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

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C07D 471/04	(2006.01)
C07D 235/18	(2006.01)
C07D 251/24	(2006.01)

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USPC **257/40**; 548/310.7; 546/255; 544/180; 544/405; 546/257; 546/88; 546/285

(57) **ABSTRACT**

A condensed-cyclic compound and an organic light-emitting diode including the condensed-cyclic compound.

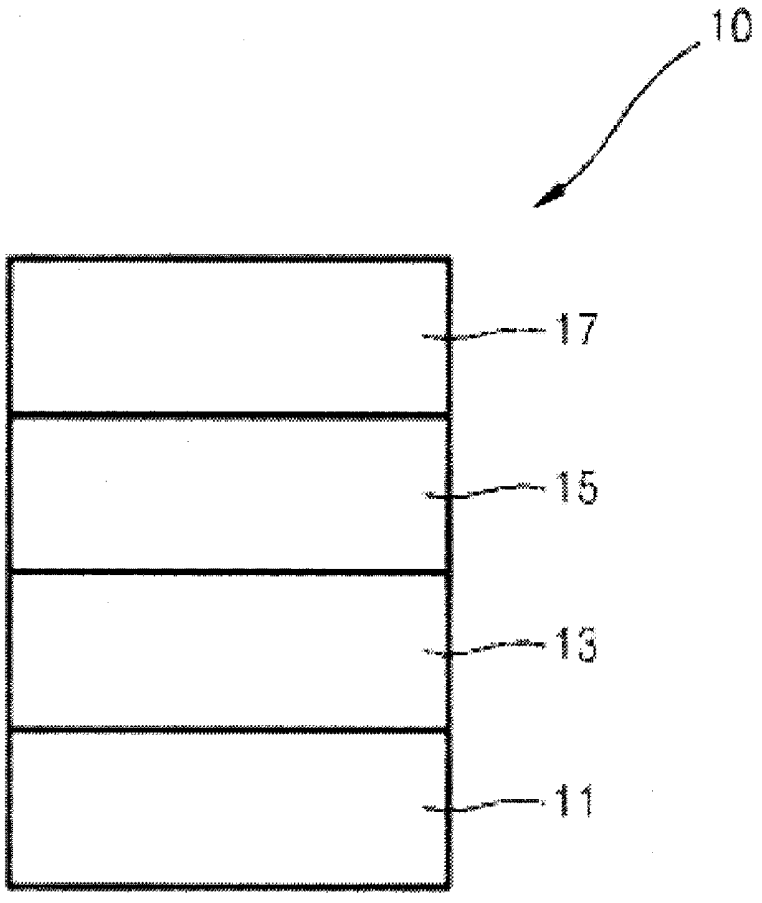
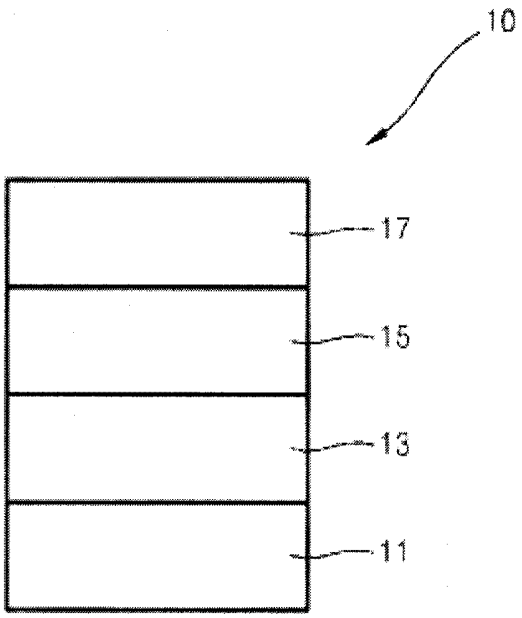


FIG. 1



CONDENSED-CYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DIODE INCLUDING THE CONDENSED-CYCLIC COMPOUND

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application No. 10-2012-0102993, filed on Sep. 17, 2012, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

[0002] 1. Field

[0003] One or more embodiments relate to a compound for an organic light-emitting diode and an organic light-emitting diode including the compound.

[0004] 2. Description of the Related Technology

[0005] Organic light-emitting diodes (OLEDs), which are self-emitting device, have advantages such as a wide viewing angle, excellent contrast, quick response, high brightness, and excellent driving voltage, and can provide multicolored images.

[0006] A general OLED has a structure including a substrate, an anode, a hole transport layer (HTL), an emission layer (EML), an electron transport layer (ETL), and a cathode which are sequentially stacked on the substrate. In this regard, the HTL, the EML, and the ETL are organic layers formed of organic compounds.

[0007] An operating principle of an OLED having the above-described structure is as follows.

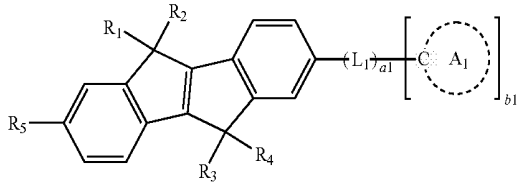
[0008] When a voltage is applied between the anode and the cathode, holes injected from the anode move to the EML via the HTL, and electrons injected from the cathode move to the EML via the ETL. The holes and electrons recombine in the EML to generate excitons. When the excitons drop from an excited state to a ground state, light is emitted.

SUMMARY

[0009] The present embodiments provide a condensed-cyclic compound having a novel structure and an organic light-emitting diode including the condensed-cyclic compound.

[0010] According to an aspect of the present embodiments, there is provided a condensed-cyclic compound represented by Formula 1 below:

Formula 1



[0011] wherein A_1 may be a substituted or unsubstituted C_2-C_{60} heteroaryl group containing at least one of N, O, and S as a ring-forming atom;

[0012] L_1 may be a substituted or unsubstituted C_6-C_{60} arylene group or a substituted or unsubstituted C_2-C_{60} heteroarylene group;

[0013] a1 may be an integer of 0 to 5;

[0014] b1 may be an integer of 1 to 5; and

[0015] R_1 through R_5 may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{60} cycloalkyl group, a substituted or unsubstituted C_3-C_{60} cycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group.

[0016] According to another aspect of the present embodiments, there is provided an organic light-emitting diode including a first electrode; a second electrode facing the first electrode; and an organic layer interposed between the first electrode and the second electrode, wherein the organic layer includes at least one of the condensed-cyclic compounds represented by Formula 1 described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The above and other features and advantages of the present embodiments will become more apparent by describing example embodiments thereof with reference to the attached drawing in which:

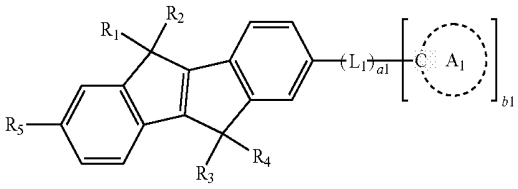
[0018] FIG. **1** is a schematic diagram illustrating an organic light-emitting diode (OLED) according to an embodiment.

DETAILED DESCRIPTION

[0019] Hereinafter, example embodiments will be described with reference to the accompanying drawing. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0020] According to an embodiment, there is provided a condensed-cyclic compound represented by Formula 1 below:

Formula 1



[0021] In Formula 1, A_1 is a substituted or unsubstituted C_2-C_{60} heteroaryl group containing at least one of N, O, and S as a ring-forming atom.

[0022] A_1 may be an electron-transporting moiety.

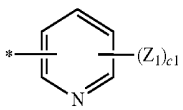
[0023] A_1 may be a substituted or unsubstituted C_2-C_{20} heteroaryl group containing at least one of N, O, and S as a ring-forming atom.

[0024] For example, A1 may be a substituted or unsubstituted pyrrolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted imidazolyl group, a substituted or unsubstituted imidazolinyl group, a substituted or unsubstituted imidazopyridinyl group, a substituted or unsubstituted imidazopyrimidinyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted indolizinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted indazolyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenazinyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted pyranyl group, a substituted or unsubstituted chromenyl group, a substituted or unsubstituted furanyl group, a substituted or unsubstituted benzofuranyl group, a substituted or unsubstituted thiophenyl group, a substituted or unsubstituted benzothiophenyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or substituted isoxazolyl group, a substituted or unsubstituted dibenzothiophenyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted oxadiazolyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted isoquinolinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted benzothiazolyl group, or a substituted or unsubstituted benzooxazolyl group.

[0025] For example, A_1 may be a substituted or unsubstituted imidazolyl group, a substituted or unsubstituted imidazolinyl group, a substituted or unsubstituted imidazopyridinyl group, a substituted or unsubstituted imidazopyrimidinyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted dibenzothiophenyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted isoquinolinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted benzothiazolyl group, or a substituted or unsubstituted benzooxazolyl group.

[0026] According to some embodiments, A_1 may be one of Formulae 3A through 3O, but is not limited thereto:

Formula 3A



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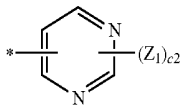
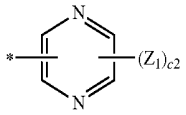
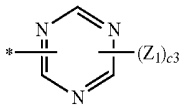
Formula 3B



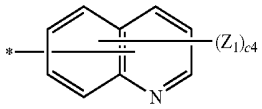
Formula 3C



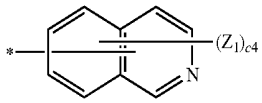
Formula 3D



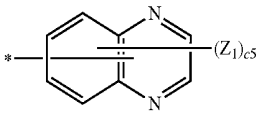
Formula 3E



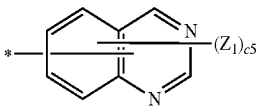
Formula 3F



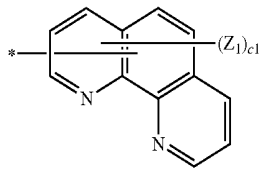
Formula 3G



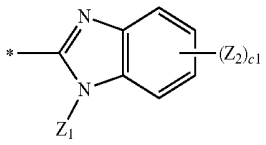
Formula 3H



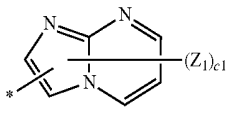
Formula 3I



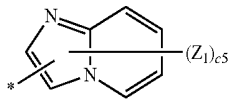
Formula 3J



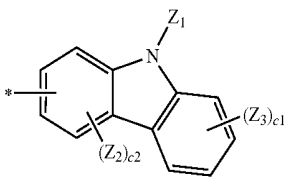
Formula 3K



Formula 3L



Formula 3M



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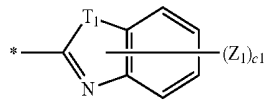
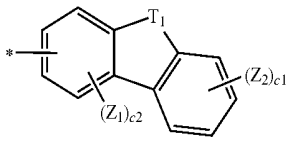
Formula 3N



Formula 3O



[0027] In Formulae 3A through 3O, Z_1 through Z_3 may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_3-C_{60} alkoxy group, a C_3-C_{60} cycloalkyl group, a C_3-C_{60} cycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group.

[0028] For example, Z_1 through Z_3 may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, a pyrenyl group, a phenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a naphthyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, an anthryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a fluorenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyrenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyridinyl group, a dibenzothiophenyl group, or a dibenzofuranyl group.

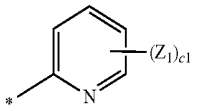
[0029] Z_1 through Z_3 may be each independently hydrogen, a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, a pyrenyl group, a fluorophenyl group, a difluorophenyl group, a cyanophenyl group, a fluoronaphthyl group, a fluoronaphthyl group, a cyanonaphthyl group, a fluorofluorenyl group, a difluorofluorenyl group, a cyanofluorenyl group, a dimethylfluorenyl group, a pyridinyl group, a dibenzothiophenyl group, or a dibenzofuranyl group.

[0030] In Formulae 3A through 3O, c1 may be an integer of 1 to 4; c2 may be an integer of 1 to 3; c3 may be an integer of 1 to 2; c4 may be an integer of 1 to 6; and c5 may be an integer of 1 to 5. For example, c1 through c5 may be each independently 1 or 2.

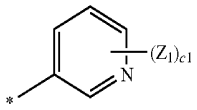
[0031] In Formulae 3N and 30, T_1 may be O or S.

[0032] A_1 may be one of Formulae 4A through 4R.

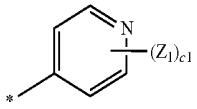
Formula 4A



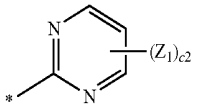
Formula 4B



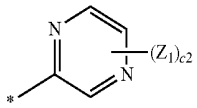
Formula 4C



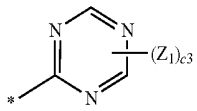
Formula 4D



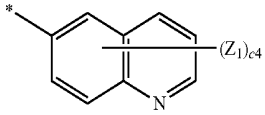
Formula 4E



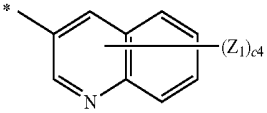
Formula 4F



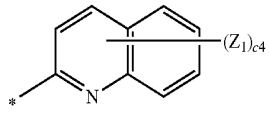
Formula 4G



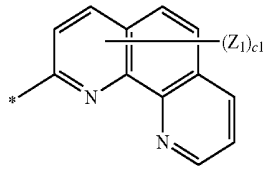
Formula 4H



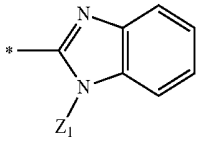
Formula 4I



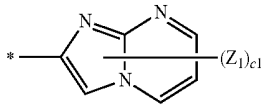
Formula 4J



Formula 4K



Formula 4L



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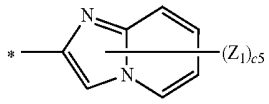
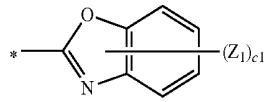
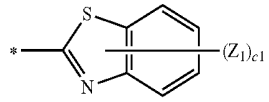
Formula 4M



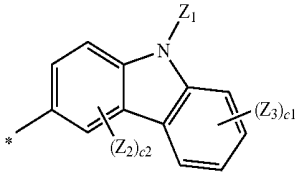
Formula 4N



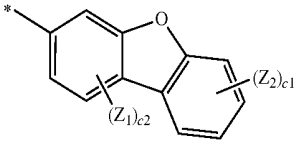
Formula 4O



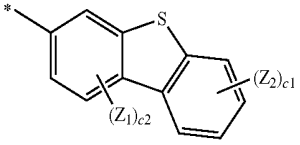
Formula 4P



Formula 4Q



Formula 4R



[0033] In Formulae 4A through 4R, a detailed description of Z_1 through Z_3 and c1 through c5 has already been described above.

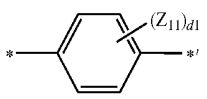
[0034] In Formula 1, L_1 may be a substituted or unsubstituted C_6-C_{60} arylene group or a substituted or unsubstituted C_2-C_{60} heteroarylene group.

[0035] For example, L_1 may be a substituted or unsubstituted phenylene group, a substituted or unsubstituted pentalenylene group, a substituted or unsubstituted indenylene group, a substituted or unsubstituted naphtylene group, a substituted or unsubstituted azulenylene group, a substituted or unsubstituted heptalenylene group, a substituted or unsubstituted indacenylene group, a substituted or unsubstituted acenaphtylene group, a substituted or unsubstituted fluorenylene group, a substituted or unsubstituted spiro-fluorenylene group, a substituted or unsubstituted phenalenylene group, a substituted or unsubstituted phenanthrenylene group, a substituted or unsubstituted anthrylene group, a substituted or unsubstituted fluoranthenylene group, a substituted or unsubstituted triphenylenylene group, a substituted or unsubstituted pyrenylene group, a substituted or unsubstituted chrysenylene group, a substituted or unsubstituted naphthacenylene group, a substituted or unsubstituted picenylene group, a substituted or unsubstituted perylenylene group, a substituted or unsubstituted pentaphenylene group, a substituted or unsubstituted hexacenylene group, a substituted or unsubstituted pyrrolylene group, a substituted or unsubstituted imidazolylene group, a substituted or unsubstituted pyrazolylene group, a substituted or unsubstituted pyridinylene group, a substituted or unsubstituted pyrazinylene group, a substituted or unsubstituted pyrimidinylene group, a substituted or unsubstituted pyridazinylene group, a substituted or unsubstituted isoindolylene group, a substituted or unsubstituted indolylene group, a substituted or unsubstituted indazolylene group, a substituted or unsubstituted purinylene group, a substituted or unsubstituted quinolinylene group, a substituted or unsubstituted benzoquinolinylene group, a substituted or unsubstituted phthalazinylene group, a substituted or unsubstituted naphthyridinylene group, a substituted or unsubstituted quinoxalinylene group, a substituted or unsubstituted quinazolinylene group, a substituted or unsubstituted cinnolinylene group, a substituted or unsubstituted carbazolylene group, a substituted or unsubstituted phenanthridinylene group, a substituted or unsubstituted acridinylene group, a substituted or unsubstituted phenanthrolinylene group, a substituted or unsubstituted phenazinylene group, a substituted or unsubstituted benzooxazolylene group, a substituted or unsubstituted benzoimidazolylene group, a substituted or unsubstituted furanylene group, a substituted or unsubstituted benzofuranylene group, a substituted or unsubstituted thiophenylene group, a substituted or unsubstituted benzothiophenylene group, a substituted or unsubstituted thiazolylene group, a substituted or unsubstituted isothiazolylene group, a substituted or unsubstituted benzothiazolylene group, a substituted or unsubstituted isoxazolylene group, a substituted or unsubstituted oxazolylene group, a substituted or unsubstituted triazolylene group, a substituted or unsubstituted tetrazolylene group, a substituted or unsubstituted oxadiazolylene group, a substituted or unsubstituted triazinylene group, a substituted or unsubstituted benzooxazolylene group, a substituted or unsubstituted dibenzofuranylene group, a substituted or unsubstituted dibenzothiophenylene, or a substituted or unsubstituted benzocarbazolylene group.

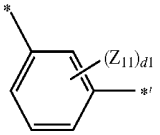
[0036] L_1 may be a substituted or unsubstituted phenylene group, a substituted or unsubstituted naphtylene group, a substituted or unsubstituted fluorenylene group, a substituted or unsubstituted spiro-fluorenylene group, a substituted or unsubstituted anthrylene group, a substituted or unsubstituted pyridinylene group, a substituted or unsubstituted pyrimidinylene group, a substituted or unsubstituted quinolinylene group, or a substituted or unsubstituted carbazolylene group.

[0037] According to some embodiments, L_1 may be one of Formulae 5A through 5M, but is not limited thereto:

Formula 5A



Formula 5B



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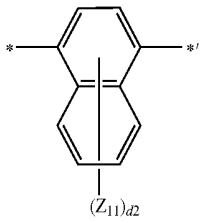
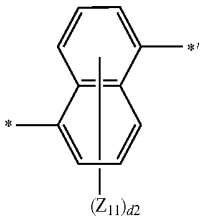
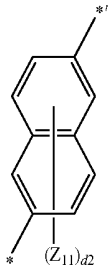
Formula 5C



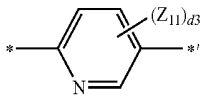
Formula 5D



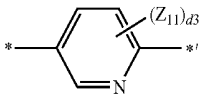
Formula 5E



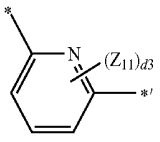
Formula 5F



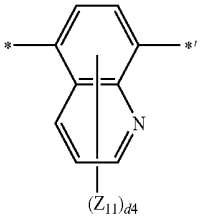
Formula 5G



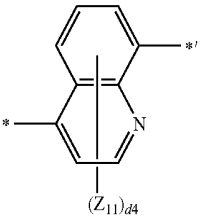
Formula 5H



Formula 5I



Formula 5J



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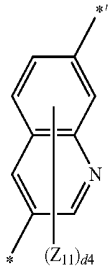
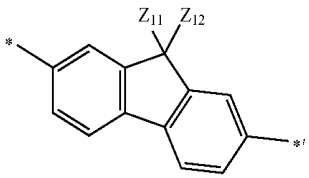
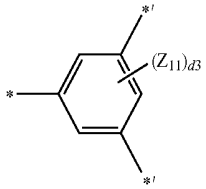
Formula 5K



Formula 5L



Formula 5M



[0038] In Formulae 5A through 5M, Z_{11} and Z_{12} may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{60} cycloalkyl group, a C_3-C_{60} cycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group.

[0039] For example, Z_{11} and Z_{12} may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, a pyrenyl group, a phenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a naphthyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, an anthryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a fluorenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyrenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyridinyl group, a dibenzothiophenyl group, or a dibenzofuranyl group.

[0040] Z_{11} and Z_{12} may be each independently hydrogen, a methyl group, an ethyl group, a propyl group, a butyl group, or a pentyl group.

[0041] In Formulae 5A through 5M, d1 may be an integer of 1 to 4; d2 may be an integer of 1 to 6; d3 may be an integer of 1 to 3; and d4 may be an integer of 1 to 5.

[0042] In Formulae 5A through 5M, *' denotes a binding site with A_1.

[0043] Formula 5M has two binding sites *', and may be L_1 of Formula 1 where b1 is 2 (for example, see Compound 36 below).

[0044] In Formula 1, a1 may be an integer of 0 to 5. When a1 is an integer of at least 2, at least two L_1 groups may be identical to or different from each other. For example, a1 may be 0 or 1. When a1 is 0, A_1 may be directly linked to the core of Formula 1.

[0045] In Formula 1, b1 may be an integer of 1 to 5. When b1 is an integer of at least 2, at least two A_1 groups may be identical to or different from each other. For example, b1 may be 1 or 2.

[0046] In Formula 1, R_1 through R_5 may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{60} cycloalkyl group, a substituted or unsubstituted C_3-C_{60} cycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group.

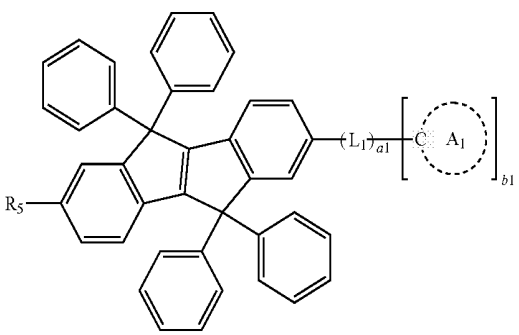
[0047] For example, in Formula 1, R_1 through R_4 may be each independently a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a phenyl group, a naphthyl group, an anthryl group, or a fluorenyl group.

[0048] According to an embodiment, in Formula 1, R_1 through R_4 may be identical to each other.

[0049] According to another embodiment, in Formula 1, R_1 and R_2 may be linked to each other by a single bond, and R_3 and R_4 may be linked to each other by a single bond. For example, in Formula 1, R1 through R4 may be each independently a phenyl group, R_1 and R_2 may be linked to each other by a single bond, and R_3 and R_4 may be linked to each other by a single bond (see Compounds 72 and 73 below).

[0050] For example, the condensed-cyclic compound may be represented by Formula 1A or 1B, but is not limited thereto:

Formula 1A



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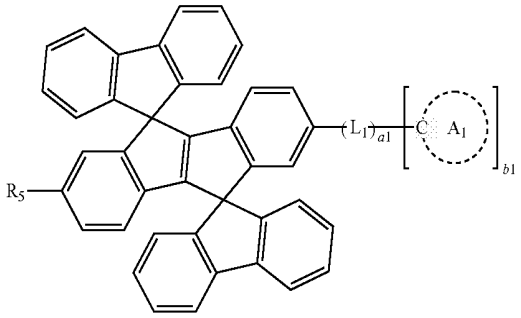
Formula 1B



[0051] A detailed description of 1A and 1B has been already described above.

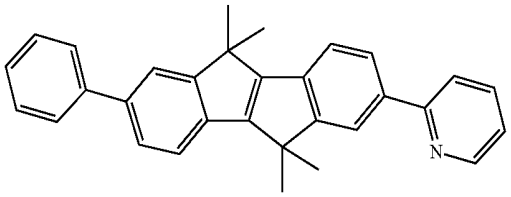
[0052] In Formula 1, R_5 may be a substituted or unsubstituted phenyl group, a substituted or unsubstituted pentalenyl group, a substituted or unsubstituted indenyl group, a substituted or unsubstituted naphtyl group, a substituted or unsubstituted azulenyl group, a substituted or unsubstituted heptalenyl group, a substituted or unsubstituted indacenyl group, a substituted or unsubstituted acenaphtyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted phenalenyl group, a substituted or unsubstituted phenanthrenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted fluoranthenyl group, a substituted or unsubstituted triphenylenyl group, a substituted or unsubstituted pyrenyl group, a substituted or unsubstituted chrysenyl group, a substituted or unsubstituted naphthacenyl group, a substituted or unsubstituted picenyl group, a substituted or unsubstituted perylenyl group, a substituted or unsubstituted pentaphenyl group, a substituted or unsubstituted hexacenyl group, a substituted or unsubstituted pyrrolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted imidazolyl group, a substituted or unsubstituted imidazolinyl group, a substituted or unsubstituted imidazopyridinyl group, a substituted or unsubstituted imidazopyrimidinyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted indolizinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted indazolyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenazinyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted pyranyl group, a substituted or unsubstituted chromenyl group, a substituted or unsubstituted furanyl group, a substituted or unsubstituted benzofuranyl group, a substituted or unsubstituted thiophenyl group, a substituted or unsubstituted benzothiophenyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted isoxazolyl, a substituted or unsubstituted dibenzothiophenyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted triazinyl group, a substituted or

unsubstituted oxadiazolyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted isoquinolinyl group, substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted benzothiazolyl group, or a substituted or unsubstituted benzooxazolyl group.

[0053] For example, in Formula 1, R_5 may be a substituted or unsubstituted phenyl group, a substituted or unsubstituted naphtyl group, a substituted or unsubstituted fluorenyl group (e.g., a fluorenyl group that is substituted with at least one of a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, and a phenyl group), a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted imidazolyl group, a substituted or unsubstituted imidazolinyl group, a substituted or unsubstituted imidazopyridinyl group, a substituted or unsubstituted imidazopyrimidinyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted dibenzothiophenyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted isoquinolinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted benzothiazolyl group, or a substituted or unsubstituted benzooxazolyl group, but is not limited thereto.

[0054] The condensed-cyclic compound of Formula 1 may be, for example, one of Compounds 1 through 74, but is not limited thereto:

1



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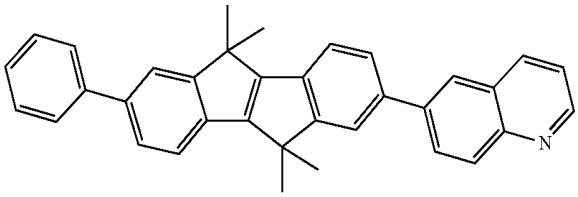

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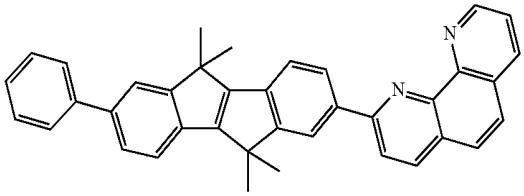

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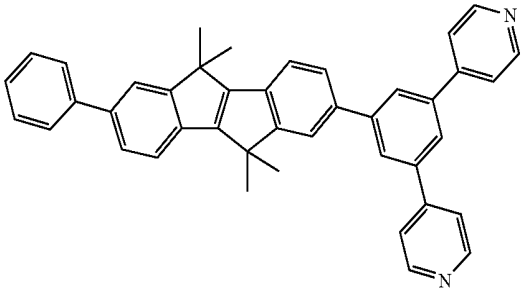

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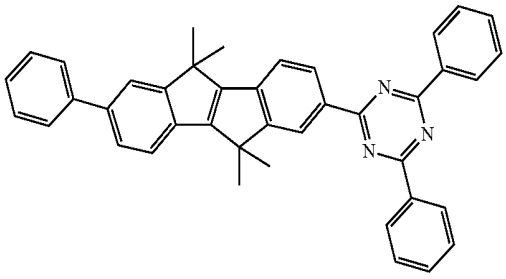

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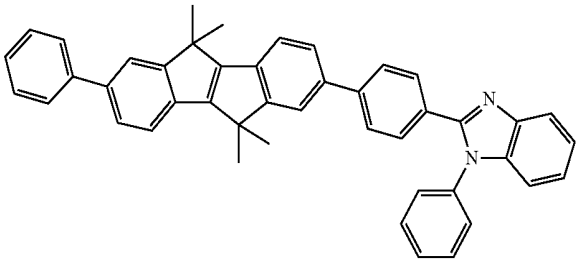

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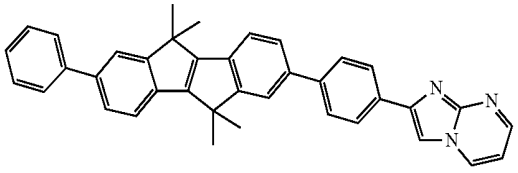

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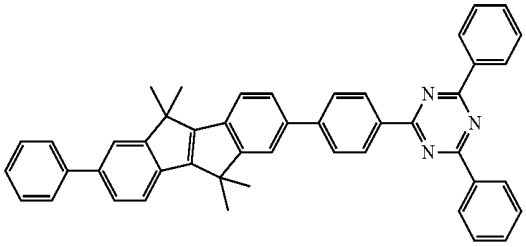

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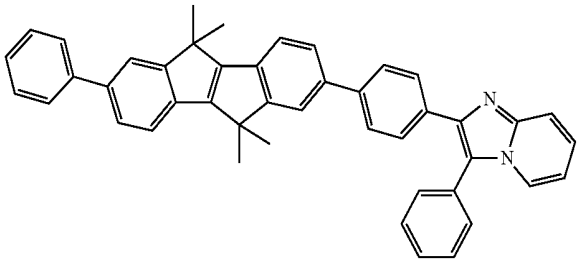
9



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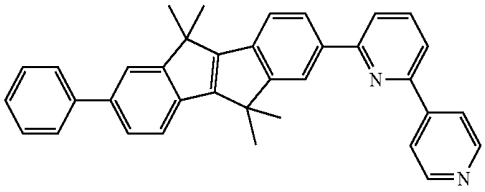

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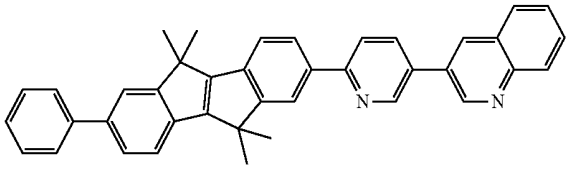

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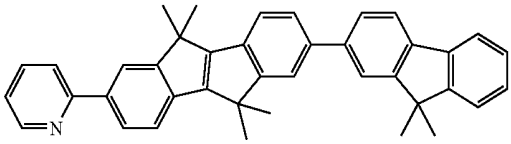

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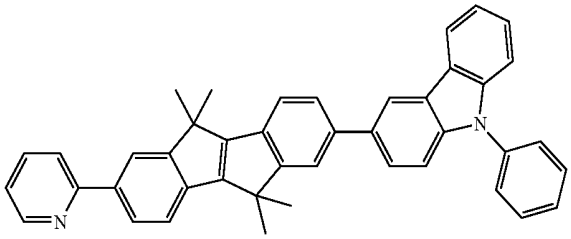

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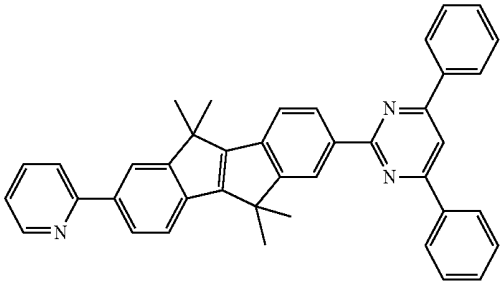

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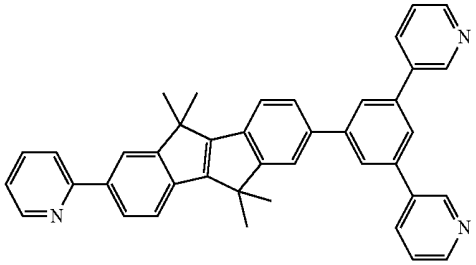

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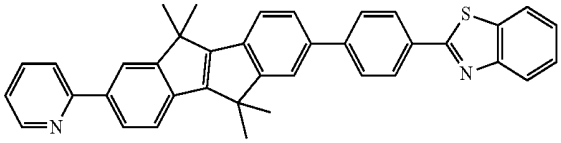

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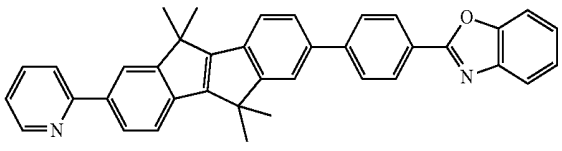

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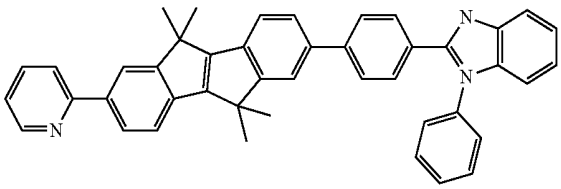

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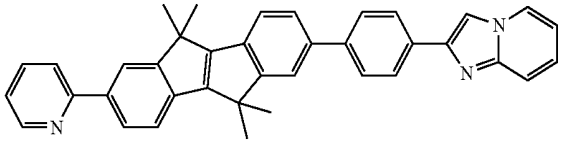

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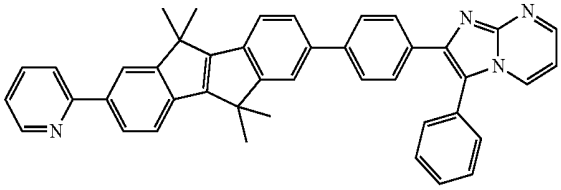

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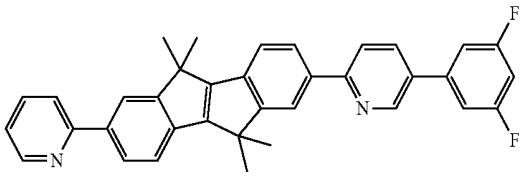

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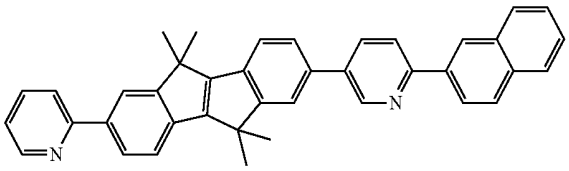

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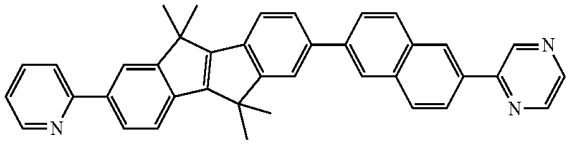

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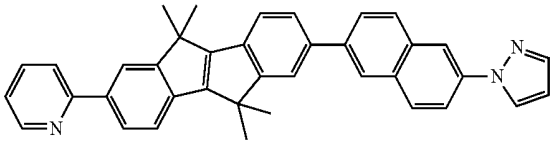

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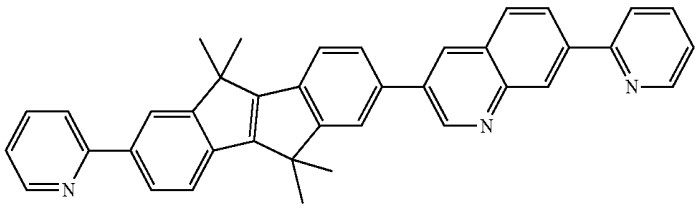

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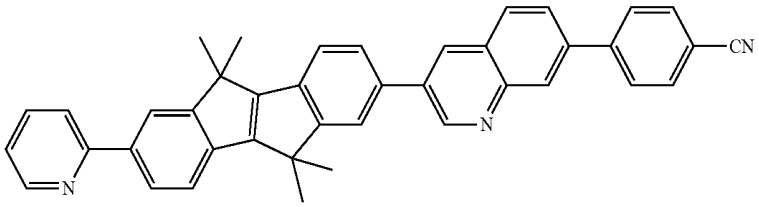

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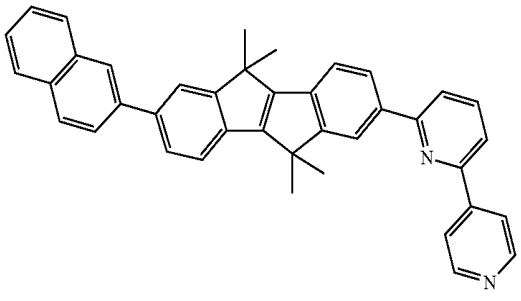

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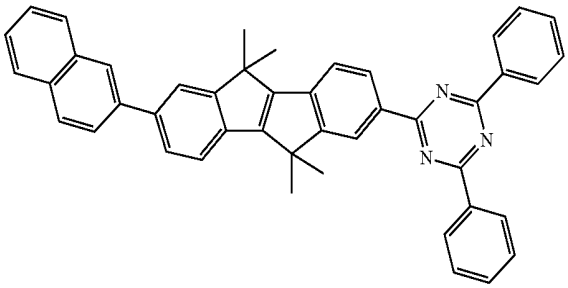

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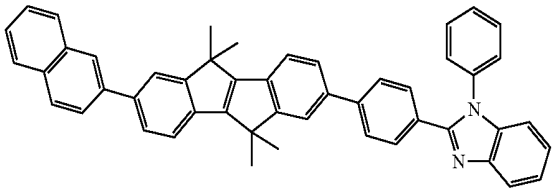

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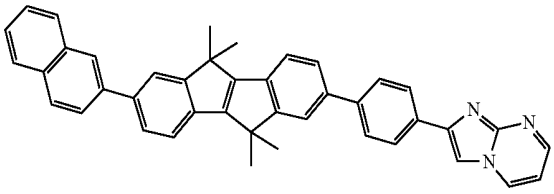

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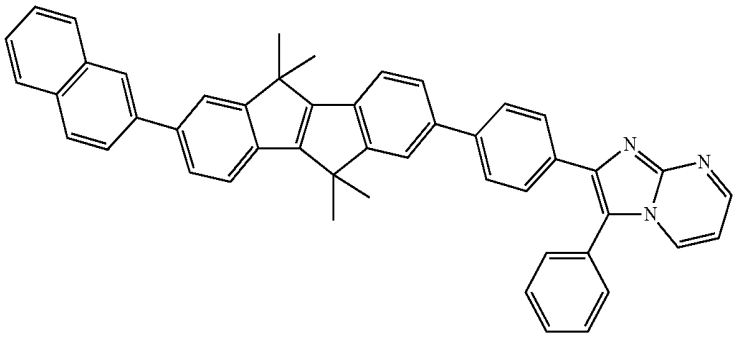

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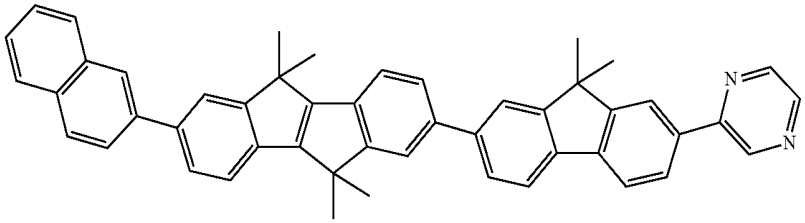

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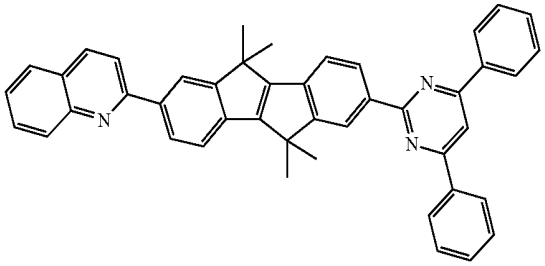

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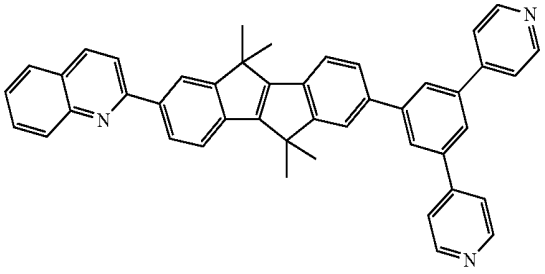

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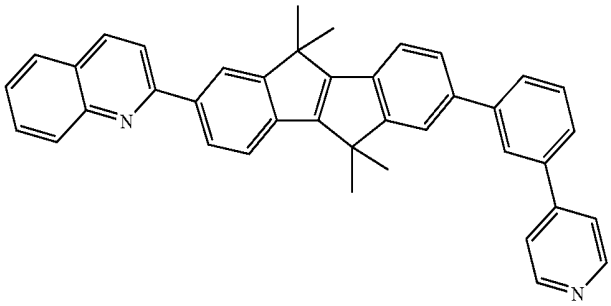

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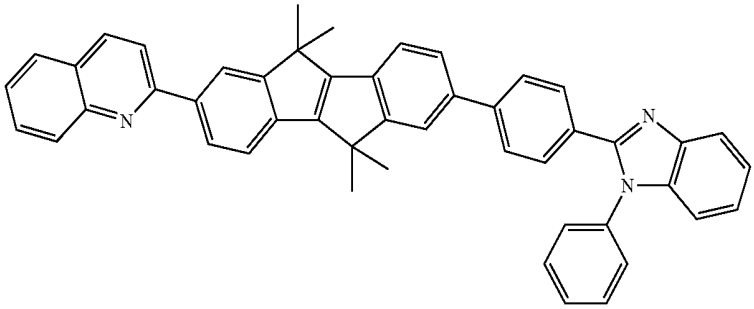

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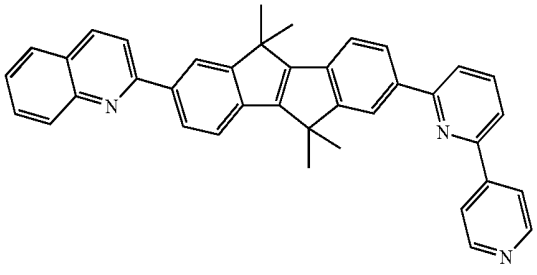

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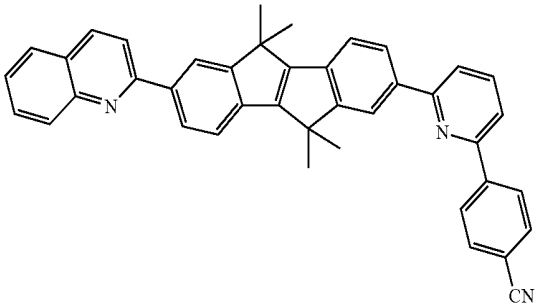

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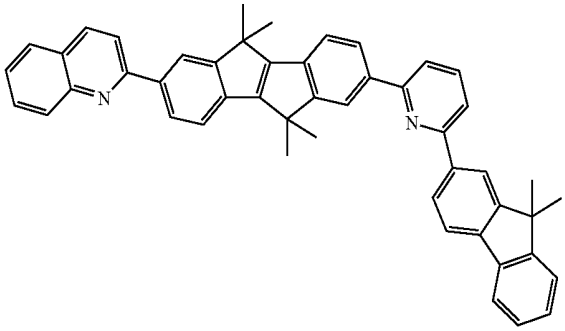

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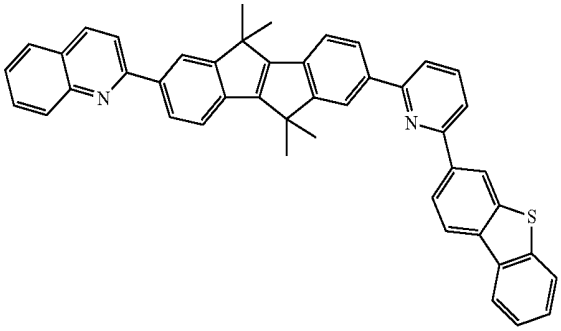

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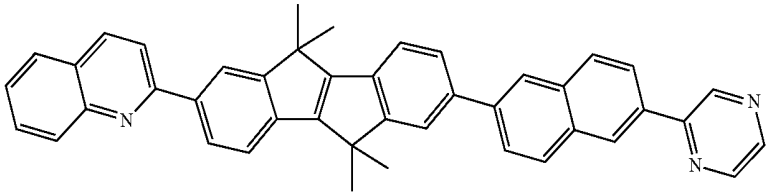

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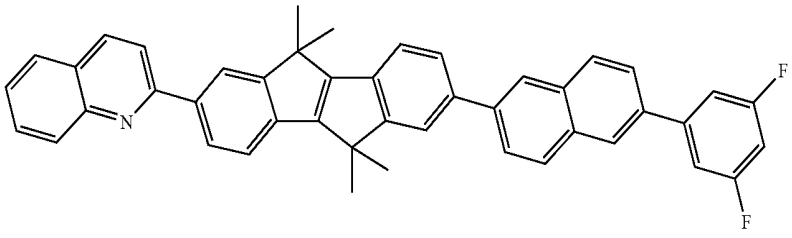

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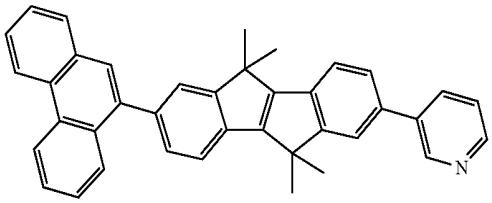

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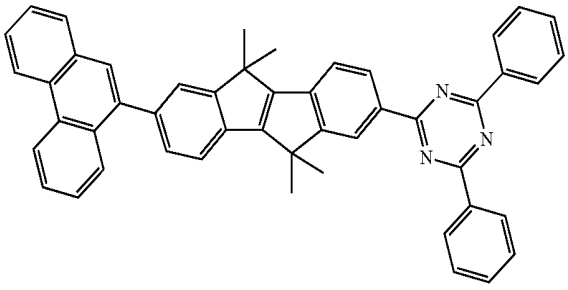

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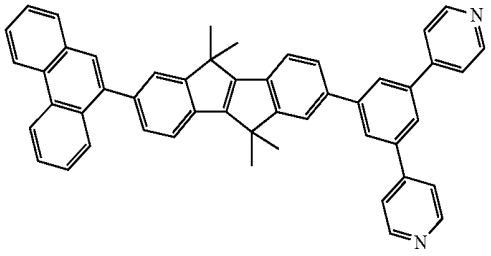

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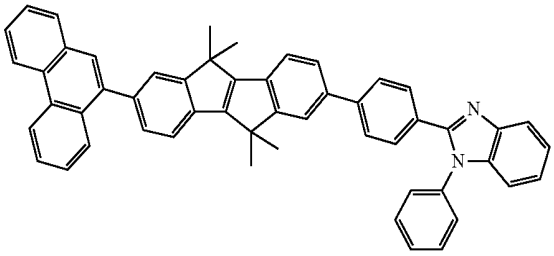

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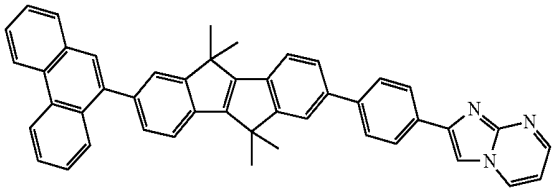

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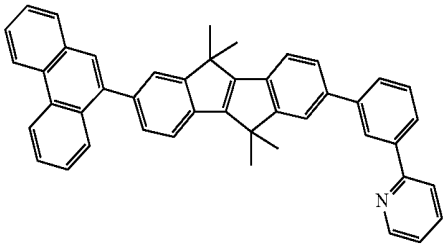

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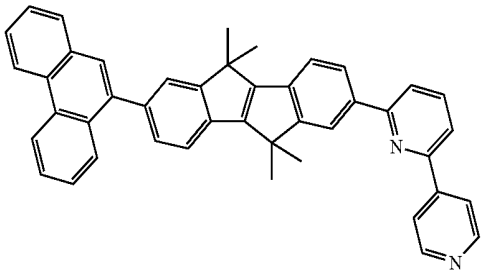

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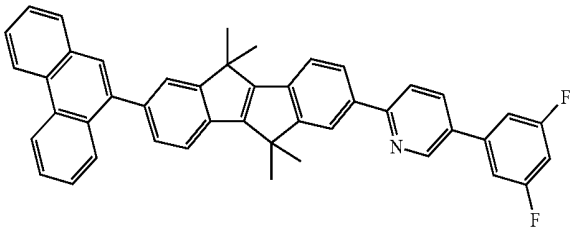

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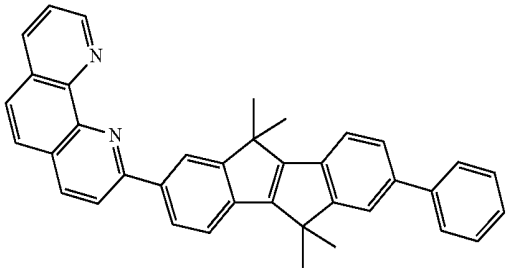

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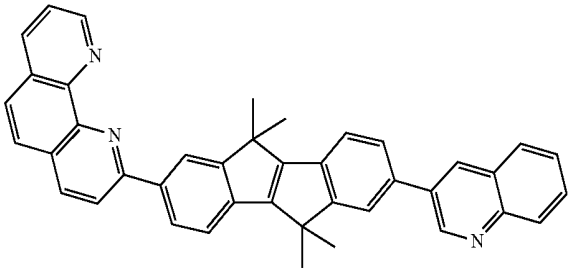

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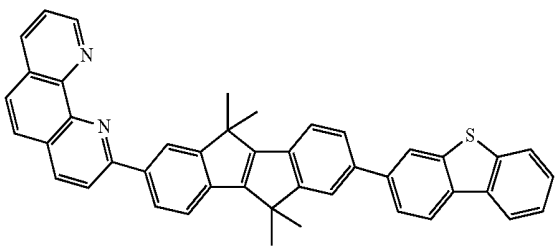

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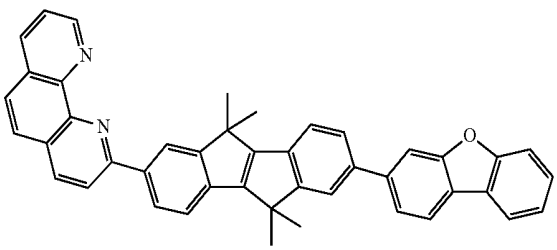

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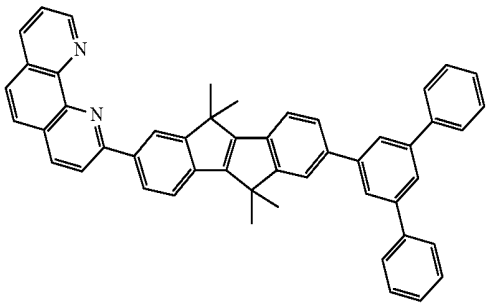

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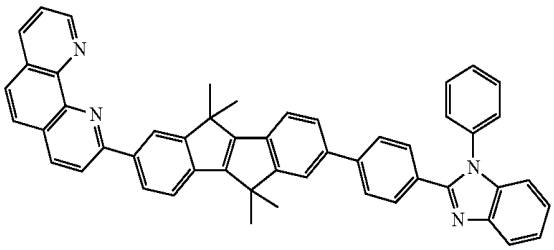

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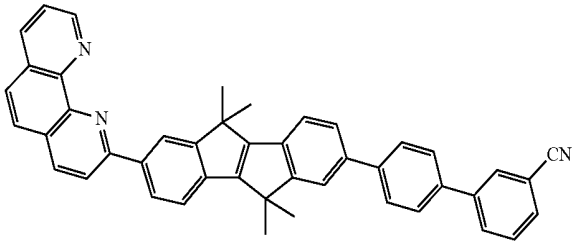

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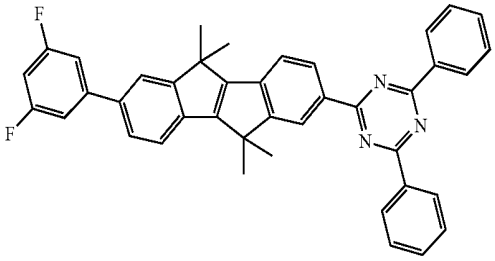

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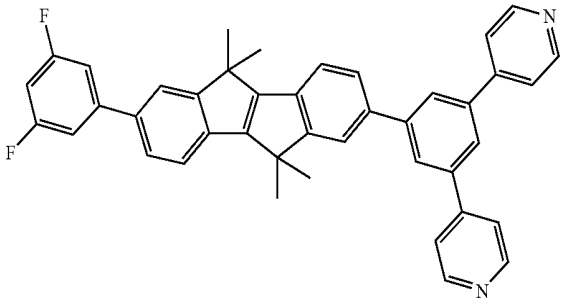

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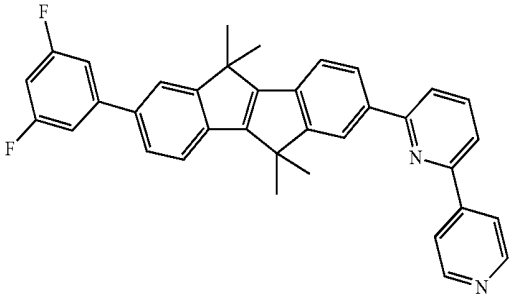

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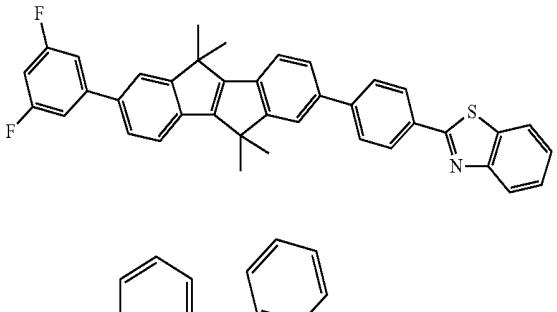

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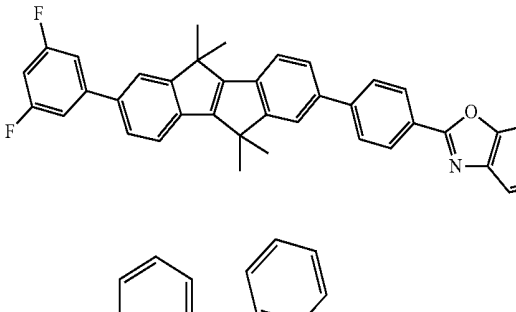

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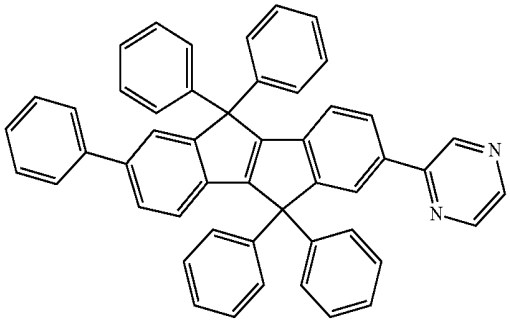

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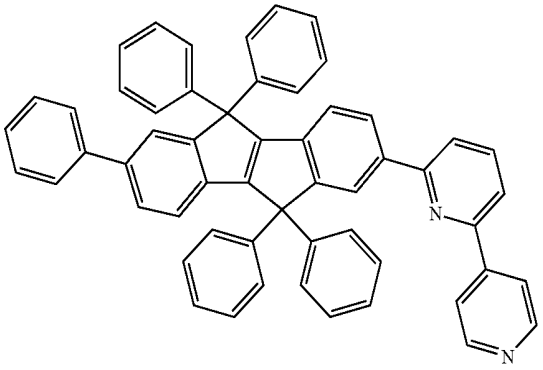

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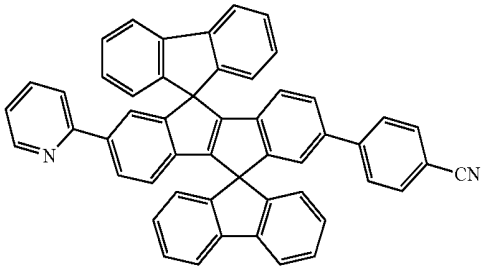

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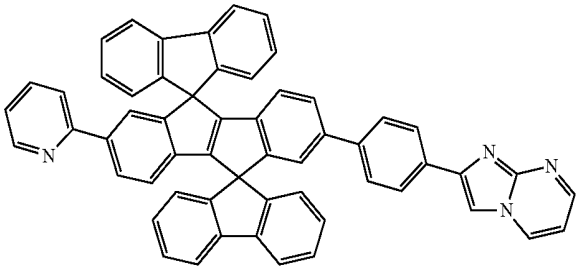

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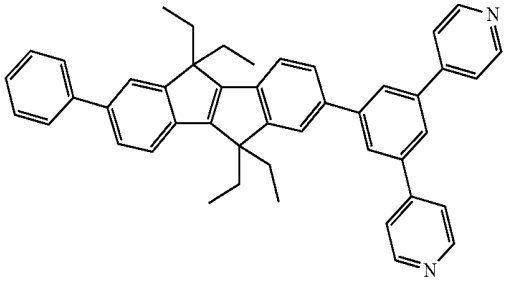

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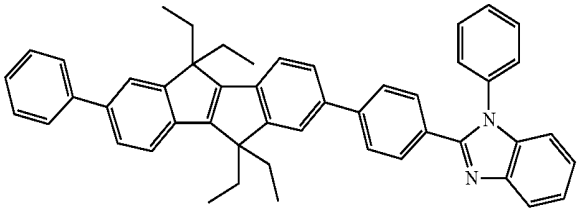

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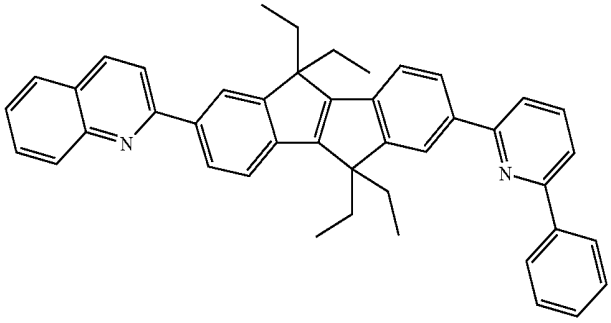

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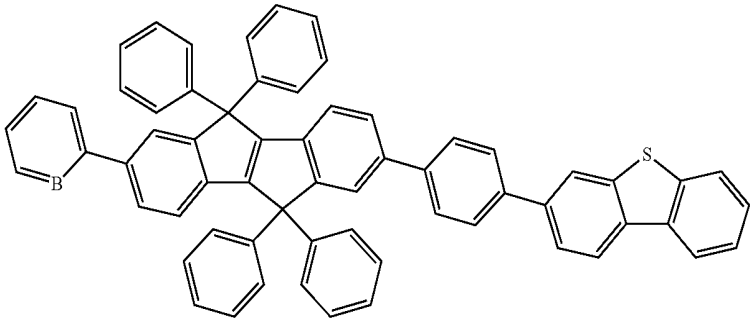

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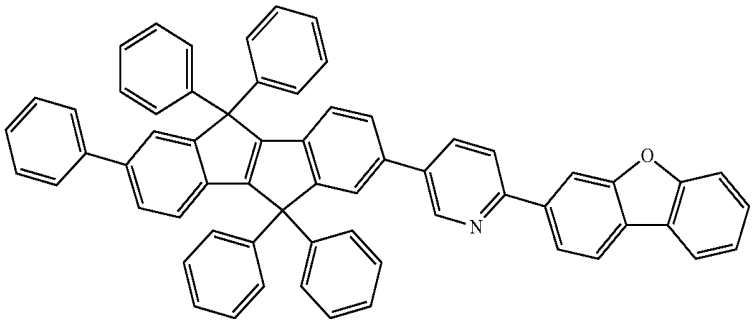

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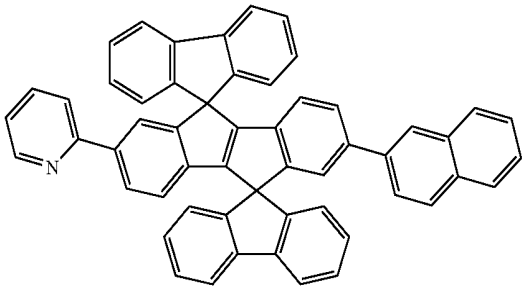

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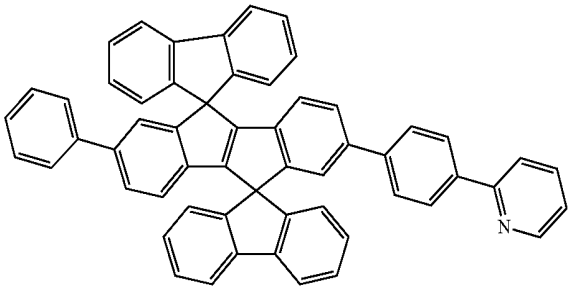

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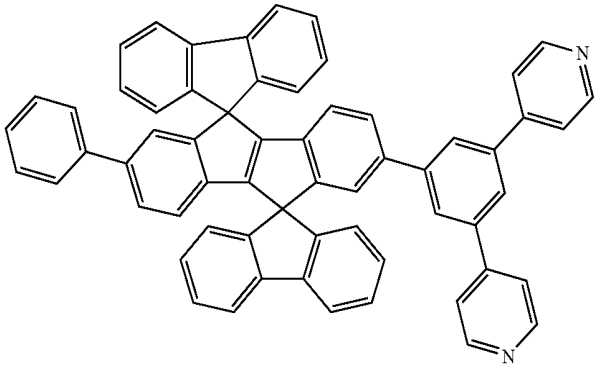


[0055] In Formula 1, "carbon" of the ring-forming atom of A_1 may be linked to the core of Formula 1 (a1=0) or L_1 (a1=1, 2, 3, 4, or 5) and include an indenoindene core, and thus, the condensed-cyclic compound of Formula 1 may have a high electron transporting ability.

[0056] Therefore, an organic light-emitting diode including the condensed-cyclic compound of Formula 1 may have a low driving voltage, a high efficiency, a high brightness, and a long lifetime.

[0057] The condensed-cyclic compound of Formula 1 may be synthesized using a known organic synthesis method. The synthesis method of the condensed-cyclic compound of Formula 1 may be easily understood by one of ordinary skill in the art with reference to Examples, which will be described later.

[0058] The condensed-cyclic compound of Formula 1 may be used between a pair of electrodes of an organic light-emitting diode (OLED). For example, the condensed-cyclic compound of Formula 1 may be used in an emission layer (EML) and/or in a layer between an EML and a cathode (e.g., an electron transport layer (ETL), an electron injection layer (EIL), or the like).

[0059] According to another embodiment, there is provided an OLED including a first electrode, a second electrode facing the first electrode, and an organic layer interposed between the first electrode and the second electrode, wherein the organic layer includes at least one of the condensed-cyclic compounds of Formula 1 described above.

[0060] The expression "the organic layer may include at least one of the condensed-cyclic compounds of Formula 1" as used herein means that the organic layer includes one of the condensed-cyclic compounds of Formula 1 or at least two different compounds selected from the condensed-cyclic compounds of Formula 1.

[0061] For example, the organic layer may include only Compound 6 above as the condensed-cyclic compound of Formula 1. In this regard, Compound 6 may be included in an ETL of the OLED. Alternatively, the organic layer may include Compounds 6 and 15 as the condensed-cyclic compound of Formula 1. In this regard, Compounds 6 and 15 may be included in the same layer (e.g., in an ETL) or in different layers (e.g., Compound 6 may be included in an ETL and Compound 15 may be included in an EML).

[0062] The organic layer may include at least one of a hole injection layer (HIL), a hole transport layer (HTL), a functional layer having hole injection and hole transport abilities (hereinafter, referred to as "H-functional layer"), a buffer layer, an electron blocking layer (EBL), an EML, a hole

blocking layer (HBL), an ETL, an electron injection layer (EIL), and a functional layer having electron transport and electron injection abilities (hereinafter, referred to as "E-functional layer").

[0063] The term "organic layer" used herein refers to a single layer or multiple layers interposed between the first electrode and the second electrode.

[0064] The organic layer may include an ETL, and the condensed-cyclic compound of Formula 1 may be included in the ETL.

[0065] The ETL may further include a metal-containing material, in addition to the condensed-cyclic compound of Formula 1.

[0066] FIG. **1** is a schematic cross-sectional view of an OLED **10** according to an embodiment. Hereinafter, structure and manufacturing method of an OLED will be described in more detail with reference to FIG. **1**.

[0067] A substrate **11** may be a substrate used in a general OLED, and may be a glass substrate or a transparent plastic substrate having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and waterproofness.

[0068] A first electrode **13** may be formed by applying a first electrode material on the substrate **11** by deposition or sputtering. When the first electrode **13** is an anode, the first electrode material may be selected from materials having a high work function so as to facilitate hole injection. The first electrode **13** may be a reflective electrode or a transparent electrode. Examples of the first electrode material may include indium-tin oxide (ITO), Indium-zinc-oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). Also, when magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) is used as the first electrode material, the first electrode **13** may be formed as a reflective electrode.

[0069] The first electrode **13** may be formed as a single layer or have a multi-layered structure having at least two layers. For example, the first electrode **13** may have a three-layered structure, e.g., ITO/Ag/ITO, but is not limited thereto.

[0070] An organic layer **15** is formed on the first electrode **13**.

[0071] The organic layer **15** may include a HIL, a HTL, a buffer layer, an EML, an ETL, and an EIL.

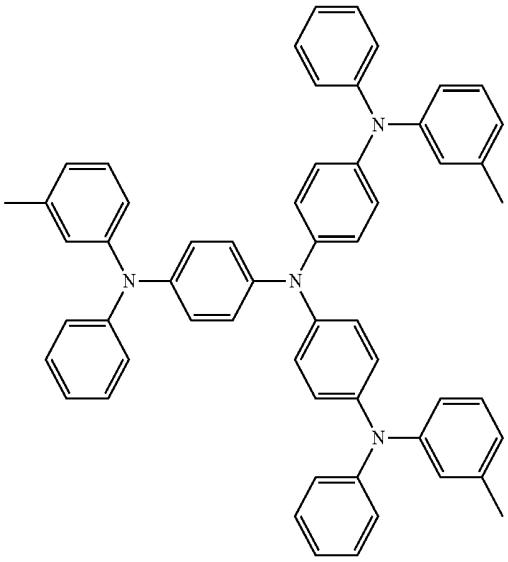
[0072] The HIL may be formed on the first electrode **13** by using various methods such as vacuum deposition, spin coating, casting, or LB deposition.

[0073] When the HIL is formed by vacuum deposition, the deposition conditions may vary according to a compound used as a material for forming the HIL, a structure of a desired HIL, and thermal characteristics. For example, the deposition condition may be, but is not limited to, a deposition temperature of about 100° C. to about 500° C., a degree of vacuum of about 10^{-8} torr to about 10^{-3} torr, and a deposition speed of about 0.01 to about 100 Å/sec.

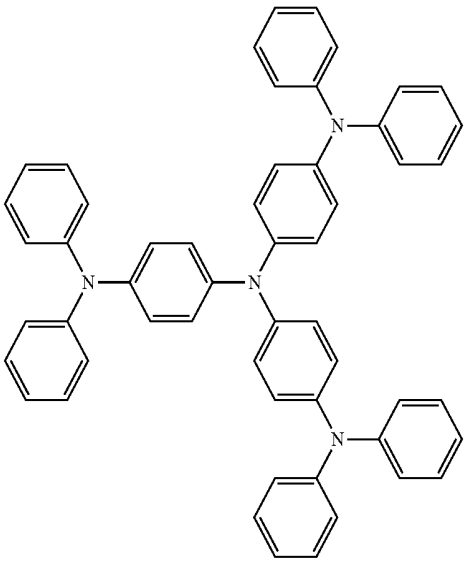
[0074] When the HIL is formed by spin coating, the coating condition may vary according to a compound used as a material for forming the HIL, a structure of a desired HIL, and thermal characteristics. For example, the coating condition may be, but is not limited to, a coating speed of about 2,000 rpm to about 5,000 rpm and a heat treatment temperature for removing a solvent after coating of about 80° C. to about 200° C.

[0075] The material for forming the HIL may be a known hole injection material. Examples of the known hole injection material include, but are limited to, N,N'-diphenyl-N,N'-bis-[4-(phenyl-m-tolyl-amino)-phenyl]-biphenyl-4,4'-diamine (DNTPD), a phthalocyanine compound such as copper phthalocyanine, 4,4',4"-tris(3-methylphenylphenylamino) triphenylamine (m-MTDATA), N,N'-di(1-naphthyl)-N,N'-diphenylbenzidine (NPB), TDATA, 2-TNATA, polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonicacid (PANI/CSA), and polyaniline/poly(4-styrenesulfonate) (PANI/PSS):

m-MTDATA



TDATA



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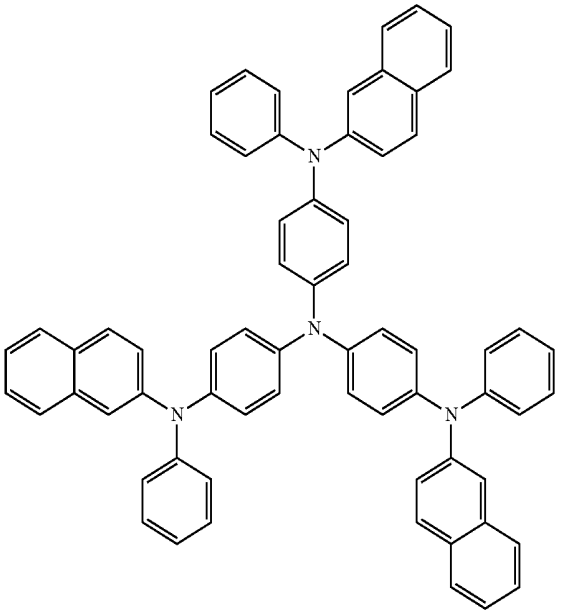
2-TNATA

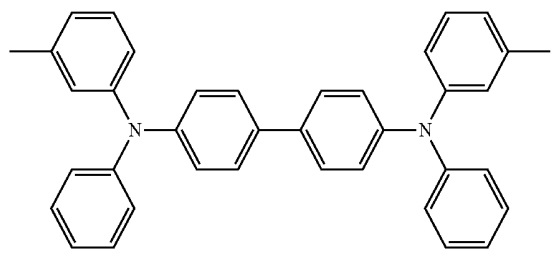


[0076] The thickness of the HIL may be in the range of about 100 Å to about 10,000 Å. In some embodiments, the thickness of the HIL may be in the range of about 100 Å to about 1,000 Å. When the thickness of the HIL is within these ranges, satisfactory hole injection properties may be obtained without a substantial increase in driving voltage.

[0077] An HTL may be formed on the HIL by using various methods such as vacuum deposition, spin coating, casting, or LB deposition. When the HTL is formed by vacuum deposition or spin coating, the deposition and coating conditions may vary according to a used compound. However, in general, the deposition and coating conditions may be almost the same as the condition for forming the HIL.

[0078] A known hole transporting material may be, for example, carbazole derivatives such as N-phenylcarbazole and polyvinylcarbazole, N,N-bis(3-methylphenyl)-N,N-diphenyl-[1,1-biphenyl]-4,4'-diamine (TPD), 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), and N,N'-di(1-naphthyl)-N,N'-diphenylbenzidine (NPB), but is not limited thereto.

TPD



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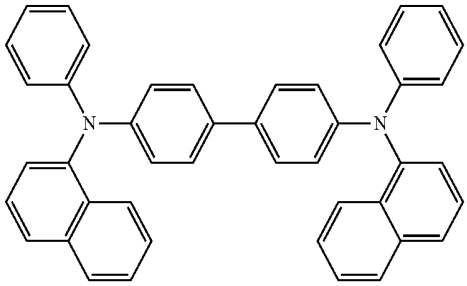
NPB

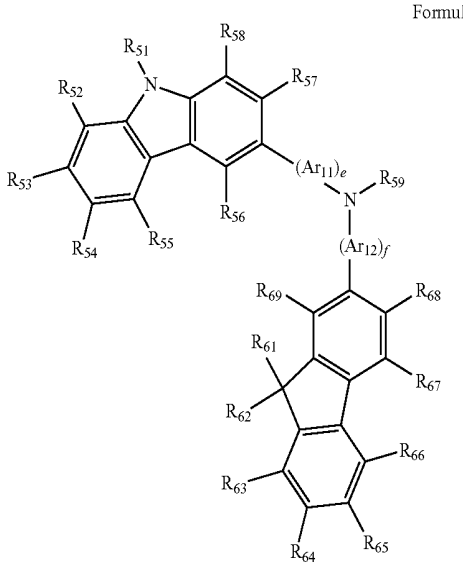


[0079] The thickness of the HTL may be in the range of about 50 Å to about 2,000 Å. In some embodiments, the thickness of the HTL may be in the range of about 100 Å to about 1,500 Å. When the thickness of the HTL is within these ranges, satisfactory hole transport properties may be obtained without a substantial increase in driving voltage.

[0080] At least one of the hole injection material and the hole transporting material as described above may be included in the H-functional layer. The thickness of the H-funcational layer may be in the range of about 500 Å to about 10,000 Å. In some embodiments, the thickness of the H-funcational layer may be in the range of about 100 Å to about 1,000 Å. When the thickness of the H-functional layer is within these ranges, satisfactory hole injection and hole transport properties may be obtained without a substantial increase in driving voltage.

[0081] At least one of the HIL, the HTL, and the H-functional layer may include at least one of compounds represented by Formulae 300 and 350 below:

Formula 300



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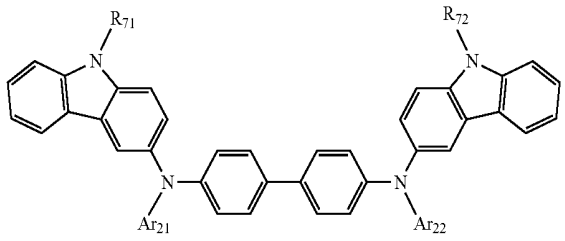
Formula 350



[0082] In Formulae 300 and 350, Ar_{11} and Ar_{12} may be each independently a substituted or unsubstituted C_6-C_{60} arylene group and Ar_{21} and Ar_{22} may be each independently a substituted or unsubstituted C_6-C_{60} aryl group. A detailed description of Ar_{11} and Ar_{12} may be found in the detailed description of L_1 above and a detailed description of Ar_{21} and Ar_{22} may be found in the detailed description of R_5 above.

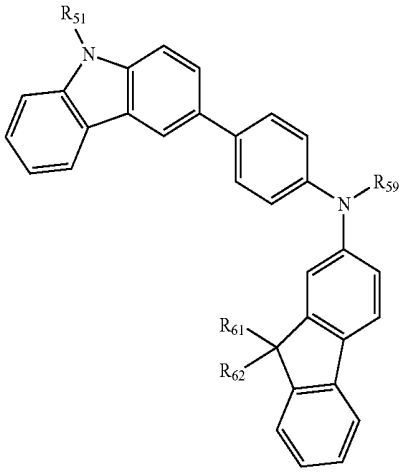
[0083] In Formula 300 above, e and f may be each independently an integer of 0 to 5. In some embodiments, e and f may be each independently 0, 1, or 2. For example, e may be 1 and f may be 0, however, e and f are not limited to the above example.

[0084] In Formulae 300 and 350 above, R_{51} through R_{58}, R_{61} through R_{69}, and R_{71} and R_{72} may be each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{60} cycloalkyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, or a substituted or unsubstituted C_6-C_{60} arylthio group. For example, R_{51} through R_{58}, R_{61} through R_{69}, and R_{71} and R_{72} may be each independently one of hydrogen; deuterium; a halogen atom; a hydroxyl group; a cyano group; a nitro group; an amino group; an amidino group; hydrazine; hydrazone; a carboxyl group or a salt thereof; a sulfonic acid group or a salt thereof; a phosphoric acid or a salt thereof; a C_1-C_{10} alkyl group (e.g., methyl, ethyl, propyl, butyl, pentyl, hexyl, and the like), a C_1-C_{10} alkoxy group (e.g., methoxy, ethoxy, propoxy, butoxy, pentoxy, and the like); a C_1-C_{10} alkyl group and a C_1-C_{10} alkoxy group that is substituted with at least one of deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid or a salt thereof; a phenyl group; a naphthyl group; an anthryl group; a fluorenyl group; a pyrenyl group; and a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, and a pyrenyl group that is substituted with at least one of deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group, but are not limited thereto.

[0085] In Formula 300 above, R_{59} may be one of a phenyl group; a naphthyl group; an anthryl group; a biphenyl group; a pyridinyl group; and a phenyl group, a naphthyl group, an anthryl group, a biphenyl group, and a pyridinyl group that is substituted with at least one of deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{20} alkyl group, and a substituted or unsubstituted C_1-C_{20} alkoxy group.

[0086] According to an embodiment, the compound of Formula 300 may be represented by Formula 300A below, but is not limited thereto:

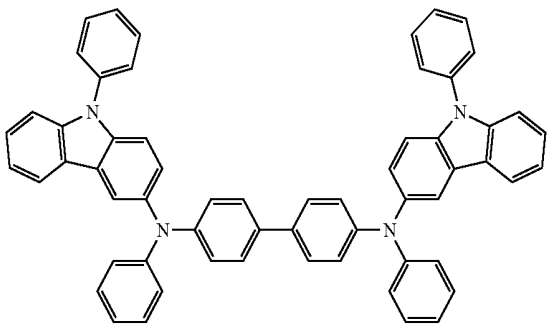
Formula 300A



[0087] In Formula 300A, a detailed description of R_{51}, R_{60}, R_{61}, and R_{59} may be the same as already provided above.

[0088] For example, at least one of the HIL, the HTL, and the H-functional layer may include at least one of Compounds 301 through 320 below, but is not limited thereto:

301



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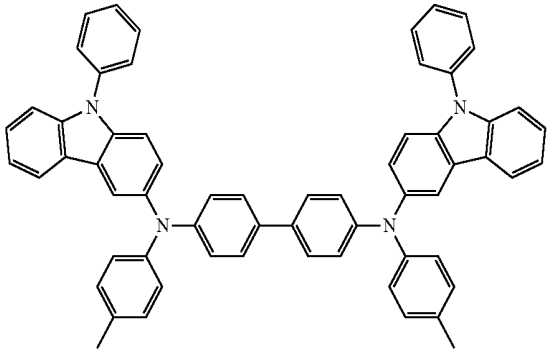
302



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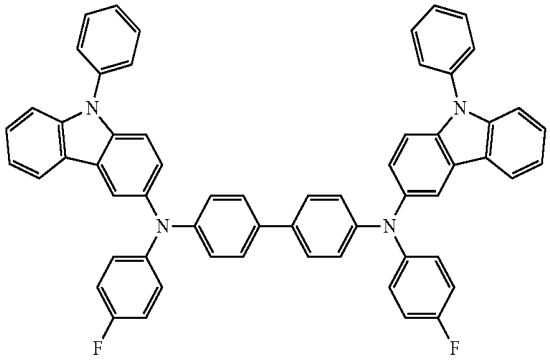

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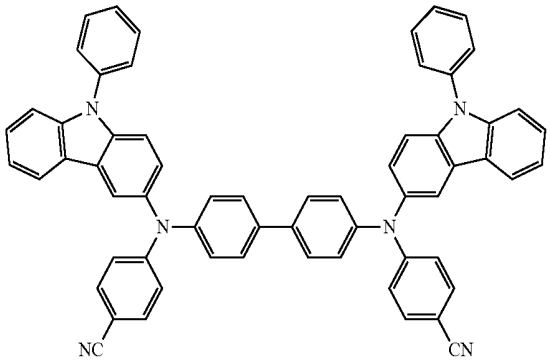

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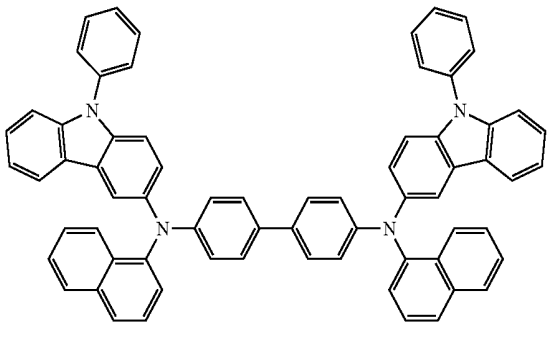

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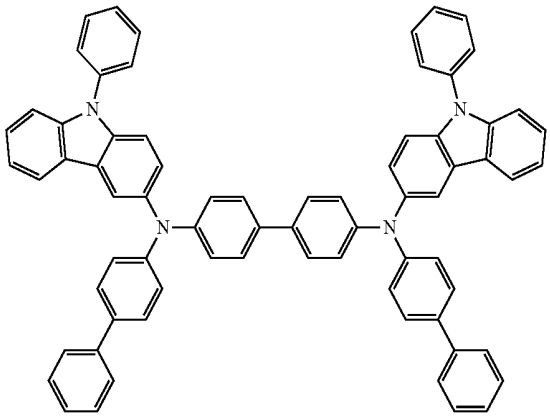
306



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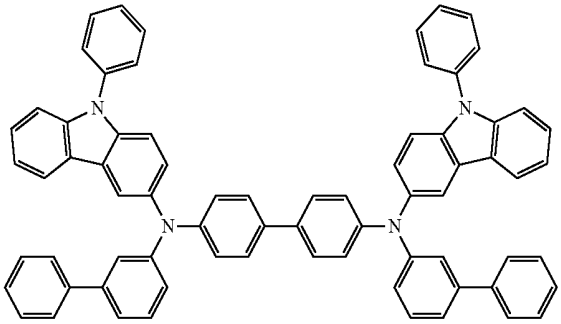

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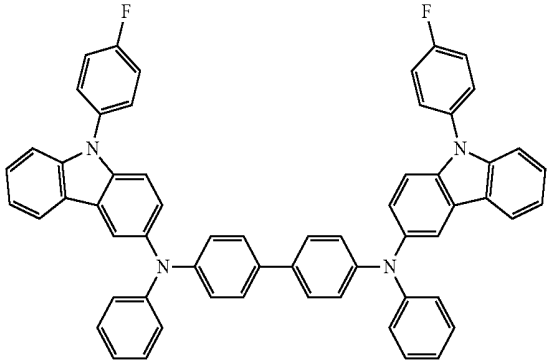

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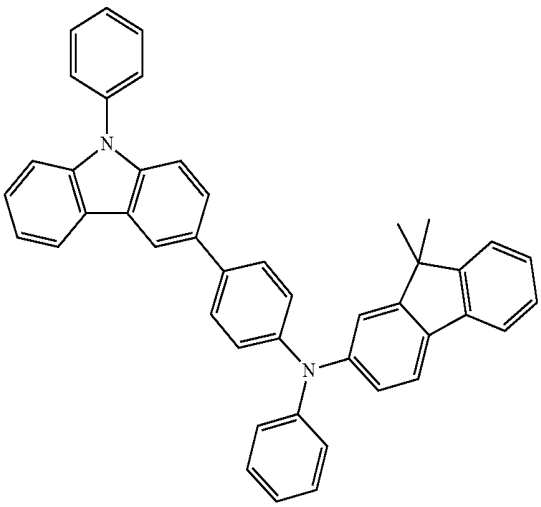

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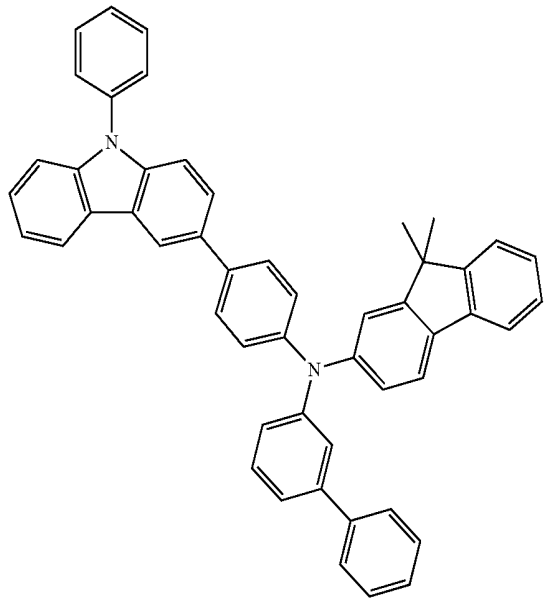

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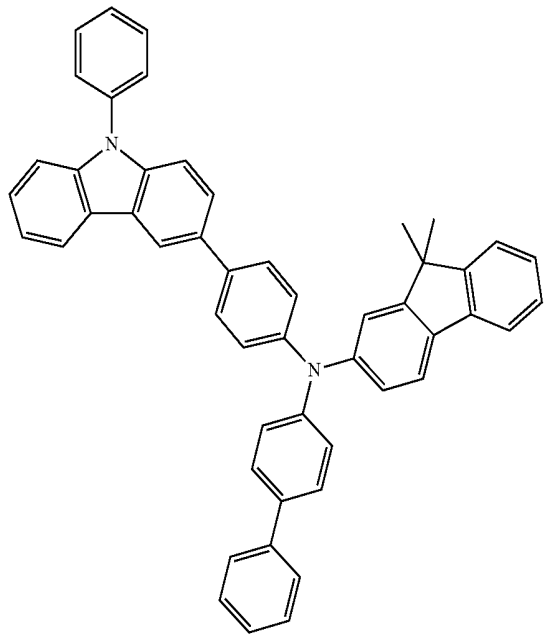

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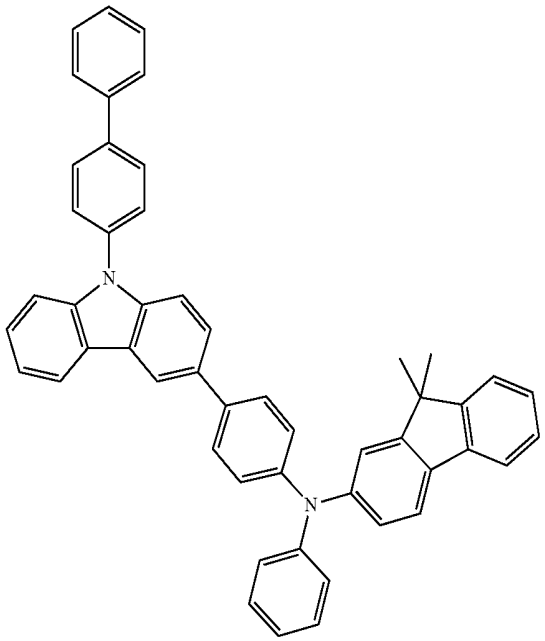

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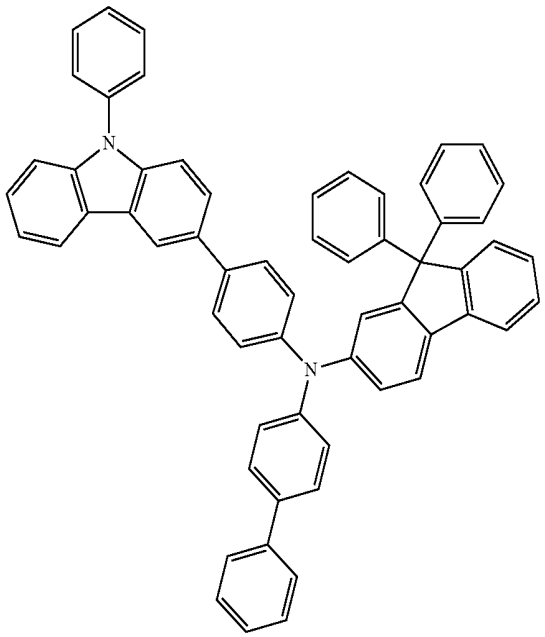

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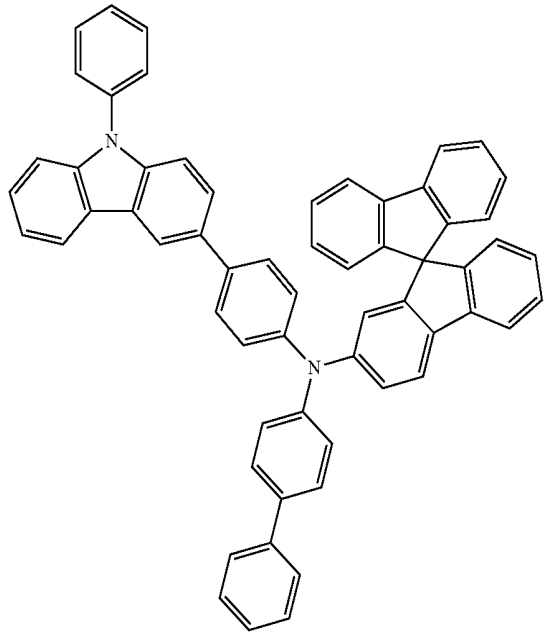

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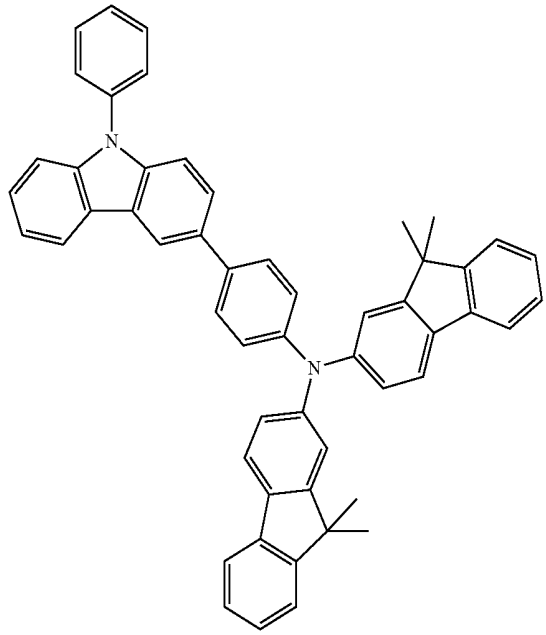

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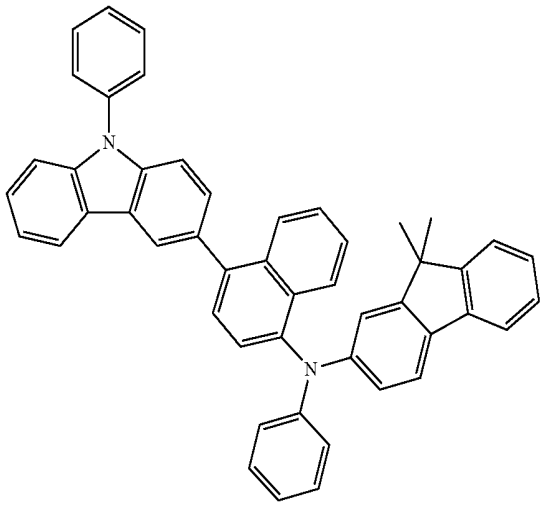
316



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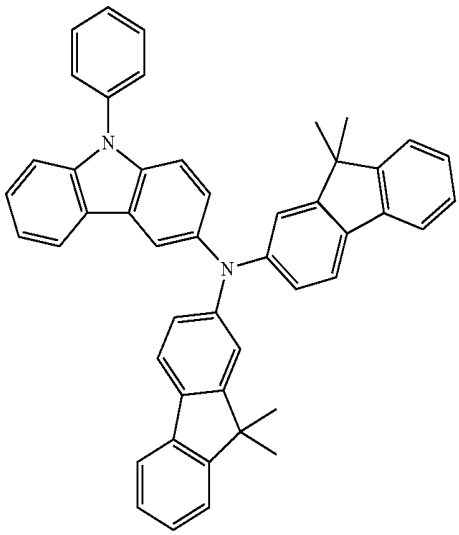

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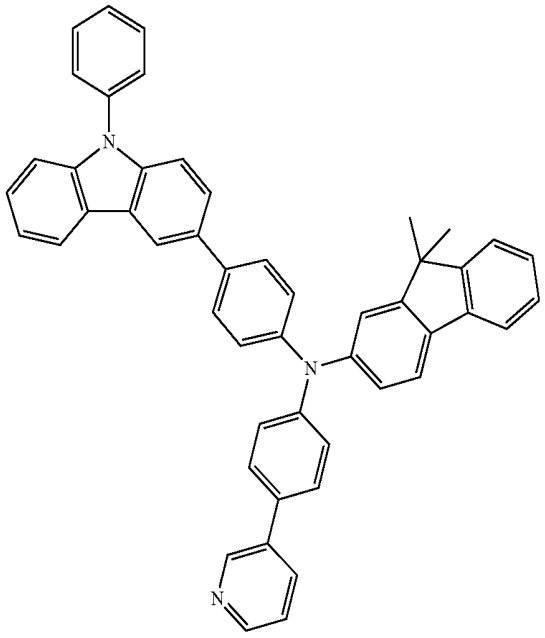

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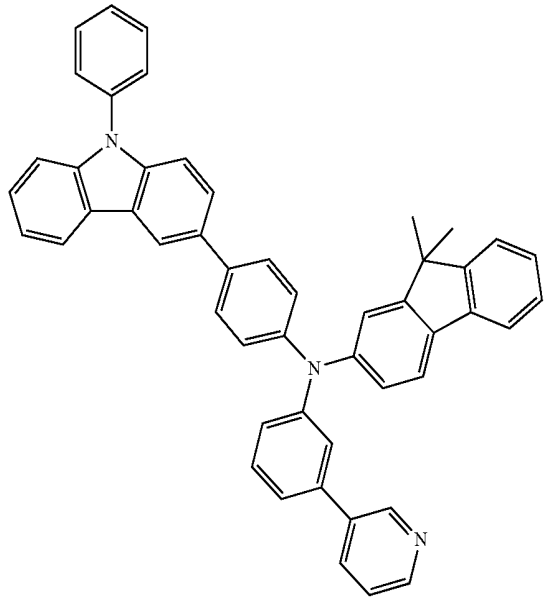
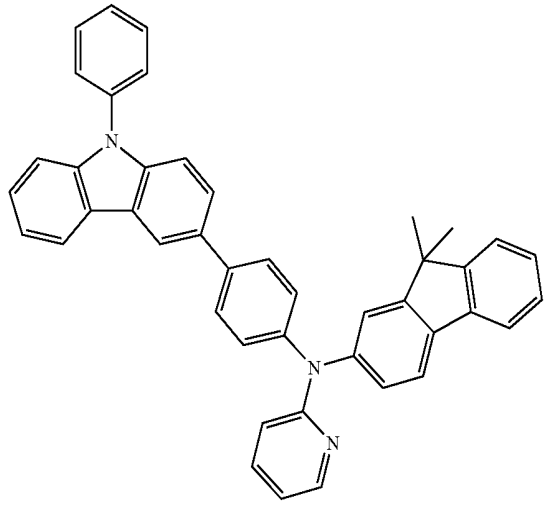
319



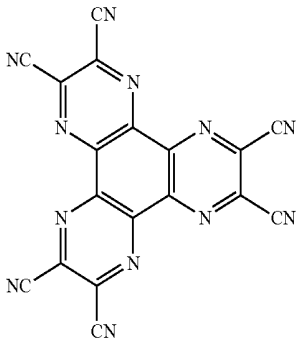
320



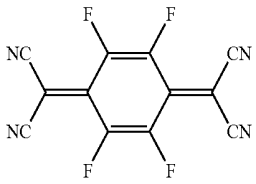
[0089] At least one of the HIL, the HTL, and the H-functional layer may further include a charge-generating material so as to increase the conductivity of the layers, in addition to the known hole injection material, the known hole transporting material and/or the material for forming the H-functional layer having hole injection and hole transport abilities.

[0090] The charge-generating material may be, for example, a p-dopant. The p-dopant may be one of a quinone derivative, a metal oxide, and a cyano-containing compound, but is not limited thereto. Examples of the p-dopant may include, but are not limited to, quinone derivatives such as tetra-cyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinodimethane (F4-TCNQ); metal oxides such as an tungsten oxide and a molybdenum oxide; and cyano-containing compounds such as Compound 200 below and the like.

Compound 200



F4-TCNQ



[0091] When the HIL, the HTL, or the H-functional layer further includes the charge-generating material, the charge-generating material may be homogeneously or inhomogeneously dispersed in the HIL, the HTL, or the H-functional layer.

[0092] A buffer layer may be interposed between the EML and at least one of the HIL, the HTL, and the H-functional layer. The buffer layer increases efficiency by compensating for an optical resonance distance according to the wavelength of light emitted from the EML. The buffer layer may include a known hole injection material and a known hole transporting material. Also, the buffer layer may include the same material as one of the materials included in the HIL, the HTL, and the H-functional layer.

[0093] An EML may be formed on the HTL, the H-functional layer, or the buffer layer by vacuum deposition, spin coating, casting, or LB deposition. When the EML is formed by vacuum deposition or spin coating, the deposition and coating conditions may vary according to a used compound. However, in general, the deposition and coating conditions may be almost the same as the condition for forming the HIL.

[0094] The EML may include a host and a dopant.

[0095] Examples of the host may include, but are not limited to, Tris(8-hydroxyquinolinato)aluminium (Alq3), 4,4'-N,N'-dicabazole-biphenyl (CBP), poly(n-vinylcabazole) (PVK), 9,10-di(naphthalene-2-yl)anthracene (ADN), 4,4',4"-tris(N-carbazolyl)-triphenylamine (TCTA), 1,3,5-tris(N-phenylbenzimidazole-2-yl)benzene (TPBI), 3-tert-butyl-9, 10-di(naphth-2-yl) anthracene (TBADN), E3, and distyrylarylene (DSA), dmCBP (see Formula below), and Compounds 501 through 509 below.

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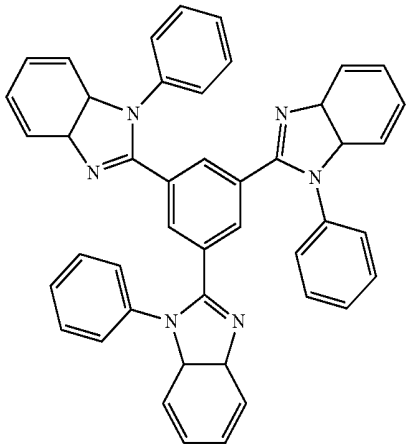
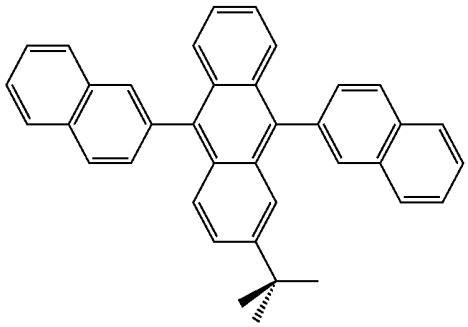
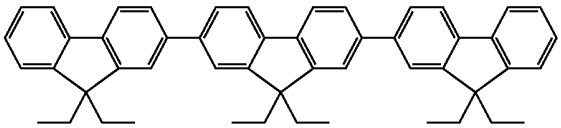
TPBI



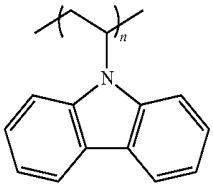
TBADN



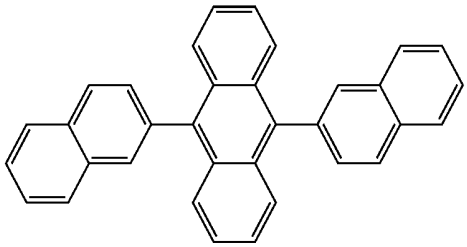
E3



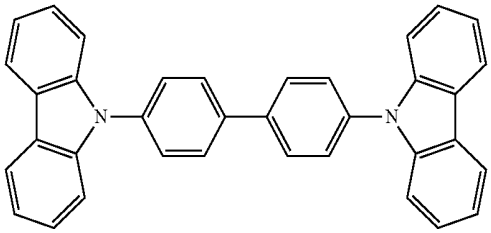
PVK



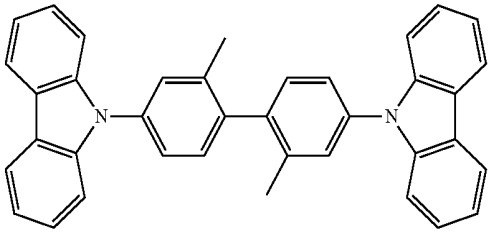
ADN



CBP



dmCBP



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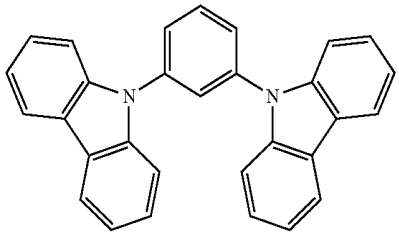

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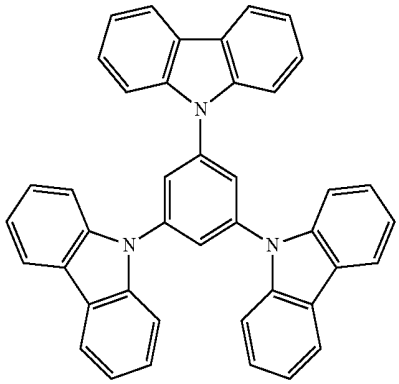

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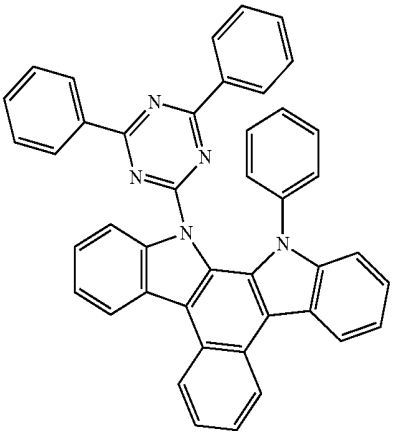

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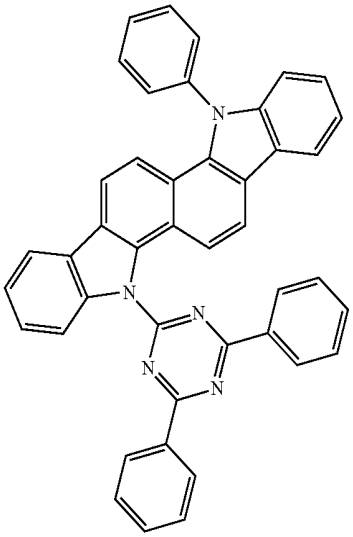

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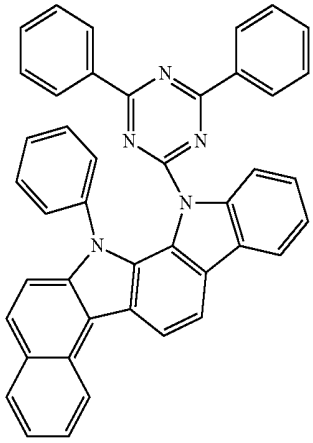

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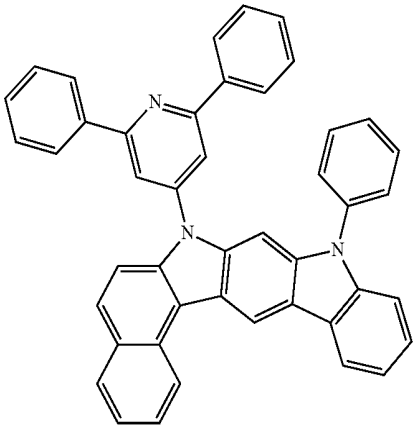

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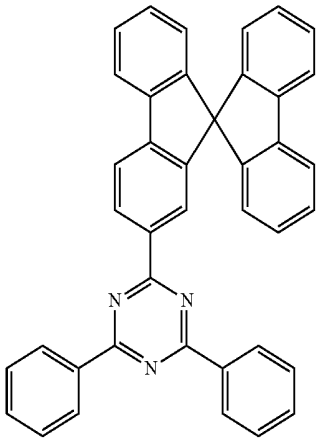

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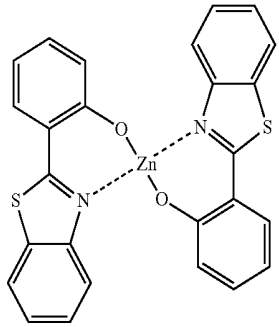

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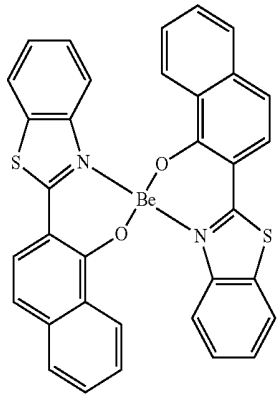
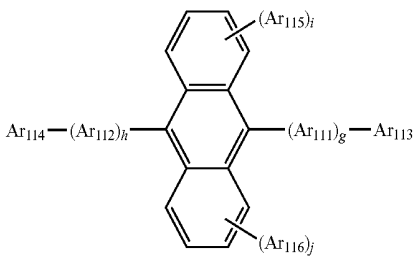


[0096] Also, the host may be an anthracene-based compound represented by Formula 400 below:

Formula 400



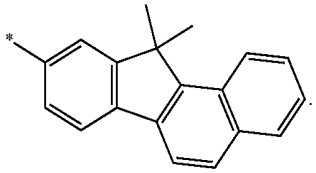
[0097] In Formula 400, Ar_{111} and Ar_{112} may be each independently a substituted or unsubstituted C_6-C_{60} arylene group; Ar_{113} through Ar_{116} may be each independently a

substituted or unsubstituted C_1-C_{10} alkyl group or a substituted or unsubstituted C_6-C_{60} aryl group; and g, h, i, and j may be each independently an integer of 0 to 4.

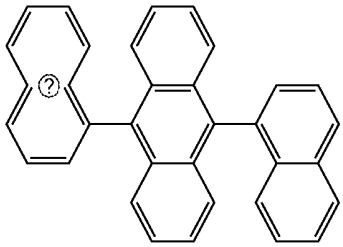
[0098] For example, in Formula 400 above, Ar_{111} and Ar_{112} may be each independently a phenylene group; a naphthylene group; a phenanthrenylene group; a pyrenylene group; or a phenylene group, a naphthylene group, a phenanthrenylene group, a fluorenyl group, or a pyrenylene group that is substituted with at least one of a phenyl group, a naphthyl group, and an anthryl group, but are not limited thereto.

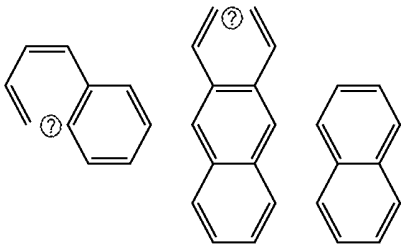
[0099] In Formula 400 above, g, h, i, and j may be each independently 0, 1, or 2.

[0100] In Formula 400 above, Ar_{113} through Ar_{116} may be each independently, but are not limited to, a C_1-C_{10} alkyl group that is substituted with at least one of a phenyl group, a naphthyl group, and an anthryl group; a phenyl group; a naphthyl group; an anthryl group; a pyrenyl group; a phenanthrenyl group; a fluorenyl group; a phenyl group, a naphthyl group, an anthryl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group that is substituted with at least one of deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a phenyl group, a naphthyl group, an anthryl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group; and



[0101] For example, the anthracene-based compound of Formula 400 may be, but is not limited to, one of the compounds below:





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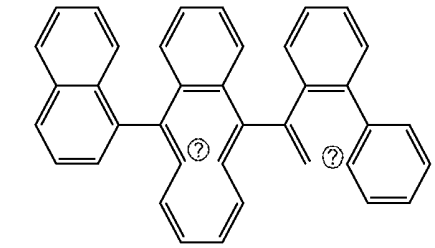

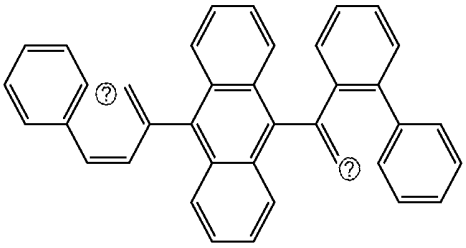

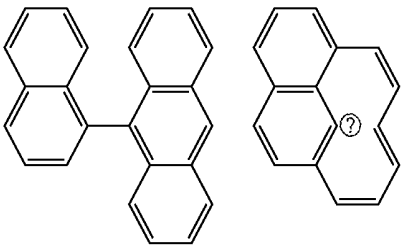

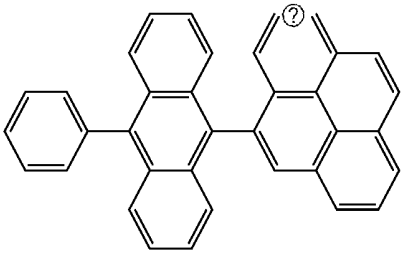

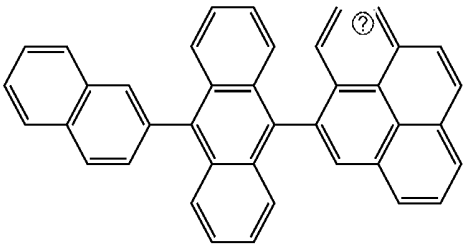

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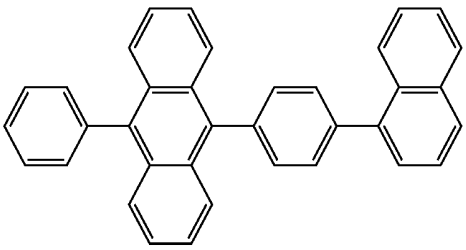

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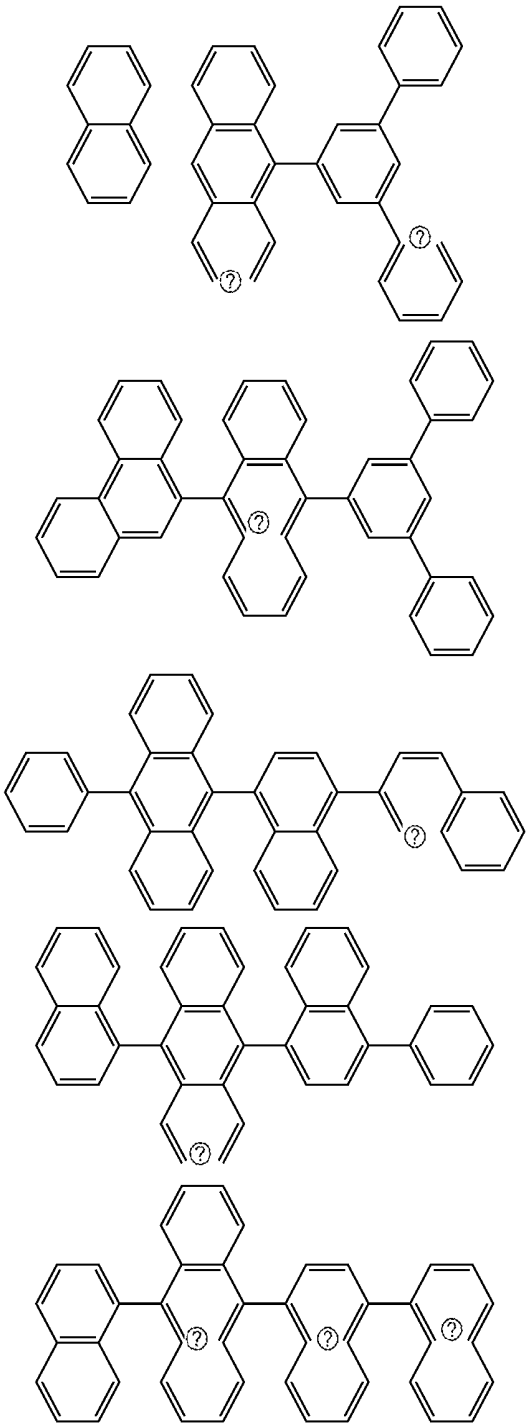

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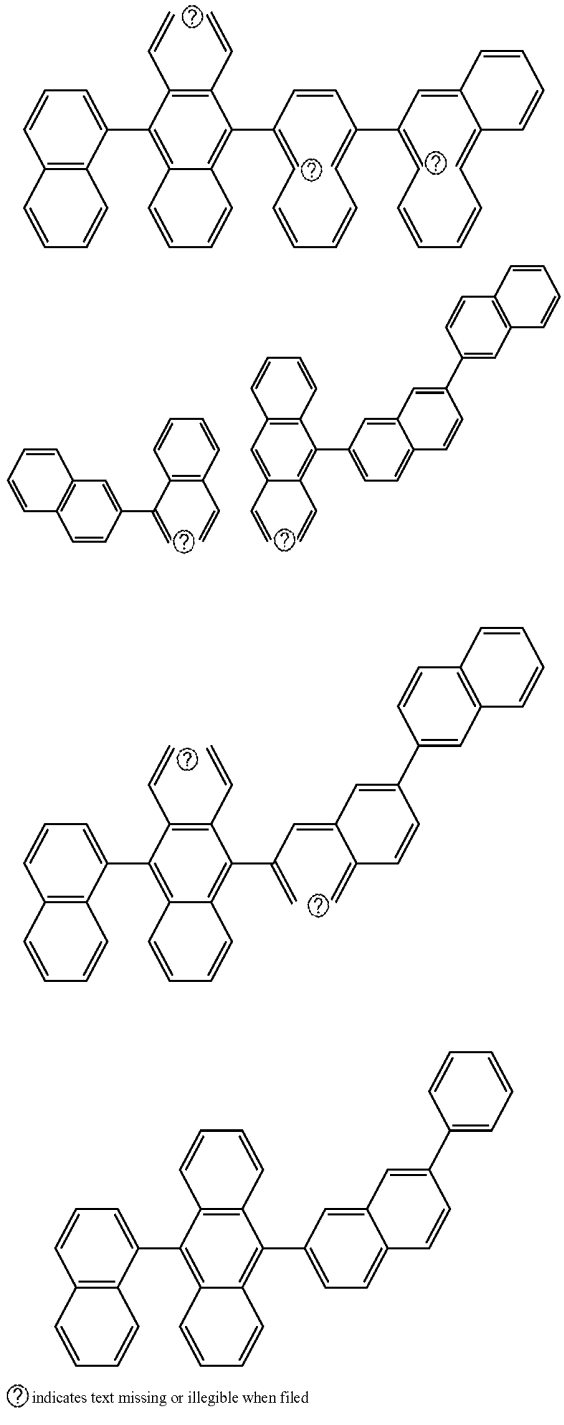

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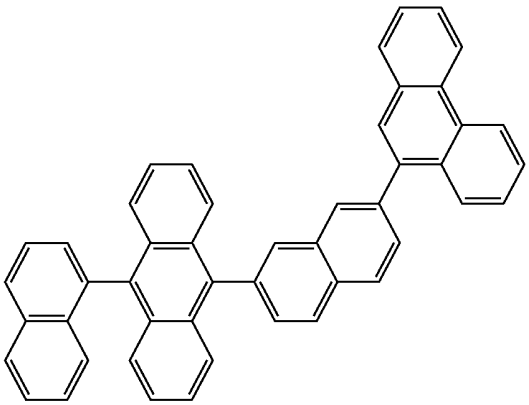

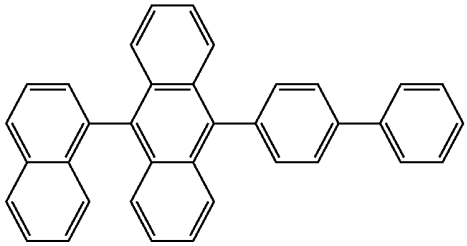

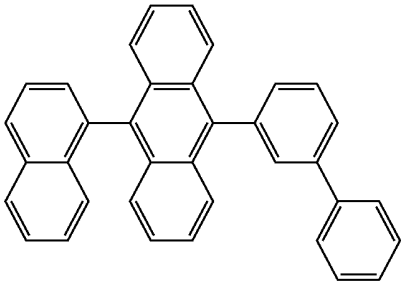

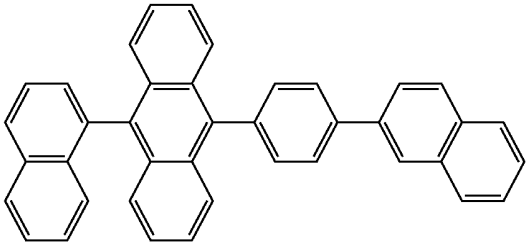

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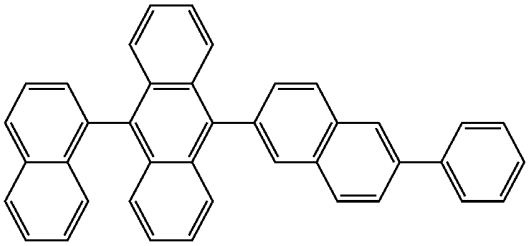

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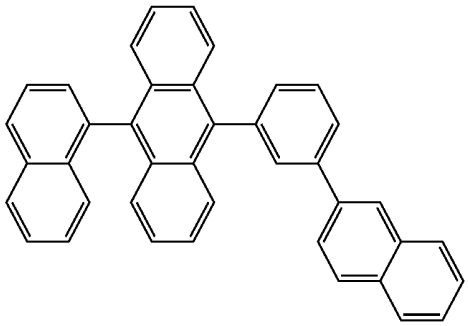

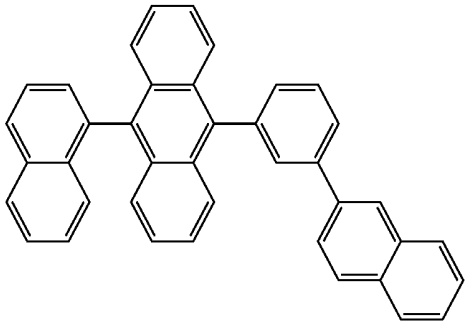

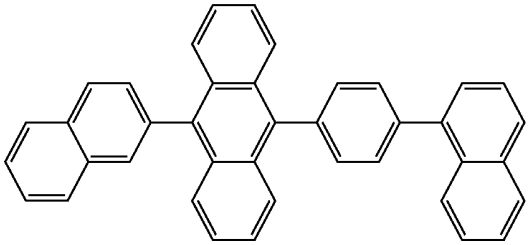

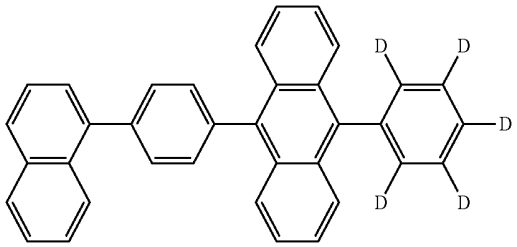

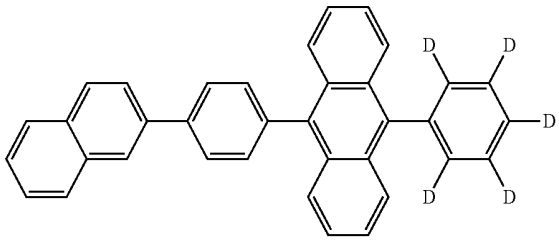

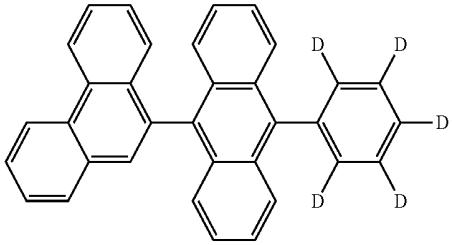

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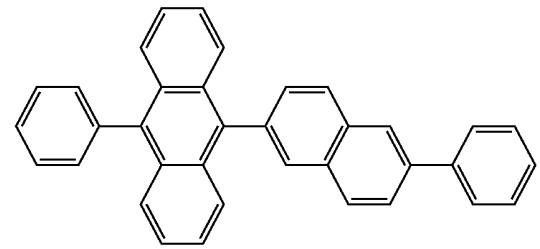

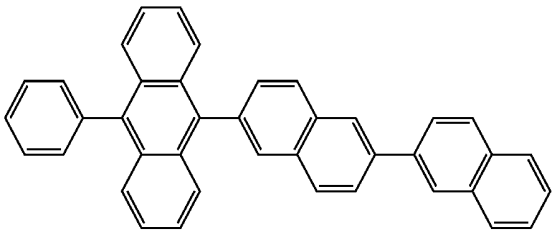

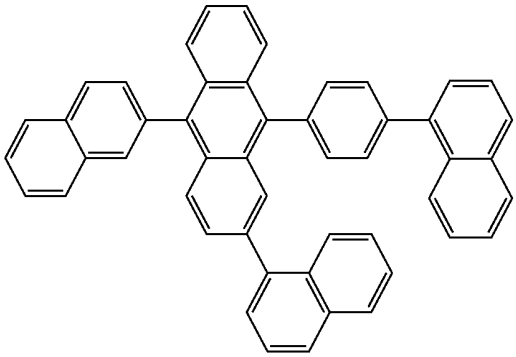

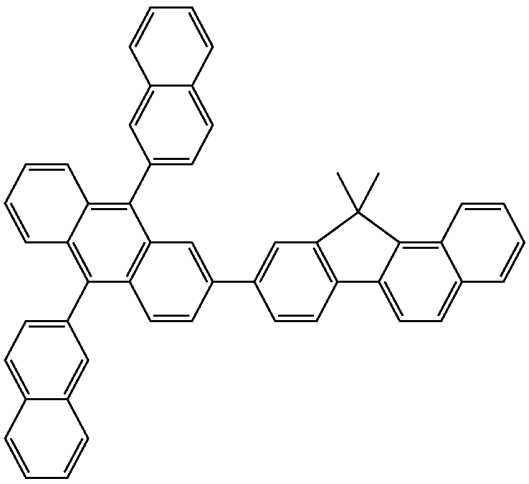

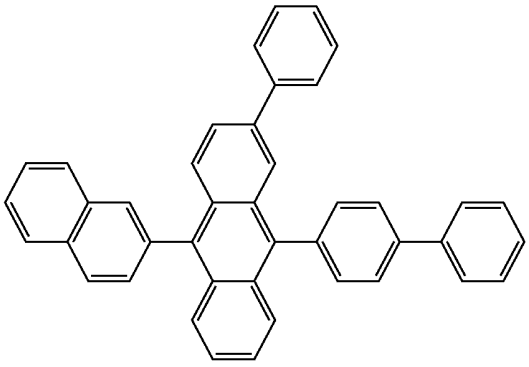

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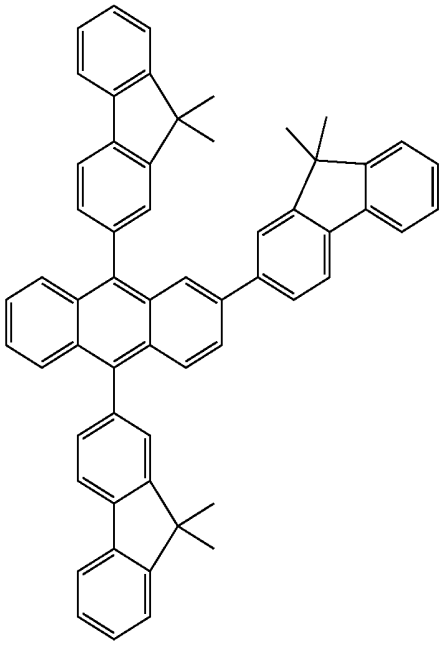

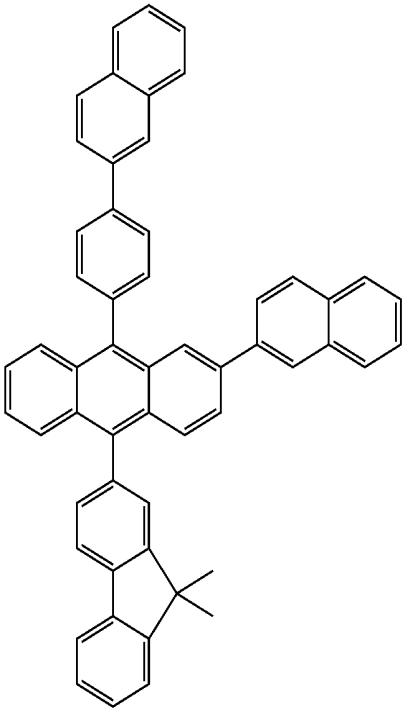

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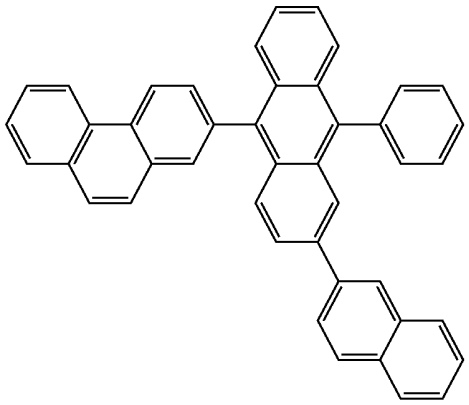
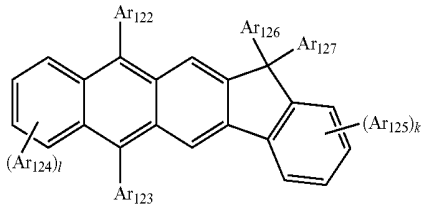


[0102] Also, an anthracene-based compound represented by Formula 401 below may be used as the host:

Formula 401

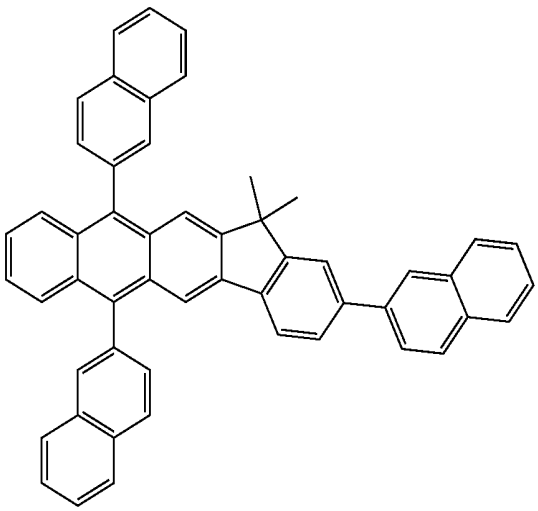


[0103] In Formula 401, a detailed description of Ar_{122} through Ar_{125} is provided above in the description of Ar_{113} of Formula 400.

[0104] In Formula 401 above, Ar_{126} and Ar_{127} may be each independently a C_1-C_{10} alkyl group (e.g., a methyl group, an ethyl group, or a propyl group).

[0105] In Formula 401 above, k and l may be each independently an integer of 0 to 4. For example, k and l may be each independently 0, 1, or 2.

[0106] For example, the anthrecene-based compound of Formula 401 may be, but is not limited to, one of the following compounds.



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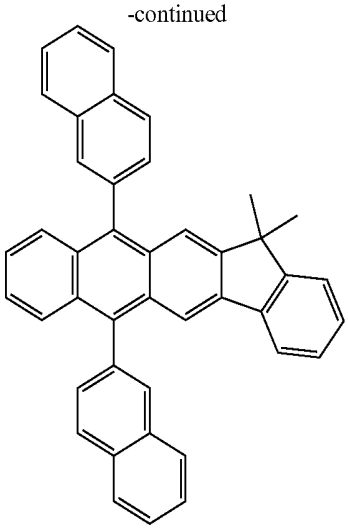
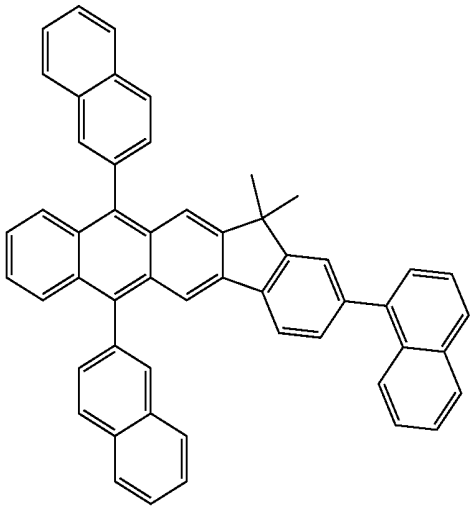
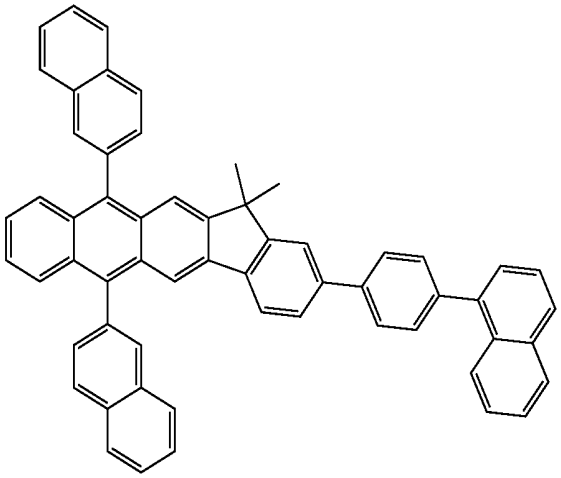


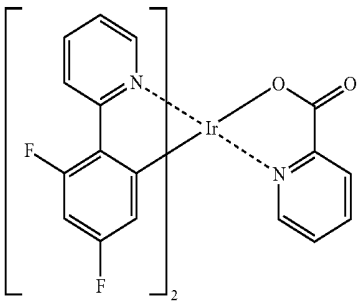




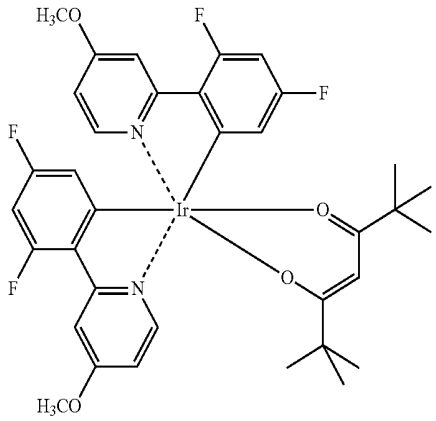
[0107] When the OLED is a full-color OLED, the EML may be patterned as a red EML, a green EML, and a blue EML.

[0108] In this regard, at least one of the red EML, the green EML, and the blue EML may include the following dopants (ppy=phenylpyridine).

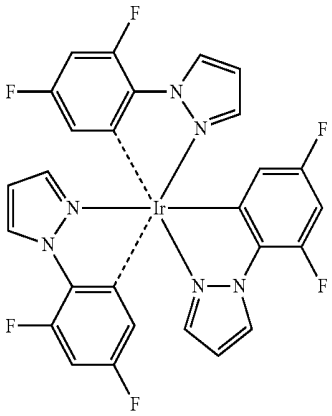
[0109] For example, compounds described below may be used as blue dopants, but are not limited thereto.



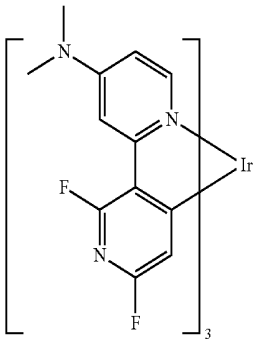
F_2Irpic

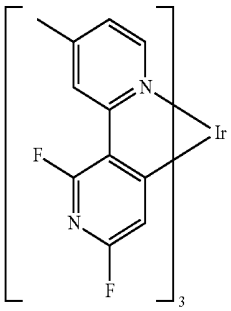


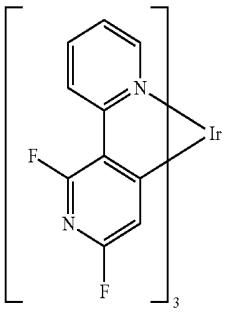
(F2ppy)2Ir(tmd)

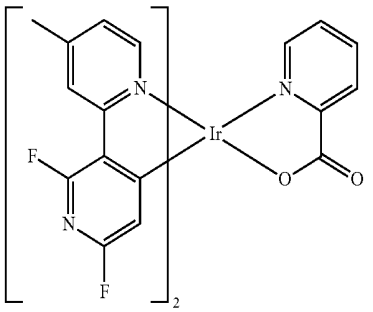


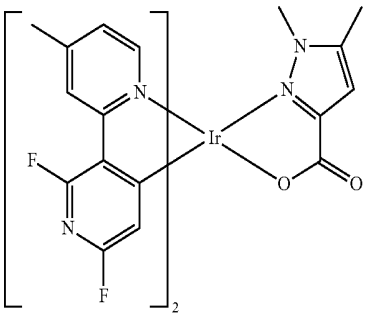
$Ir(dfppz)_3$

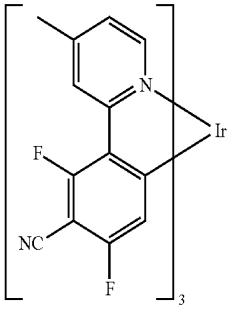


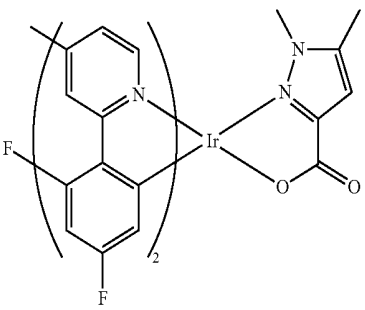


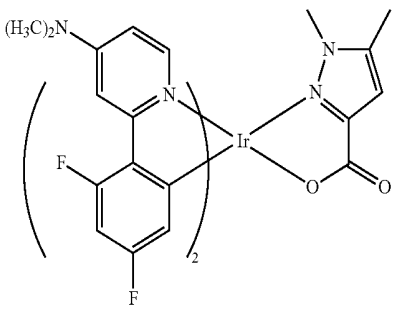












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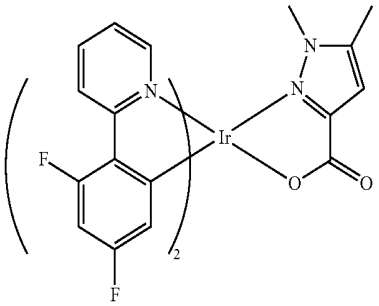
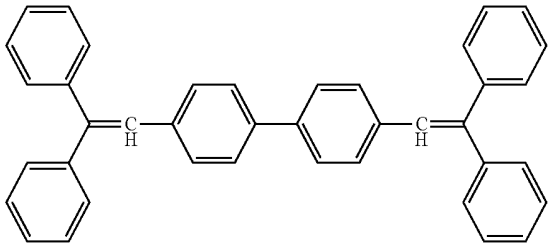
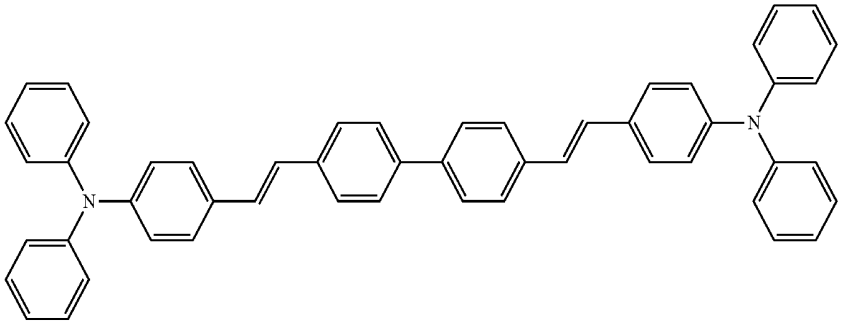
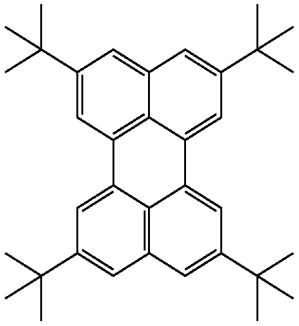




DPVBi



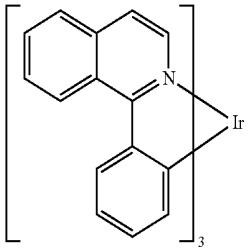
DPAVBi



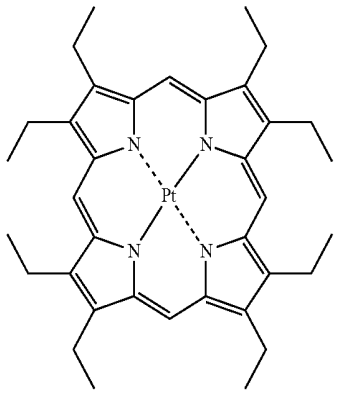
TBPe

[0110] For example, compounds described below may be used as red dopants, but are not limited thereto. Alternatively, DCM or DCJTB, which will be described below, may be used as the red dopant.

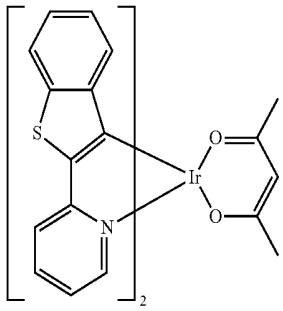
-continued



$Ir(piq)_3$



PtOEP



$Btp_2Ir(acac)$

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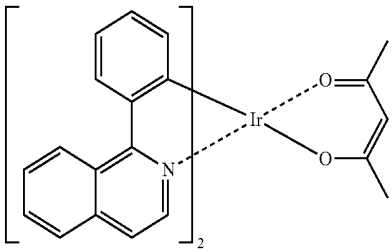
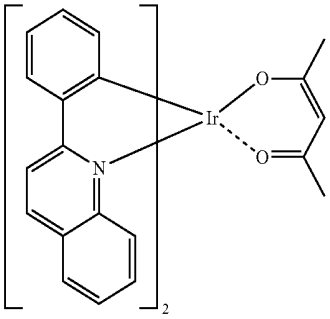
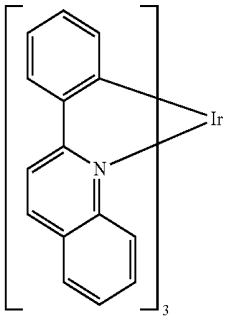
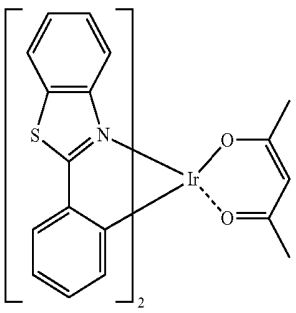




$Ir(pq)_2(acac)$



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



$Ir(BT)_2(acac)$

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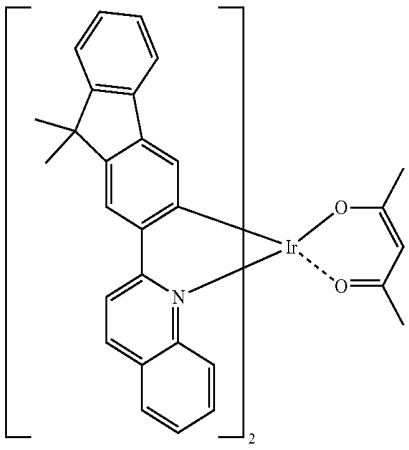
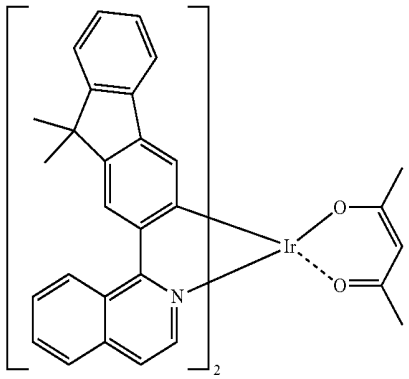
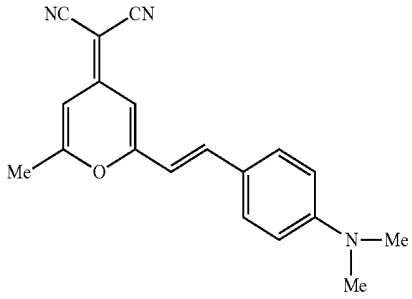


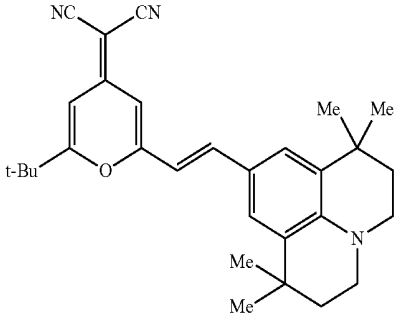
$Ir(flq)_2(acac)$



$Ir(fliq)_2(acac)$

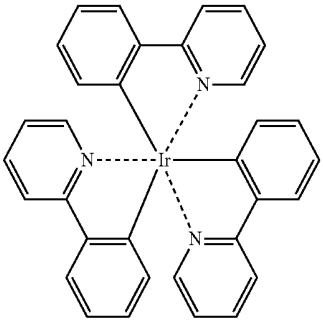


DCM

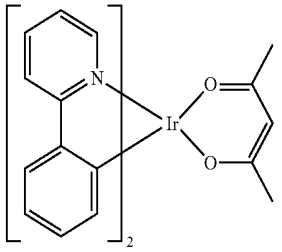


DCJTB

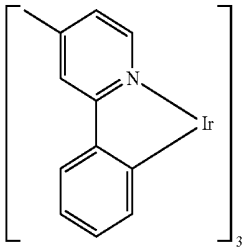
[0111] For example, compounds described below may be used as green dopants, but are not limited thereto. Alternatively, C545T below may be used as a green dopant.



$Ir(ppy)_3$

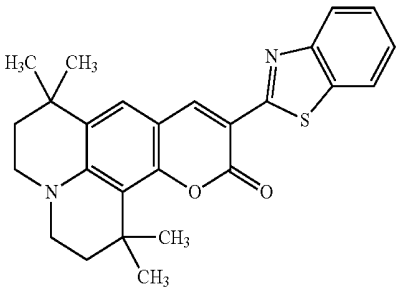


$Ir(ppy)_2(acac)$



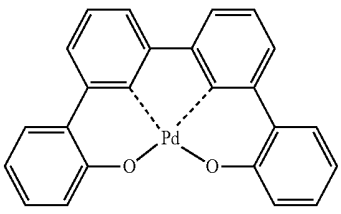
$Ir(mpyp)_3$

C545T



[0112] Examples of the dopant included in the EML include complexes below, but are not limited thereto:

D1



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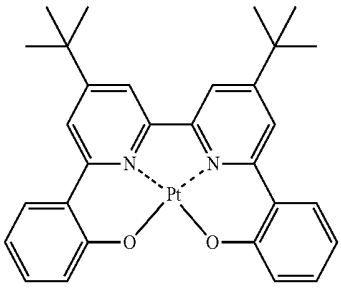
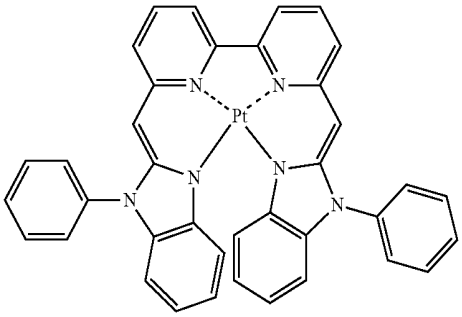
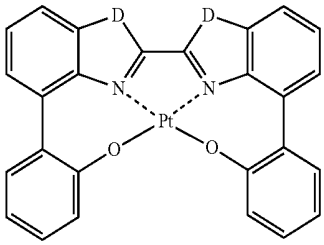
D2



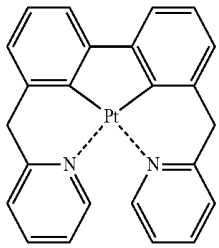
D3



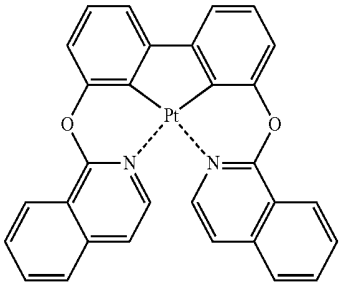
D4



D5



D6



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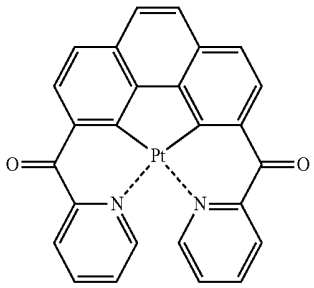
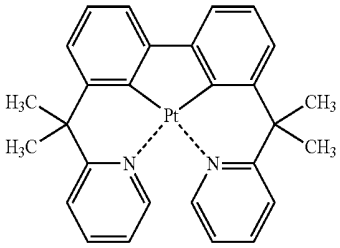
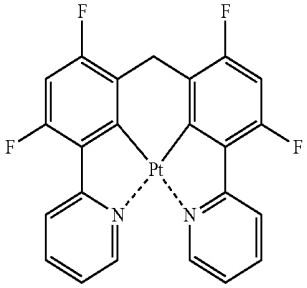
D7



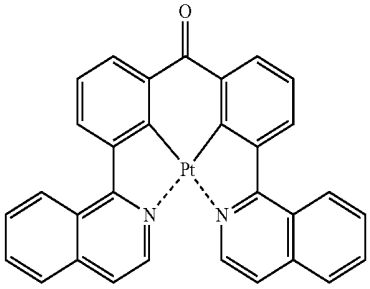
D8



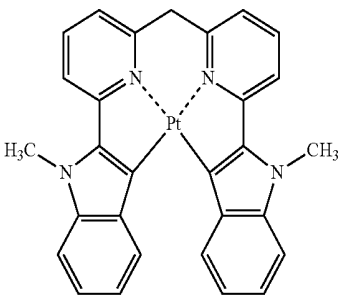
D9



D10



D11



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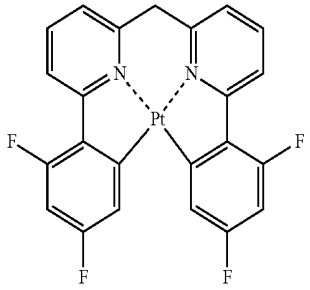
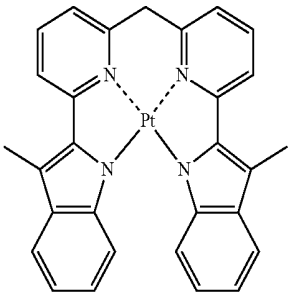
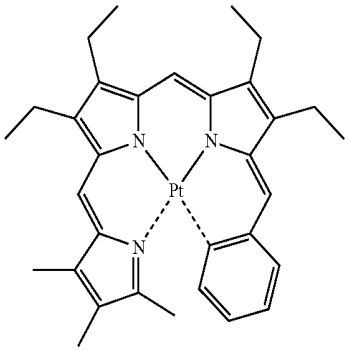
D12



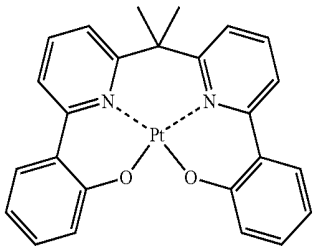
D13



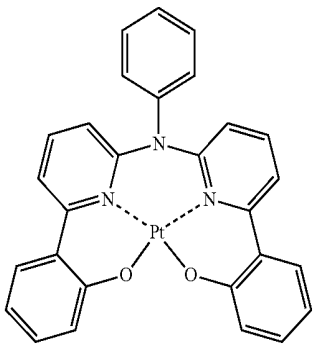
D14



D15



D16



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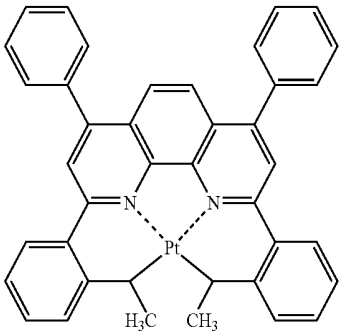
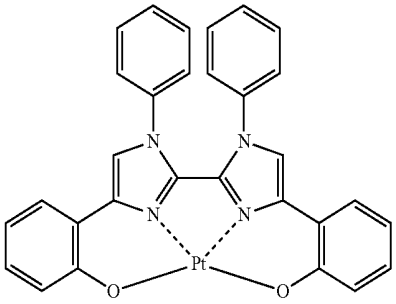
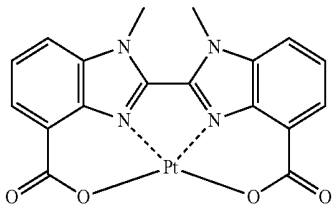
D17



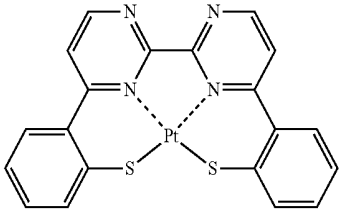
D18



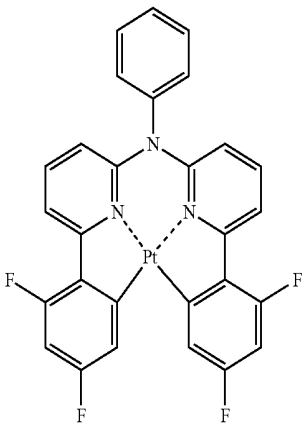
D19



D20



D21



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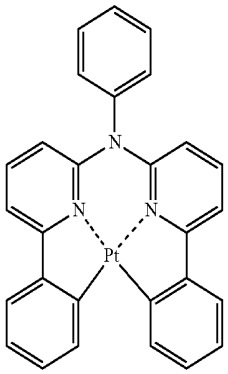
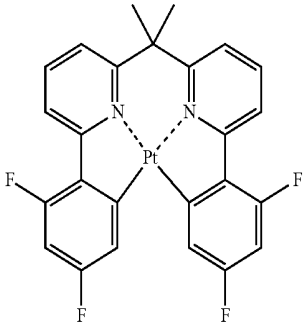
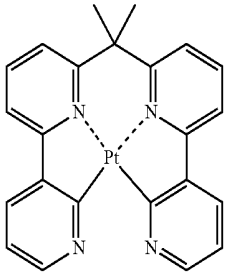
D22



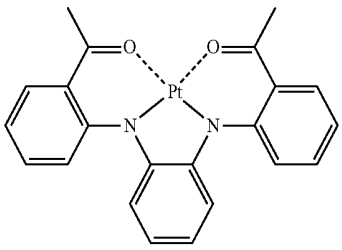
D23



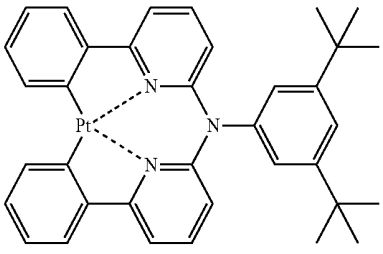
D24



D25



D26



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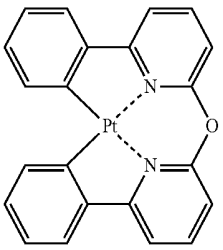

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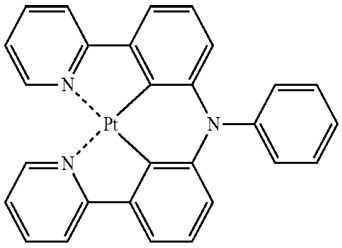

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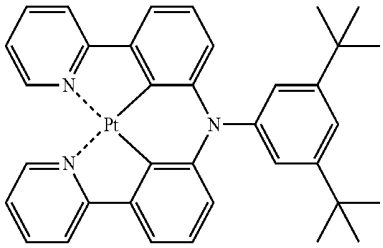

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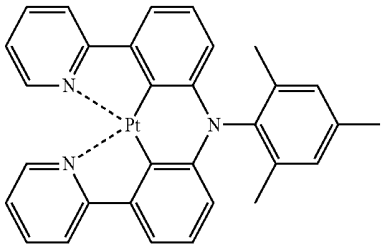

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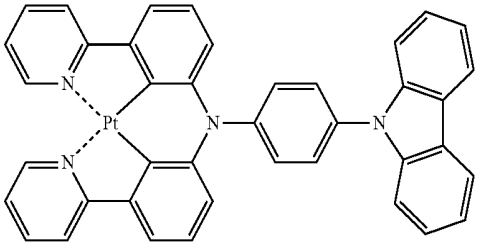

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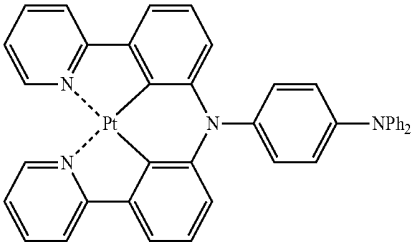

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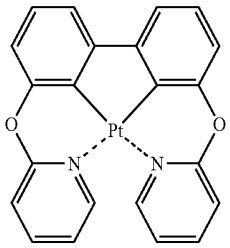

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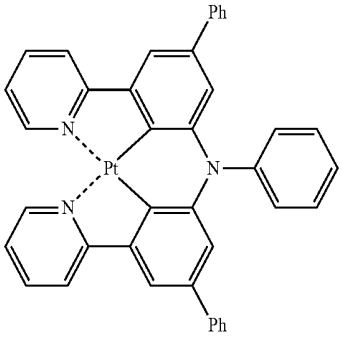

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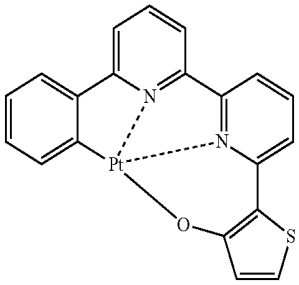

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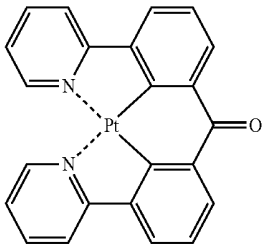

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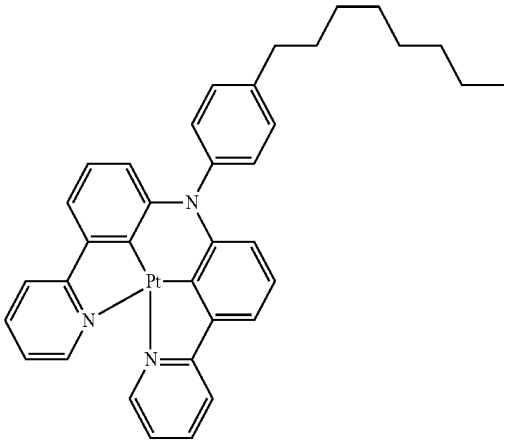

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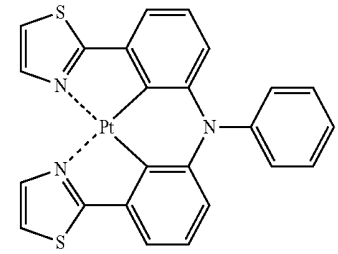

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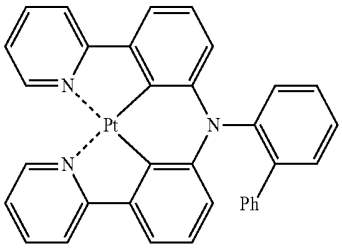

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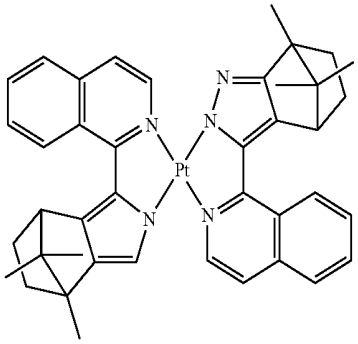

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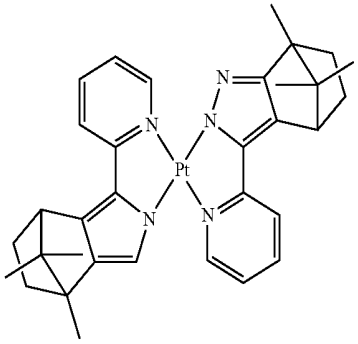

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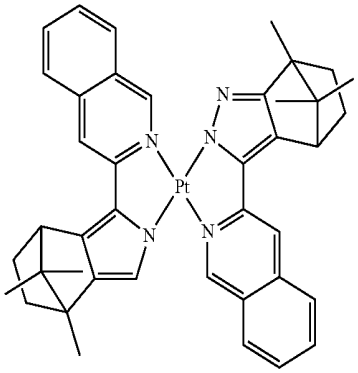

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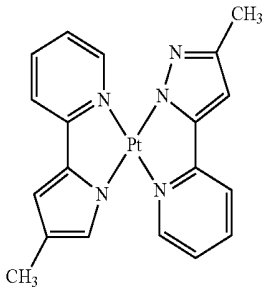

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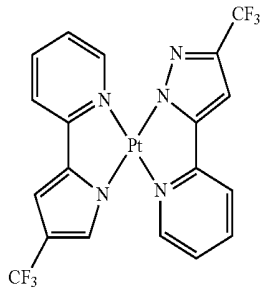

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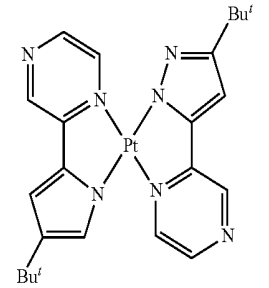

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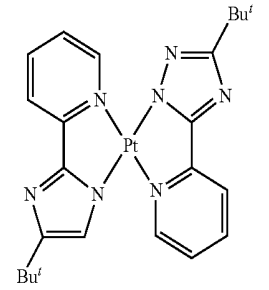

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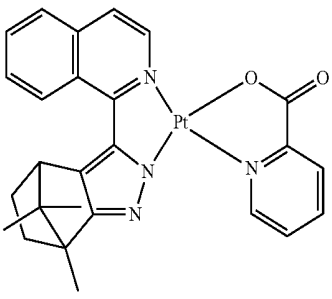

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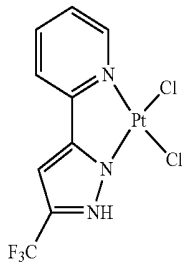

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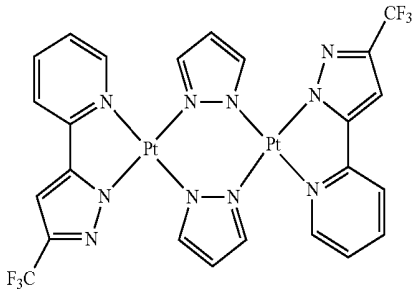

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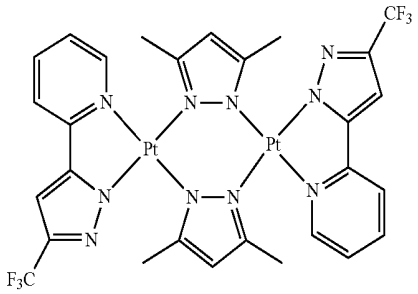
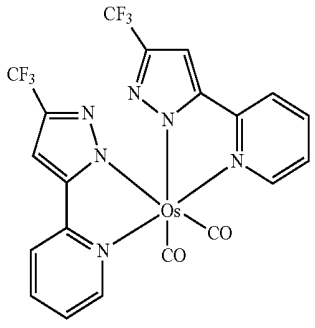


[0113] Also, examples of the dopant included in the EML may include, but are not limited to, Os-complexes:



$Os(fppz)_2(CO)_2$

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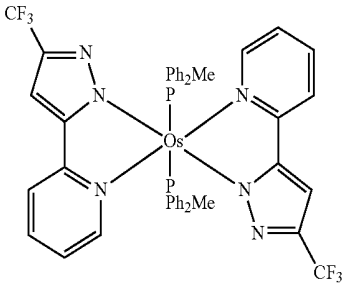
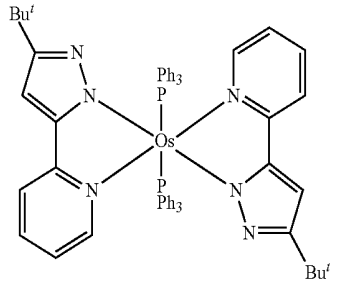
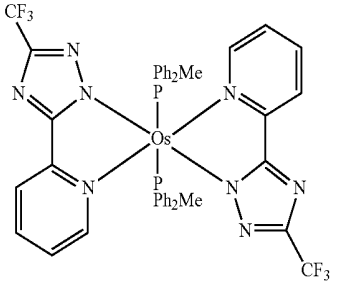


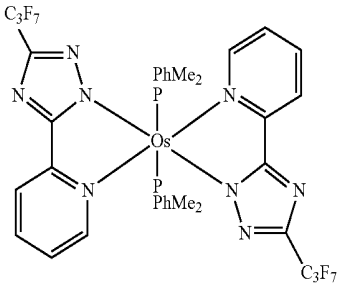
$Os(fppz)_2(PPh_2Me)_2$



$Os(bppz)_2(PPh_3)_2$



$Os(fptz)_2(PPh_2Me)_2$



$Os(hptz)_2(PPhMe_2)_2$

[0114] When the EML includes a host and a dopant, the amount of the dopant in the EML may be generally in the range of about 0.01 to about 15 parts by weight based on 100 parts by weight of the host, but is not limited thereto.

[0115] The thickness of the EML may be in the range of about 100 Å to about 1,000 Å. In some embodiments, the thickness of the EML may be in the range of about 200 Å to about 600 Å. When the thickness of the EML is within these ranges, excellent luminescent properties may be obtained without a substantial increase in driving voltage.

[0116] An ETL may be formed on the EML by using various methods such as vacuum deposition, spin coating, or casting. When the ETL is formed by vacuum deposition or spin coating, the deposition and coating conditions may vary according to a used compound. However, in general, the

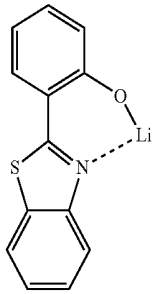
deposition and coating conditions may be almost the same as the condition for forming the HIL. A material for forming the ETL may be the condensed-cyclic compound of Formula 1 described above that stably transports electrons injected from a cathode.

[0117] The thickness of the ETL may be in the range of about 100 Å to about 1,000 Å. In some embodiments, the thickness of the ETL may be in the range of about 150 Å to about 500 Å. When the thickness of the ETL is within these ranges, satisfactory electron transport properties may be obtained without a substantial increase in driving voltage

[0118] In addition, the ETL may further include a metal-containing material, in addition to the condensed-cyclic compound of Formula 1 described above.

[0119] The metal-containing material may include a Li-complex. Examples of the Li-complex may include, but are not limited to, lithium quinolate (LiQ) and Compound 203 below:

Compound 203



[0120] Also, an EIL, which facilitates electron injection from a cathode, may be formed on the ETL, and a material for forming the EIL is not particularly limited.

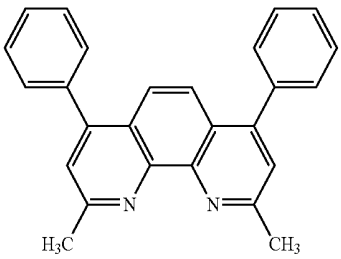
[0121] The material for forming the EIL may include a known material for forming an EIL, such as LiF, NaCl, CsF, Li_2O, or BaO. The deposition condition of the EIL may vary according a used compound. However, in general, the condition may be almost the same as the condition for forming the HIL.

[0122] The thickness of the EIL may be in the range of about 1 Å to about 100 Å. In some embodiments, the thickness of the EIL may be in the range of about 3 Å to about 90 Å. When the thickness of the EIL is within these ranges, satisfactory electron injection properties may be obtained without a substantial increase in driving voltage.

[0123] A second electrode **17** is formed on the organic layer **15**. The second electrode **17** may be a cathode, which is an electron injection electrode. In this regard, a metal for forming the second electrode **17** may include a metal having low work function, such as metal, an alloy, an electric conducting compound, and mixtures thereof. The second electrode **17** may be formed as a thin film by using lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag), thus being transparent. In order to obtain a top-emission type organic light-emitting diode, the second electrode **17** may be formed as a transparent electrode by using ITO or IZO.

[0124] The OLED has been described with reference to FIG. **1**, but is not limited thereto.

[0125] Also, when a phosphorescent dopant is included in the EML, a HBL may be formed between the ETL and the EML or between the H-functional layer and the EML by vacuum deposition, spin coating, casting or LB deposition so as to prevent triplet excitons or holes from being diffused to the ETL. When the HBL is formed by vacuum deposition or spin coating, the conditions thereof may vary according to a used compound. However, in general, the deposition and coating conditions may be almost the same as the condition for forming the HIL. The HBL may include a known hole blocking material. Examples of the known hole blocking material include an oxadiazole derivative, a triazole derivative, and a phenanthroline derivative. For example, BCP may be used as a hole blocking material.



BCP

[0126] The thickness of the HBL may be in the range of about 20 Å to about 1,000 Å. In some embodiments, the thickness of the HBL may be in the range of about 30 Å to about 300 Å. When the thickness of the HBL is within these ranges, excellent hole blocking properties may be obtained without a substantial increase in driving voltage.

[0127] Examples of the unsubstituted C_1-C_{60} alkyl group (or C_1-C_{60} alkyl group) include C_1-C_{60} linear or branched alkyl groups such as methyl, ethyl, propyl, isobutyl, sec-butyl, pentyl, iso-amyl, hexyl, and the like. The substituted C_1-C_{60} alkyl group may be a group in which at least one hydrogen of the unsubstituted C_1-C_{60} alkyl group is substituted with deuterium, a halogen atom, a hydroxyl group, a nitro group, a cyano group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_6-C_{60} aryl group, a C_2-C_{60} heteroaryl group, —$N(Q_{11})(Q_{12})$, and —$Si(Q_{13})(Q_{14})(Q_{15})$ (where Q_{11} through Q_{15} may be each independently selected from hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_6-C_{60} aryl group, and a C_2-C_{60} heteroaryl group).

[0128] The unsubstituted C_1-C_{60} alkoxy group (or C_1-C_{60} alkoxy group) has a formula of —OA (in this regard, A is the unsubstituted C_1-C_{60} alkyl group as described above) and examples thereof include methoxy, ethoxy, isopropyloxy, and the like. At least one hydrogen atom of the unsubstituted C_1-C_{60} alkoxy group may be substituted with the same substituent as in the substituted C_1-C_{60} alkyl group described above.

[0129] The unsubstituted C_2-C_{60} alkenyl group (or C_2-C_{60} alkenyl group) is interpreted to contain at least one carbon-carbon double bond in the center or at a terminal of the unsubstituted C_2-C_{60} alkyl group. Examples of the unsubstituted C_2-C_{60} alkenyl group include ethenyl, propenyl, bute-

nyl, and the like. At least one hydrogen atom of the unsubstituted C_2-C_{60} alkenyl group may be substituted with the same substituent as in the substituted C_1-C_{60} alkyl group described above.

[0130] The unsubstituted C_2-C_{60} alkynyl group (or C_2-C_{60} alkynyl group) is interpreted to contain at least one carbon-carbon triple bond in the center or at a terminal of the C_2-C_{60} alkyl group defined above. Examples of the unsubstituted C_2-C_{60} alkynyl group include ethynyl, propynyl, and the like. At least one hydrogen atom of the unsubstituted C_2-C_{60} alkynyl group may be substituted with the same substituent as in the substituted C_1-C_{60} alkyl group described above.

[0131] The unsubstituted C_6-C_{60} aryl group indicates a monovalent group having an aromatic carbocyclic system that has 5 to 60 carbon atoms and at least one aromatic ring and the unsubstituted C_6-C_{60} arylene group indicates a divalent group having an aromatic carbocyclic system that has 5 to 60 carbon atoms and at least one aromatic ring. If the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each independently have two or more aromatic rings, the rings may be fused with each other. At least one hydrogen atom of each of the unsubstituted C_6-C_{60} aryl group and the unsubstituted C_6-C_{60} arylene group may be substituted with the same substituent as in the substituted C_1-C_{60} alkyl group described above.

[0132] Examples of the substituted or unsubstituted C_6-C_{60} aryl group include, but are not limited to, a phenyl group, a C_1-C_{10} alkylphenyl group (e.g., an ethylphenyl group), a C_1-C_{10} alkylbiphenyl group (e.g., an ethylbiphenyl group), a halophenyl group (e.g., an o-, m- and p-fluorophenyl group, and a dichlorophenyl group), a dicyanophenyl group, a trifluoromethoxyphenyl group, an o-, m-, and p-tolyl group, an o-, m- and p-cumenyl group, a mesityl group, a phenoxyphenyl group, an (α,α-dimethylbenzene)phenyl group, a (N,N'-dimethyl)aminophenyl group, a (N,N'-diphenyl)aminophenyl group, a pentalenyl group, an indenyl group, a naphthyl group, a halonaphthyl group (e.g., a fluoronaphthyl group), a C_1-C_{10} alkylnaphthyl group (e.g., a methylnaphthyl group), a C_1-C_{10} alkoxynaphthyl group (e.g., a methoxynaphthyl group), an anthracenyl group, an azulenyl group, a heptalenyl group, an acenaphthylenyl group, a phenalenyl group, a fluorenyl group, an anthraquinolyl group, a methylanthryl group, a phenanthryl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, an ethyl-chrysenyl group, a picenyl group, a perylenyl group, a chloroperylenyl group, a pentaphenyl group, a pentacenyl group, a tetraphenylenyl group, a hexaphenyl group, a hexacenyl group, a rubicenyl group, a coroneryl group, a trinaphthylenyl group, a heptaphenyl group, a heptacenyl, a pyranthrenyl group, and an ovalenyl group. Examples of the substituted C_6-C_{60} aryl group may be easily understood with reference to the examples of the unsubstituted C_6-C_{60} aryl group described above and the substituents of the substituted C_1-C_{60} alkyl group. Examples of the substituted or unsubstituted C_6-C_{60} arylene group may be easily understood with reference to the substituted or unsubstituted C_6-C_{60} aryl group described above.

[0133] The unsubstituted C_2-C_{60} heteroaryl group indicates a monovalent group having at least one aromatic ring system including carbon rings and at least one hetero atom selected from the group consisting of N, O, P, and S, and the unsubstituted C_2-C_{60} heteroarylene group indicates a divalent group having at least one aromatic ring system including carbon rings and at least one hetero atom selected from the group consisting of N, O, P, and S. In this regard, if the C_2-C_{60} heteroaryl group and the C_2-C_{60} heteroarylene group each independently have two or more aromatic rings, the rings may be fused with each other. At least one hydrogen atom of each of the unsubstituted C_2-C_{60} heteroaryl group and the unsubstituted C_2-C_{60} heteroarylene group may be substituted with the same substituents as in the C_1-C_{60} alkyl group described above.

[0134] Examples of the unsubstituted C_2-C_{60} heteroaryl group include, but are not limited to, a pyrazolyl group, an imidazolyl group, an oxazolyl group, a thiazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a pyridinyl group, a pyridazinyl group, a pyrimidinyl group, a triazinyl group, a carbazolyl group, an indolyl group, a quinolinyl group, an isoquinolinyl group, a benzoimidazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group. Examples of the unsubstituted C_2-C_{60} heteroarylene group may be easily understood with reference to the examples of the substituted or unsubstituted C_2-C_{60} arylene group.

[0135] The substituted or unsubstituted C_6-C_{60} aryloxy group has a formula of —OA2 wherein A2 is the substituted or unsubstituted C_6-C_{60} aryl group as described above, and the substituted or unsubstituted C_6-C_{60} arylthio group has a formula of —SA_3 wherein A_3 is the substituted or unsubstituted C_6-C_{60} aryl group described above.

[0136] An OLED according to an embodiment will now be described in greater detail with reference to the following Examples. These Examples are for illustrative purposes only and are not intended to limit the scope of the embodiments.

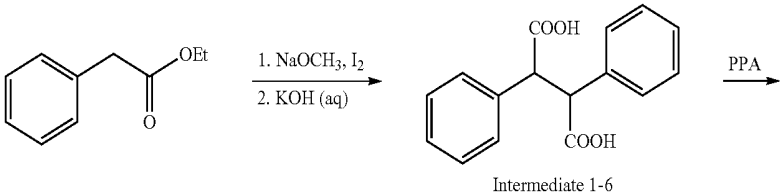
EXAMPLES

Synthesis Example 1

Synthesis of Compound 6

[0137] Compound 6 was synthesized according to Reaction Scheme 1 below:

Reaction scheme 1



Intermediate 1-6

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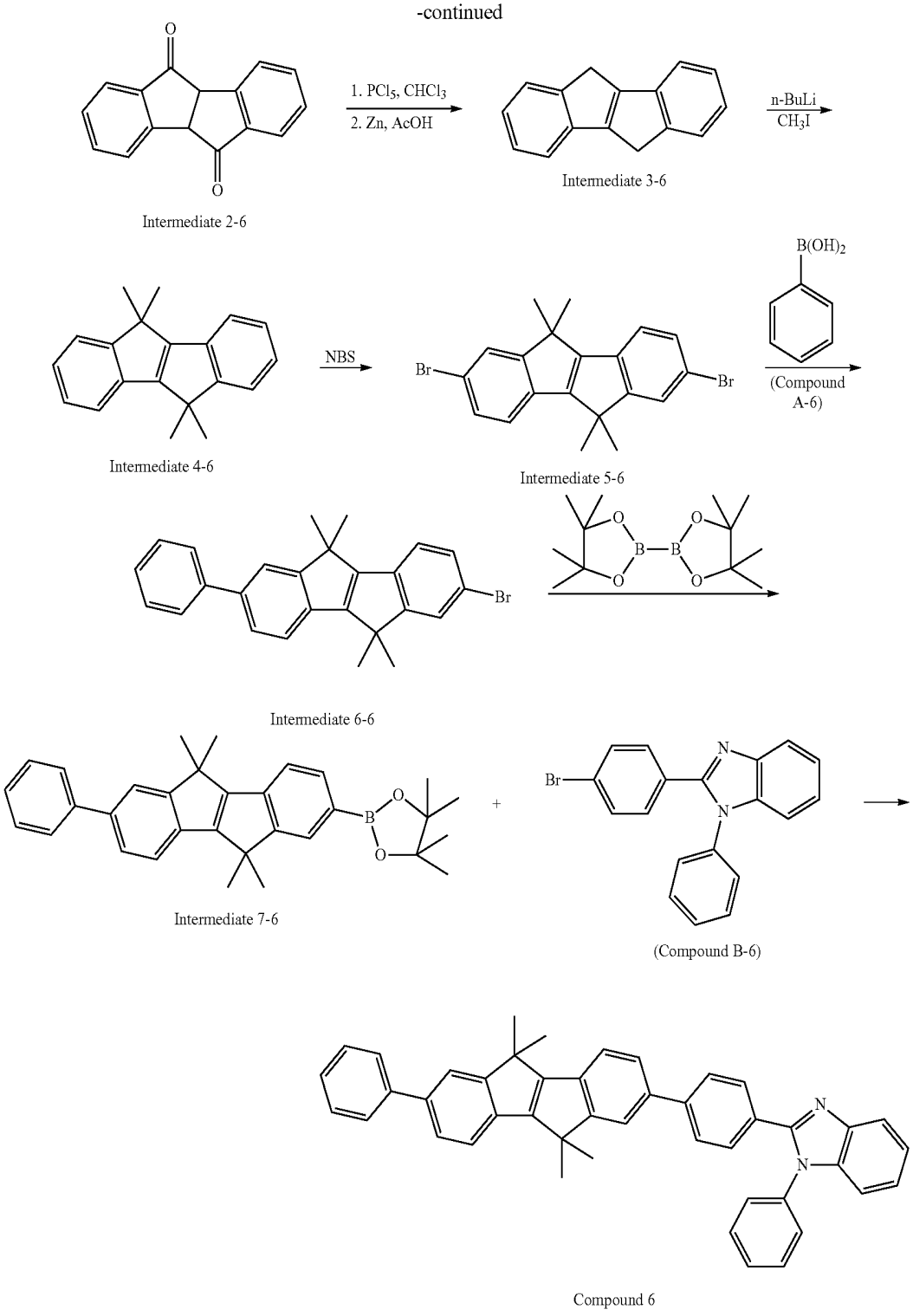


Synthesis of Intermediate 1-6

[0138] A solution prepared by dissolving 2.54 g (10 mmol) of I_2 in 12 ml of THF was added to a reactant prepared by dissolving 3.3 ml (20 mmol) of ethyl phenylacetate and 1.08 g (20 mmol) of $NaOCH_3$ in 25 ml of THF. The reaction solution was stirred at −78° C. for 10 minutes and 5 ml of 5% $NaHSO_4$(aq) was then added to the reaction solution at room temperature. Thereafter, 4.21 g (75 mmol) of KOH dissolved in 65 ml of water was added to the resulting reaction solution and stirred at 40° C. for 5 hours, and 5 ml of concentrated HCl was added thereto. The obtained reaction solution was cooled down to room temperature to obtain a precipitate. The precipitate was filtered, the filtrate was washed with 5 ml of water and dried in vacuum for 24 hours to obtain 2.66 g of Interme-

diate 1-6 (yield: 49%). The obtained compound was confirmed by mass spectrometry/fast atom bombardment (MS/FAB).

[0139] $C_{16}H_{14}O_4$: calc. 270.09. found 270.25

Synthesis of Intermediate 2-6

[0140] 5.41 g (20 mmol) of Intermediate 1-6 was added to 500 ml of a polyphosphoric acid (PPA) solution heated at 100° C. and the resulting solution was then stirred at 125° C. for 21 hours. Subsequently, the reaction solution was further heated at 150° C. for 2 hours. The reaction solution was cooled down to 80° C., 600 ml of water was added thereto, and the resulting reaction solution was stirred for 2 hours to obtain a precipitate. The precipitate was filtered, the filtrate was dissolved in 140 ml of hot aqueous $NaHCO_3$ solution, and the resultant solution was stirred for 30 hours to obtain a precipitate. The precipitate was filtered and the filtrate was dried in vacuum for 12 hours to obtain 4.03 g of Intermediate 2-6 (yield: 86%). The obtained compound was confirmed by MS/FAB.

[0141] $C_{16}H_{10}O_2$: calc. 234.07. found 234.20

Synthesis of Intermediate 3-6

[0142] 4.69 g (20 mmol) of Intermediate 2-6 was dissolved in 20 ml of chloroform, 8.75 g (42 mmol) of PCl_5 was added thereto, and the resulting solution was refluxed at 50° C. for 30 hours. The reaction solution was cooled down to room temperature and the solvent was removed in vacuum therefrom to obtain a crude product. The crude product was diluted with boiling acetic acid and 25 g of zinc dust was slowly added thereto. The obtained precipitate was filtered and washed with boiling acetic acid. Thereafter, the obtained crude product was purified with silicagel column chromatography to obtain 3.71 g of Intermediate 3-6 (yield: 91%). The obtained compound was confirmed by MS/FAB.

[0143] $C_{16}H_{12}$: calc. 204.09. found 204.31

Synthesis of Intermediate 4-6

[0144] 2.04 g (10 mmol) of Intermediate 3-6 and 37.5 ml (60 mmol) of n-BuLi (1.60M hexane solution) were mixed in THF at −78° C. to induce a reaction therebetween. Subsequently, 3.8 ml (60 mmol) of iodomethane was added to the reaction solution, the resulting solution was stirred at room temperature for 3 hours, and 5 ml of 1N HCl (aq) was added thereto. An organic layer was separated from the reaction solution and the remaining water layer was extracted twice with 100 ml of dichloromethane. The obtained organic layer was dried with magnesium sulfate and a solvent was evaporated therefrom to obtain a crude product. The crude product was purified with silicagel column chromatography to obtain 2.03 g of Intermediate 4-6 (yield: 78%). The obtained compound was confirmed by MS/FAB.

[0145] $C_{20}H_{20}$: calc. 260.15. found 260.21

Synthesis of Intermediate 5-6

[0146] 3.56 g (20 mmol) of N-bromosuccinimide (NBS) was completely dissolved in 50 ml of dimethylformamide (DMF), 2.60 g (10 mmol) of Intermediate 4-6 was then added thereto, and the resulting solution was stirred at room temperature for 24 hours. The reaction solution was extracted twice with 50 ml of water and 50 ml of dichloromethane. The obtained organic layer was dried with magnesium sulfate and a solvent was evaporated therefrom to obtain a crude product. The crude product was purified with silicagel column chromatography to obtain 2.55 g of Intermediate 5-6 (yield: 61%). The obtained compound was confirmed by MS/FAB.

[0147] $C_{20}H_{18}Br_2$: calc. 415.97. found 416.11

Synthesis of Intermediate 6-6

[0148] 2.11 g (5.09 mmol) of Intermediate 5-6, 0.34 g (2.99 mmol) of phenyl boronic acid (Compound A-6), 0.29 g (0.25 mmol) of tetrakis(triphenylphosphin)palladium ($Pd(PPh_3)_4$), and 0.62 g (4.48 mmol) of K_2CO_3 were dissolved in 60 ml of a mixed solution of THF and H_2O (a volume ratio of 2:1), and the resultant solution was then stirred at 70° C. for 5 hours. The reaction solution was cooled down to room temperature, 40 ml of water was added thereto, and the resultant solution was extracted three times with 50 ml of ethylether. The obtained organic layer was dried with magnesium sulfate and a solvent was evaporated therefrom to obtain a crude product. The crude product was purified with silicagel column chromatography to obtain 0.88 g of Intermediate 6-6 (yield: 74%). The obtained compound was confirmed by MS/FAB.

[0149] $C_{26}H_{23}Br$: calc. 414.09. found 414.21

Synthesis of Intermediate 7-6

[0150] 4.15 g (10.0 mmol) of Intermediate 6-6, 2.54 g (10.0 mmol) of bis(pinacolato)diborane, 0.36 g (0.5 mmol) of [1,1'-bis(diphenylphosphino)ferrocene]dichloro palladium (II) ($PdCl_2(dppf)_2$), and 2.94 g (30.0 mmol) of KOAc were dissolved in 40 ml of DMSO, and the resultant solution was stirred at 80° C. for 6 hours. The reaction solution was cooled down to room temperature and then extracted three times with 50 ml of water and 50 ml of diethylether. The obtained organic layer was dried with magnesium sulfate and a solvent was evaporated therefrom to obtain a crude product. The crude product was purified with silicagel column chromatography to obtain 3.69 g of Intermediate 7-6 (yield: 80%). The obtained compound was confirmed by MS/FAB.

[0151] $C_{32}H_{35}BO_2$: calc. 462.27. found 462.33

Synthesis of Compound 6

[0152] 1.02 g (2.20 mmol) of Intermediate 7-6, 0.69 g (2.20 mmol) of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6), 0.127 g (0.11 mmol) of $Pd(PPh_3)_4$, and 0.45 g (3.3 mmol) of K_2CO_3 were dissolved in 40 ml of a mixed solution of THF and H_2O (a volume ratio of 2:1), and the resultant solution was stirred at 70° C. for 5 hours. The reaction solution was cooled down to room temperature, 30 ml of water was added thereto, and the resultant solution was then extracted three times with 30 ml of ethylether. The obtained organic layer was dried with magnesium sulfate and a solvent was evaporated therefrom to obtain a crude product. The crude product was purified with silicagel column chromatography to obtain 1.01 g of Compound 6 (yield: 76%). The obtained compound was confirmed by ^1H nuclear magnetic resonance (NMR) and MS/FAB.

[0153] ^1H NMR ($CDCl_3$, 400 MHz) □ δ: 8.82-8.78 (m, 4H), 8.28 (dd, 1H), 7.98-7.96 (m, 1H), 7.85 (d, 1H), 7.73 (d, 1H), 7.67-7.59 (m, 6H), 7.53-7.47 (m, 2H), 7.43-7.37 (m, 4H), 7.35-7.33 (m, 1H), 1.45 (s, 6H), 1.35 (s, 6H)

[0154] $C_{45}H_{36}N_2$: calc. 604.28. found 605.33

Synthesis Example 2

Synthesis of Compound 15

[0155] Compound 15 was synthesized in the same manner as in Synthesis Example 1, except that pyridin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 3-(3-bromo-5-(pyridin-3-yl)phenyl)pyridine) was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0156] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.96-8.94 (m, 2H), 8.68-8.65 (m, 3H), 8.34 (dd, 1H), 8.14 (d, 1H), 8.05 (dt, 2H), 7.97-7.88 (m, 4H), 7.77-7.66 (m, 3H), 7.50-7.43 (m, 3H), 7.38-7.35 (m, 1H), 7.16 (dd, 1H) 1.45 (s, 6H), 1.37 (s, 6H))

[0157] $C^{41}H^{33}N^3$: calc. 567.26. found 568.38

Synthesis Example 3

Synthesis of Compound 28

[0158] Compound 28 was synthesized in the same manner as in Synthesis Example 1, except that naphthalen-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-4,6-diphenyl-1,3,5-triazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0159] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.83-8.78 (m, 4H), 8.28 (dd, 1H), 8.20-8.18 (m, 1H), 8.02 (d, 1H), 7.97-7.96 (m, 1H), 7.93-7.85 (m, 4H), 7.80-7.72 (m, 2H), 7.63-7.57 (m, 5H), 7.44-7.38 (m, 4H), 1.47 (s, 6H), 1.37 (s, 6H)

[0160] $C_{45}H_{35}N_3$: calc. 617.28. found 618.39

Synthesis Example 4

Synthesis of Compound 41

[0161] Compound 41 was synthesized in the same manner as in Synthesis Example 1, except that quinolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-(2-bromonaphthalen-6-yl)pyrazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0162] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.94 (t, 1H), 8.69-8.67 (m, 1H), 8.53 (t, 1H), 8.47-8.43 (m, 2H), 8.40-8.38 (m, 1H), 8.32-8.28 (m, 2H), 8.19-8.17 (m, 1H), 8.05-7.97 (m, 4H), 7.93-7.65 (m, 6H), 7.42 (d, 1H), 7.38-7.36 (m, 1H), 1.43 (s, 6H), 1.38 (s, 6H)

[0163] $C_{43}H_{33}N_3$: calc. 591.26. found 592.29

Synthesis Example 5

Synthesis of Compound 49

[0164] Compound 49 was synthesized in the same manner as in Synthesis Example 1, except that phenanthren-9-yl-9-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-6-(pyridin-4-yl)pyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0165] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.66-8.63 (m, 3H), 8.43-8.41 (m, 1H), 8.37 (dd, 1H), 8.20 (d, 1H), 8.05-7.96 (m, 4H), 7.89-7.85 (m, 1H), 7.80-7.61 (m, 7H), 7.54-7.51 (m, 2H), 7.22-7.20 (m, 1H), 7.15-7.12 (m, 1H), 1.42 (s, 6H), 1.37 (s, 6H)

[0166] $C_{43}H_{34}N_2$: calc. 590.27. found 591.30

Synthesis Example 6

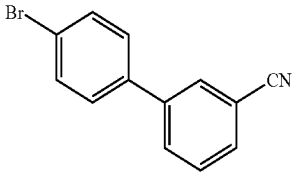
Synthesis of Compound 57

[0167] Compound 57 was synthesized in the same manner as in Synthesis Example 1, except that 1,10-phenanthrolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and Compound B-57 below was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0168] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 9.17 (dd, 1H), 8.48 (dd, 1H), 8.33-8.26 (m, 2H), 8.20-8.16 (m, 2H), 8.10-8.08 (m, 1H), 7.91-7.88 (m, 1H), 7.83-7.76 (m, 4H), 7.72-7.69 (m, 2H), 7.65-7.58 (m, 4H), 7.50-7.40 (m, 3H), 1.42 (s, 6H), 1.38 (s, 6H)

[0169] $C_{45}H_{33}N_3$: calc. 615.26. found 616.37

Compound B-57



Synthesis Example 7

Synthesis of Compound 1

[0170] Compound 1 was synthesized in the same manner as in Synthesis Example 1, except that 2-bromopyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0171] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.68-8.65 (m, 1H), 8.33 (dd, 1H), 7.93-7.91 (m, 1H), 7.85 (d, 1H), 7.77-7.73 (m, 1H), 7.69-7.65 (m, 4H), 7.54-7.47 (m, 2H), 7.44-7.38 (m, 2H), 7.35-7.33 (m, 1H), 7.18-7.15 (m, 1H), 1.47 (s, 6H), 1.37 (s, 6H)

[0172] $C_{31}H_{27}1\backslash1$: calc. 413.21. found 414.32

Synthesis Example 8

Synthesis of Compound 2

[0173] Compound 2 was synthesized in the same manner as in Synthesis Example 1, except that 6-bromoquinoline was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0174] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.73 (dd, 1H), 8.25-8.23 (m, 1H), 8.18-8.15 (m, 2H), 8.05-8.00 (m, 2H),

7.85 (d, 1H), 7.67-7.65 (m, 2H), 7.55-7.45 (m, 4H), 7.43-7.38 (m, 2H), 7.33-7.31 (m, 2H), 1.45 (s, 6H), 1.37 (s, 6H)

[0175] $C_{35}H_{29}N$: calc. 463.23. found 464.31

Synthesis Example 9

Synthesis of Compound 5

[0176] Compound 5 was synthesized in the same manner as in Synthesis Example 1, except that 2-bromo-4,6-diphenyl-1,3,5-triazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0177] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.82-8.78 (m, 4H), 8.28 (dd, 1H), 7.98-7.96 (m, 1H), 7.85 (d, 1H), 7.73 (d, 1H), 7.67-7.59 (m, 6H), 7.53-7.47 (m, 2H), 7.43-7.37 (m, 4H), 7.35-7.33 (m, 1H), 1.45 (s, 6H), 1.35 (s, 6H)

[0178] $C_{41}H_{33}N_3$: calc. 567.26. found 568.31

Synthesis Example 10

Synthesis of Compound 8

[0179] Compound 8 was synthesized in the same manner as in Synthesis Example 1, except that 2-(4-bromo-phenyl)-4,6-diphenyl-1,3,5-triazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0180] 1H NMR ($CDCl_3$, 400 MHz) δ: 8.10-8.04 (m, 4H), 7.90 (d, 1H), 7.85 (d, 1H), 7.79-7.77 (m, 1H), 7.65-7.58 (m, 6H), 7.52-7.28 (m, 9H), 7.21-7.17 (m, 3H), 1.48 (s, 6H), 1.37 (s, 6H)

[0181] $C_{45}H_{36}N_2$: calc. 643.29. found 644.32

Synthesis Example 11

Synthesis of Compound 11

[0182] Compound 11 was synthesized in the same manner as in Synthesis Example 1, except that 3-(6-bromopyridin-3-yl)quinoline was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0183] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 9.13-9.11 (m, 1H), 8.89-8.85 (m, 1H), 8.58-8.57 (m, 1H), 8.35 (dd, 1H), 8.16-8.14 (m, 1H), 8.05-8.01 (m, 2H), 7.96-7.94 (m, 1H), 7.90-7.84 (m, 2H), 7.71-7.65 (m, 4H), 7.51-7.48 (m, 3H), 7.42-7.38 (m, 2H), 7.34-7.31 (1H), 1.42 (s, 6H), 1.37 (s, 6H)

[0184] $C_{40}H_{32}N_2$: calc. 540.25. found 541.36

Synthesis Example 12

Synthesis of Compound 13

[0185] Compound 13 was synthesized in the same manner as in Synthesis Example 1, except that pyridin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 3-bromo-9-phenyl-9H-carbazole was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0186] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.68-8.65 (m, 1H), 8.33 (dd, 1H), 8.24-8.22 (m, 1H), 8.08-8.06 (m, 1H), 7.95-7.93 (m, 2H), 7.77-7.66 (m, 5H), 7.54-7.47 (m, 6H), 7.39-7.28 (m, 3H), 7.21-7.15 (m, 2H), 1.42 (s, 6H), 1.37 (s, 6H)

[0187] $C_{43}H_{34}N_2$: calc. 578.27. found 579.39

Synthesis Example 13

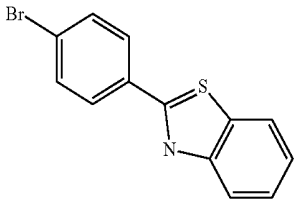
Synthesis of Compound 16

[0188] Compound 16 was synthesized in the same manner as in Synthesis Example 1, except that pyridin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and Compound B-16 below was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0189] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.68-8.66 (m, 1H), 8.35-8.30 (m, 3H), 8.03-8.01 (m, 1H), 7.94-7.85 (m, 5H), 7.77-7.75 (m, 1H), 7.68-7.65 (m, 2H), 7.47-7.40 (m, 3H), 7.37-7.33 (m, 1H), 7.16 (dd, 1H) 1.43 (s, 6H), 1.36 (s, 6H)

[0190] $C_{37}H_{31}N_2S$: calc. 546.21. found 547.33

Compound B-16



Synthesis Example 14

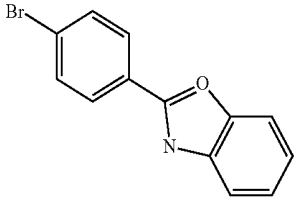
Synthesis of Compound 17

[0191] Compound 17 was synthesized in the same manner as in Synthesis Example 1, except that pyridin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and Compound B-17 below was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0192] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.68-8.66 (m, 1H), 8.33 (dd, 1H), 8.23-8.20 (m, 2H), 7.94-7.59 (m, 2H), 7.83-7.81 (m, 1H), 7.77-7.66 (m, 5H), 7.45-7.39 (m, 4H), 7.29-7.23 (m, 1H), 7.18-7.15 (m, 1H) 1.42 (s, 6H), 1.37 (s, 6H)

[0193] $C_{37}H_{31}N_2O$: calc. 530.23. found 531.34

Compound B-17



Synthesis Example 15

Synthesis of Compound 21

[0194] Compound 21 was synthesized in the same manner as in Synthesis Example 1, except that pyridin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-5-(3,5-difluorophenyl)pyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0195] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 9.01-9.00 (m, 1H), 8.68-8.67 (m, 1H), 8.37-8.32 (m, 2H), 8.05-7.94 (m, 4H), 7.77-7.66 (m, 4H), 7.21-7.15 (m, 3H), 6.72-6.77 (m, 1H), 1.43 (s, 6H), 1.38 (s, 6H)

[0196] $C_{36}H_{29}N_2F_2$: calc. 526.22. found 527.31

Synthesis Example 16

Synthesis of Compound 23

[0197] Compound 23 was synthesized in the same manner as in Synthesis Example 1, except that pyridin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-(2-bromonaphthalen-6-yl)pyrazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0198] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.94-8.92 (m, 1H), 8.69-8.66 (m, 2H), 8.55-8.53 (m, 1H), 8.46-8.44 (m, 1H), 8.40-8.29 (m, 3H), 8.03-7.97 (m, 2H), 7.94-7.88 (m, 3H), 7.77-7.73 (m, 1H), 7.68-7.66 (m, 2H), 7.44-7.38 (m, 2H), 7.16 (dd, 1H), 1.42 (s, 6H), 1.37 (s, 6H)

[0199] $C_{39}H_{32}N_3$: calc. 541.25. found 542.39

Synthesis Example 17

Synthesis of Compound 27

[0200] Compound 27 was synthesized in the same manner as in Synthesis Example 1, except that naphthalen-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-6-(pyridin-4-yl)pyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0201] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.65-8.63 (m, 2H), 8.37 (dd, 1H), 8.20-8.18 (m, 1H), 8.04-8.01 (m, 3H), 7.97-7.96 (m, 1H), 7.93-7.85 (m, 4H), 7.80-7.70 (m, 4H), 7.62-7.57 (m, 1H), 7.53-7.49 (m, 1H), 7.44-7.41 (m, 1H), 7.38-7.36 (m, 1H), 1.42 (s, 6H), 1.37 (s, 6H)

[0202] $C_{39}H_{32}N_3$: calc. 540.25. found 541.36

Synthesis Example 18

Synthesis of Compound 29

[0203] Compound 29 was synthesized in the same manner as in Synthesis Example 1, except that naphthalen-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0204] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.18-8.17 (m, 1H), 8.07-8.01 (m, 3H), 7.93-7.83 (m, 4H), 7.80-7.74 (m, 4H), 7.66 (dd, 1H), 7.62-7.49 (m, 4H), 7.45-7.35 (m, 7H), 7.32-7.28 (m, 1H), 7.24-7.20 (m, 1H), 1.45 (s, 6H), 1.35 (s, 6H)

[0205] $C_{49}H_{38}N_2$: calc. 654.30. found 655.45

Synthesis Example 19

Synthesis of Compound 32

[0206] Compound 32 was synthesized in the same manner as in Synthesis Example 1, except that naphthalen-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-(2-bromo-9,9-dimethyl-9H-fluoren-7-yl)pyrazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0207] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.87 (t, 1H), 8.46 (dt, 2H), 8.20-8.18 (m, 1H), 8.07-7.98 (m, 3H), 7.93-7.72 (m, 9H), 7.65-7.58 (m, 5H), 7.53-7.51 (m, 1H), 7.44-7.41 (m, 1H), 7.38-7.35 (m, 5H), 1.63 (m, 6H), 1.37 (s, 6H)

[0208] $C_{49}H_{37}N_2$: calc. 656.31. found 657.33

Synthesis Example 20

Synthesis of Compound 33

[0209] Compound 33 was synthesized in the same manner as in Synthesis Example 1, except that quinolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-4,6-diphenylpyrimidine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0210] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.45 (dd, 1H), 8.31-8.26 (m, 5H), 8.19-8.15 (m, 2H), 8.05-8.01 (m, 2H), 7.99 (s, 1H), 7.88-7.83 (m, 2H), 7.80-7.65 (m, 4H), 7.53-7.48 (m, 4H), 7.31-7.26 (m, 2H), 1.47 (m, 6H), 1.42 (s, 6H)

[0211] $C_{45}H_{35}N_3$: calc. 617.28. found 618.31

Synthesis Example 21

Synthesis of Compound 34

[0212] Compound 34 was synthesized in the same manner as in Synthesis Example 1, except that quinolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 4-(3-bromo-5-(pyridin-4-yl)phenyl)pyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0213] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.80-8.76 (m, 4H), 8.45 (dd, 1H), 8.29 (d, 1H), 8.19-8.14 (m, 2H), 8.05-8.01 (m, 2H), 7.97-7.96 (m, 1H), 7.93-7.91 (m, 2H), 7.86-7.65 (m, 4H), 7.55-7.50 (m, 4H), 7.43 (d, 1H), 7.38-7.36 (m, 1H), 1.42 (s, 6H), 1.37 (s, 6H)

[0214] $C_{40}H_{35}N3$: calc. 617.28. found 618.39

Synthesis Example 22

Synthesis of Compound 38

[0215] Compound 38 was synthesized in the same manner as in Synthesis Example 1, except that quinolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 4-(6-

bromopyridin-2-yl)benzonitrile was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0216] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.45 (dd, 1H), 8.37 (dd, 1H), 8.34-8.28 (m, 3H), 8.19-8.15 (m, 1H), 8.05-8.01 (m, 2H), 7.97-7.95 (m, 1H), 7.86-7.72 (m, 7H), 7.69-7.63 (m, 3H), 1.45 (s, 6H), 1.35 (s, 6H)

[0217] $C_{41}H_{31}N_3$: calc. 565.25. found 566.37

Synthesis Example 23

Synthesis of Compound 40

[0218] Compound 40 was synthesized in the same manner as in Synthesis Example 1, except that quinolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and Compound B-40 below was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0219] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.46-8.43 (m, 3H), 8.37 (dd, 1H), 8.30-8.25 (m, 2H), 8.19-8.17 (m, 1H), 8.10-8.08 (m, 1H), 8.05-8.01 (m, 2H), 7.97-7.95 (m, 1H), 7.86-7.84 (m, 1H), 7.80-7.72 (m, 6H), 7.68-7.65 (m, 2H), 7.46-7.35 (m, 2H), 1.42 (s, 6H), 1.37 (s, 6H)

[0220] $C_{46}H_{33}N_2S$: calc. 646.24. found 647.35

Synthesis Example 24

Synthesis of Compound 43

[0221] Compound 43 was synthesized in the same manner as in Synthesis Example 1, except that phenanthren-9-yl-9-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 3-bromopyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0222] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 8.97-8.95 (m, 1H), 8.66-8.63 (m, 2H), 8.43-8.41 (m, 1H), 8.20 (d, 1H), 8.08 (dt, 1H), 8.00 (dd, 1H), 7.91 (d, 1H), 7.80-7.75 (m, 2H), 7.68-7.61 (m, 3H), 7.54-7.46 (m, 3H), 7.42-7.40 (m, 1H), 7.20-7.11 (m, 2H), 1.39 (s, 6H), 1.37 (s, 6H)

[0223] $C_{39}H_{31}N$: calc. 513.24. found 514.35

Synthesis Example 25

Synthesis of Compound 44

[0224] Compound 44 was synthesized in the same manner as in Synthesis Example 1, except that phenanthren-9-yl-9-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-4,6-diphenyl-1,3,5-triazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0225] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.85-8.78 (m, 4H), 8.65-8.63 (m, 1H), 8.43-8.41 (m, 1H), 8.28 (dd, 1H), 8.21-8.19 (m, 1H), 8.01-7.97 (m, 2H), 7.80-7.77 (m, 1H), 7.73 (d, 1H), 7.69-7.59 (m, 7H), 7.54-7.50 (m, 2H), 7.42-7.38 (m, 2H), 7.20-7.18 (m, 1H), 7.15-7.12 (m, 1H), 1.47 (s, 6H), 1.39 (s, 6H)

[0226] $C_{49}H_{37}N_3$: calc. 667.29. found 668.39

Synthesis Example 26

Synthesis of Compound 45

[0227] Compound 45 was synthesized in the same manner as in Synthesis Example 1, except that phenanthren-9-yl-9-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 3-(3-bromo-5-(pyridin-3-yl)phenyl)pyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0228] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.80-8.78 (m, 4H), 8.65-8.63 (m, 1H), 8.43-8.41 (m, 1H), 8.20 (d, 1H), 8.15 (d, 1H), 8.01-7.93 (m, 4H), 7.80-7.78 (m, 1H), 7.68-7.61 (m, 3H), 7.54-7.50 (m, 6H), 7.44 (dd, 1H), 7.38-7.36 (m, 1H), 7.22-7.20 (m, 1H), 7.15-7.12 (m, 1H), 1.39 (s, 6H), 1.37 (s, 6H)

[0229] $C_{50}H_{38}N_2$: calc. 666.30. found 667.31

Synthesis Example 27

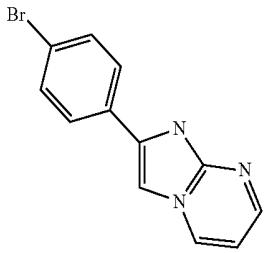
Synthesis of Compound 47

[0230] Compound 47 was synthesized in the same manner as in Synthesis Example 1, except that phenanthren-9-yl-9-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and Compound B-47 below was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0231] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.65-8.63 (m, 1H), 8.48 (dd, 1H), 8.43-8.41 (m, 2H), 8.21-8.15 (m, 3H), 7.99 (dd, 1H), 7.94-7.89 (m, 4H), 7.80-7.77 (m, 1H), 7.68-7.61 (m, 3H), 7.54-7.50 (m, 2H), 7.43-7.40 (m, 2H), 7.22-7.20 (m, 1H), 7.15-7.12 (m, 1H), 6.81 (dd, 1H), 1.39 (s, 6H), 1.37 (s, 6H)

[0232] $C_{46}H_{39}N_3$: calc. 629.28. found 630.39

Compound B-47



Synthesis Example 28

Synthesis of Compound 50

[0233] Compound 50 was synthesized in the same manner as in Synthesis Example 1, except that phenanthren-9-yl-9-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-5-(3,5-difluorophenyl)pyridine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6)

in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0234] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 9.02-9.00 (m, 1H), 8.65-8.63 (m, 1H), 8.43-8.41 (m, 1H), 8.36 (dd, 1H), 8.05-7.95 (m, 4H), 7.80-7.77 (m, 1H), 7.71-7.61 (m, 4H), 7.54-7.50 (m, 3H), 7.21-7.12 (m, 4H), 6.72-6.67 (m, 1H), 1.42 (s, 6H), 1.39 (s, 6H)

[0235] $C_{45}H_{33}NF_3$: calc. 625.25. found 626.35

Synthesis Example 29

Synthesis of Compound 52

[0236] Compound 52 was synthesized in the same manner as in Synthesis Example 1, except that 1,10-phenanthrolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 3-bromoquinoline was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0237] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 9.19 (dd, 1H), 9.06-9.04 (m, 1H), 8.59-8.57 (m, 1H), 8.49 (dd, 1H), 8.35-8.28 (m, 3H), 8.20-8.14 (m, 2H), 8.09-8.05 (m, 2H), 7.84-7.76 (m, 3H), 7.72-7.66 (m, 2H), 7.60-7.57 (m, 1H), 7.52-7.48 (m, 1H), 7.36 (s, 1H), 1.42 (s, 6H), 1.37 (s, 6H)

[0238] $C_{41}H_{31}N_3$: calc. 565.25. found 566.36

Synthesis Example 30

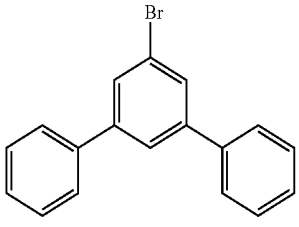
Synthesis of Compound 55

[0239] Compound 55 was synthesized in the same manner as in Synthesis Example 1, except that 1,10-phenanthrolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and Compound B-55 below was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0240] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 9.19 (dd, 1H), 8.50 (dd, 1H), 8.33-8.26 (m, 2H), 8.20-8.09 (m, 3H), 7.83-7.78 (m, 4H), 7.74-7.66 (m, 6H), 7.59 (dd, 1H), 7.49-7.37 (m, 8H), 1.42 (s, 6H), 1.37 (s, 6H)

[0241] $C_{50}H_{38}N_2$: calc. 666.30. found 667.41

Compound B-55



Synthesis Example 31

Synthesis of Compound 56

[0242] Compound 56 was synthesized in the same manner as in Synthesis Example 1, except that 1,10-phenanthrolin-2-yl-2-boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0243] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 9.19 (dd, 1H), 8.50 (dd, 1H), 8.33-8.26 (m, 2H), 8.20-8.18 (m, 1H), 8.10-8.03 (m, 3H), 7.90-7.88 (m, 1H), 7.83-7.55 (m, 10H), 7.45-7.37 (m, 5H), 7.33-7.20 (m, 2H), 1.43 (s, 6H), 1.40 (s, 6H)

[0244] $C_{51}H_{38}N_4$: calc. 706.30. found 707.31

Synthesis Example 32

Synthesis of Compound 58

[0245] Compound 58 was synthesized in the same manner as in Synthesis Example 1, except that 3,5-difluorophenylboronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6 and 2-bromo-4,6-diphenyl-1,3,5-triazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0246] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.81-8.78 (m, 4H), 8.33-8.27 (m, 2H), 7.97-7.95 (m, 1H), 7.73 (d, 1H), 7.63-7.59 (m, 4H), 7.48-7.40 (m, 3H), 7.35-7.33 (m, 1H), 7.14-7.07 (m, 2H), 6.67-6.62 (m, 1H), 1.47 (s, 6H), 1.37 (s, 6H)

[0247] $C_{41}H_{31}N_3F_2$: calc. 603.24. found 604.35

Synthesis Example 33

Synthesis of Compound 63

[0248] Compound 63 was synthesized in the same manner as in Synthesis Example 1, except that iodobenzene was used instead of iodomethane in the synthesis of Intermediate 4-6 and 2-bromopyrazine was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0249] ^{1}H NMR ($CDCl_3$, 400 MHz) □ δ: 9.02-9.00 (m, 1H), 8.56-8.55 (m, 1H), 8.46-8.42 (m, 2H), 8.05-8.01 (m, 2H), 7.82 (d, 1H), 7.75-7.72 (m, 1H), 7.61-7.59 (m, 1H), 7.52-7.48 (m, 2H), 7.42-7.40 (m, 1H), 7.35-7.33 (m, 1H), 7.19-7.10 (m, 12H), 7.05-6.97 (m, 9H)

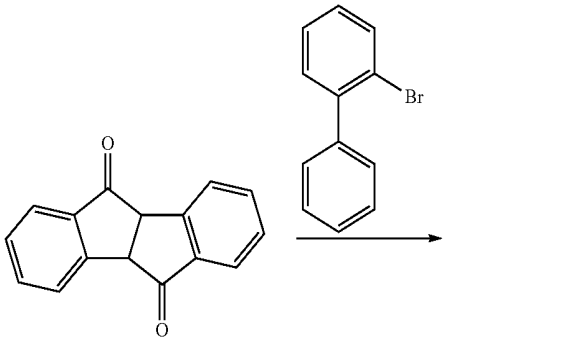
[0250] $C_{50}H_{59}N_2$: calc. 662.27. found 663.37

Synthesis Example 34

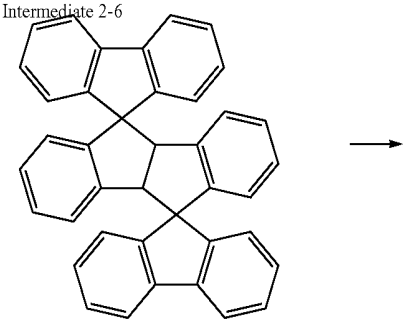
Synthesis of Compound 65

[0251] Compound 65 was synthesized according to Reaction Scheme 2 below:

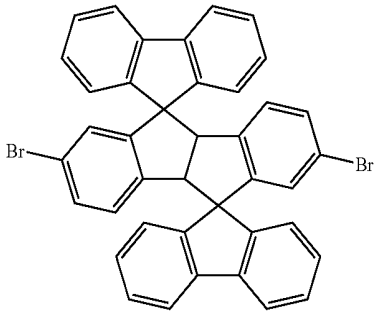
Reaction Scheme 2



Intermediate 2-6



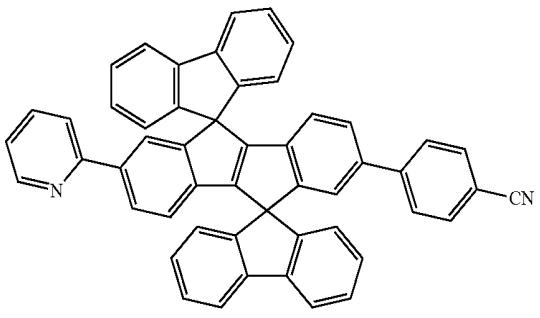
Intermediate 3-65



Intermediate 5-65

Compound 65

65



Synthesis of Intermediate 3-65

[0252] 5.00 g (21.4 mmol) of 2-bromobiphenyl was dissolved in 11.0 ml of THF and 0.57 g (23.3 mmol) of magnesium was added thereto at room temperature. When a Grenia product was produced therefrom, a solution prepared by dissolving 5.06 g (21.4 mmol) of Intermediate 2-6 in 5 ml of THF was added to the resulting solution, the resultant solution was stirred at 85° C. for 4 hours, and the temperature thereof was cooled down to room temperature to obtain a yellow precipitate. The yellow precipitate was washed with methanol to obtain 6.83 g of Intermediate 3-65 (yield: 63%). The synthesized compound was confirmed by MS/FAB.

[0253] $C_{40}H_{26}$: calc. 506.20. found 507.30

Synthesis of Intermediate 5-65

[0254] Intermediate 5-65 was synthesized in the same manner as Synthesis of Intermediate 5-6 in Synthesis Example 1, except that Intermediate 3-65 was used instead of Inter mediate 4-6.

Synthesis of Compound 65

[0255] Compound 65 was synthesized in the same manner as in Synthesis Example 1, except that pyridine boronic acid was used instead of phenyl boronic acid (Compound A-6) in the synthesis of Intermediate 6-6, Intermediate 5-65 was used instead of Intermediate 5-6, and benzonitrile was used instead of 2-(4-bromophenyl)-1-phenyl-1-benzoimidazole (Compound B-6) in the synthesis of Compound 6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0256] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.68-8.66 (m, 1H), 8.29-8.27 (m, 1H), 8.19 (dd, 1H), 8.00 (d, 2H), 7.83-7.72 (m, 7H), 7.67-7.60 (m, 4H), 7.49-7.47 (m, 1H), 7.36-7.32 (m, 4H), 7.18-7.15 (m, 1H), 7.05-7.01 (m, 4H), 6.53-6.50 (m, 4H)

[0257] $C_{52}H_{30}N_2$: calc. 682.24. found 683.34

Synthesis Example 35

Synthesis of Compound 68

[0258] Compound 68 was synthesized in the same manner as in Synthesis Example 1, except that iodoethane was used instead of iodomethane in the synthesis of Intermediate 4-6. The synthesized compound was confirmed by ^{1}H NMR and MS/FAB.

[0259] ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.27-8.24 (m, 2H), 8.07-8.03 (m, 2H), 7.96 (d, 1H), 7.91 (d, 1H), 7.80-7.74 (m, 3H), 7.68-7.64 (m, 3H), 7.58-7.55 (m, 2H), 7.51-7.47 (m, 2H), 7.44-7.35 (m, 6H), 7.32-7.28 (m, 1H), 7.25-7.20 (m, 1H), 1.81-1.72 (m, 4H), 1.58-1.53 (m, 4H), 0.79-0.74 (m, 12H)

[0260] $C_{49}H_{44}N_2$: calc. 660.35. found 661.46

Example 1

[0261] As an anode, a 15 Ω/cm2 (1200 Å) Corning ITO glass substrate was cut to a size of 50 mm×50 mm×0.7 mm, washed with ultrasonic waves in isopropyl alcohol and pure water for 5 minutes each, and then cleaned with UV and ozone for 30 minutes. The ITO glass substrate was mounted on a vacuum depositor.

[0262] 2-TNATA was deposited on the ITO glass substrate to form a HIL having a thickness of 600 Å and 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB) was then deposited on the HIL to form a HTL having a thickness of 300 Å.

[0263] Next, 9,10-di-naphthalene-2-yl-anthracene (ADN) as host and DPVBi as a dopant were co-deposited on the HTL at a weight ratio of 98:2 to form an EML having a thickness of 300 Å.

[0264] Thereafter, Compound 6 was deposited on the EML 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 EIL to form a second electrode (cathode) having a thickness of 3,000 Å, thereby completing the manufacture of an OLED.

Example 2

[0265] An OLED was manufactured in the same manner as in Example 1, except that Compound 15 was used instead of Compound 6 in the formation of the ETL.

Example 3

[0266] An OLED was manufactured in the same manner as in Example 1, except that Compound 28 was used instead of Compound 6 in the formation of the ETL.

Example 4

[0267] An OLED was manufactured in the same manner as in Example 1, except that Compound 41 was used instead of Compound 6 in the formation of the ETL.

Example 5

[0268] An OLED was manufactured in the same manner as in Example 1, except that Compound 49 was used instead of Compound 6 in the formation of the ETL.

Example 6

[0269] An OLED was manufactured in the same manner as in Example 1, except that Compound 57 was used instead of Compound 6 in the formation of the ETL.

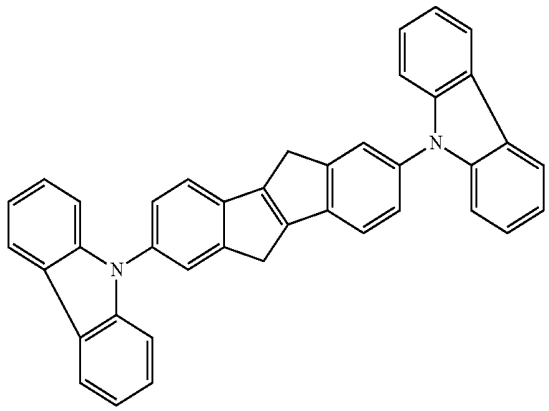
Comparative Example 1

[0270] An OLED was manufactured in the same manner as in Example 1, except that Alq3 was used instead of Compound 6 in the formation of the ETL.

Comparative Example 2

[0271] An OLED was manufactured in the same manner as in Example 1, except that Compound E1 below was used instead of Compound 6 in the formation of the ETL.

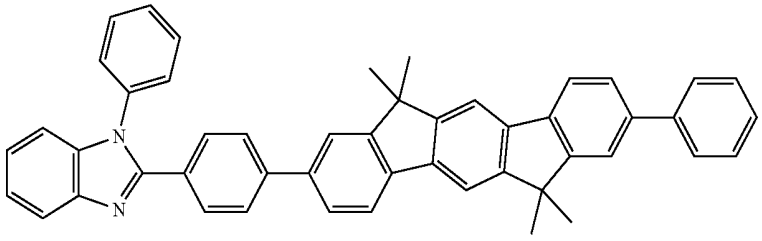
Compound E1



Comparative Example 3

[0272] An OLED was manufactured in the same manner as in Example 1, except that Compound E2 below was used instead of Compound 6 in the formation of the ETL.

Compound E2



Evaluation Example 1

[0273] Driving voltage, current density, brightness, emission color, efficiency, and half lifetime (@100 mA/cm^2) of each of the OLEDs of Examples 1 through 6 and Comparative Examples 1 through 3 were evaluated using PR650 Spectroscan Source Measurement Unit (available from PhotoResearch), and the results are shown in Table 1 below.

TABLE 1

	ETL	Driving voltage (V)	Current density (mA/cm^2)	Brightness (cd/m^2)	Efficiency (cd/A)	Emission color	Half lifetime (hr)
Example 1	Compound 6	5.27	50	2,254	4.50	blue	293
Example 2	Compound 15	5.53	50	2,257	4.51	blue	245
Example 3	Compound 28	5.22	50	2,430	4.86	blue	224
Example 4	Compound 41	5.24	50	2,108	4.21	blue	285
Example 5	Compound 49	5.48	50	2,260	4.52	blue	251
Example 6	Compound 57	5.32	50	2,221	4.44	blue	298
Comparative Example 1	Alq_3	7.85	50	1,560	3.12	blue	113
Comparative Example 2	Compound E1	7.35	50	1,680	3.36	blue	125
Comparative Example 3	Compound E2	6.15	50	1,870	3.74	blue	156

[0274] From the results shown in Table 1, it is confirmed that the OLEDs of Examples 1 through 6 have higher driving voltage, higher brightness, higher efficiency, higher color purity, and longer lifetime than the OLEDs of Comparative Examples 1 through 3.

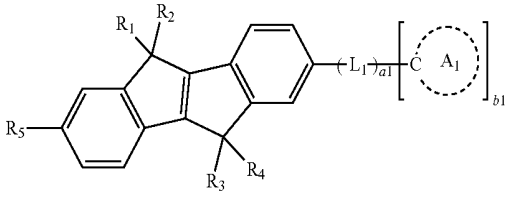
[0275] As described above, according to the one or more embodiments, an OLED including the condensed-cyclic compound may have a low driving voltage, high brightness, high efficiency, and long lifetime.

[0276] While the present embodiments have been particularly shown and described with reference to example embodiments thereof, 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 embodiments as defined by the following claims.

What is claimed is:

1. A compound represented by Formula 1 below:

Formula 1



wherein A_1 is a substituted or unsubstituted C_2-C_{60} heteroaryl group containing at least one of N, O, and S as a ring-forming atom;

L_1 is a substituted or unsubstituted C_6-C_{60} arylene group or a substituted or unsubstituted C_2-C_{60} heteroarylene group;

a1 is an integer of 0 to 5;

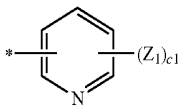
b1 is an integer of 1 to 5; and

R_1 through R_5 are each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{60} cycloalkyl group, a substituted or unsubstituted C_3-C_{60} cycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group.

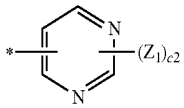
2. The compound of claim **1**, wherein A1 is a substituted or unsubstituted pyrrolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted imidazolyl group, a substituted or unsubstituted imidazolinyl group, a substituted or unsubstituted imidazopyridinyl group, a substituted or unsubstituted imidazopyrimidinyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted indolizinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted indazolyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenazinyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted pyranyl group, a substituted or unsubstituted chromenyl group, a substituted or unsubstituted furanyl group, a substituted or unsubstituted benzofuranyl group, a substituted or unsubstituted thiophenyl group, a substituted or unsubstituted benzothiophenyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted isoxazolyl group, a substituted or unsubstituted dibenzothiophenyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted oxadiazolyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted isoquinolinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted benzothiazolyl group, or a substituted or unsubstituted benzooxazolyl group.

3. The compound of claim **1**, wherein A1 is one of Formulae 3A through 30 below:

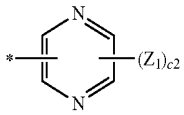
Formula 3A



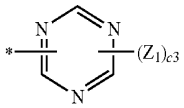
Formula 3B



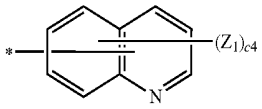
Formula 3C



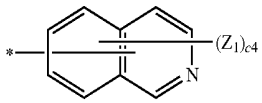
Formula 3D



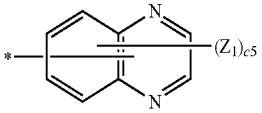
Formula 3E



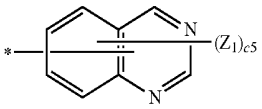
Formula 3F



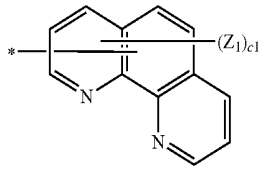
Formula 3G



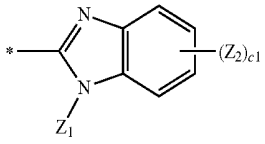
Formula 3H



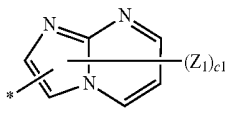
Formula 3I



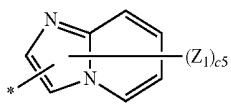
Formula 3J



Formula 3K



Formula 3L



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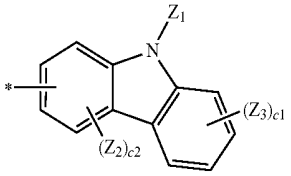
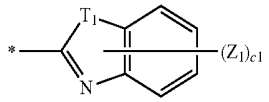
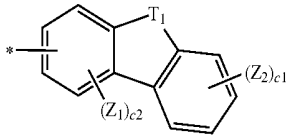
Formula 3M



Formula 3N



Formula 3O



wherein Z_1 through Z_3 are each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60}, alkoxy group, a C_3-C_{60} cycloalkyl group, a C_3-C_{60} cycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group;

c1 is an integer of 1 to 4;

c2 is an integer of 1 to 3;

c3 is an integer of 1 to 2;

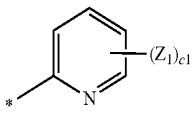
c4 is an integer of 1 to 6;

c5 is an integer of 1 to 5; and

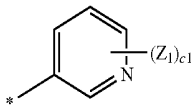
T_1 is O or S.

4. The compound of claim **1**, wherein A_1 is one of Formulae 4A through 4R below:

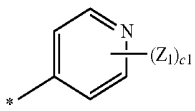
Formula 4A



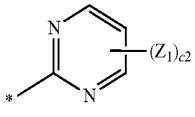
Formula 4B



Formula 4C



Formula 4D



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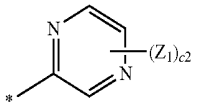
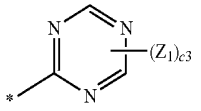
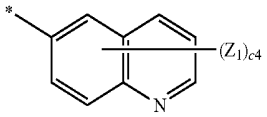
Formula 4E



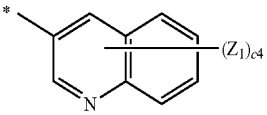
Formula 4F



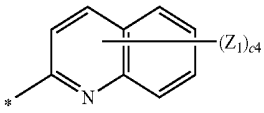
Formula 4G



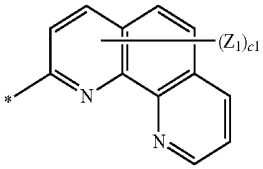
Formula 4H



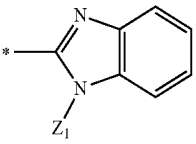
Formula 4I



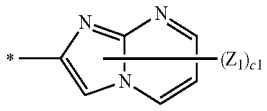
Formula 4J



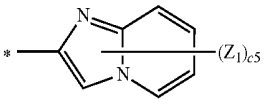
Formula 4K



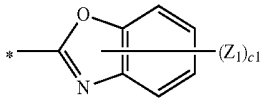
Formula 4L



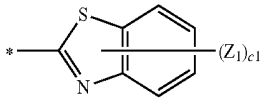
Formula 4M



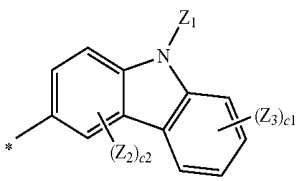
Formula 4N



Formula 4O



Formula 4P



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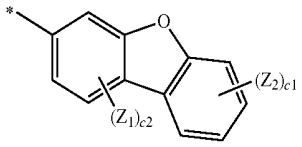
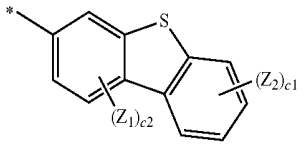
Formula 4Q



Formula 4R



wherein Z_1 through Z_3 are each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, a pyrenyl group, a phenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a naphthyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, an anthryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a fluorenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyrenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyridinyl group, a dibenzothiophenyl group, or a dibenzofuranyl group; and

c1 through c5 are 1 or 2.

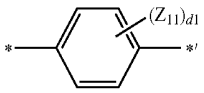
5. The compound of claim **4**, wherein Z_1 through Z_3 are each independently hydrogen, a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, a pyrenyl group, a phenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a naphthyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, an anthryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a fluorenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyrenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyridinyl group, a dibenzothiophenyl group, or a dibenzofuranyl group.

6. The compound of claim **1**, wherein L_1 is a substituted or unsubstituted phenylene group, a substituted or unsubstituted pentalenylene group, a substituted or unsubstituted indenylene group, a substituted or unsubstituted naphtylene group, a substituted or unsubstituted azulenylene group, a substituted or unsubstituted heptalenylene group, a substituted or unsubstituted indacenylene group, a substituted or unsubstituted acenaphtylene group, a substituted or unsubstituted fluorenylene group, a substituted or unsubstituted spirofluorenylene group, a substituted or unsubstituted phenalenylene group, a substituted or unsubstituted phenanthrenylene group, a substituted or unsubstituted anthrylene group, a substituted or unsubstituted fluoranthenylene group, a substituted or unsubstituted triphenylenylene group, a substituted or unsubstituted pyrenylene group, a substituted or unsubstituted chrysenylene group, a substituted or unsubstituted naphthacenylene group, a substituted or unsubstituted picenylene group, a substituted or unsubstituted perylenylene group, a substituted or unsubstituted pen-

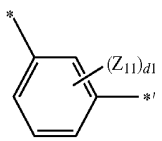
taphenylene group, a substituted or unsubstituted hexacenylene group, a substituted or unsubstituted pyrrolylene group, a substituted or unsubstituted imidazolylene group, a substituted or unsubstituted pyrazolylene group, a substituted or unsubstituted pyridinylene group, a substituted or unsubstituted pyrazinylene group, a substituted or unsubstituted pyrimidinylene group, a substituted or unsubstituted pyridazinylene, a substituted or unsubstituted isoindolylene group, a substituted or unsubstituted indolylene group, a substituted or unsubstituted indazolylene group, a substituted or unsubstituted purinylene group, a substituted or unsubstituted quinolinylene group, a substituted or unsubstituted benzoquinolinylene group, a substituted or unsubstituted phthalazinylene group, a substituted or unsubstituted naphthyridinylene group, a substituted or unsubstituted quinoxalinylene group, a substituted or unsubstituted quinazolinylene group, a substituted or unsubstituted cinnolinylene group, a substituted or unsubstituted carbazolylene group, a substituted or unsubstituted phenanthridinylene group, a substituted or unsubstituted acridinylene group, a substituted or unsubstituted phenanthrolinylene group, a substituted or unsubstituted phenazinylene group, a substituted or unsubstituted benzooxazolylene group, a substituted or unsubstituted benzoimidazolylene group, a substituted or unsubstituted furanylene group, a substituted or unsubstituted benzofuranylene group, a substituted or unsubstituted thiophenylene group, a substituted or unsubstituted benzothiophenylene group, a substituted or unsubstituted thiazolylene group, a substituted or unsubstituted isothiazolylene group, a substituted or unsubstituted benzothiazolylene group, a substituted or unsubstituted isoxazolylene group, a substituted or unsubstituted oxazolylene group, a substituted or unsubstituted triazolylene group, a substituted or unsubstituted tetrazolylene group, a substituted or unsubstituted oxadiazolylene group, a substituted or unsubstituted triazinylene group, a substituted or unsubstituted benzooxazolylene group, a substituted or unsubstituted dibenzofuranylene group, a substituted or unsubstituted dibenzothiophenylene, or a substituted or unsubstituted benzocarbazolylene group.

7. The compound of claim **1**, wherein L_1 is one of Formulae 5A through 5M below:

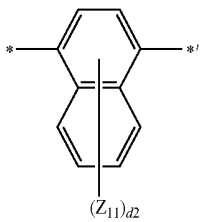
Formula 5A



Formula 5B



Formula 5C



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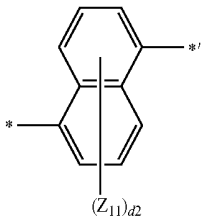
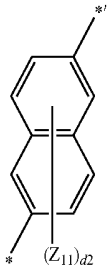
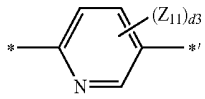
Formula 5D



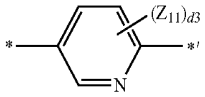
Formula 5E



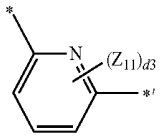
Formula 5F



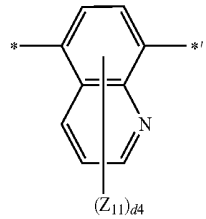
Formula 5G



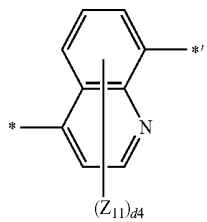
Formula 5H



Formula 5I



Formula 5J



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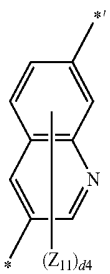

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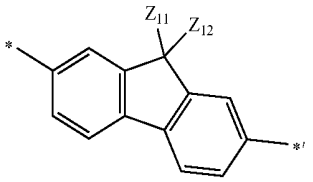

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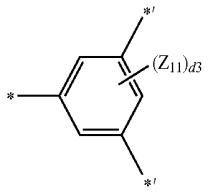


wherein Z_{11} and Z_{12} are each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{60} cycloalkyl group, a C_3-C_{60} cycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group;

d1 is an integer of 1 to 4;

d2 is an integer of 1 to 6;

d3 is an integer of 1 to 3;

d4 is an integer of 1 to 5;

*' denotes a binding side with A_1.

8. The compound of claim **7**, wherein Z_{11} and Z_{12} are each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a naphthyl group, an anthryl group, a fluorenyl group, a pyrenyl group, a phenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a naphthyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, an anthryl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a fluorenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyrenyl group that is substituted with at least one of —F, —CN, and a C_1-C_{10} alkyl group, a pyridinyl group, a dibenzothiophenyl group, or a dibenzofuranyl group.

9. The compound of claim **1**, wherein a1 is 0 or 1; and b1 is 1 or 2.

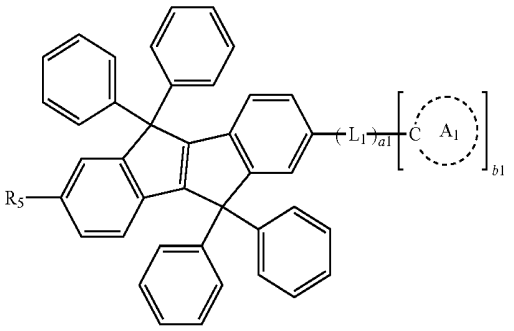
10. The compound of claim **1**, wherein R_1 through R_4 are each independently a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a phenyl group, a naphthyl group, an anthryl group, or a fluorenyl group.

11. The compound of claim **1**, wherein R_1 through R_4 are identical.

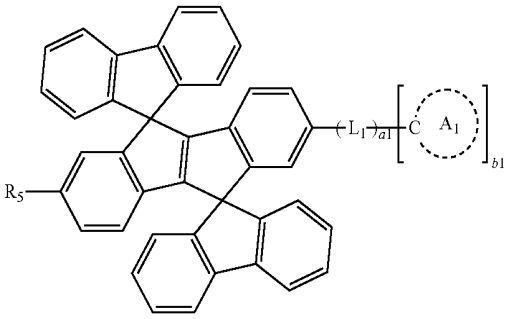
12. The compound of claim **1**, wherein R_1 and R_2 are linked to each other by a single bond, and R_3 and R_4 are linked to each other by a single bond.

13. The compound of claim **1**, wherein the compound is represented by Formula 1A or 1B:

Formula 1A



Formula 1B



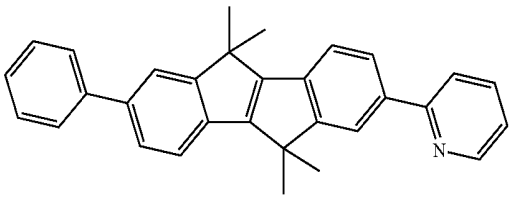
wherein L_1, a_1, b_1, A_1 ring, and R_5 are the same as defined in claim **1**.

14. The compound of claim **1**, wherein R_5 is a substituted or unsubstituted phenyl group, a substituted or unsubstituted pentalenyl group, a substituted or unsubstituted indenyl group, a substituted or unsubstituted naphtyl group, a substituted or unsubstituted azulenyl group, a substituted or unsubstituted heptalenyl group, a substituted or unsubstituted indacenyl group, a substituted or unsubstituted acenaphtyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted phenalenyl group, a substituted or unsubstituted phenanthrenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted fluoranthenyl group, a substituted or unsubstituted triphenylenyl group, a substituted or unsubstituted pyrenyl group, a substituted or unsubstituted chrysenyl group, a substituted or unsubstituted naphthacenyl group, a substituted or unsubstituted picenyl group, a substituted or unsubstituted perylenyl group, a substituted or unsubstituted pentaphenyl group, a substituted or unsubstituted hexacenyl group, a substituted or unsubstituted pyrrolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted imidazolyl group, a substituted or unsubstituted imidazolinyl group, a substituted or unsubstituted imidazopyridinyl group, a substituted or unsubstituted imidazopyrimidinyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted indolizinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted

indazolyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenazinyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted pyranyl group, a substituted or unsubstituted chromenyl group, a substituted or unsubstituted furanyl group, a substituted or unsubstituted benzofuranyl group, a substituted or unsubstituted thiophenyl group, a substituted or unsubstituted benzothiophenyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted isoxazolyl group, a substituted or unsubstituted dibenzothiophenyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted oxadiazolyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted isoquinolinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted benzothiazolyl group, or a substituted or unsubstituted benzooxazolyl group.

15. The compound of claim **1**, wherein the compound is one of Compounds 1 through 74 below:

1



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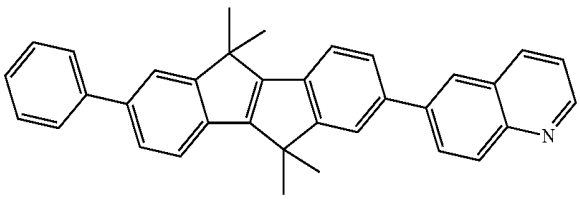

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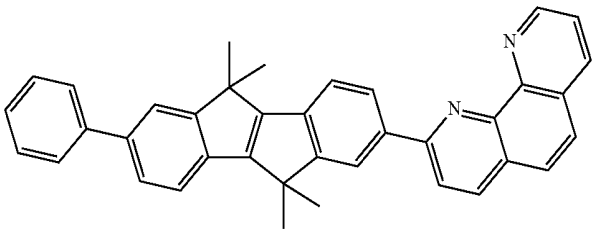

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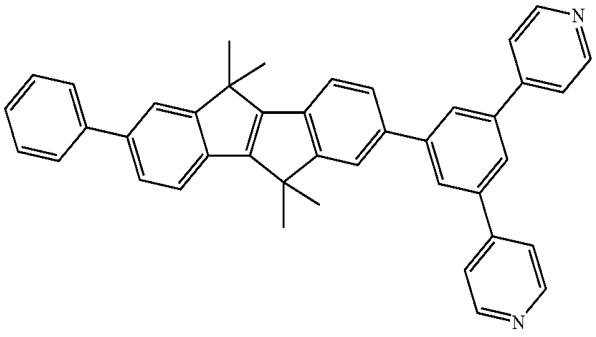

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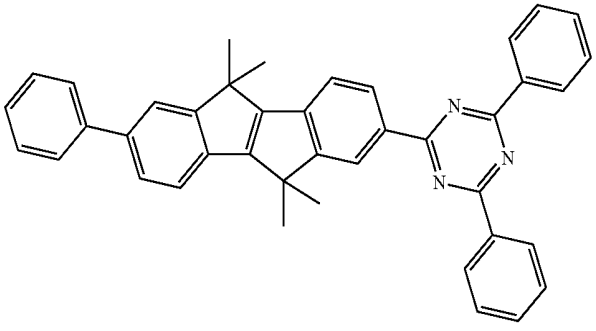

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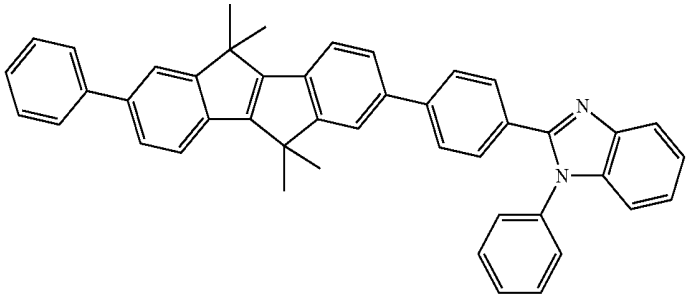

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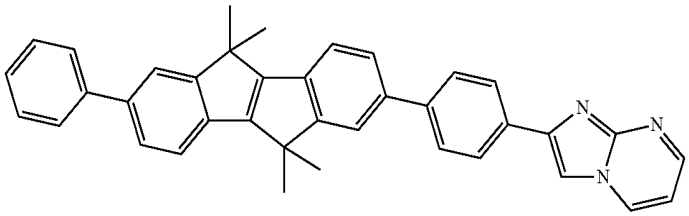

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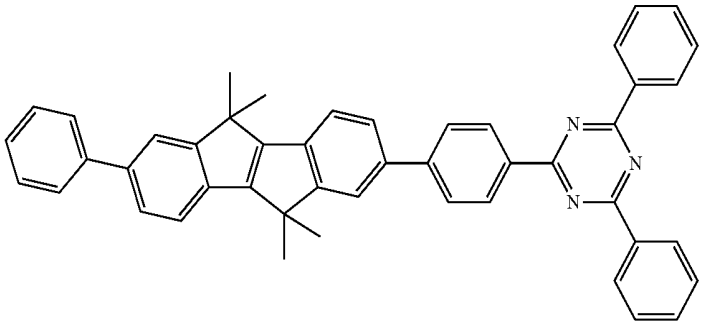

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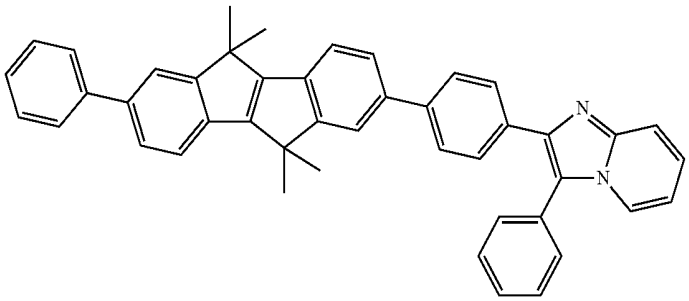

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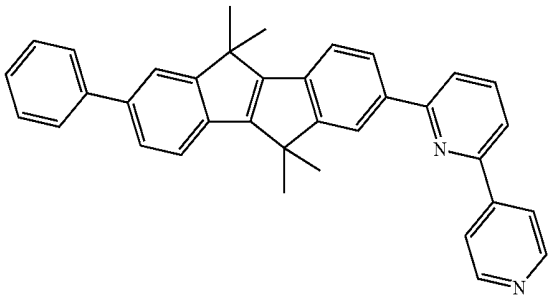

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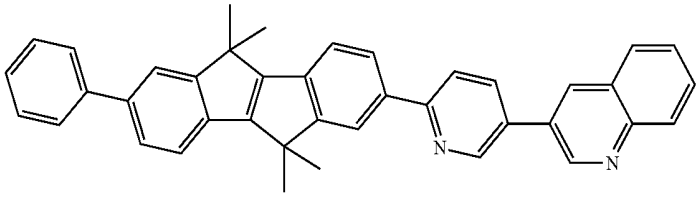

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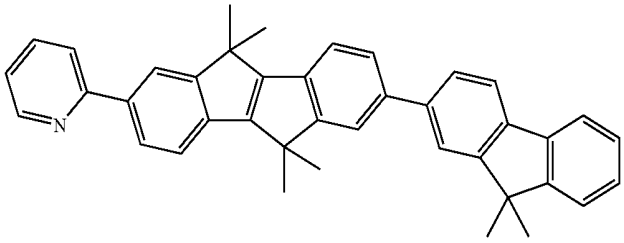

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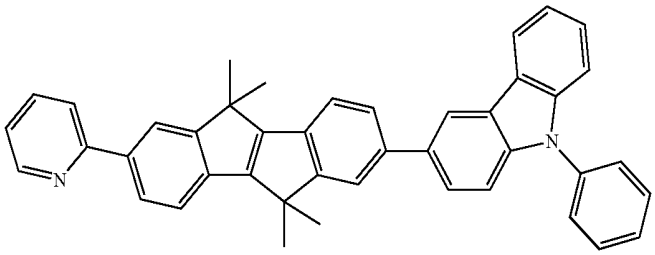

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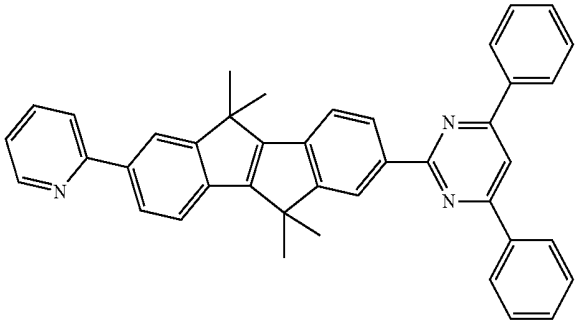

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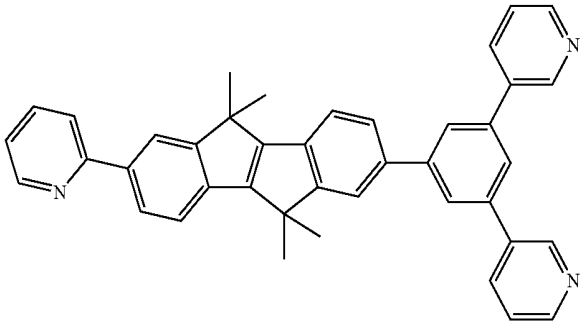

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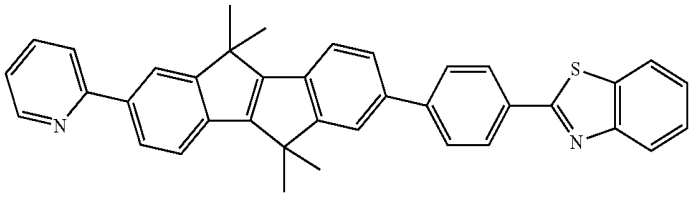

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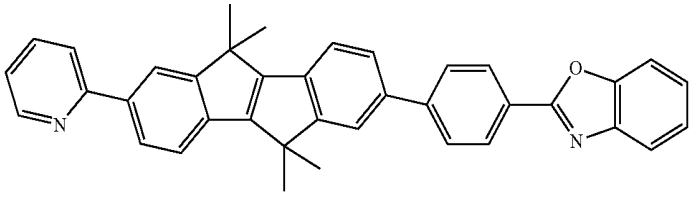

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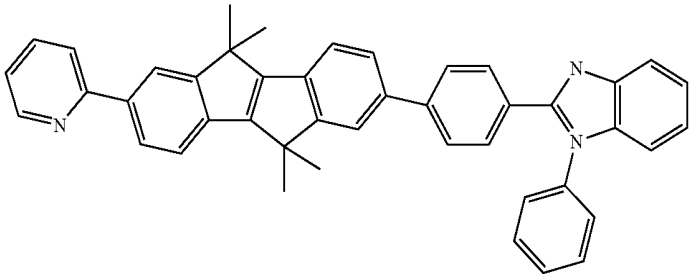

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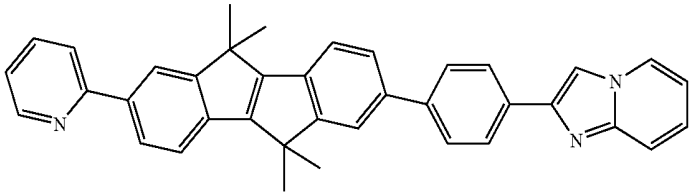

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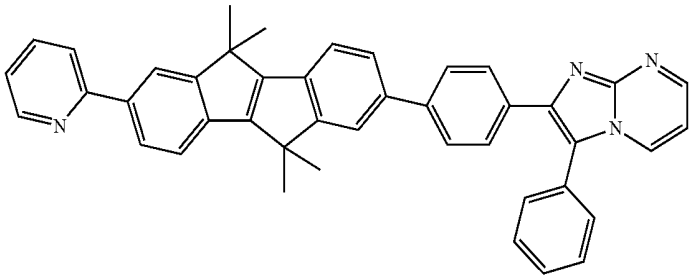

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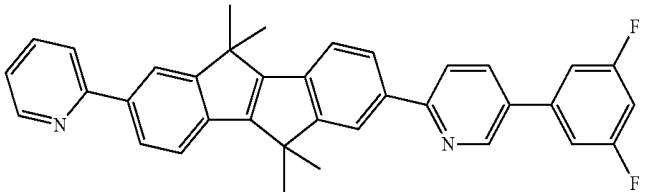

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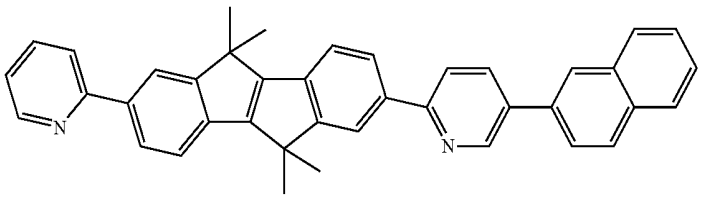

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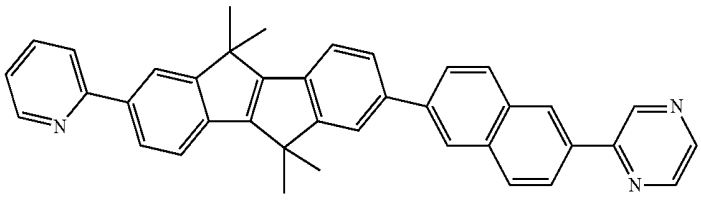

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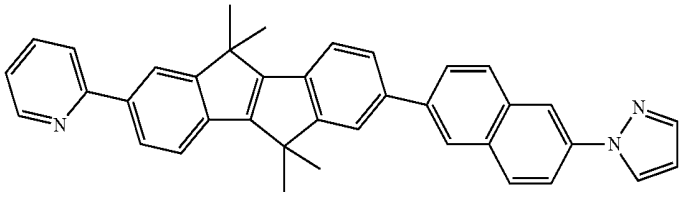

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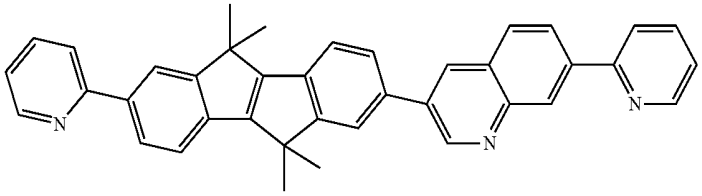

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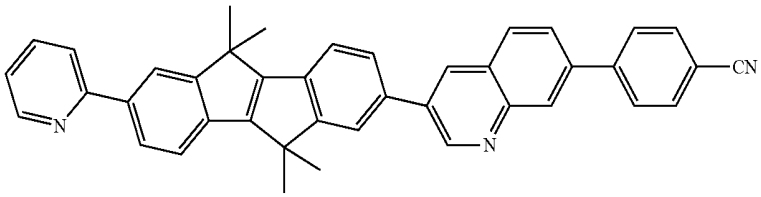

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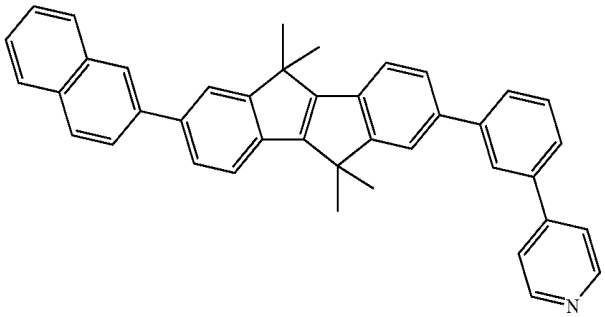

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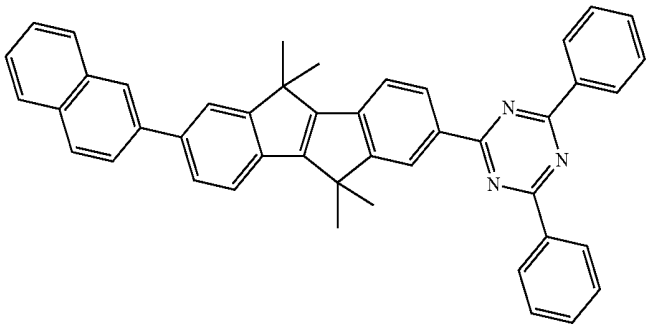

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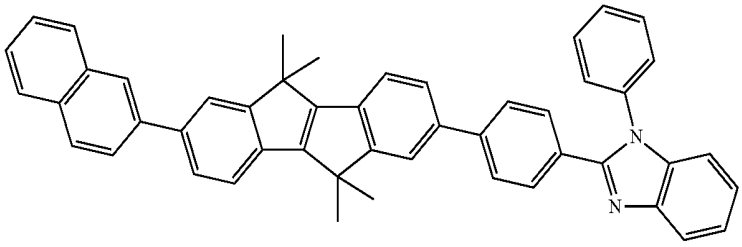

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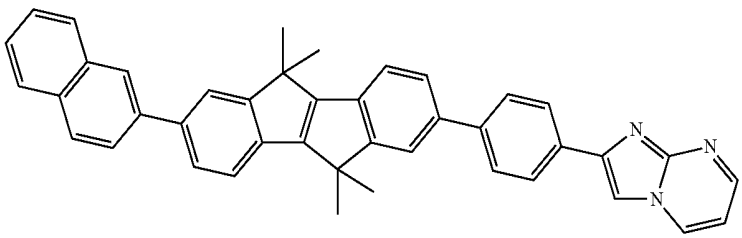

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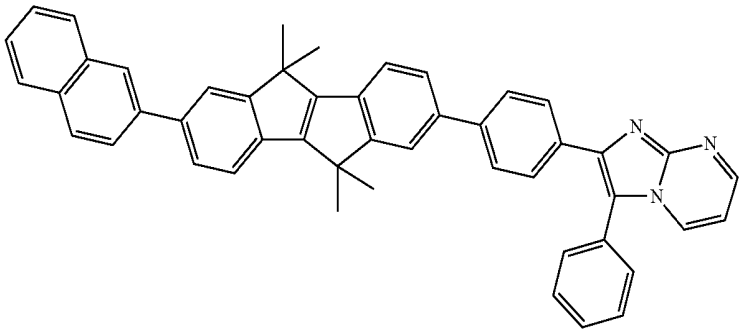

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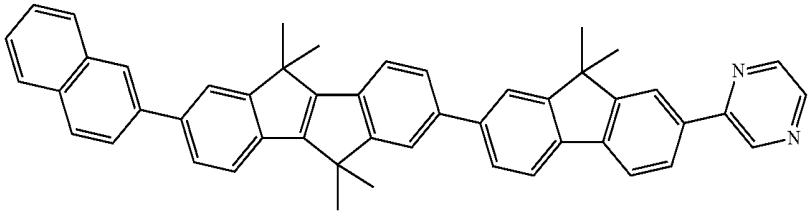

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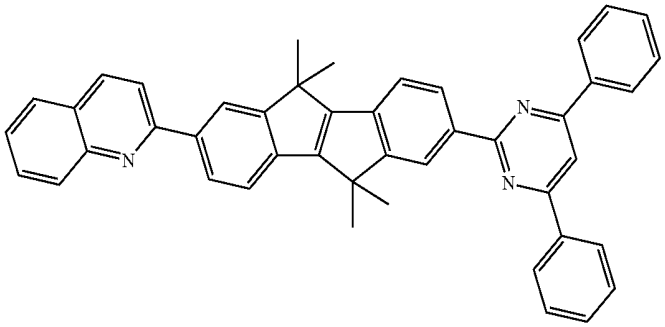

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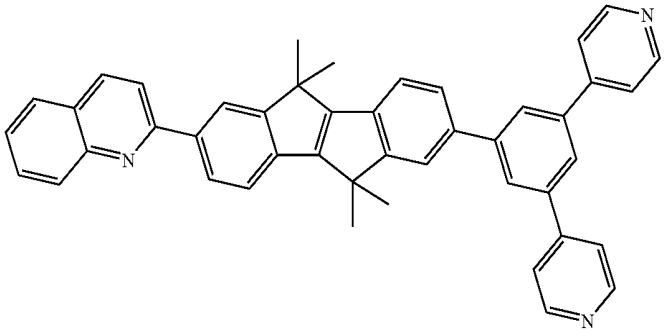

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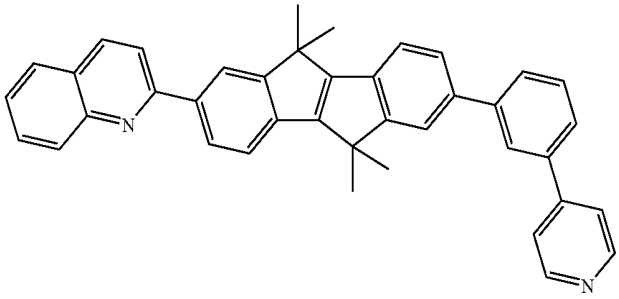

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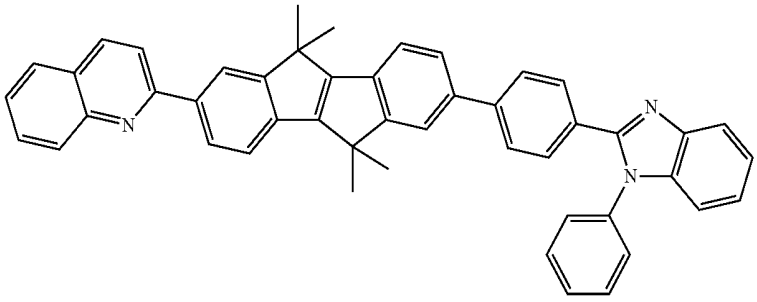

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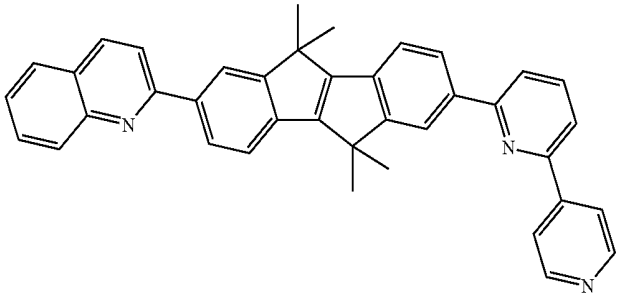

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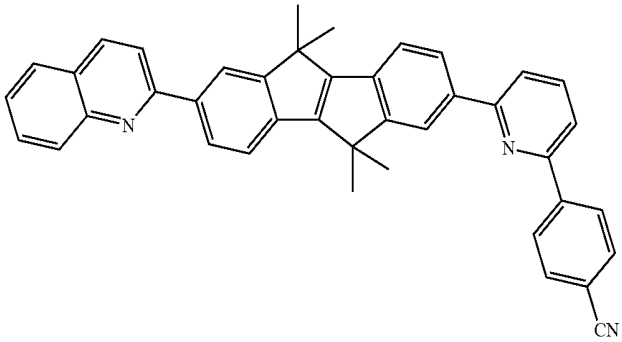

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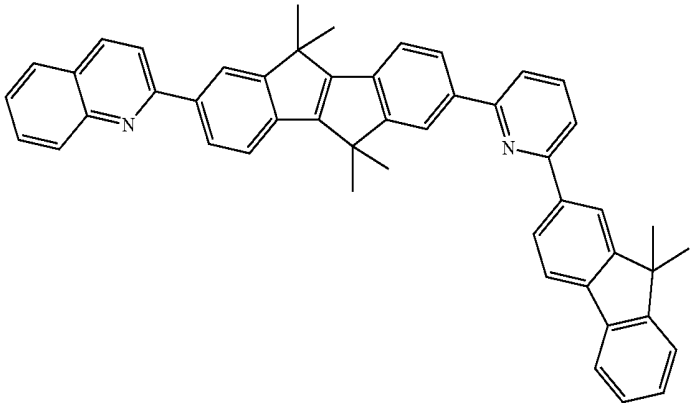

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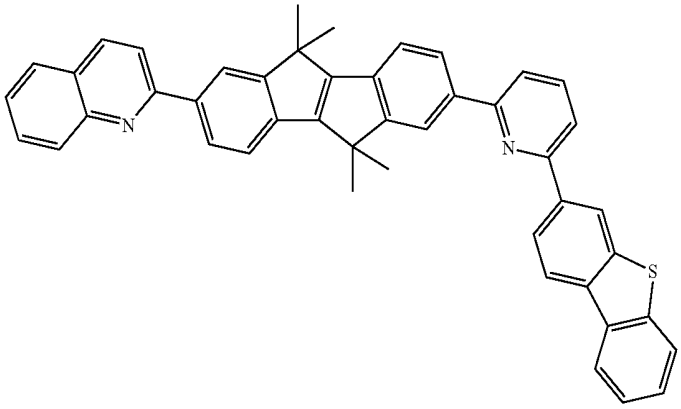

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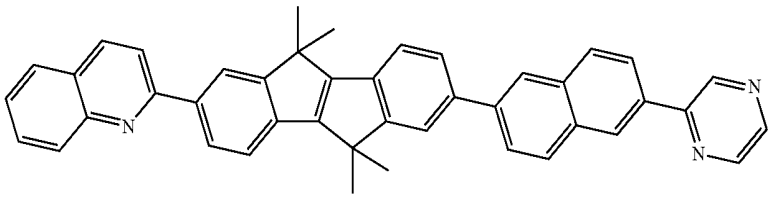

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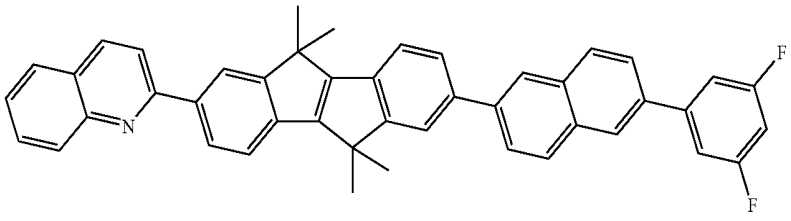

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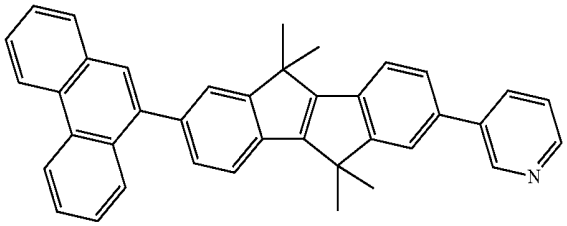

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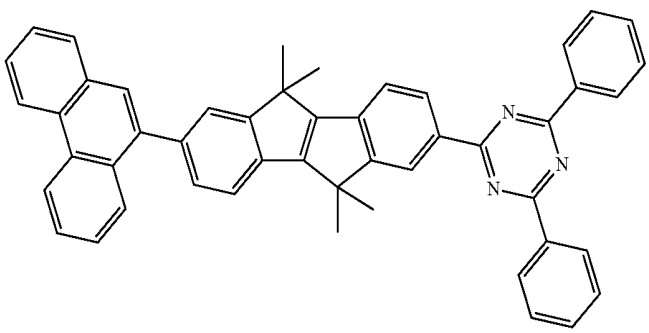

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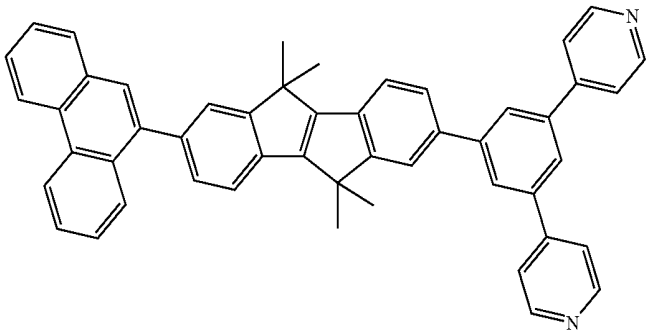

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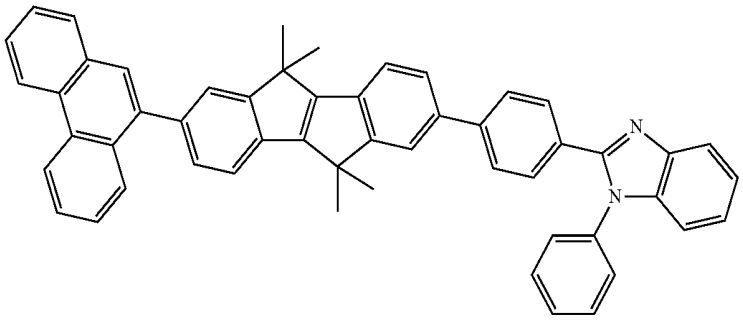

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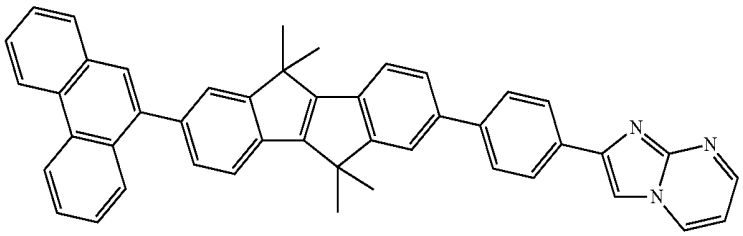

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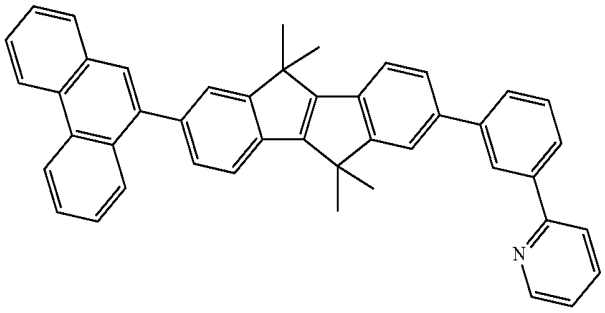

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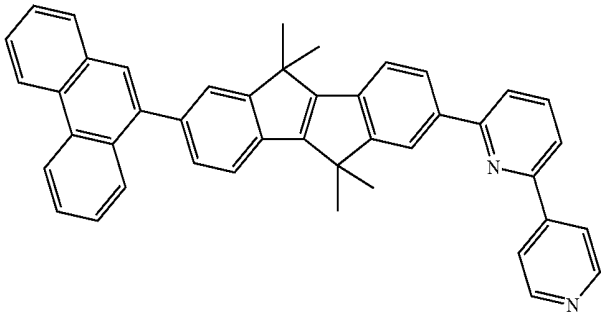

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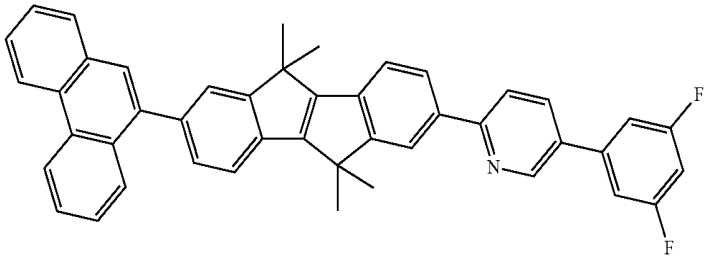

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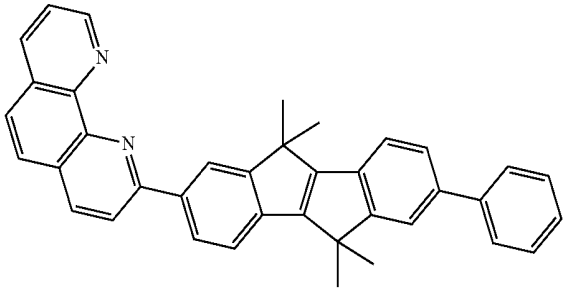

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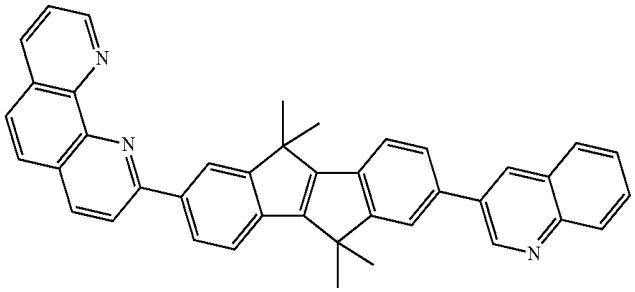

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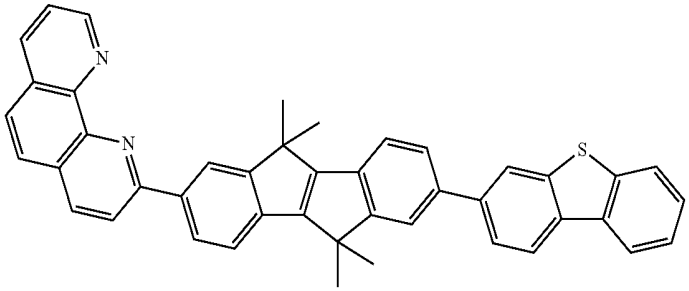

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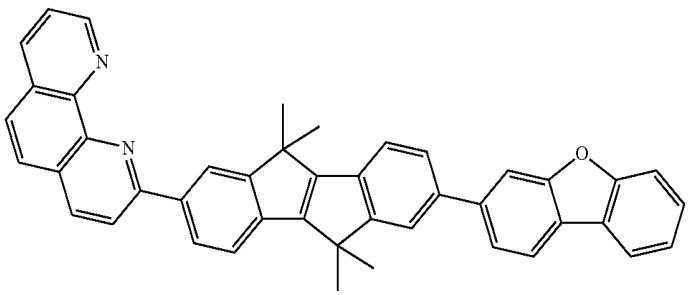

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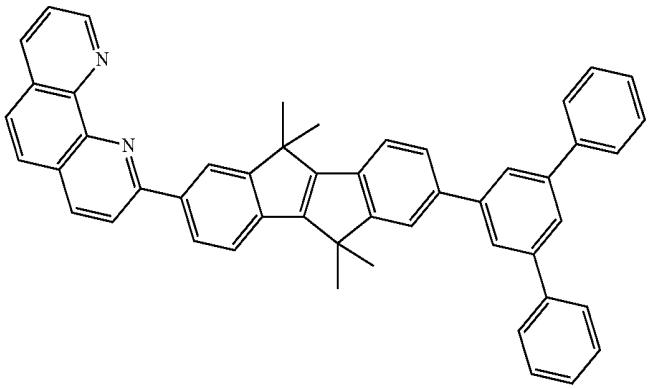

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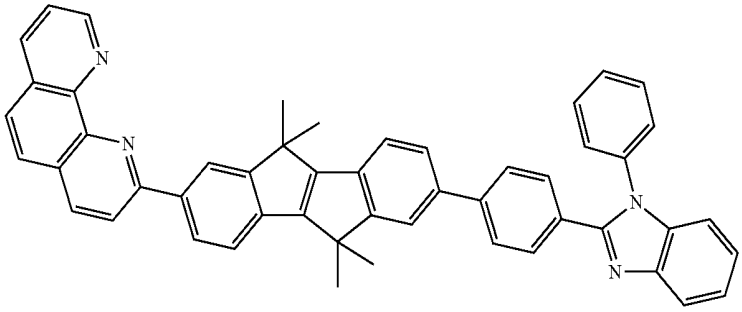

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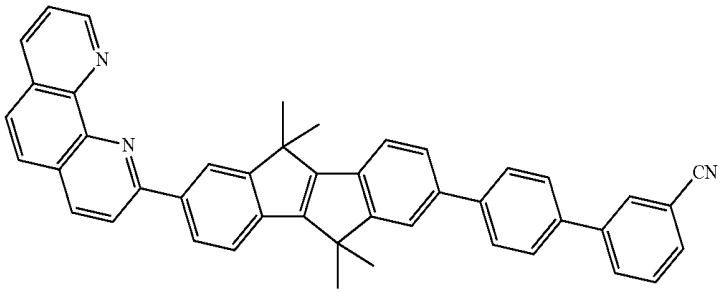

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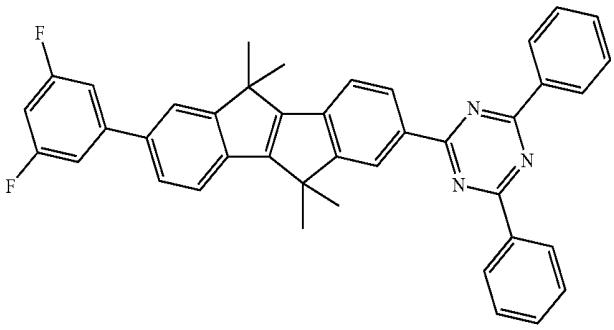

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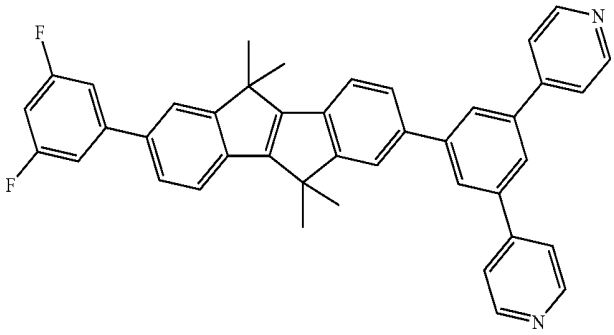

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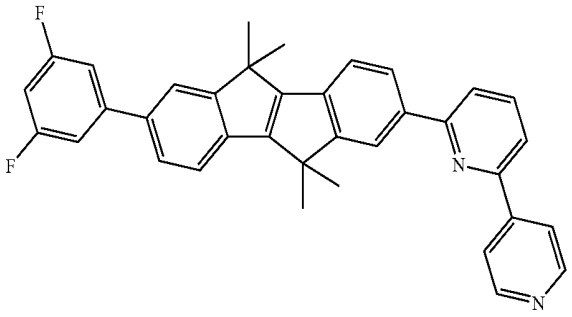

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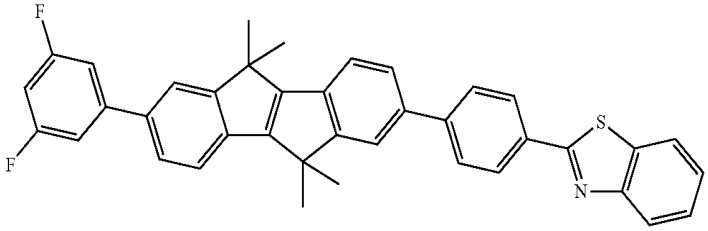

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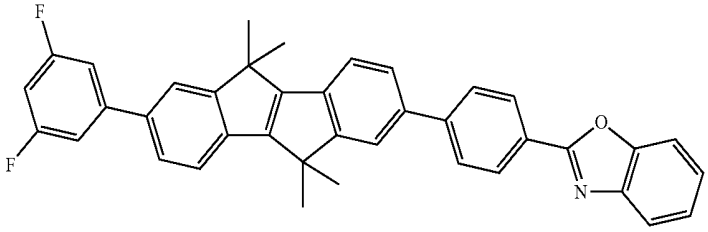

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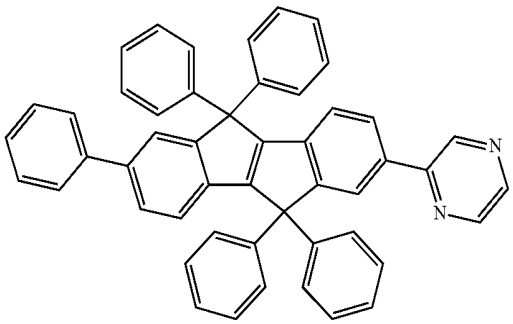

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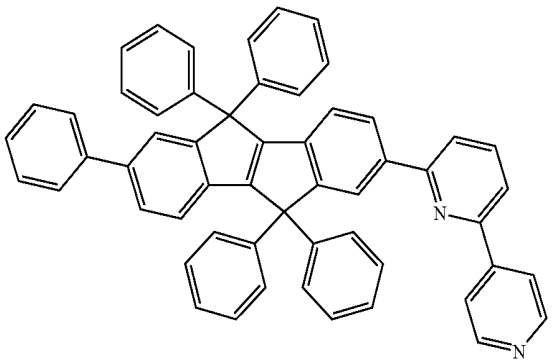

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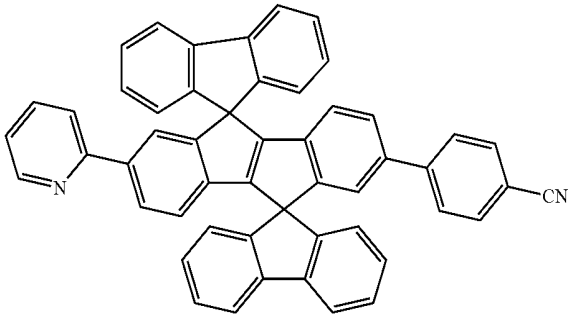

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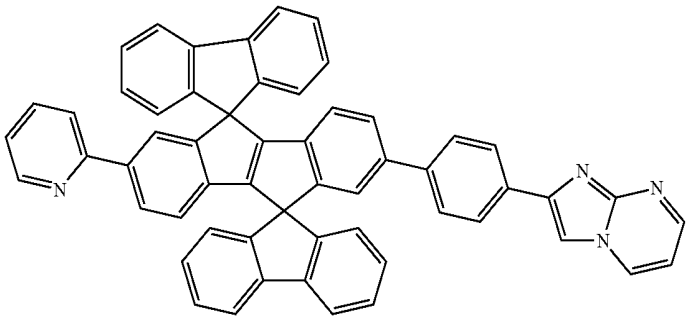

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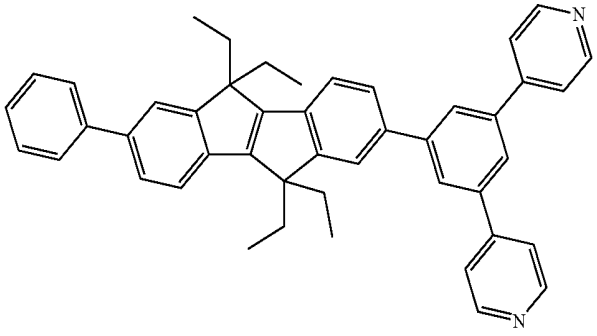

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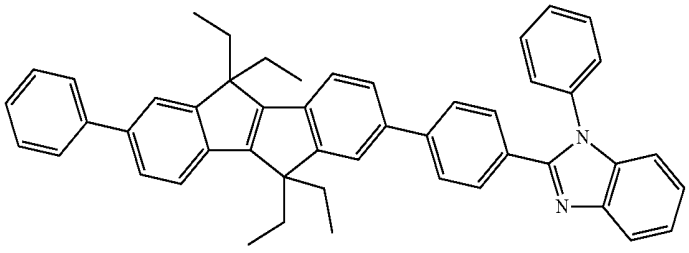

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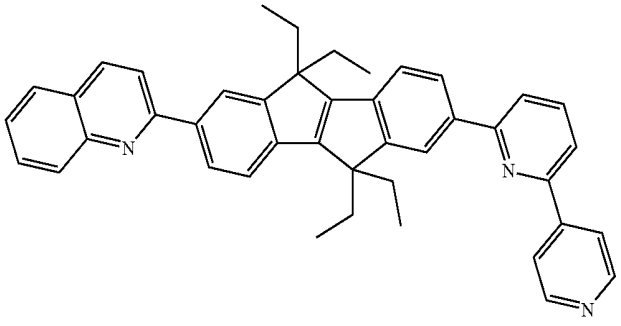

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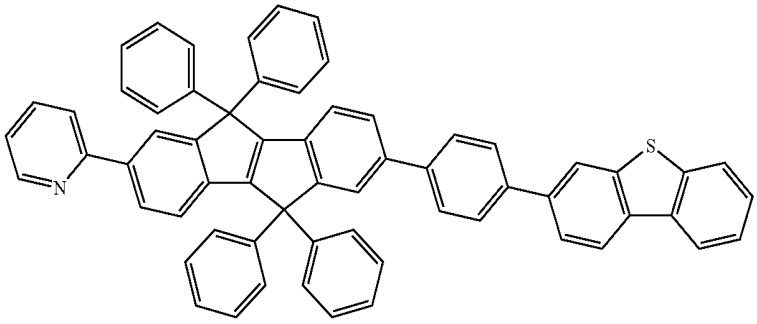

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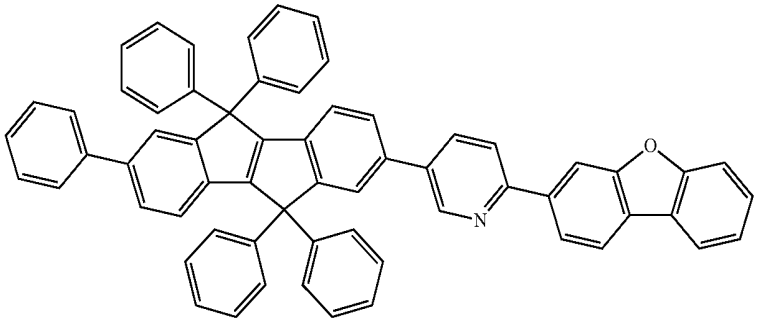

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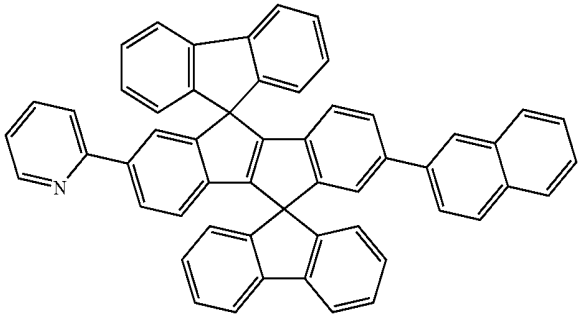

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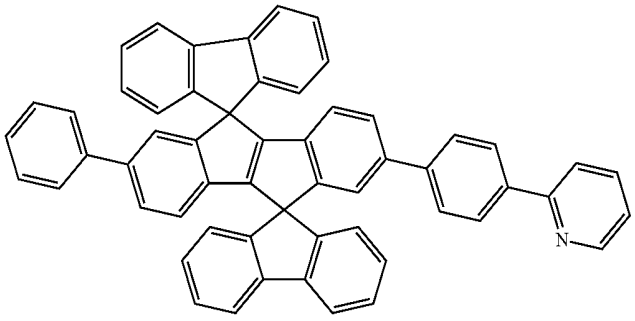

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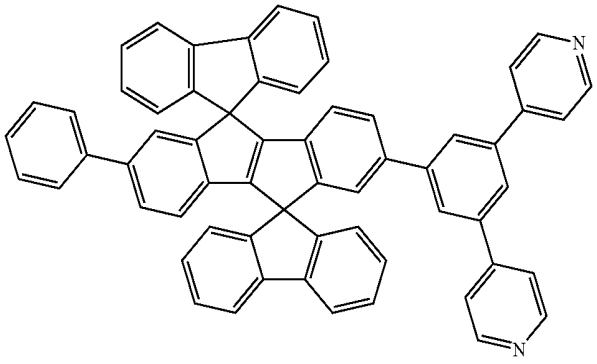
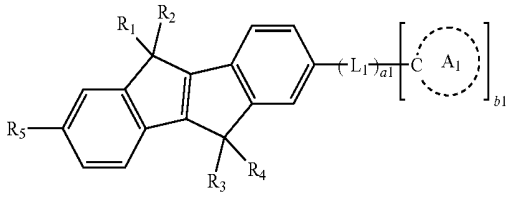


16. An organic light-emitting diode comprising: a first electrode; a second electrode facing the first electrode; and an organic layer interposed between the first electrode and the second electrode, wherein the organic layer comprises at least one compound represented by Formula 1 below:

Formula 1



wherein A_1 is a substituted or unsubstituted C_2-C_{60} heteroaryl group containing at least one of N, O, and S as a ring-forming atom;

L_1 is a substituted or unsubstituted C_6-C_{60} arylene group or a substituted or unsubstituted C_2-C_{60} heteroarylene group;

a1 is an integer of 0 to 5;

b1 is an integer of 1 to 5; and

R_1 through R_5 are each independently hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, hydrazine, hydrazone, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{60} cycloalkyl group, a substituted or unsubstituted C_3-C_{60} cycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, or a substituted or unsubstituted C_2-C_{60} heteroaryl group.

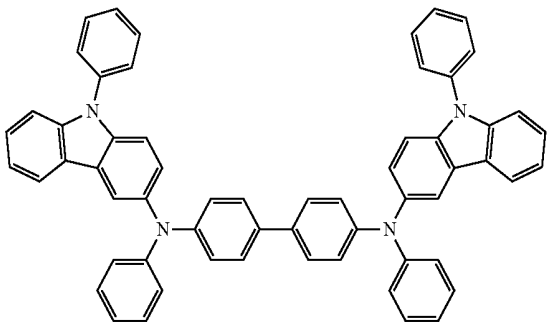
17. The organic light-emitting diode of claim **16**, wherein the organic layer comprises at least one of a hole injection layer, a hole transport layer, a functional layer having hole injection and hole transport abilities, a buffer layer, an electron blocking layer, an emission layer, a hole blocking layer, an electron transport layer, an electron injection layer, and a functional layer having electron injection and electron transport abilities.

18. The organic light-emitting diode of claim **17**, wherein the organic layer comprises an electron transport layer, wherein the compound is included in the electron transport layer.

19. The organic light-emitting diode of claim **18**, wherein the electron transport layer further comprises a metal-containing material.

20. The organic light-emitting diode of claim **17**, wherein the organic layer comprises at least one of a hole injection layer, a hole transport layer, and a functional layer having hole injection and hole transport abilities, wherein at least one of the hole injection layer, the hole transport layer, and the functional layer having hole injection and hole transport abilities comprises at least one of Compounds 301 through 320 below:

301



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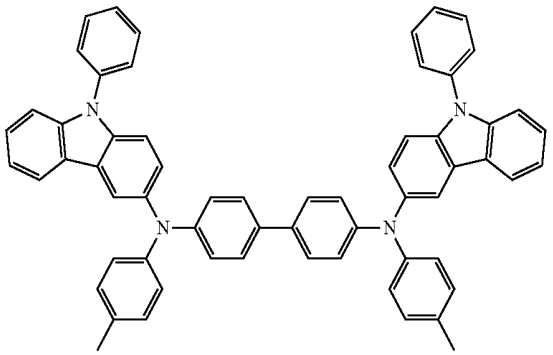

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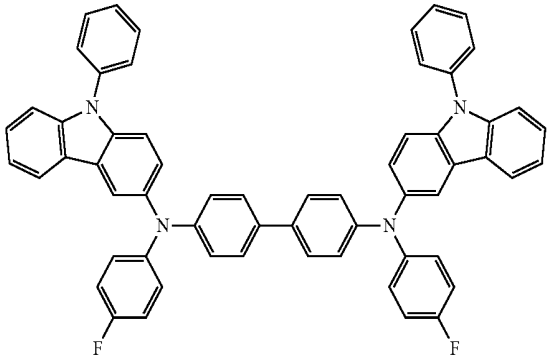

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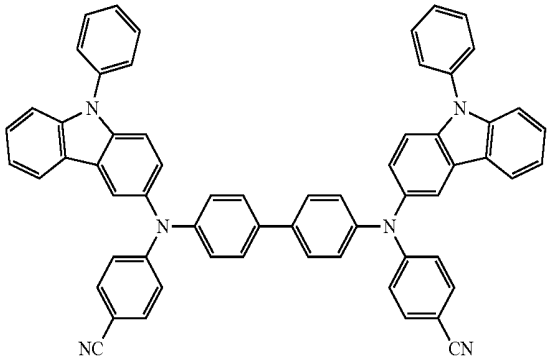

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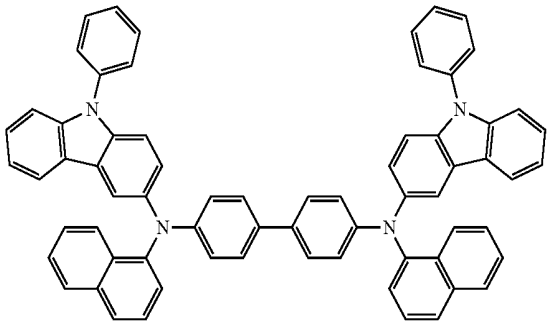

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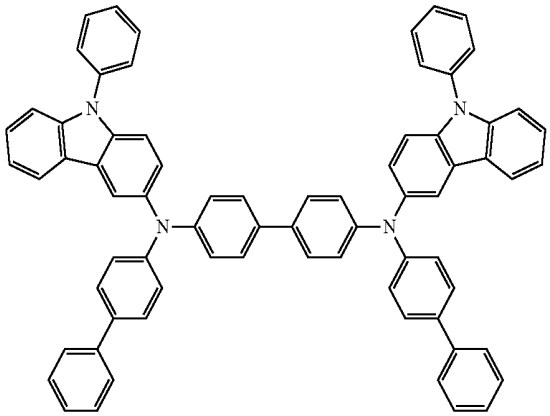

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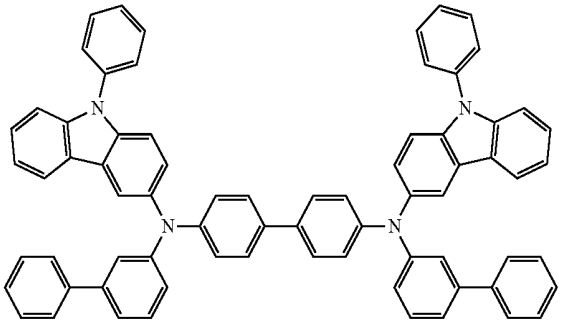

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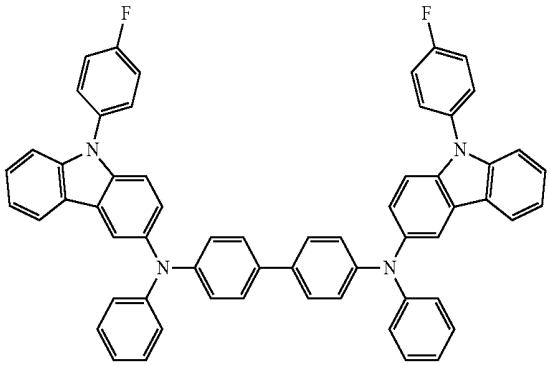

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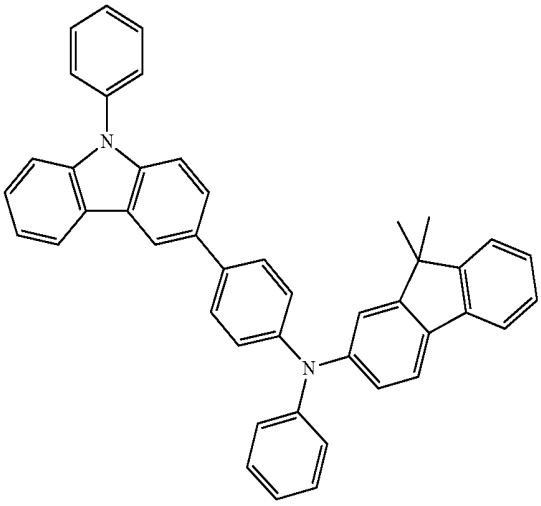

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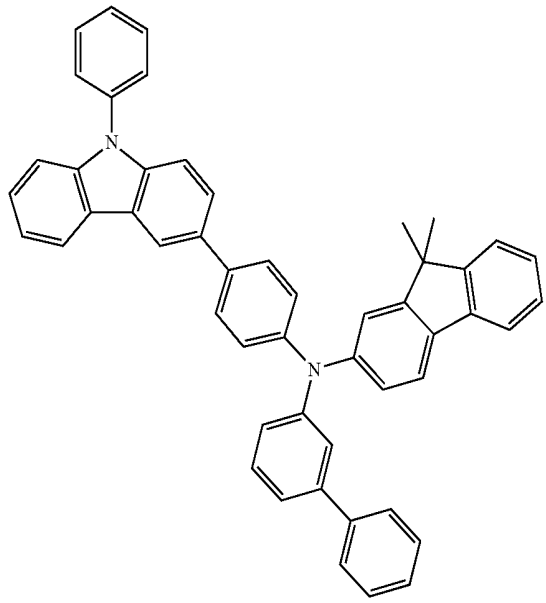

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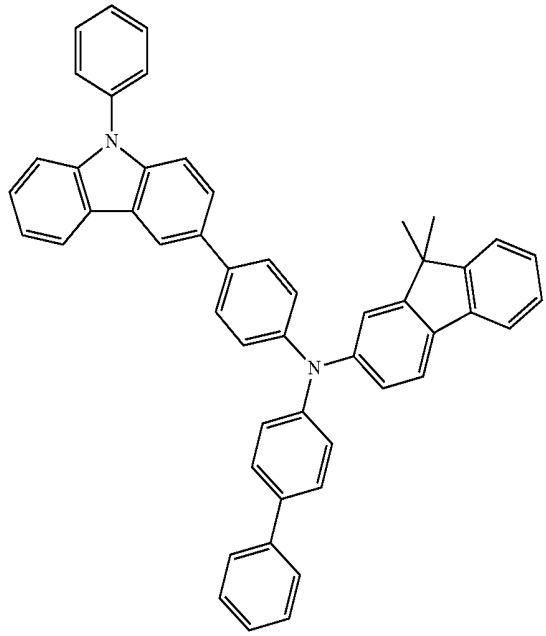

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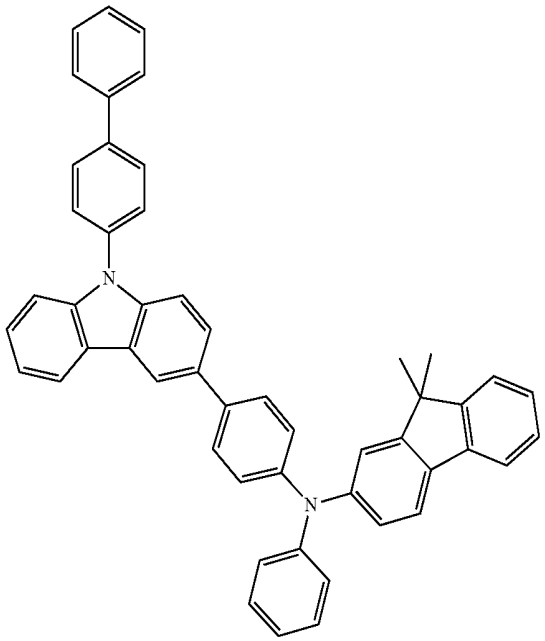

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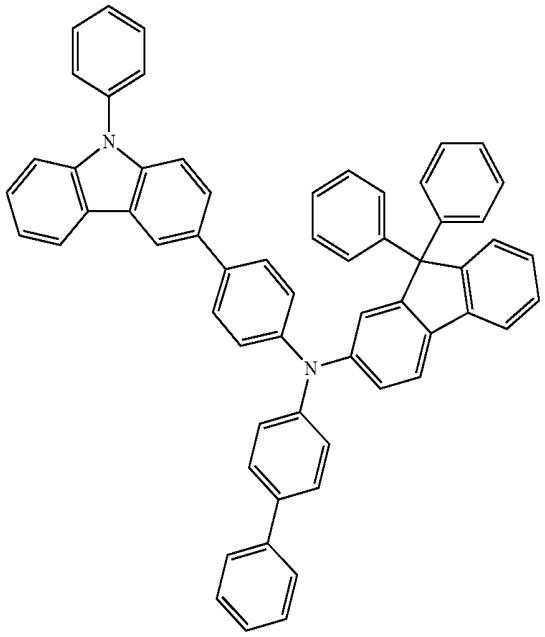

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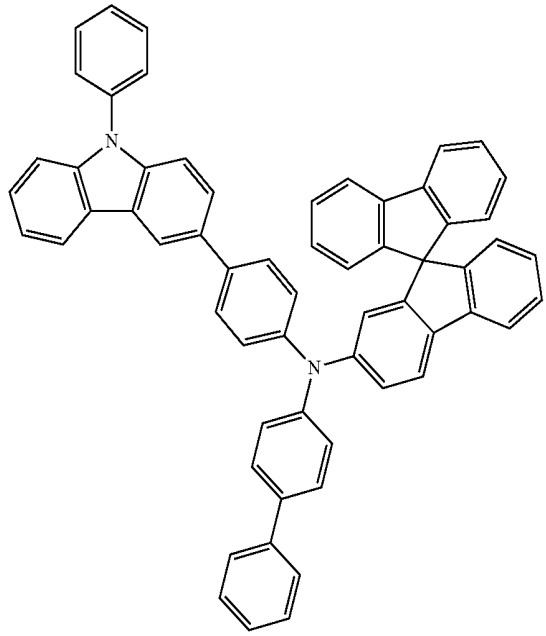

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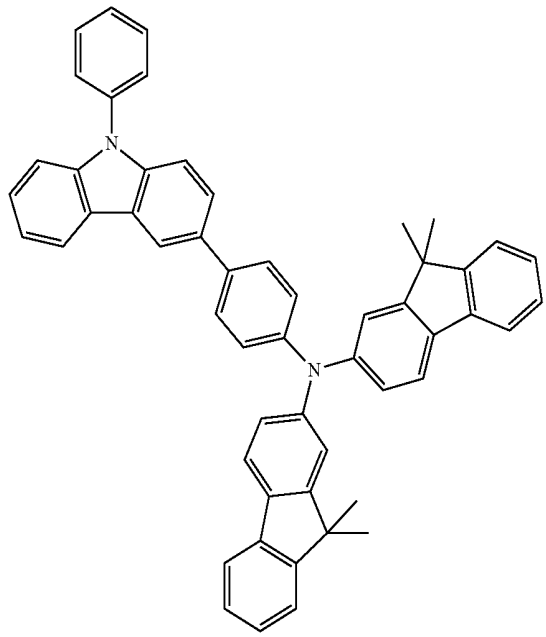

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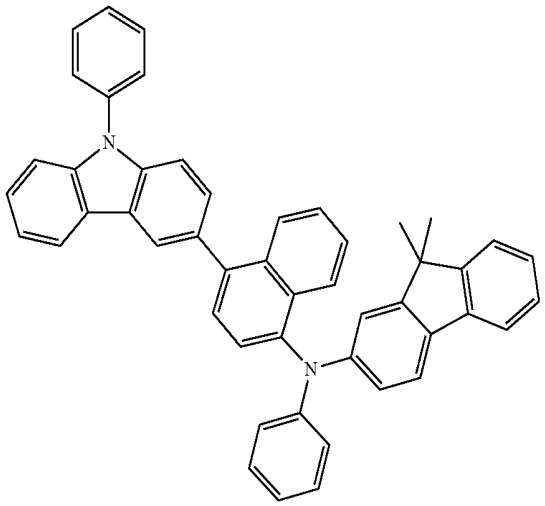
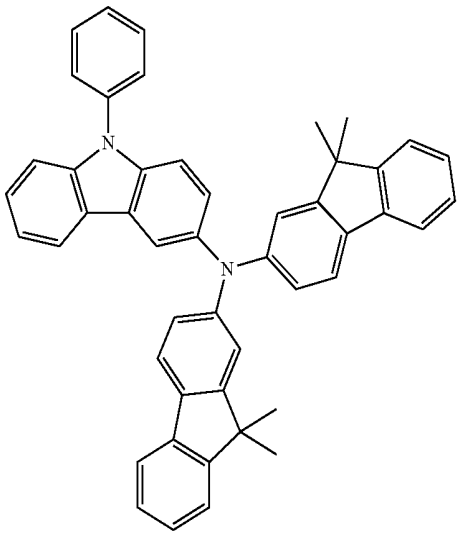
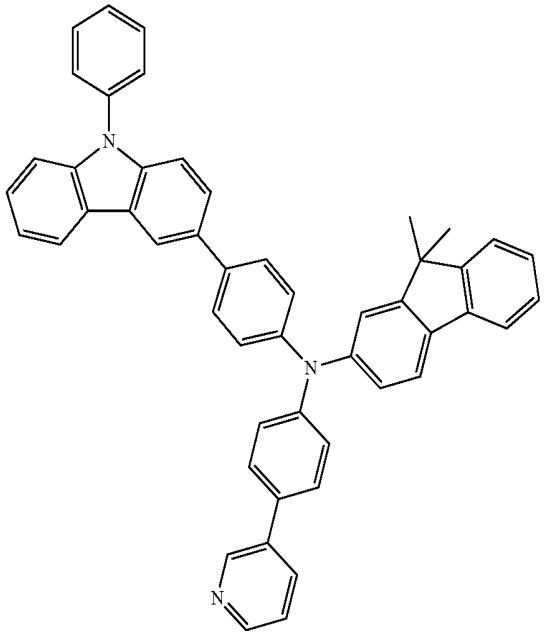


317



318



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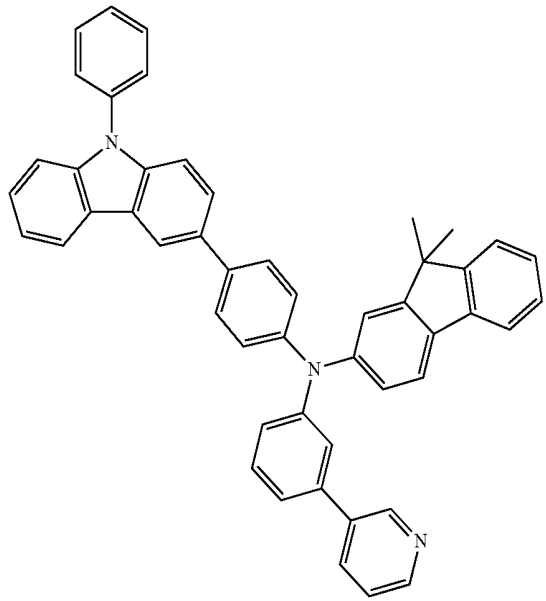
319



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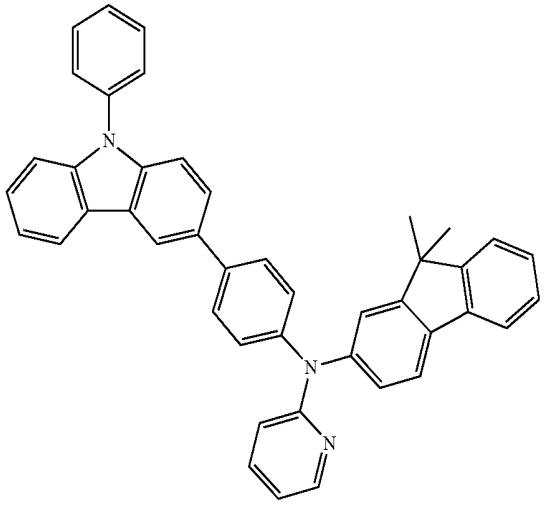

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专利名称(译)	缩合环状化合物和包含缩环化合物的有机发光二极管		
公开(公告)号	US20140077175A1	公开(公告)日	2014-03-20
申请号	US13/800144	申请日	2013-03-13
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
[标]发明人	JUNG HYE JIN HWANG SEOK HWAN KIM YOUNG KOOK LIM JIN O HAN SANG HYUN JEONG EUN JAE KIM SOO YON PARK JUN HA LEE EUN YOUNG LEE CHANG HO LEE JONG HYUK		
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IPC分类号	H01L51/00 C07D213/06 C07D213/16 C07D403/10 C07D213/22 C07D471/04 C07D235/18 C07D251/24		
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优先权	1020120102993 2012-09-17 KR		
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外部链接	Espacenet USPTO		

摘要(译)

缩合环化合物和包含缩环化合物的有机发光二极管。

Formula 1