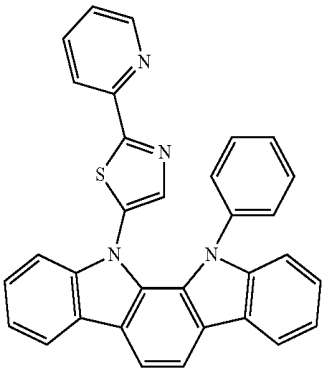


-continued

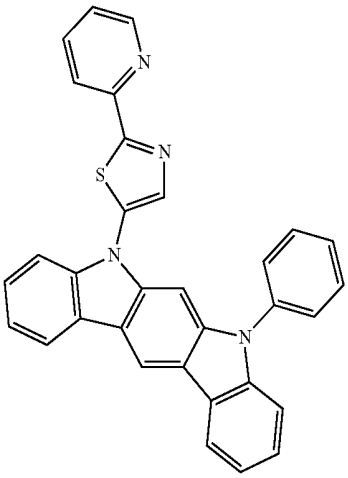
120



121

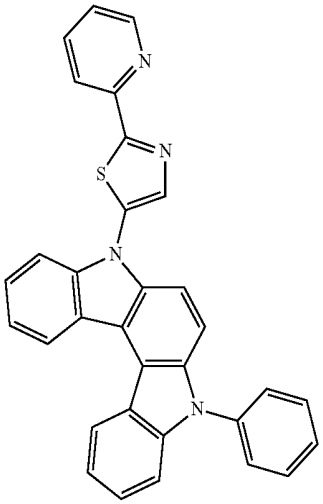


122

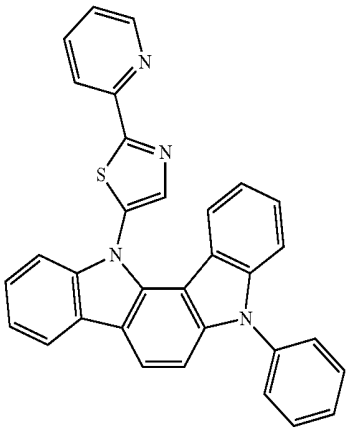


-continued

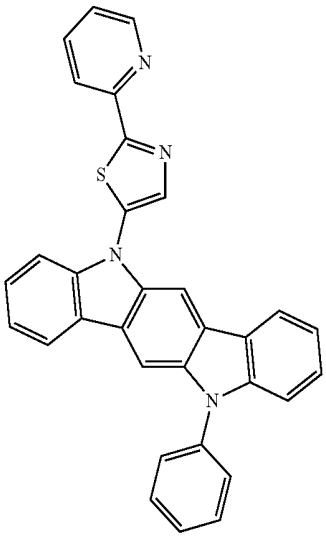
123



124

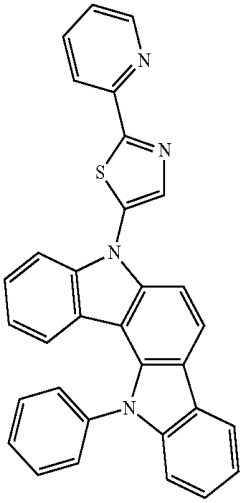


125

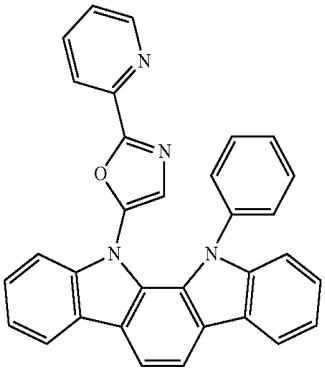


-continued

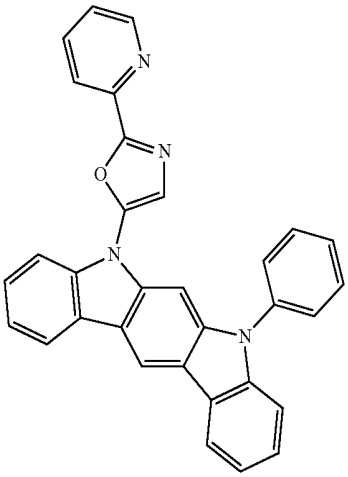
126



127

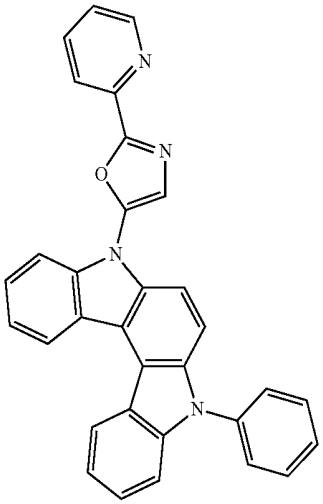


128

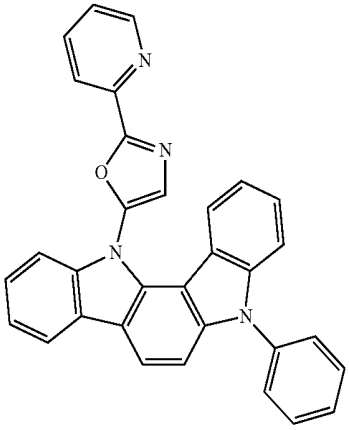


-continued

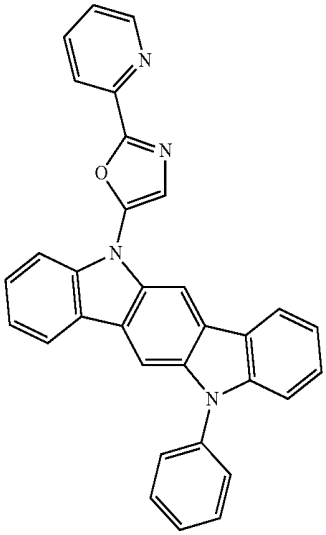
129



130

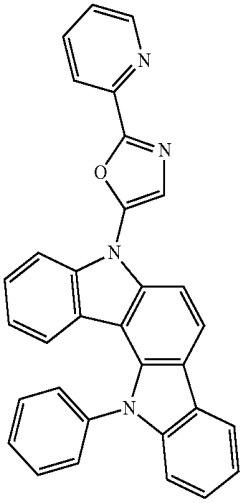


131

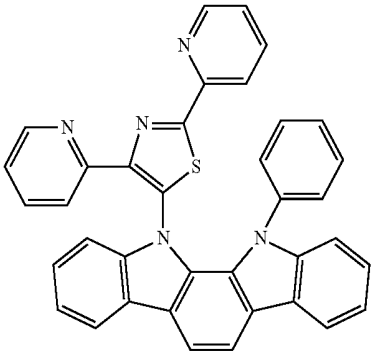


-continued

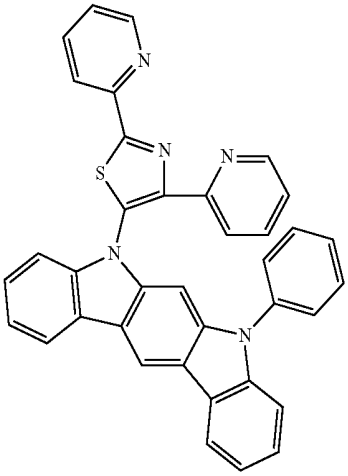
132



133

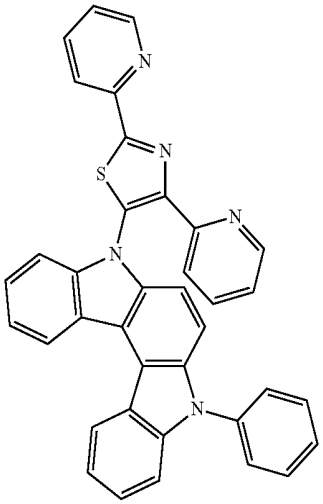


134

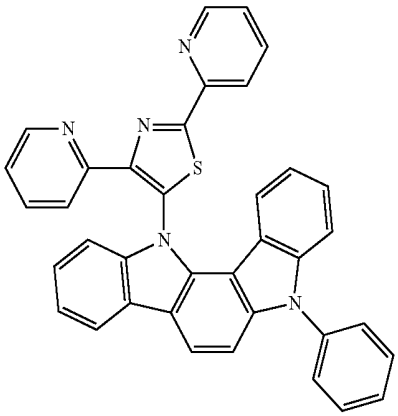


-continued

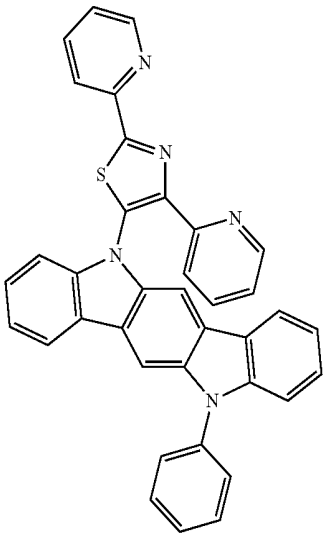
135



136

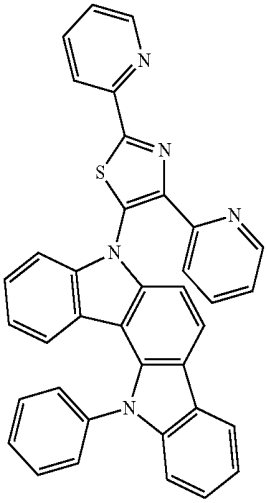


137

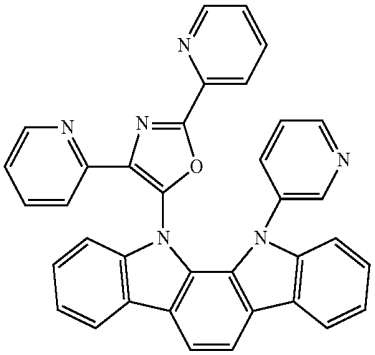


-continued

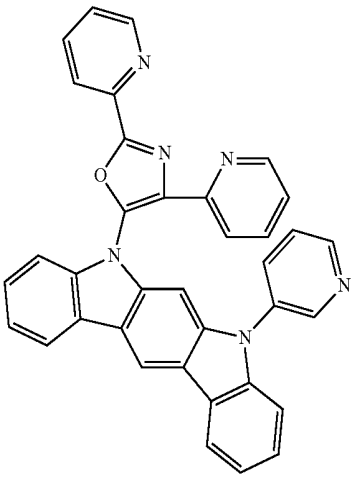
138



139

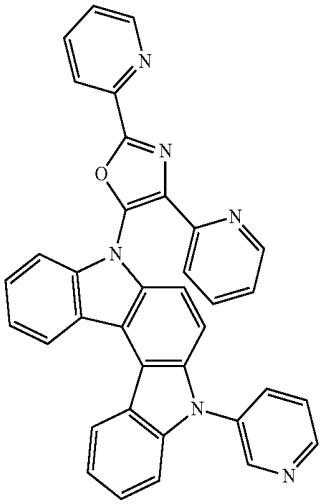


140

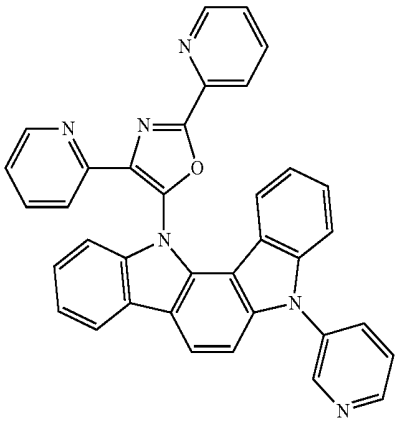


-continued

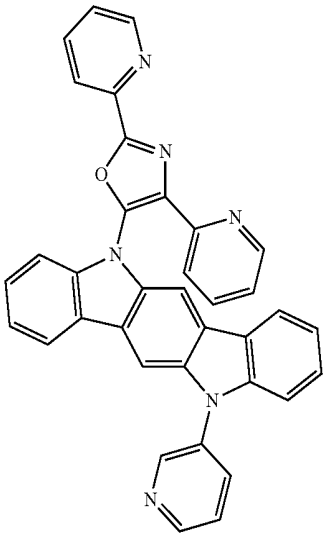
141



142

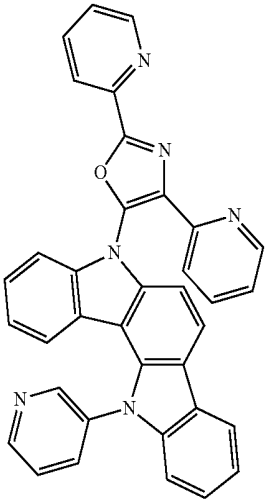


143

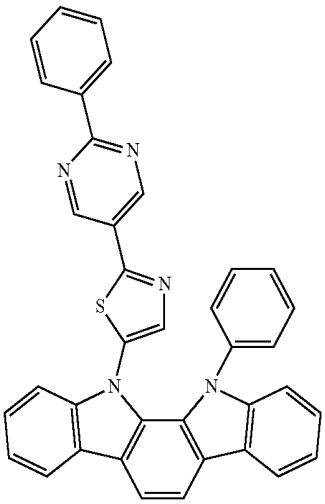


-continued

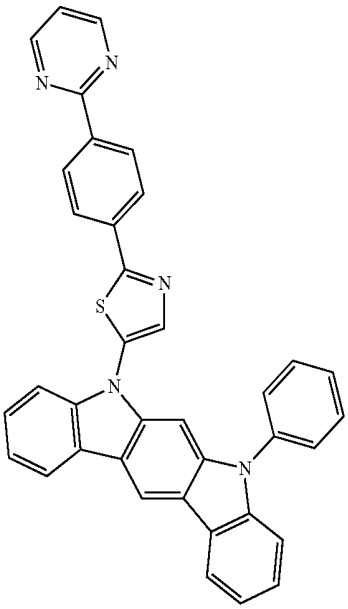
144



145

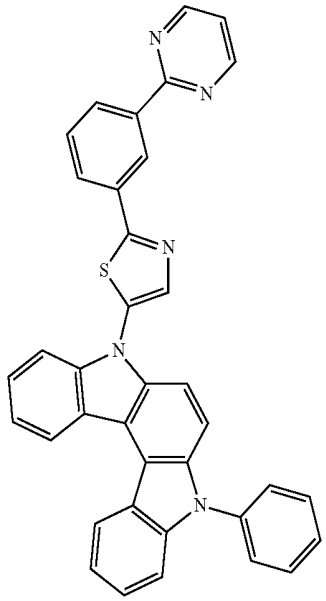


146

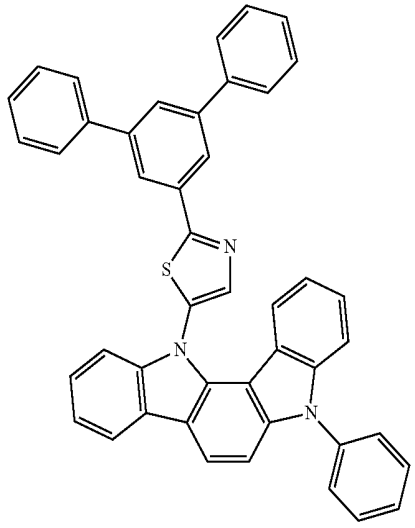


-continued

147

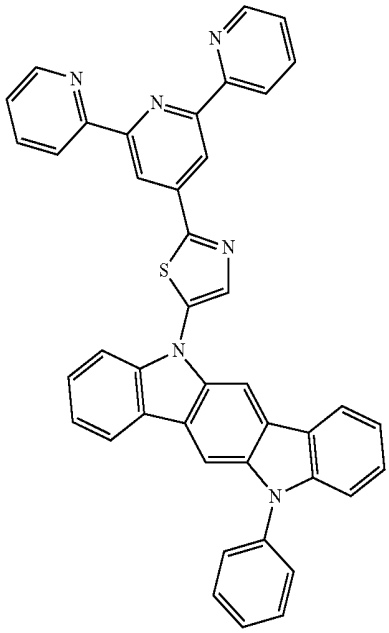


148

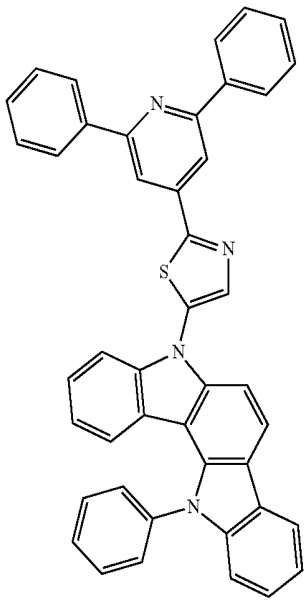


-continued

149

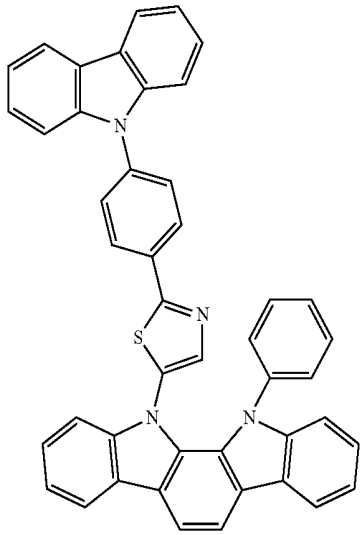


150

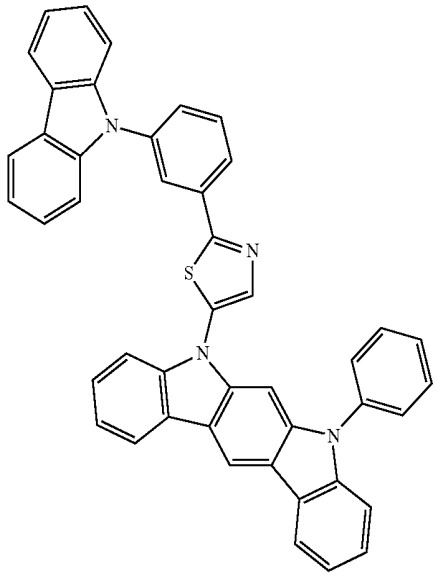


-continued

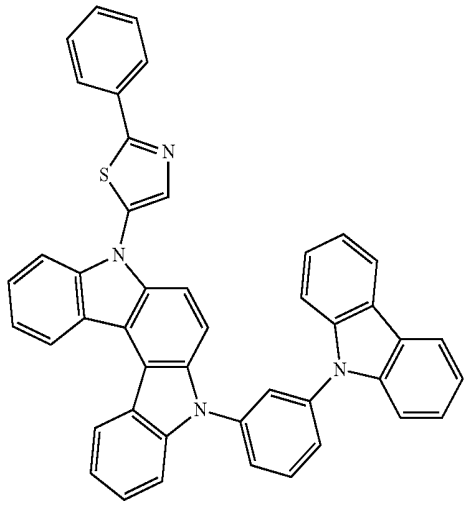
151



152

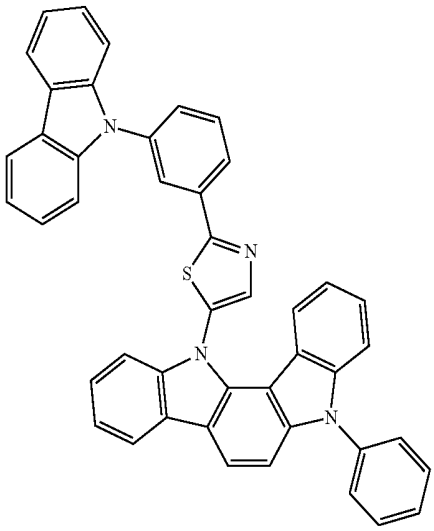


153

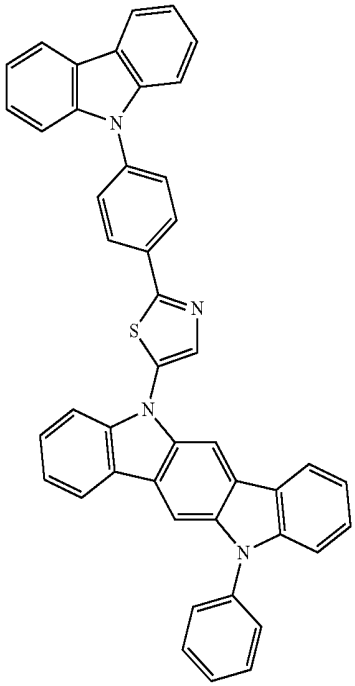


-continued

154

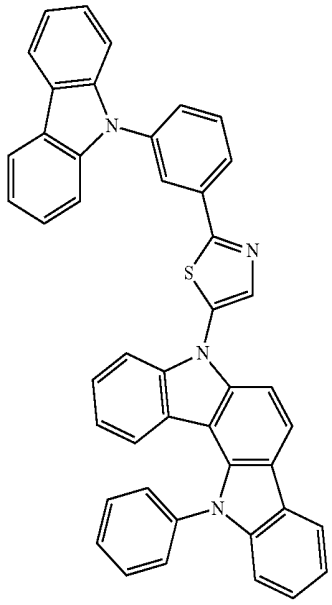


155

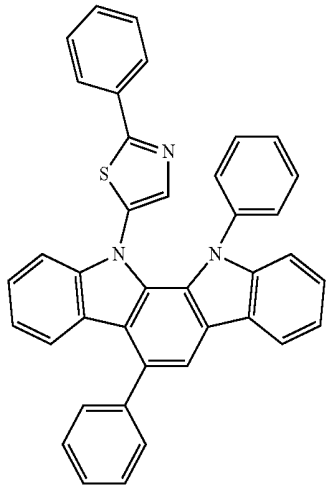


-continued

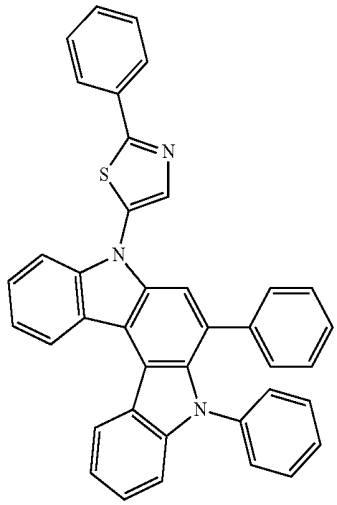
156



157

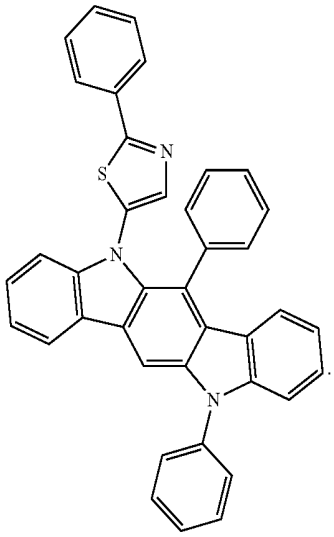


158



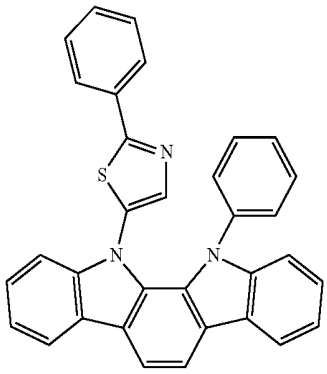
-continued

159

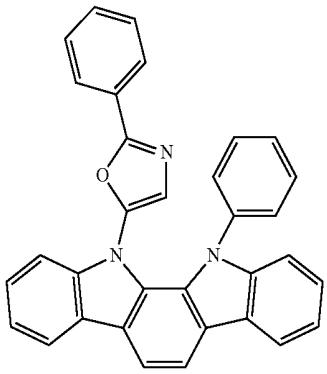


14. The condensed cyclic compound of claim **1**, wherein the condensed cyclic compound is any one of Compounds 1, 7, 29, 59, 70, 88, 101, 112, 133, 149, 152, 155, and 159:

1

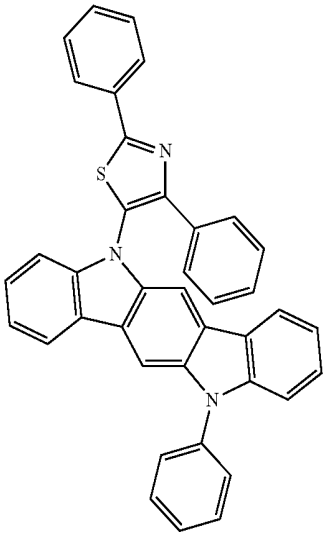


7

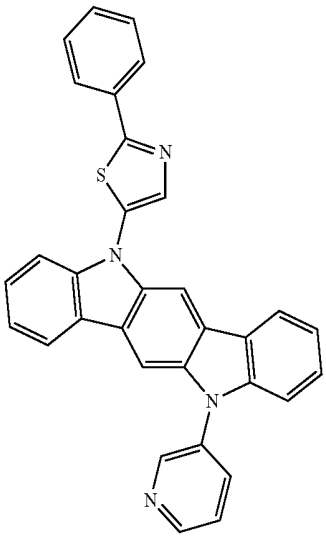


-continued

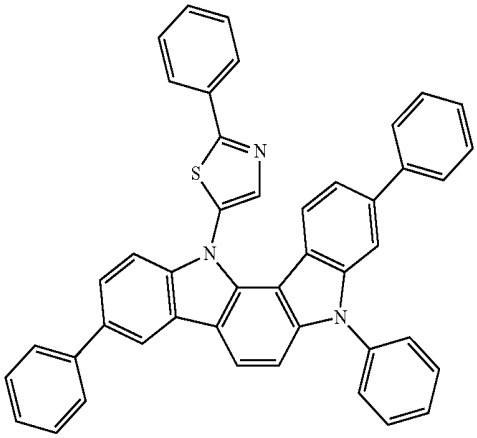
29



59

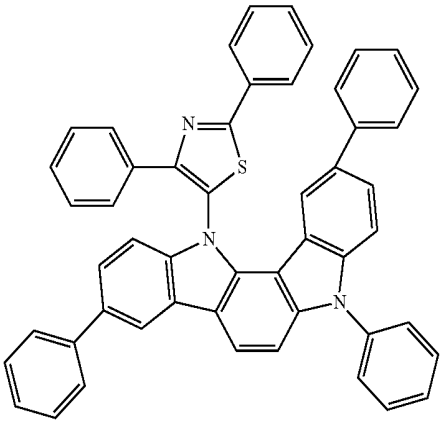


70

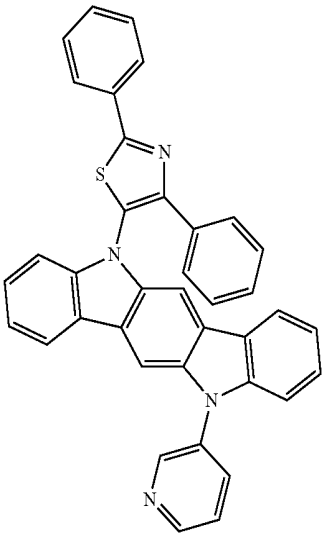


-continued

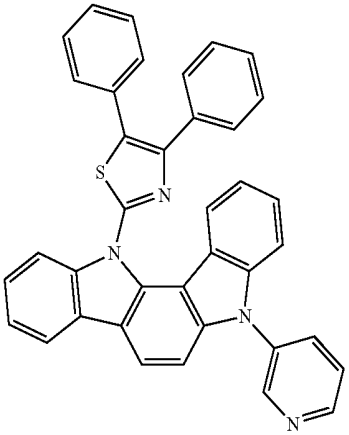
88



101

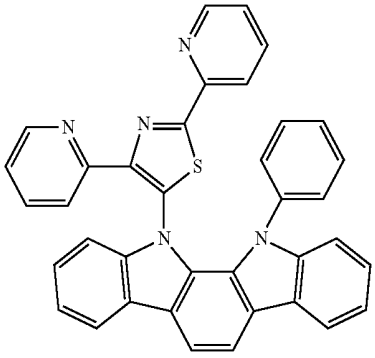


112

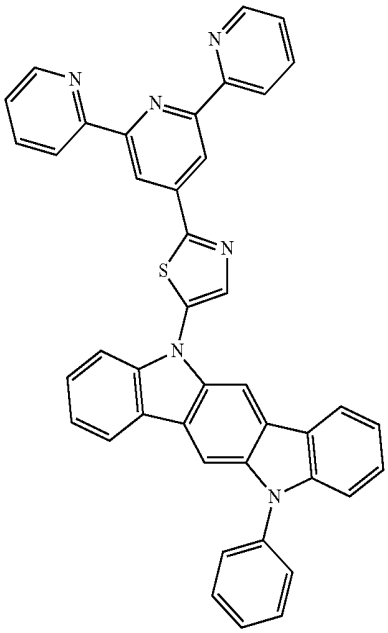


-continued

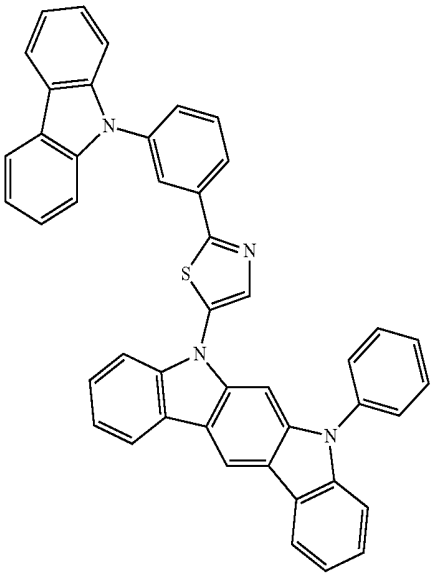
133



149

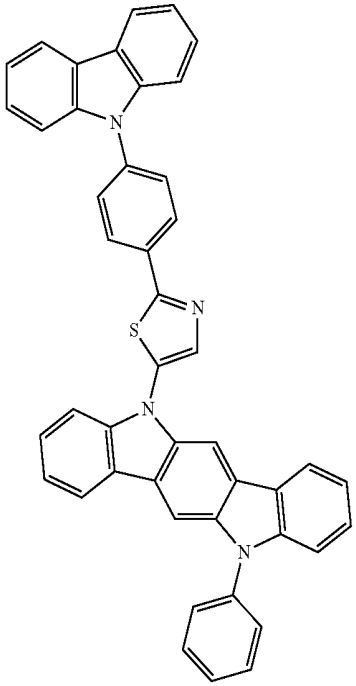


152

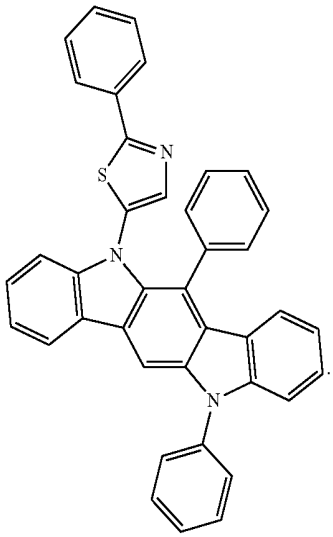


-continued

155



159



15. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

an organic layer between the first and second electrodes and comprising an emission layer,

wherein the organic layer comprises the condensed cyclic compound of claim **1**.

16. The organic light-emitting device of claim **15**, wherein the organic layer 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.

17. The organic light-emitting device of claim **16**, wherein the electron transport region comprises at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

18. The organic light-emitting device of claim **16**, wherein the hole transport region comprises at least one selected from an electron blocking layer, a hole transport layer, and a hole injection layer.

19. The organic light-emitting device of claim **16**, wherein the emission layer comprises the condensed cyclic compound.

20. The organic light-emitting device of claim **16**, wherein the electron transport region comprises the condensed cyclic compound.

* * * * *

专利名称(译)	缩合环状化合物和包括其的有机发光器件		
公开(公告)号	US20150228911A1	公开(公告)日	2015-08-13
申请号	US14/338201	申请日	2014-07-22
[标]申请(专利权)人(译)	三星显示有限公司 釜山NAT UNIV UNIV IND合作FOUND		
申请(专利权)人(译)	三星DISPLAY CO.，LTD. 釜山大学产学合作基金会		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD. 釜山大学产学合作基金会		
[标]发明人	KIM JAE HONG KIM MYEONG SUK KIM SUNG WOOK HWANG JIN SOO SUH HONG SUK		
发明人	KIM, JAE-HONG KIM, MYEONG-SUK KIM, SUNG-WOOK HWANG, JIN-SOO SUH, HONG-SUK		
IPC分类号	H01L51/00 H01L51/50		
CPC分类号	H01L51/0072 H01L51/0069 H01L51/0067 H01L51/5088 H01L51/5056 H01L51/5096 H01L51/5092 H01L51/5072 C07D487/04 H01L51/0081		
优先权	1020140016791 2014-02-13 KR		
其他公开文献	US9966540		
外部链接	Espacenet USPTO		

摘要(译)

式1表示稠合环状化合物。有机发光装置包括式1表示的稠环化合物。 本文描述了式1的X，Y 1 ，Y 2 ，A，B和R 1 。包括含有缩合环状化合物的有机层的有机发光装置可以具有低驱动电压，高效率，高亮度和长寿命。