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(54) **CONDENSED-CYCLIC COMPOUND, ORGANIC LIGHT-EMITTING DEVICE COMPRISING THE SAME, AND FLAT PANEL DISPLAY APPARATUS INCLUDING THE DEVICE**

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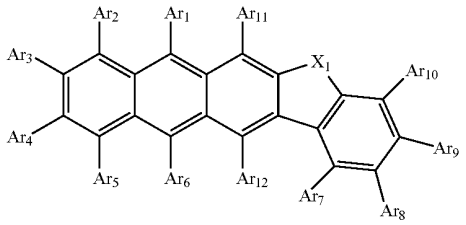
(57) **ABSTRACT**

A condensed-cyclic compound is represented by Formula 1 below. An organic light-emitting device includes the condensed-cyclic compound. A flat panel display apparatus includes the organic light-emitting device.

Formula 1



The organic light-emitting device includes an organic layer including the compound of Formula 1 and has low driving voltage, high emission efficiency, and a long lifetime.

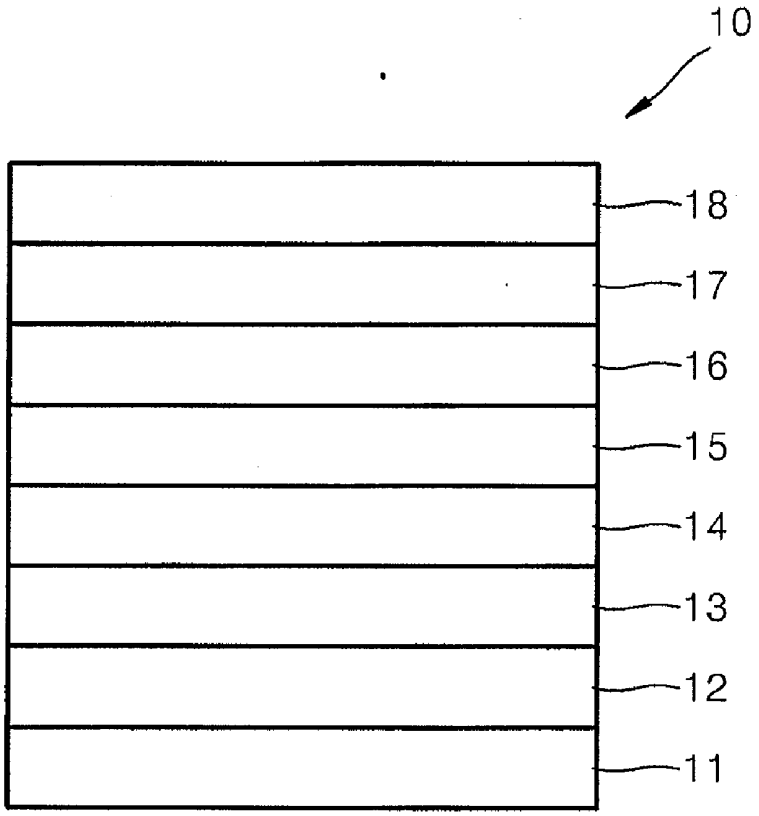
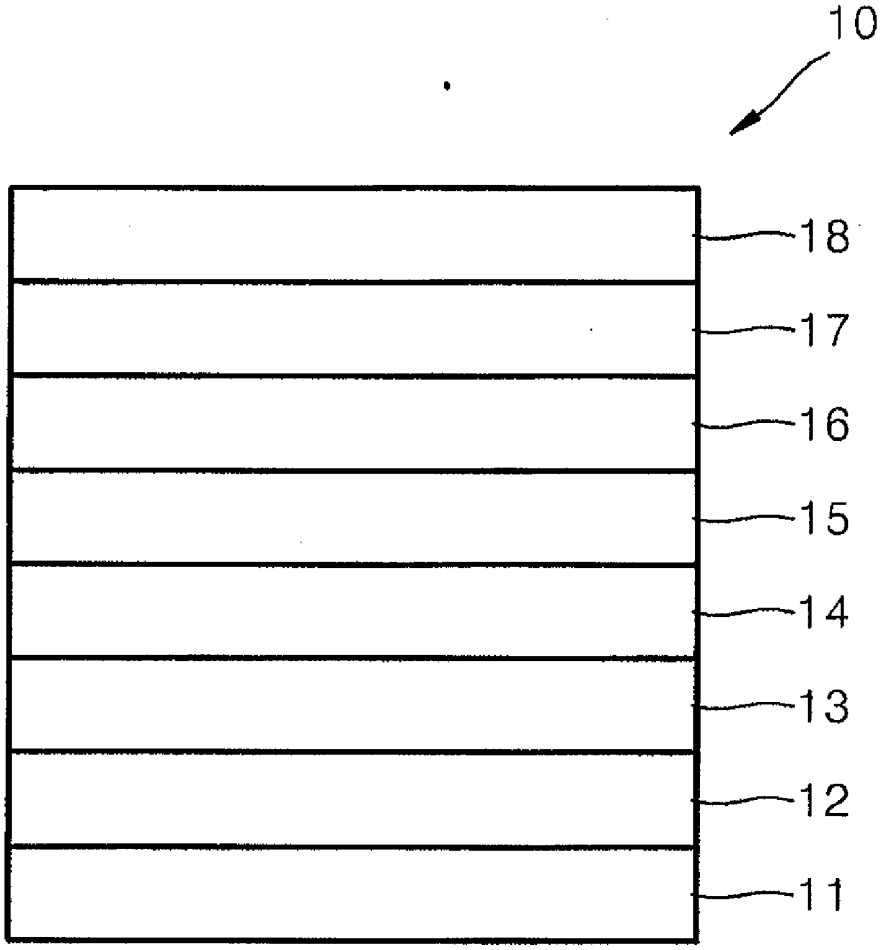


FIG. 1



CONDENSED-CYCLIC COMPOUND, ORGANIC LIGHT-EMITTING DEVICE COMPRISING THE SAME, AND FLAT PANEL DISPLAY APPARATUS INCLUDING THE DEVICE

CROSS-REFERENCE TO RELATED PATENT APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2011-0045118, filed on May 13, 2011 in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to a condensed-cyclic compound, an organic light-emitting device including the same, and a flat panel display apparatus including the organic light-emitting device.

[0004] 2. Description of Related Art

[0005] Organic light-emitting devices are self light-emitting devices which have wide viewing angles, good contrast, rapid response times, good brightness, driving voltage, and response speeds, and are multicolored.

[0006] In general, an organic light-emitting device includes an anode formed on a substrate, and a hole transport layer, an emission layer, an electron transport layer, and a cathode are sequentially formed on the anode. Each of the hole transport layer, the emission layer, and the electron transport layer is an organic thin-film layer including an organic compound.

[0007] The driving method of the organic light-emitting device is as follows. When voltage is applied between the anode and the cathode, holes injected from the anode move to the emission layer through the hole transport layer, and electrons injected from the cathode move to the emission layer through the electron transport layer. Carriers, such as holes and electrons, are recombined in the emission layer and produce excitons. The excitons are changed from an excitation state to a ground state, thereby generating light.

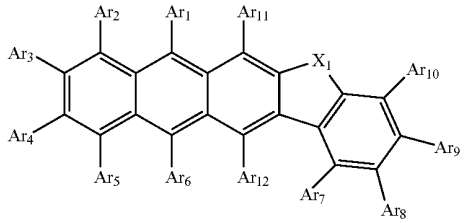
[0008] A need still exists for organic light-emitting devices with improved driving voltage, light-emitting efficiency, and lifetime.

SUMMARY OF THE INVENTION

[0009] Embodiments of the present invention provide a condensed-cyclic compound, an organic light-emitting device including the condensed-cyclic compound, and a flat panel display apparatus including the organic light-emitting device.

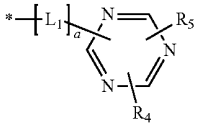
[0010] According to embodiments of the present invention, a condensed-cyclic compound is represented by Formula 1 below:

Formula 1



In Formula 1, X_1 may be CR_1R_2, NR_3, O, or S. Each of Ar_1 through Ar_{12} is independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, substituted or unsubstituted C_1-C_{30} alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, substituted or unsubstituted C_2-C_{30} heterocyclic groups, groups represented by Formula 2 below, groups represented by $N(Q_1)(Q_2)$, and groups represented by $Si(Q_3)(Q_4)(Q_5)$. Each of Q_1 through Q_5 is independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted or unsubstituted C_1-C_{30}alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, and substituted or unsubstituted C_2-C_{30} heterocyclic groups. In some embodiments, at least one of Ar_1 through Ar_{12} is a group represented by Formula 2 below;

Formula 2



In Formula 2, L_1 is a substituted or unsubstituted C_1-C_{30} alkylene group, a substituted or unsubstituted C_5-C_{30} arylene group, or a substituted or unsubstituted divalent C_2-C_{30} heterocyclic group. Also, a is an integer from 0 to , and each of R_1 through R_5 is independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted or unsubstituted C_1-C_{30}alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted

C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, and substituted or unsubstituted C_2-C_{30} heterocyclic groups. Plural numbers in R_4 and R_5 are optionally the same as each other or different from each other.

[0011] According to other embodiments of the present invention, an organic light-emitting device includes: a first electrode; a second electrode facing the first electrode; and an organic light-emitting device including at least one organic layer between the first electrode and the second electrode, where the at least one organic layer is formed of the condensed-cyclic compound described above.

[0012] According to still other embodiments of the present invention, a flat panel display apparatus includes a transistor including a source electrode, a drain electrode, a gate, and an active layer, and the organic light-emitting device described above, where the first electrode of the organic light-emitting device is electrically connected to the source electrode or the drain electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

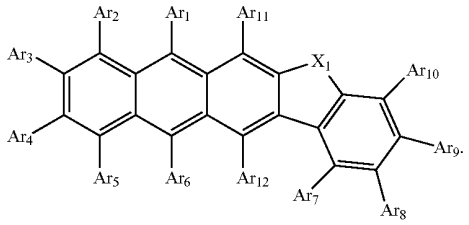
[0013] The above and other features and advantages of the present invention will become more apparent by reference to the following detailed description when considered in conjunction with the attached drawings in which:

[0014] FIG. **1** is a schematic cross-sectional view of an organic light-emitting device according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

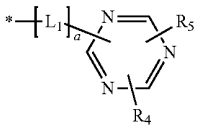
[0015] According to embodiments of the present invention, a condensed-cyclic compound is represented by Formula 1 below:

Formula 1



[0016] In Formula 1, X_1 is CR_1R_2, NR_3, O, or S. Each of Ar_1 through Ar_{12} is independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, substituted or unsubstituted C_{10}-C_{30} alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, substituted or unsubstituted C_2-C_{30} heterocyclic groups, groups represented by Formula 2 below, groups represented by $N(Q_1)(Q_2)$, and groups represented by $Si(Q_3)(Q_4)(Q_5)$.

Formula 2



[0017] In Formula 2, L_1 is a substituted or unsubstituted C_1-C_{30} alkylene group, a substituted or unsubstituted C_5-C_{30} arylene group, or a substituted or unsubstituted divalent C_2-C_{30} heterocyclic group. Also, a is an integer from 0 to 5, and each of R_1 through R_5 is independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted or unsubstituted C_1-C_{30} alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, and substituted or unsubstituted C_2-C_{30} heterocyclic groups. Plural numbers in R_4 and R_5 are optionally the same as each other or different from each other.

[0018] Each of Q_1 through Q_5 is independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted or unsubstituted C_1-C_{30} alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, and substituted or unsubstituted C_2-C_{30} heterocyclic groups. For example, each of Q_1 through Q_5 may be independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted or unsubstituted methyl groups, substituted or unsubstituted ethyl groups, substituted or unsubstituted propyl groups, substituted or unsubstituted butyl groups, substituted or unsubstituted pentyl groups, substituted or unsubstituted phenyl groups, substituted or unsubstituted biphenyl groups, substituted or unsubstituted pentalenyl groups, substituted or unsubstituted indenyl groups, substituted or unsubstituted naphthyl groups, substituted or unsubstituted azulenyl groups, substituted or unsubstituted heptalenyl groups, substituted or unsubstituted indacenyl groups, substituted or unsubstituted acenaphthyl groups, substituted or unsubstituted fluorenyl groups, substituted or unsubstituted spiro-fluorenyl groups, substituted or unsubstituted phenalenyl groups, substituted or unsubstituted phenanthrenyl groups, substituted or unsubstituted anthryl groups, substituted or unsubstituted fluoranthenyl groups, substituted or unsubstituted triphenylenyl groups, substituted or unsubstituted pyrenyl groups, substituted or unsubstituted chrysenyl groups, substituted or unsubstituted naphthacenyl groups, substituted or unsubstituted picenyl groups, substituted or

unsubstituted perylenyl groups, substituted or unsubstituted pentaphenyl groups, substituted or unsubstituted hexacenyl groups, substituted or unsubstituted pyrrolyl groups, substituted or unsubstituted imidazolyl groups, substituted or unsubstituted pyrazolyl groups, substituted or unsubstituted pyridinyl groups, substituted or unsubstituted pyrazinyl groups, substituted or unsubstituted pyrimidinyl groups, substituted or unsubstituted pyridazinyl groups, substituted or unsubstituted isoindolyl groups, substituted or unsubstituted indolyl groups, substituted or unsubstituted indazolyl groups, substituted or unsubstituted purinyl groups, substituted or unsubstituted quinolinyl groups, substituted or unsubstituted benzoquinolinyl groups, substituted or unsubstituted phthalazinyl groups, substituted or unsubstituted naphthyridinyl groups, substituted or unsubstituted quinoxalinyl groups, substituted or unsubstituted quinazolinyl groups, substituted or unsubstituted cinnolinyl groups, substituted or unsubstituted carbazolyl groups, substituted or unsubstituted phenanthridinyl groups, substituted or unsubstituted acridinyl groups, substituted or unsubstituted phenanthrolinyl groups, substituted or unsubstituted phenazinyl groups, substituted or unsubstituted benzooxazolyl groups, substituted or unsubstituted benzoimidazolyl groups, substituted or unsubstituted furanyl groups, substituted or unsubstituted benzofuranyl groups, substituted or unsubstituted thiophenyl groups, substituted or unsubstituted benzothiophenyl groups, substituted or unsubstituted thiazolyl groups, substituted or unsubstituted isothiazolyl groups, substituted or unsubstituted benzothiazolyl groups, substituted or unsubstituted isoxazolyl groups, substituted or unsubstituted oxazolyl groups, substituted or unsubstituted triazolyl groups, substituted or unsubstituted tetrazolyl groups, substituted or unsubstituted oxadiazolyl groups, substituted or unsubstituted triazinyl groups, substituted or unsubstituted benzooxazolyl groups, substituted or unsubstituted dibenzofuranyl groups, and substituted or unsubstituted dibenzothiophenyl groups.

[0019] The condensed-cyclic compound represented by Formula 1 above includes a core, in which a fluorene moiety having good fluorescent characteristics, a carbazole moiety, a furane moiety, or a thiophene moiety is fused to an anthracene moiety having good device characteristics, and at least one triazine moiety having good electron transport capability is combined with the core.

[0020] According to an embodiment of the present invention, in the condensed-cyclic compound represented by Formula 1, a part of the core fused to an anthracene moiety may be a fluorene moiety having good fluorescent characteristics. In this case, in the condensed-cyclic compound represented by Formula 1, X_1 in Formula 1 may be CR_1R_2. For example, X_1 in Formula 1 may be $C(CH_3)(CH_3)$.

[0021] According to an embodiment of the present invention, R_1 and R_3 may be a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted pentalenyl group, a substituted or unsubstituted indenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted azulenyl group, a substituted or unsubstituted heptalenyl group, a substituted or unsubstituted indacenyl group, a substituted or unsubstituted acenaphthyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spirofluorenyl 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 imidazolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted isoindolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted indazolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted benzoquinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinoxalinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted acridinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted phenazinyl group, a substituted or unsubstituted benzooxazolyl group, a substituted or unsubstituted benzoimidazolyl 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 thiazolyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzothiazolyl group, a substituted or unsubstituted isoxazolyl group, a substituted or unsubstituted oxazolyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted oxadiazolyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted benzooxazolyl group, a substituted or unsubstituted dibenzofuranyl group, or a substituted or unsubstituted dibenzothiophenyl group. For example, each of R_1 and R_3 may be independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted or unsubstituted methyl groups, substituted or unsubstituted ethyl groups, substituted or unsubstituted propyl groups, substituted or unsubstituted butyl groups, substituted or unsubstituted pentyl groups, substituted or unsubstituted phenyl groups, substituted or unsubstituted naphthyl groups, substituted or unsubstituted fluorenyl groups, substituted or unsubstituted spiro-fluorenyl groups, substituted or unsubstituted anthryl groups, substituted or unsubstituted pyrazolyl groups, substituted or unsubstituted pyridinyl groups, substituted or unsubstituted pyrazinyl groups, substituted or unsubstituted pyrimidinyl groups, and substituted or unsubstituted pyridazinyl groups.

[0022] According to an embodiment of the present invention, in the condensed-cyclic compound represented by Formula 1, at least one of Ar_1 through Ar_{12} in Formula 1 may be

a group represented by Formula 2 above, and more specifically, at least one selected from Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 may be a group represented by Formula 2 above. For example, any one or any two of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 may be a group represented by Formula 2 above.

[0023] According to an embodiment of the present invention, Ar_2, Ar_5, Ar_7, Ar_8, Ar_{10}, Ar_{11}, and Ar_{12} may all be hydrogen atoms, and Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 may each be independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, substituted or unsubstituted C_1-C_{30} alkyl groups, substituted or unsubstituted C_2-C_{30} alkenyl groups, substituted or unsubstituted C_2-C_{30} alkynyl groups, substituted or unsubstituted C_1-C_{30} alkoxy groups, substituted or unsubstituted C_3-C_{30} cycloalkyl groups, substituted or unsubstituted C_3-C_{30} cycloalkenyl groups, substituted or unsubstituted C_5-C_{30} aryl groups, substituted or unsubstituted C_5-C_{30} aryloxy groups, substituted or unsubstituted C_5-C_{30} arylthio groups, substituted or unsubstituted C_2-C_{30} heterocyclic groups, groups represented by Formula 2 above, groups represented by $N(Q_1)(Q_2)$, and groups represented by $Si(Q_3)(Q_4)(Q_5)$. In this case, at least one selected of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 may be a group represented by Formula 2 above.

[0024] According to an embodiment of the present invention, Ar_2, Ar_5, Ar_7, Ar_8, Ar_{10}, Ar_{11}, and Ar_{12} may all be hydrogen atoms, and Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 may each be independently selected from hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, substituted or unsubstituted methyl groups, substituted or unsubstituted ethyl groups, substituted or unsubstituted propyl groups, substituted or unsubstituted butyl groups, substituted or unsubstituted pentyl groups, substituted or unsubstituted phenyl groups, substituted or unsubstituted biphenyl groups, substituted or unsubstituted pentalenyl groups, substituted or unsubstituted indenyl groups, substituted or unsubstituted naphthyl groups, substituted or unsubstituted azulenyl groups, substituted or unsubstituted heptalenyl groups, substituted or unsubstituted indacenyl groups, substituted or unsubstituted acenaphthyl groups, substituted or unsubstituted fluorenyl groups, substituted or unsubstituted spiro-fluorenyl groups, substituted or unsubstituted phenalenyl groups, substituted or unsubstituted phenanthrenyl groups, substituted or unsubstituted anthryl groups, substituted or unsubstituted fluoranthenyl groups, substituted or unsubstituted triphenylenyl groups, substituted or unsubstituted pyrenyl groups, substituted or unsubstituted chrysenyl groups, substituted or unsubstituted naphthacenyl groups, substituted or unsubstituted picenyl groups, substituted or unsubstituted perylenyl groups, substituted or unsubstituted pentaphenyl groups, substituted or unsubstituted hexacenyl groups, substituted or unsubstituted pyrrolyl groups, substituted or unsubstituted imidazolyl groups, substituted or unsubstituted pyrazolyl groups, substituted or unsubstituted pyridinyl groups, substituted or unsubstituted pyrazinyl groups, substituted or unsubstituted pyrimidinyl groups, substituted or unsubstituted pyridazinyl groups, substituted or unsubstituted isoindolyl groups, substituted or unsubstituted indolyl groups, substituted or unsubstituted indazolyl groups, substituted or unsubstituted purinyl groups, substituted or unsubstituted quinolinyl groups, substituted or unsubstituted benzoquinolinyl groups, substituted or unsubstituted phthalazinyl groups, substituted or unsubstituted naphthyridinyl groups, substituted or unsubstituted quinoxalinyl groups, substituted or unsubstituted quinazolinyl groups, substituted or unsubstituted cinnolinyl groups, substituted or unsubstituted carbazolyl groups, substituted or unsubstituted phenanthridinyl groups, substituted or unsubstituted acridinyl groups, substituted or unsubstituted phenanthrolinyl groups, substituted or unsubstituted phenazinyl groups, substituted or unsubstituted benzooxazolyl groups, substituted or unsubstituted benzimidazolyl groups, substituted or unsubstituted furanyl groups, substituted or unsubstituted benzofuranyl groups, substituted or unsubstituted thiophenyl groups, substituted or unsubstituted benzothiophenyl groups, substituted or unsubstituted thiazolyl groups, substituted or unsubstituted isothiazolyl groups, substituted or unsubstituted benzothiazolyl groups, substituted or unsubstituted isoxazolyl groups, substituted or unsubstituted oxazolyl groups, substituted or unsubstituted triazolyl groups, substituted or unsubstituted tetrazolyl groups, substituted or unsubstituted oxadiazolyl groups, substituted or unsubstituted triazinyl groups, substituted or unsubstituted benzoxazolyl groups, substituted or unsubstituted dibenzofuranyl groups, substituted or unsubstituted dibenzothiophenyl groups, and groups represented by Formula 2 above, where at least one of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 may be a group represented by Formula 2 above.

[0025] The condensed-cyclic compound represented by Formula 1 above includes a core, in which a fluorene moiety, a carbazole moiety, a furane moiety, or a thiophene moiety is fused to an anthracene moiety, and a triazine moiety represented by Formula 2 is included in at least one of Ar_1 through Ar_{12}, which is a substitution product of the core. An organic light-emitting device including the condensed-cyclic compound represented by Formula 1 above has good electron transport capability due to the characteristics of the moieties.

[0026] According to an embodiment of the present invention, the condensed-cyclic compound represented by Formula 1 above includes the triazine moiety represented by Formula 2, and L_1 in the triazine moiety represented by Formula 2 may be a substituted or unsubstituted phenylene group, a substituted or unsubstituted pentalenylene group, a substituted or unsubstituted indenylene group, a substituted or unsubstituted naphthylene group, a substituted or unsubstituted azulenylene group, a substituted or unsubstituted heptalenylene group, a substituted or unsubstituted indacenylene group, a substituted or unsubstituted acenaphthylene group, a substituted or unsubstituted fluorenylene group, a substituted or unsubstituted spiro-fluorenyl 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 chrysenyl group, a substituted or unsubstituted naphthacenyl group, a substituted or unsubstituted picenyl group, a substituted or unsubstituted perylenylene group, a substituted or unsubstituted pentaphenylene group, and a substituted or unsubstituted hexylenylene group.

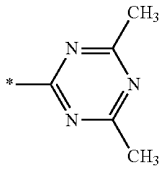
[0027] According to an embodiment of the present invention, a in Formula 2 above may be 0 or 1. When a is 0, it indicates a simple single combination. When a is 0 or 1, the condensed-cyclic compound represented by Formula 1 above may have good electron transport capability.

[0028] According to an embodiment of the present invention, each of R_4 through R_8 in Formula 2 may independently

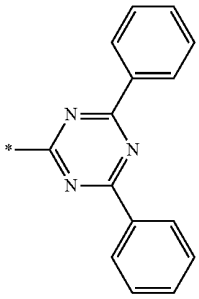
be a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted biphenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted indenoanthracenyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted bipyridinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted quinolinyl group, or a substituted or unsubstituted phenanthrolinyl group. For example, R_4 and R_5 may be the same as each other and each may be a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted biphenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted indenoanthracenyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted bipyridinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted quinolinyl group, or a substituted or unsubstituted phenanthrolinyl group.

[0029] In the condensed-cyclic compound represented by Formula 1, the group represented by Formula 2 above may be a condensed-cyclic compound represented by one of Formulas 2A through 2U below:

Formula 2A



Formula 2B



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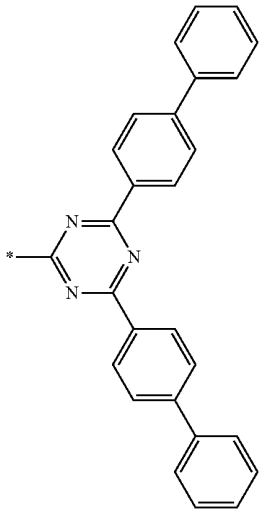
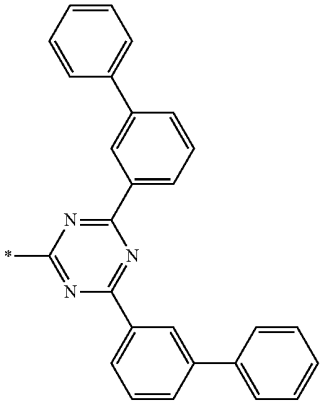
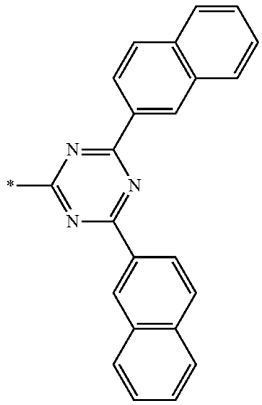
Formula 2C



Formula 2D



Formula 2E



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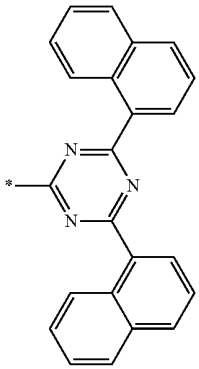
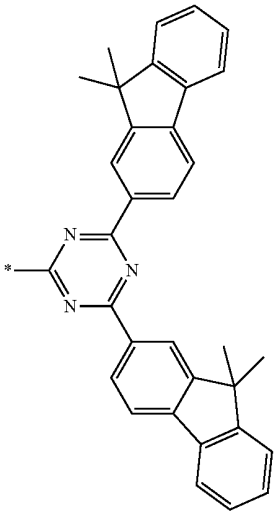
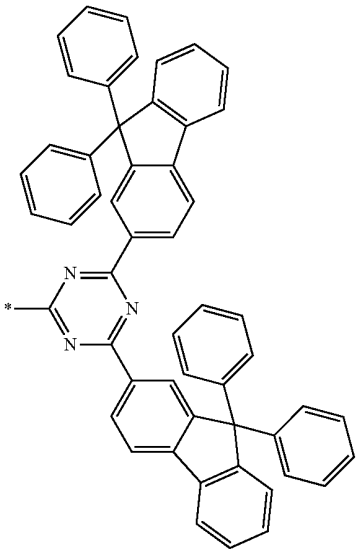
Formula 2F



Formula 2G



Formula 2H



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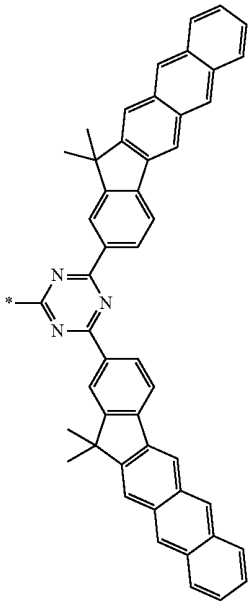
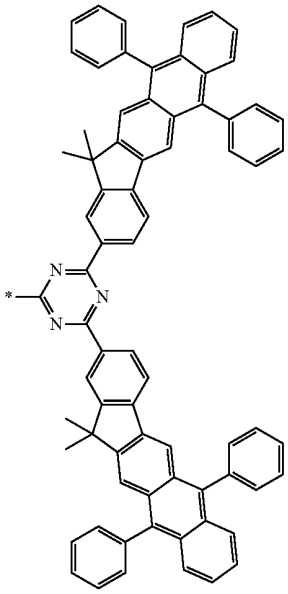
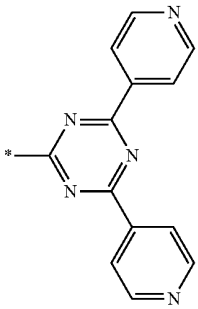
Formula 2I



Formula 2J



Formula 2K



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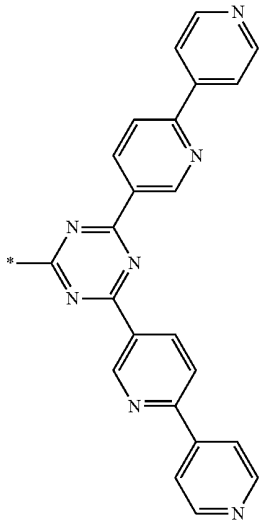
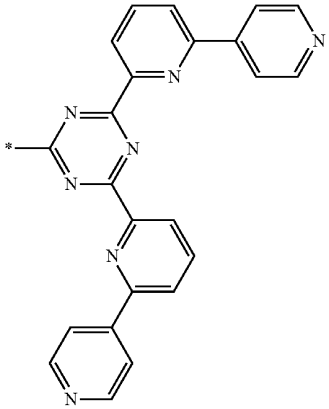
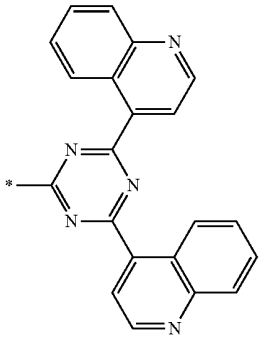
Formula 2L



Formula 2M



Formula 2N



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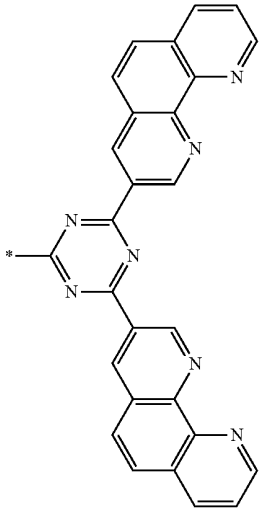
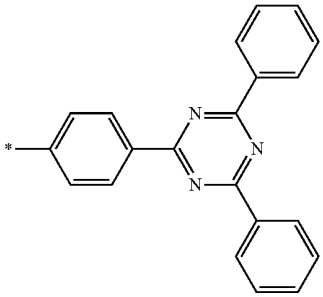
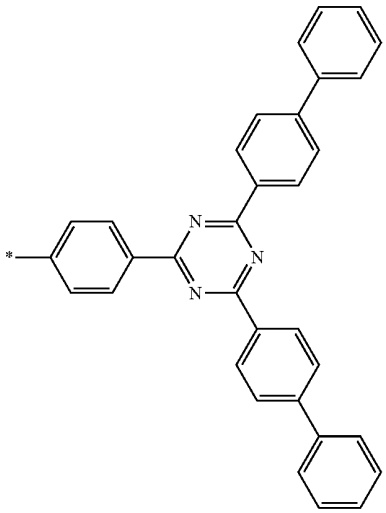
Formula 2O



Formula 2P



Formula 2Q



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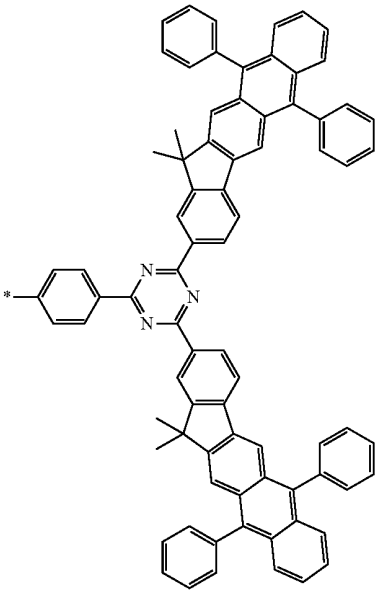
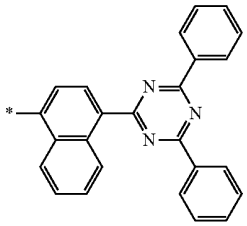
Formula 2R



Formula 2S



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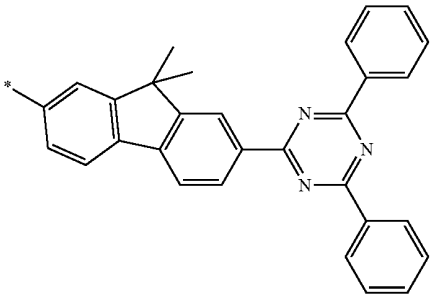
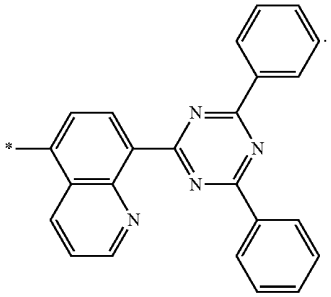
Formula 2T

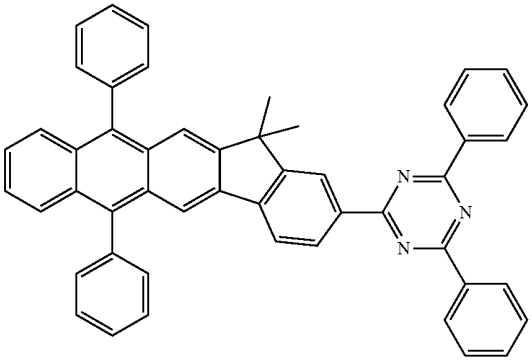


Formula 2U

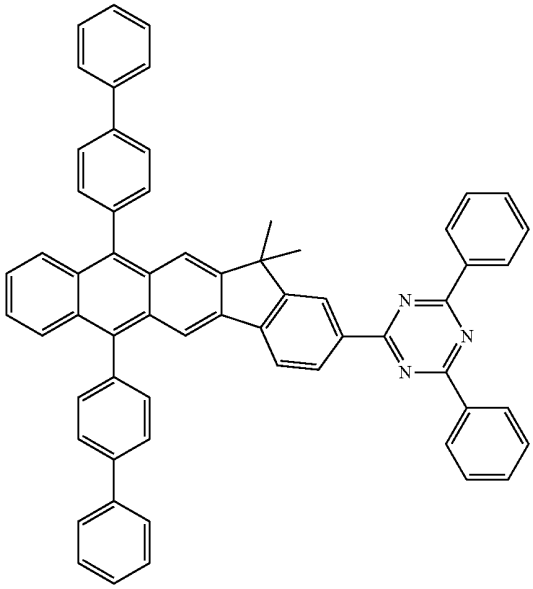


[0030] Nonlimiting examples of the condensed-cyclic compound represented by Formula 1 include the compounds represented by Compounds 1 through 40 below:

Compound 1



Compound 2



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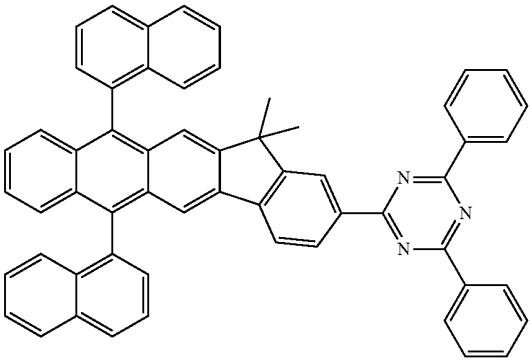
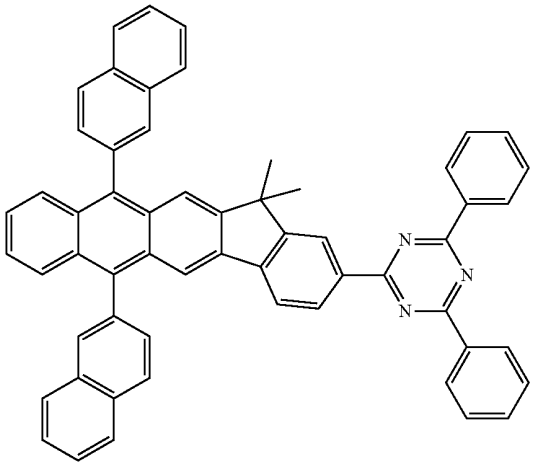
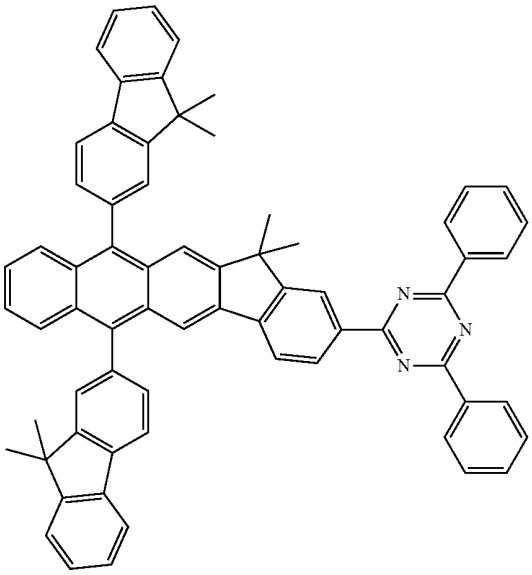
Compound 3



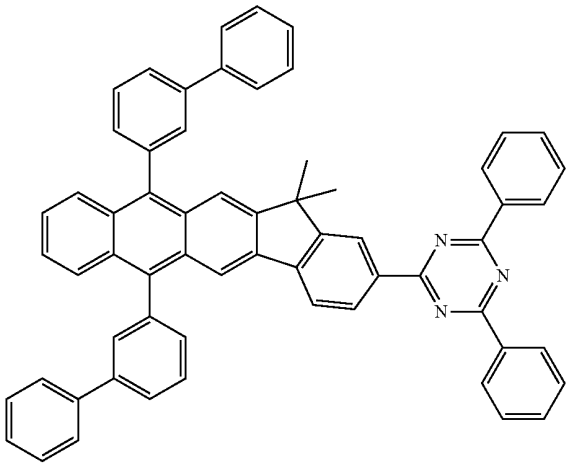
Compound 4



Compound 5



Compound 6



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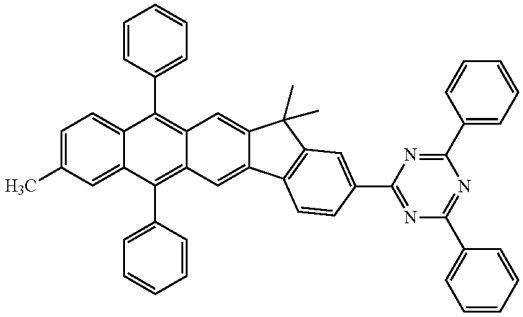
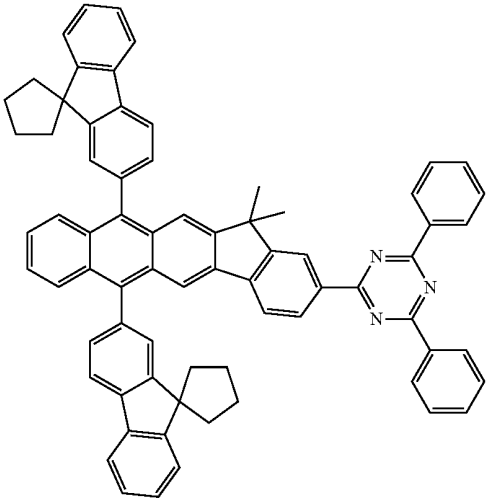
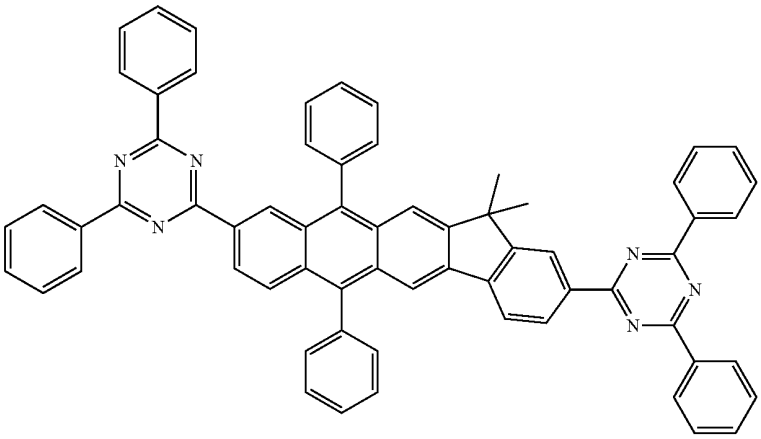
Compound 7



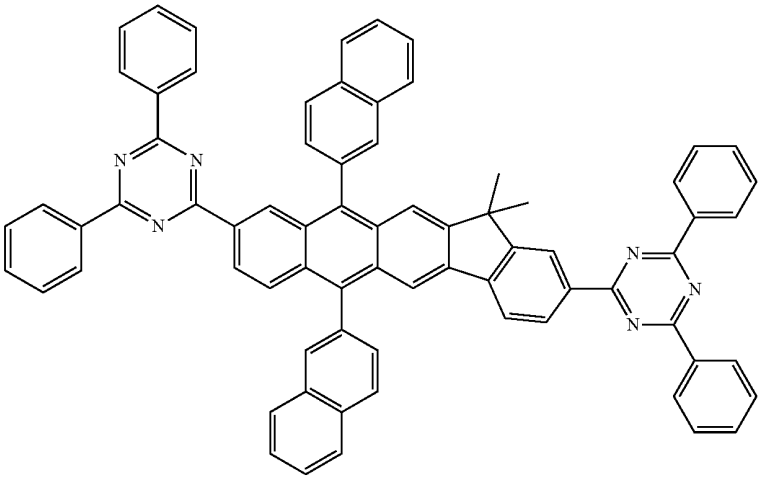
Compound 8



Compound 9



Compound 10



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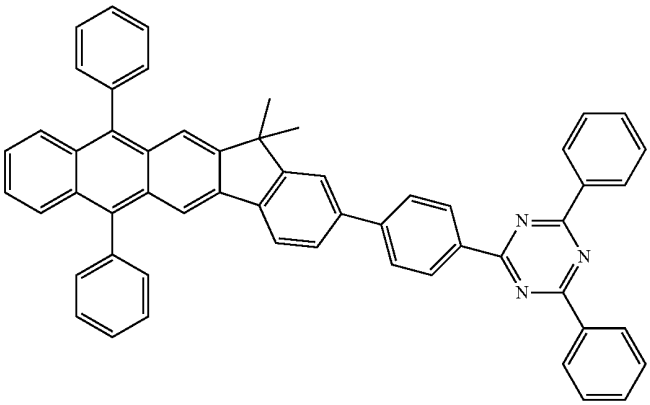
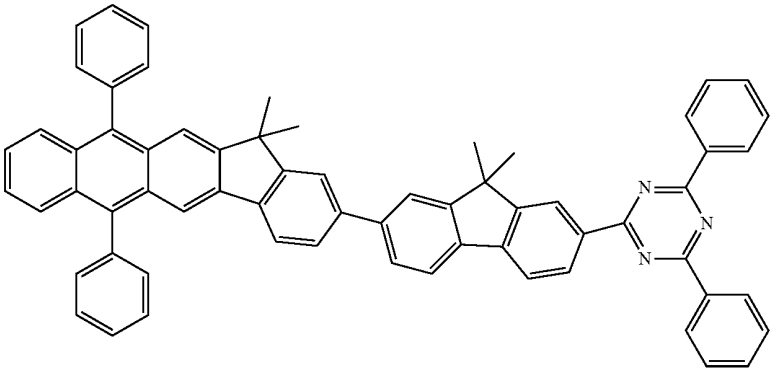
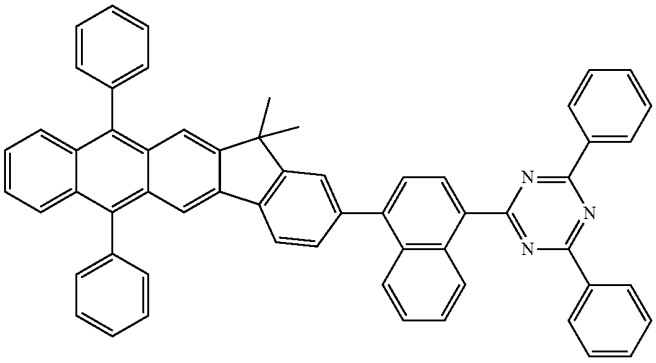
Compound 11



Compound 12



Compound 13



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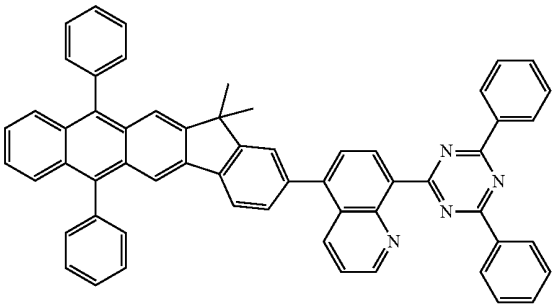
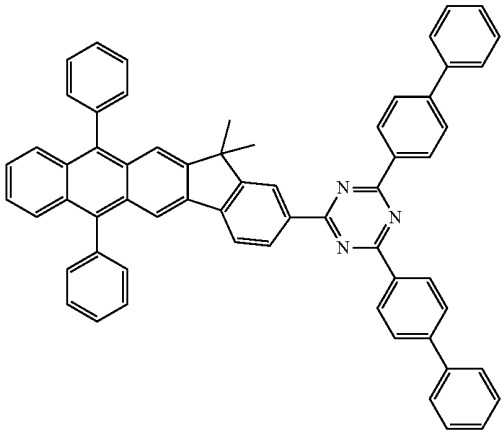
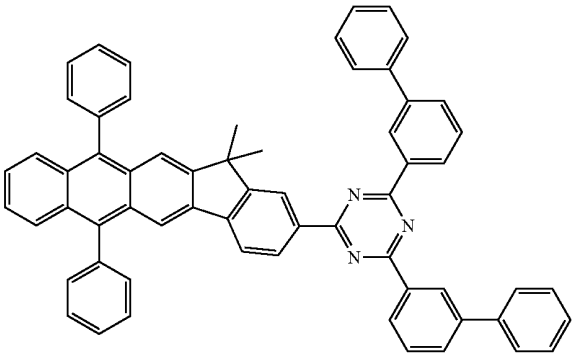
Compound 14



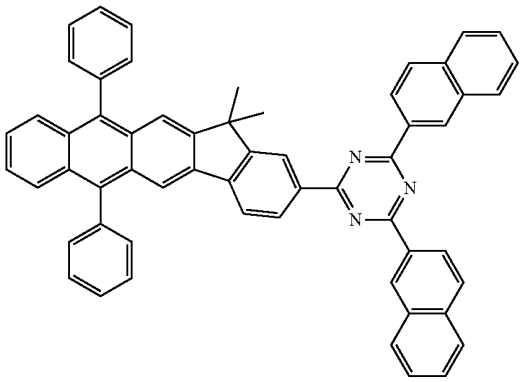
Compound 15



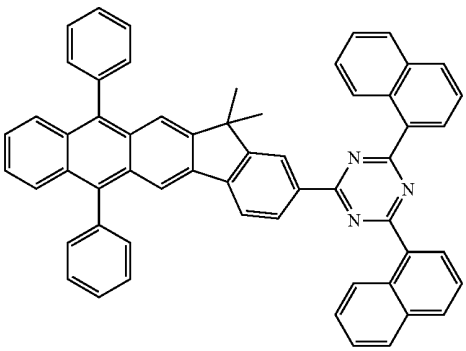
Compound 16



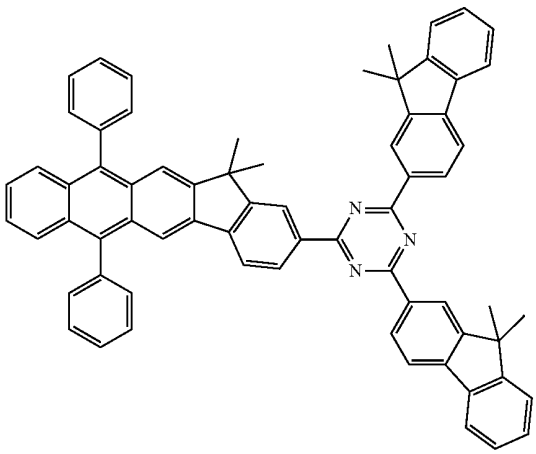
Compound 17



Compound 18



Compound 19



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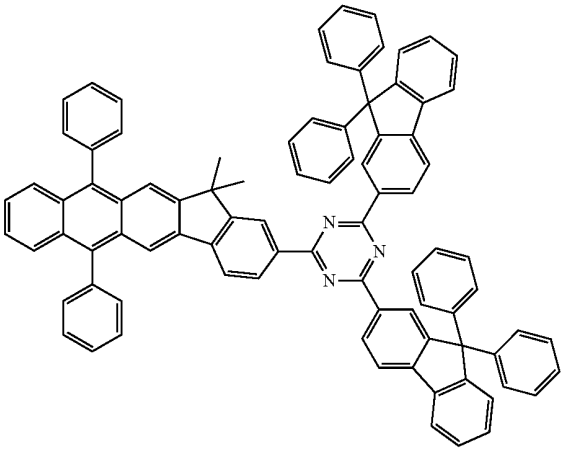
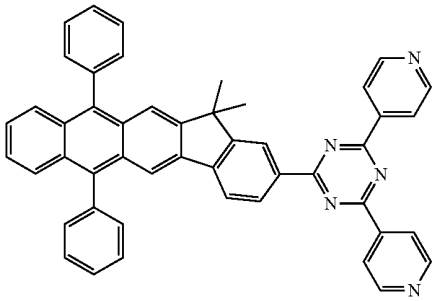
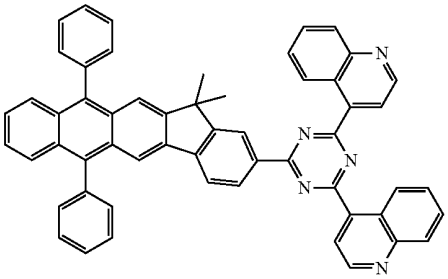
Compound 20



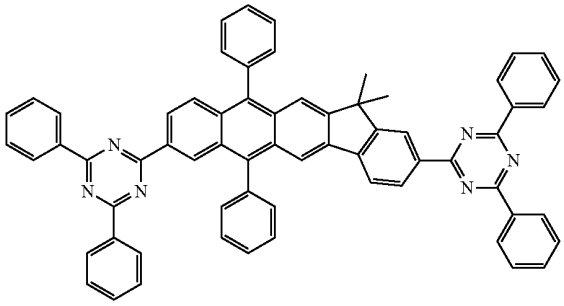
Compound 21



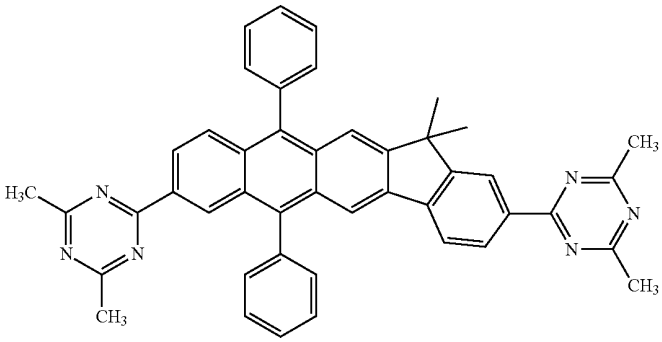
Compound 22



Compound 23



Compound 24



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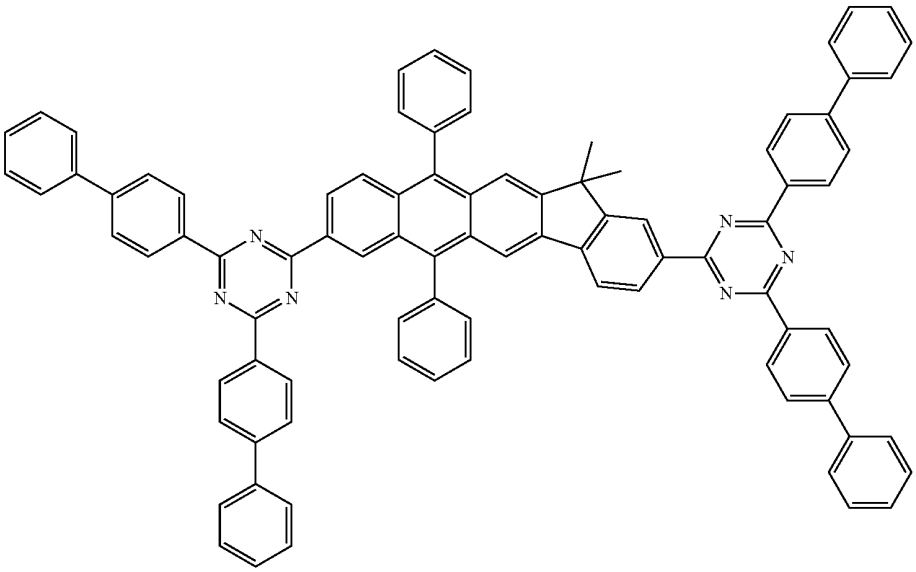
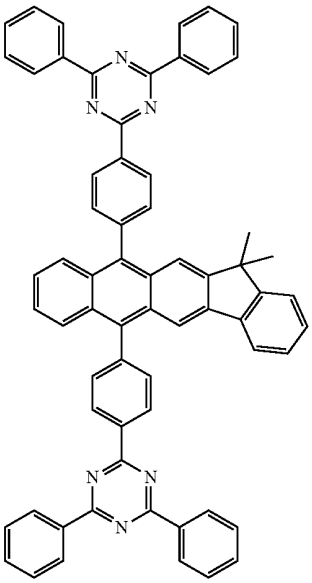
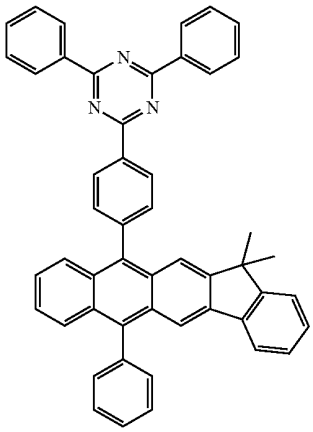
Compound 25



Compound 26



Compound 27



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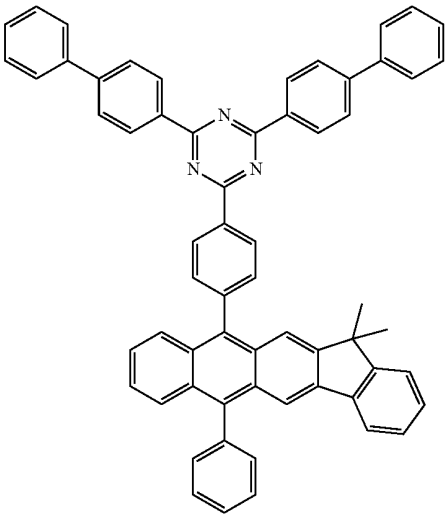
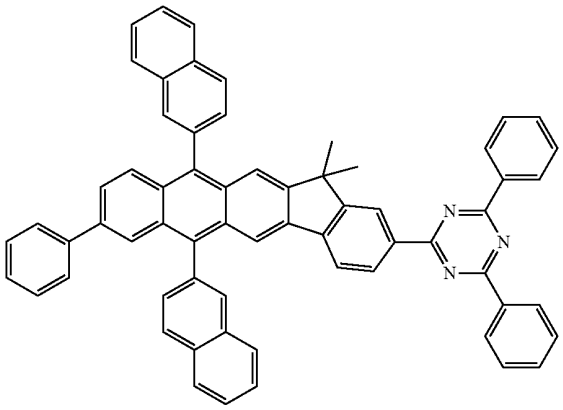
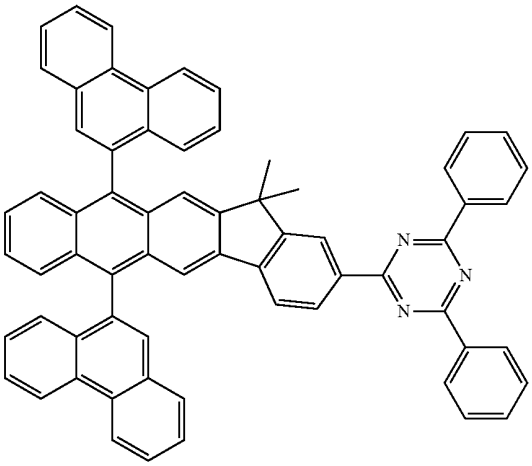
Compound 28



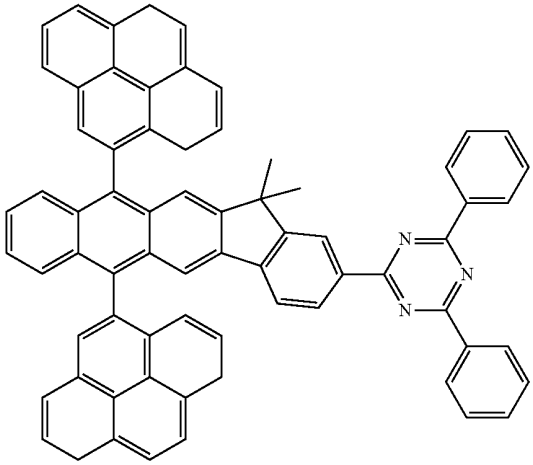
Compound 29



Compound 30



Compound 31



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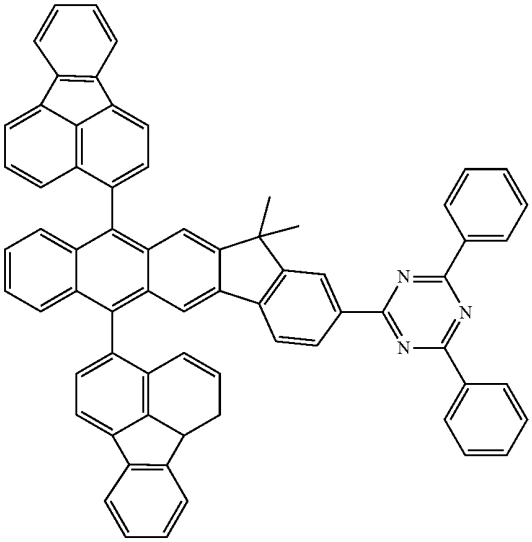
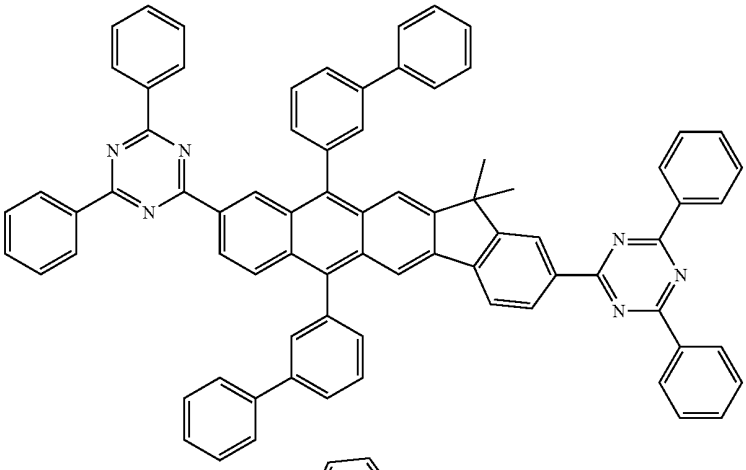
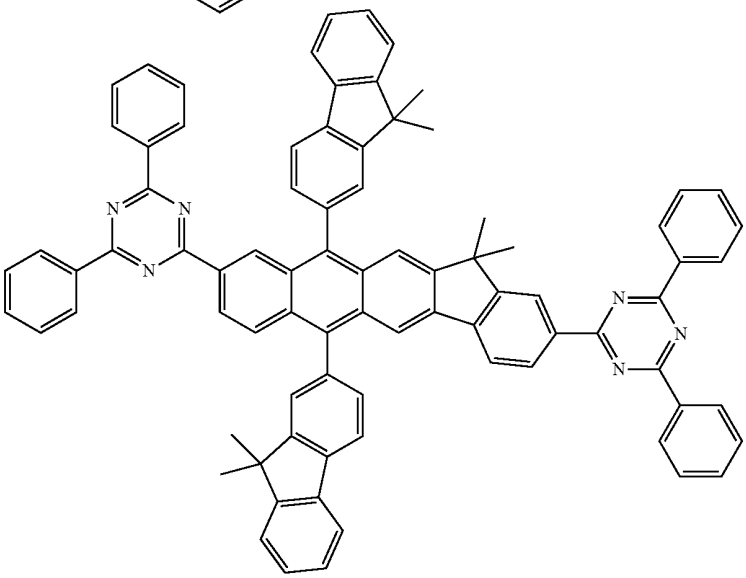
Compound 32



Compound 33



Compound 34



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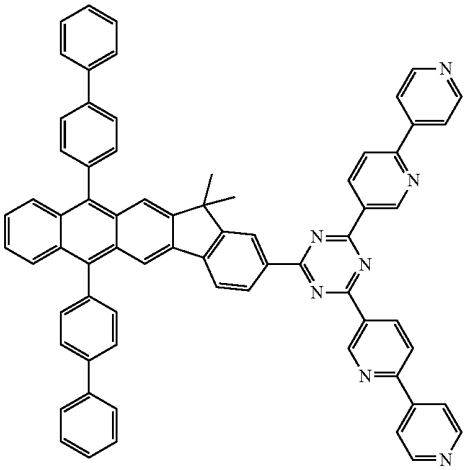
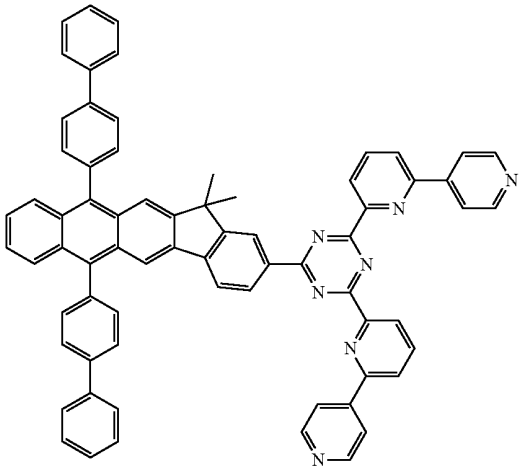
Compound 35



Compound 36



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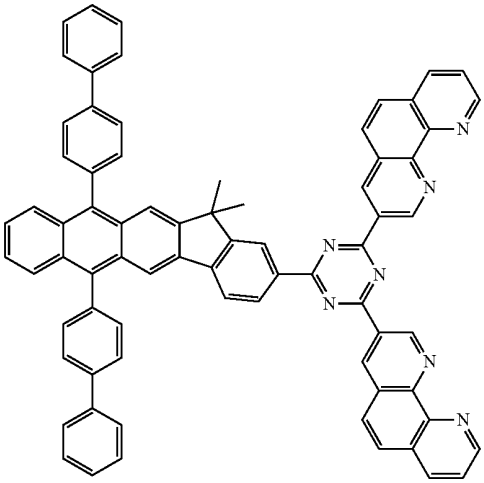

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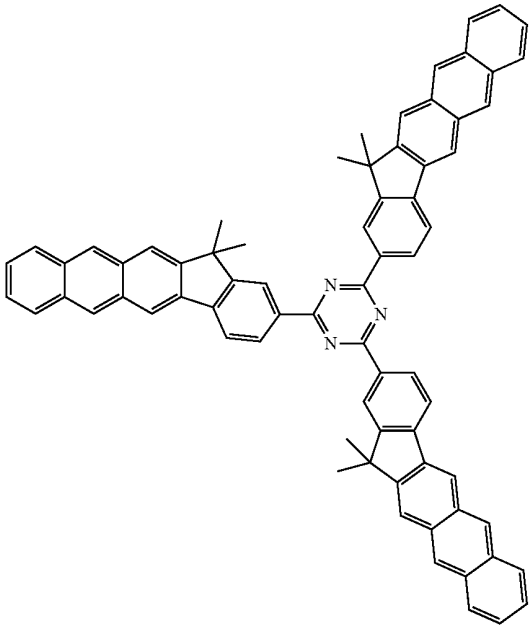

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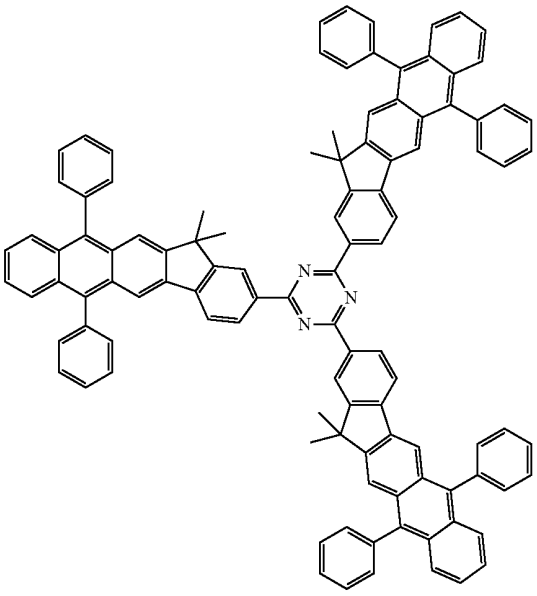
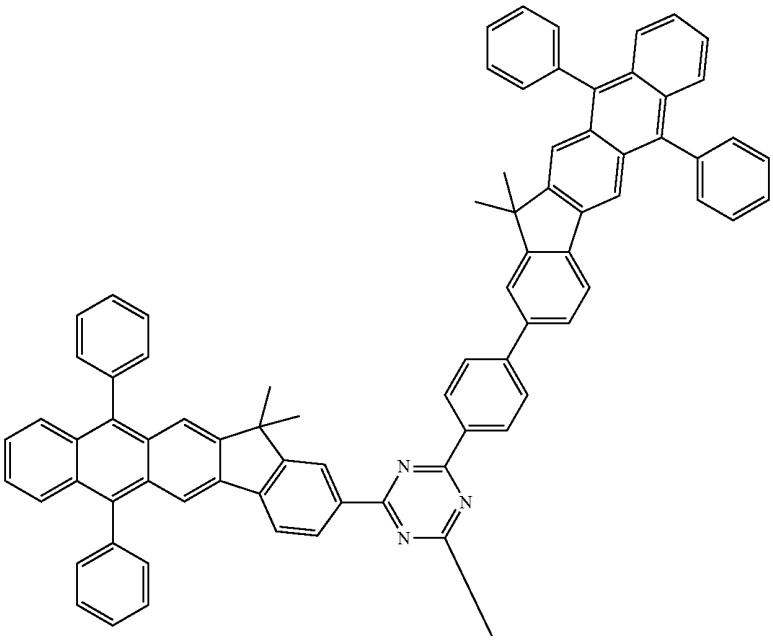
Compound 39



Compound 40



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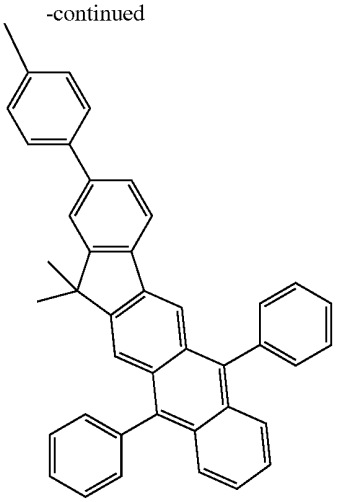


[0031] In the expression "substituted or unsubstituted A (in which A is an arbitrary substituent)," the term "substituted A" denotes "A, in which at least one hydrogen atom of A is substituted with a substituent selected from deuterium, halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups or salt derivatives thereof, sulfonic acid groups or salt derivatives thereof, phosphate groups or salt derivatives thereof, C_1-C_{30} alkyl groups, C_2-C_{30} alkenyl groups, C_2-C_{30} alkynyl groups, C_1-C_{30} alkoxy groups, C_3-C_{30} cycloalkyl groups, C_3-C_{30} cycloalkenyl groups, C_5-C_{30} aryl groups, C_5-C_{30} aryloxy groups, C_5-C_{30} arylthio groups, C_2-C_{30} heterocyclic groups, groups represented by $N(Q_{101})(Q_{102})$, and groups represented by $Si(Q_{103})(Q_{104})(Q_{105})$." Here, each of Q_{101} through Q_{105} may independently be a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a C_1-C_{30} alkyl group, a C_2-C_{30} alkenyl group, a C_2-C_{30} alkynyl group, a C_1-C_{30} alkoxy group, a C_3-C_{30} cycloalkyl group, a C_3-C_{30} cycloalkenyl group, a C_5-C_{30} aryl group, a C_5-C_{30} aryloxy group, a C_5-C_{30} arylthio group, or a C_2-C_{30} heterocyclic group.

[0032] For example, "the substituted A" may denote "A, in which at least one hydrogen atom is substituted with deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a substituted or unsubstituted a methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted pentalenyl group, a substituted or unsubstituted indenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted azulenyl group, a substituted or unsubstituted heptalenyl group, a substituted or unsubstituted indacenyl group, a substituted or unsubstituted acenaphthyl 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 imidazolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted isoindolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted indazolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted benzoquinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinoxalinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted acridinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted phenazinyl group a substituted or unsubstituted benzoxazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted furanyl, a substituted or unsubstituted benzofuranyl group, a substituted or unsubstituted thiophenyl group, a substituted or unsubstituted benzothiophenyl group, a substituted or unsubstituted thiazolyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzothiazolyl group, a substituted or unsubstituted isoxazolyl group, a substituted or unsubstituted oxazolyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted oxadiazolyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted benzoxazolyl group, a substituted or unsubstituted dibenzofuranyl group, or a substituted or unsubstituted dibenzothiophenyl group."

[0033] The unsubstituted C_1-C_{30} alkyl group denotes a saturated hydrocarbon group having a linear or branched structure in which one hydrogen atom is missing from the corresponding alkane. Nonlimiting examples of the unsubstituted C_1-C_{30} alkyl group may include methyl, ethyl, propyl, isobutyl, sec-butyl, pentyl, iso-amyl, hexyl, and the like. The substituents of the substituted C_1-C_{30} alkyl group are described in the description for the "substituted A."

[0034] The unsubstituted C_2-C_{30} alkenyl group denotes a C_2-C_{30} alkyl group having at least one carbon-carbon double bond at the middle or end. Nonlimiting examples of the unsubstituted C_2-C_{30} alkenyl group may include ethenyl, prophenyl, butenyl, pentanyl, hexenyl, heptenyl, octenyl, propadienyl, isoprenyl, allyl, and the like. The substituents of the substituted C_2-C_{30} alkenyl group are described in the description for the "substituted A."

[0035] The unsubstituted C_2-C_{30} alkynyl group denotes a C_2-C_{60} alkyl group having at least one carbon-carbon triple bond at the middle or end. Nonlimiting examples of the unsubstituted C_2-C_{30} alkynyl group may include acetylenyl groups. The substituents of the substituted C_2-C_{30} alkynyl group are described in the description for the "substituted A."

[0036] The unsubstituted C_1-C_{30} alkoxy group has the Formula —OY (in which Y is the unsubstituted C_1-C_{30} alkyl group) and may be, for example, methoxy, ethoxy, isopropyloxy, butoxy, pentoxy, and the like. The substituents of the substituted C_1-C_{30} alkoxy group are described in the description for the "substituted A."

[0037] The unsubstituted C_3-C_{30} cycloalkyl group denotes a ring-type saturated hydrocarbon group and may be, for example, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cyclooctyl, and the like. The substituents of the substituted C_3-C_{30} cycloalkyl group are described in the description for the "substituted A."

[0038] The unsubstituted C_3-C_{30} cycloalkenyl group denotes a ring-type unsaturated hydrocarbon group which has at least one carbon-carbon double bond but is not an aromatic ring. Nonlimiting examples of the unsubstituted C_3-C_{30} cycloalkenyl group include cyclopropenyl groups, cyclobutenyl groups, cyclopentenyl groups, cyclohexenyl groups, cycloheptenyl groups, 1,3-cyclohexadienyl groups, 1,4-cyclohexadienyl groups, 2,4-cycloheptadienyl groups, 1,5-cyclooctadienyl groups, and the like. The substituents of the substituted C_3-C_{60} cycloalkenyl group are described in the description for the "substituted A."

[0039] The unsubstituted C_5-C_{30} aryl group denotes a monovalent group having a C_5-C_{30} carbocyclic aromatic system, wherein the monovalent group may be a monocyclic or polycyclic group. In the polycyclic group, at least two rings included therein may be fused to each other. Nonlimiting examples of the unsubstituted C_5-C_{30} aryl group may include phenyl, pentalenyl, indenyl, naphthyl, azulenyl, heptalenyl, indacenyl, acenaphthyl, fluorenyl, spiro-fluorenyl, phenalenyl, phenanthrenyl, anthryl, fluoranthenyl, triphenylenyl, pyrenyl, chrysenyl, naphthacenyl, picenyl, perylenyl, pentaphenyl, hexacenyl, and the like. The substituents of the substituted C_5-C_{30} aryl group are described in the description for the "substituted A."

[0040] The unsubstituted C_5-C_{30} aryloxy group denotes a monovalent group to which carbon atoms of a C_5-C_{30} aryl group are attached through an oxygen linking group (—O—). The substituents of the substituted C_5-C_{30} aryloxy group are described in the description for the "substituted A."

[0041] The unsubstituted C_5-C_{30} arylthio group denotes a monovalent group to which carbon atoms of a C_5-C_{30} aryl group are attached through a sulfur linking group (—S—). Nonlimiting examples of the unsubstituted C_5-C_{30} arylthio group include phenylthio, naphthylthio, indanylthio, and indenylthio. The substituents of the substituted C_5-C_{30} arylthio group are described in the description for the "substituted A."

[0042] The unsubstituted C_2-C_{30} heterocyclic group denotes a monocyclic or polycyclic group including at least one ring containing at least one heteroatom selected from N, O, P, and S. In the polycyclic group, at least two rings included therein may be fused to each other. Nonlimiting examples of the unsubstituted C_2-C_{30} heterocyclic group include pyrrolyl, imidazolyl, pyrazolyl, pyridinyl, pyrazinyl, pyrimidinyl, pyridazinyl, isoindolyl, indolyl, indazolyl, purinyl, quinolinyl, benzoquinolinyl, phthalazinyl, naphthyridinyl, quinoxalinyl, quinazolinyl, cinnolinyl, carbazolyl, phenanthridinyl, acridinyl, phenanthrolinyl, phenazinyl, benzooxazolyl, benzoimidazolyl, furanyl, benzofuranyl, thiophenyl, benzothiophenyl, thiazolyl, isothiazolyl, benzothiazolyl, isoxazolyl, oxazolyl, triazolyl, tetrazole, oxadiazolyl, triazinyl, benzooxazolyl, and the like. The substituents of the substituted C_2-C_{30} heterocyclic group are described in the description for the "substituted A."

[0043] The unsubstituted C_1-C_{30} alkylene group denotes a divalent group having a linear or chain structure, in which two hydrogen atoms are missing from the corresponding alkane. Nonlimiting examples of the unsubstituted C_1-C_{30} alkylene group would be understood to those of ordinary skill in the art by reference to the examples for the unsubstituted C_1-C_{30} alkyl group. The substituents of the substituted C_1-C_{30} alkylene group are described in the description for the "substituted A."

[0044] The unsubstituted C_5-C_{30} arylene group denotes a divalent group having a C_5-C_{30} carbocyclic aromatic system, where the divalent group may be a monocyclic or polycyclic group. Nonlimiting examples of the unsubstituted C_5-C_{30} arylene group may be understood to those of ordinary skill in the art by reference to the examples for the unsubstituted C_5-C_{30} aryl group. The substituents of the substituted C_5-C_{30} arylene group are described in the description for the "substituted A."

[0045] The unsubstituted divalent C_2-C_{30} heterocyclic group denotes a monocyclic or polycyclic divalent group including at least one ring containing at least one heteroatom selected from N, O, P, and S, and may be a monocyclic or a polycyclic group. Nonlimiting examples of the unsubstituted divalent C_2-C_{30} heterocyclic group may be understood to those of ordinary skill in the art by reference to the examples for the unsubstituted C_2-C_{30} heterocyclic group. The substituents of the substituted divalent C_2-C_{30} heterocyclic group are described in the description for the "substituted A."

[0046] The condensed-cyclic compound represented by Formula 1 may be synthesized using known organic synthesis methods. The synthesis method of the condensed-cyclic compound would be readily recognized by one of ordinary skill in the art with reference to the Examples which are described below.

[0047] The condensed-cyclic compound represented by Formula 1 may be used in an organic light-emitting device. That is, according to embodiments of the present invention, an organic light-emitting device includes a first electrode, a second electrode facing the first electrode, and at least one

organic layer between the first electrode and the second electrode, where the at least one organic layer includes the condensed-cyclic compound represented by Formula 1.

[0048] The organic layer may be an electron injection layer, an electron transport layer, or a functional layer having both electron injection and electron transport functions. For example, in the organic light-emitting device, the organic layer including the condensed-cyclic compound represented by Formula 1 may be an electron transport layer.

[0049] The organic layer may be a hole injection layer, a hole transport layer or a single layer simultaneously having hole injection and hole transport functions.

[0050] Also, the organic layer may be an emission layer in an organic light-emitting device and may include the condensed-cyclic compound represented by Formula 1. More specifically, the emission layer may include only the condensed-cyclic compound represented by Formula 1, or may further include another compound in addition to the condensed-cyclic compound represented by Formula 1.

[0051] For example, the condensed-cyclic compound represented by Formula 1 may be used as a fluorescent host or a phosphorescent host in the emission layer. In this case, the emission layer may further include a fluorescent dopant or a phosphorescent dopant. That is, the emission layer may include the condensed-cyclic compound represented by Formula 1 functioning as a fluorescent host and further include a compound functioning as a fluorescent dopant. Alternatively the emission layer may include the condensed-cyclic compound represented by Formula 1 functioning as a phosphorescent host and further include a compound functioning as a phosphorescent dopant.

[0052] Also, the condensed-cyclic compound represented by Formula 1 may be used as a fluorescent dopant of the emission layer. In this case, the emission layer may further include a fluorescent host or a phosphorescent host, in addition to the condensed-cyclic compound represented by Formula 1. That is, the emission layer may include the condensed-cyclic compound represented by Formula 1 functioning as a fluorescent dopant and further include a compound functioning as a phosphorescent host or a fluorescent host.

[0053] The organic light-emitting device may further include at least one of a hole injection layer, a hole transport layer, an electron blocking layer, a hole blocking layer, an electron transport layer, and an electron injection layer between the first electrode and the second electrode, in addition to the emission layer.

[0054] For example, the organic light-emitting device may have a first electrode/hole injection layer/emission layer/electron transport layer/electron injection layer/second electrode structure, a first electrode/hole injection layer/hole transport layer/emission layer/electron transport layer/electron injection layer/second electrode structure, or a first electrode/hole injection layer/hole transport layer/emission layer/hole blocking layer/electron transport layer/electron injection layer/second electrode structure. However, the present invention is not limited thereto.

[0055] The at least one layer between the first electrode and the second electrode may be formed by deposition or a wet process. For example, at least one of a hole injection layer, a hole transport layer, an emission layer, a hole blocking layer, an electron transport layer, and an electron injection layer between the first electrode and the second electrode may be formed by deposition or a wet process.

[0056] As used herein, "wet process" is a process for obtaining a mixture by mixing a predetermined material with a predetermined solvent, applying the mixture to a predetermined substrate, and drying and/or thermally treating the predetermined substrate to remove at least part of the predetermined solvent, thereby forming a film including the predetermined material on the substrate.

[0057] In the wet process, the organic layer including the condensed-cyclic compound represented by Formula 1 may be applied to the substrate by general vacuum deposition. For example, a mixture of the condensed-cyclic compound represented by Formula 1 and the solvent are applied to an electron transport layer region by spin coating, spraying, inkjet printing, dipping, casting, gravure coating, bar coating, roll coating, wirebar coating, screen coating, flexo coating, offset coating, or laser transferring, and then the mixture applied to the electron transport layer region is dried and/or heat treated to remove at least part of the solvent. Thus, the electron transport layer including the condensed-cyclic compound represented by Formula 1 may be formed.

[0058] Also, a layer including the condensed-cyclic compound represented by Formula 1 may be formed on the base film by using a wet process, and the layer may be transferred on the electron transport layer region by laser transferring using laser.

[0059] FIG. **1** is a schematic cross-sectional view of an organic light-emitting device **10** according to an embodiment of the present invention. Hereinafter, a structure and a manufacturing method of the organic light-emitting device **10** will be described with reference to FIG. **1**.

[0060] The organic light-emitting device **10** includes a first electrode **12**, a hole injection layer **13**, a hole transport layer **14**, an emission layer **15**, an electron transport layer **16**, an electron injection layer **17**, and a second electrode **18** sequentially on a substrate **11** in this order.

[0061] The substrate **11** may be any substrate generally used in organic light-emitting devices, and may be, for example, a glass substrate or a transparent plastic substrate having good mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and waterproofness.

[0062] The first electrode **12** may be formed by providing a first electrode material on the substrate **11** using deposition or sputtering. When the first electrode **12** 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 **12** may be a reflective electrode or a transparent electrode. Nonlimiting examples of the first electrode material 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, the first electrode **12** may be formed as a reflective electrode. The first electrode **12** may include two different materials. The structure of the first electrode **12** may vary and, for example, the first electrode **12** may be formed to have a two-layered structure including two different materials.

[0063] The hole injection layer **13** is formed on the first electrode **12**.

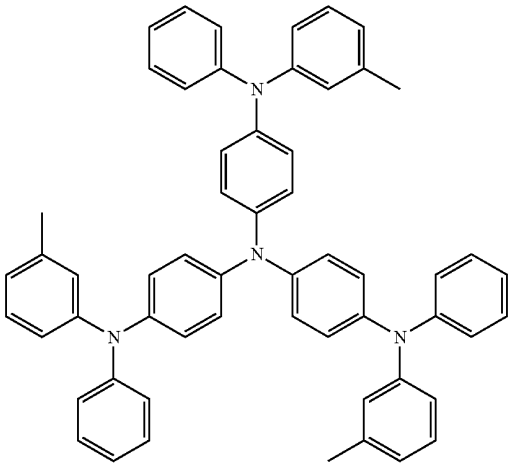
[0064] The hole injection layer **13** may be formed on the first electrode **12** by any of various methods such as vacuum deposition, a wet process, or laser transferring.

[0065] When the hole injection layer **13** is formed by using vacuum deposition, the deposition conditions may vary according to the compound used as the material for the hole injection layer, the structure of the desired hole injection layer, and the thermal characteristics. For example, the deposition conditions may be, but are not limited to, a deposition temperature of about 100 to about 500° C., a degree of vacuum of about 10^{-8} to about 10^{-3} torr, and a deposition speed of about 0.01 to about 100 Å/sec.

[0066] When the hole injection layer **13** is formed by spin coating and a wet process, the coating conditions may vary according to the compound used as the material for the hole injection layer, the structure of the desired hole injection layer, and the thermal characteristics. For example, the coating conditions may be, but are not limited to, a coating speed of about 2000 rpm to about 5000 rpm and a heat treatment temperature for removing the solvent after coating of about 80 to about 200° C.

[0067] The condensed-cyclic compound may be used as the material for a hole injection layer. Also, the material for the hole injection layer may include at least one of the condensed-cyclic compound and a known material for the hole injection layer and may include, for example, a phthalocyanine compound such as copper phthalocyanine, m-MTDATA (refer to Formula below), TDATA (refer to Formula below), 2-TNATA (refer to Formula below), Polyaniline/Dodecylbenzenesulfonic acid (Pani/DBSA), Poly(3,4-ethylenedioxythiophene)/Poly(4-styrenesulfonate) (PEDOT/PSS), Polyaniline/Camphor sulfonicacid (Pani/CSA), or Polyaniline/Poly(4-styrenesulfonate) (PANI/PSS). However, the present invention is not limited thereto.

m-MTDATA



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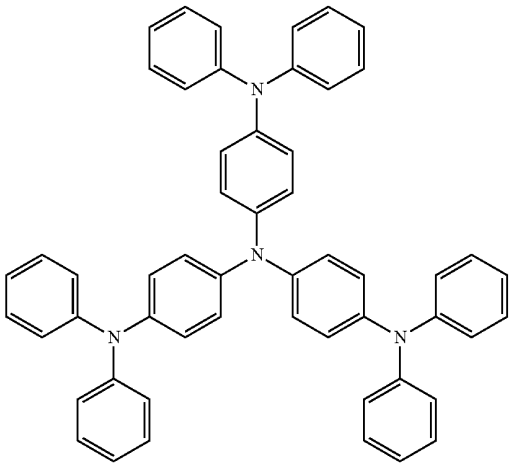
TDATA



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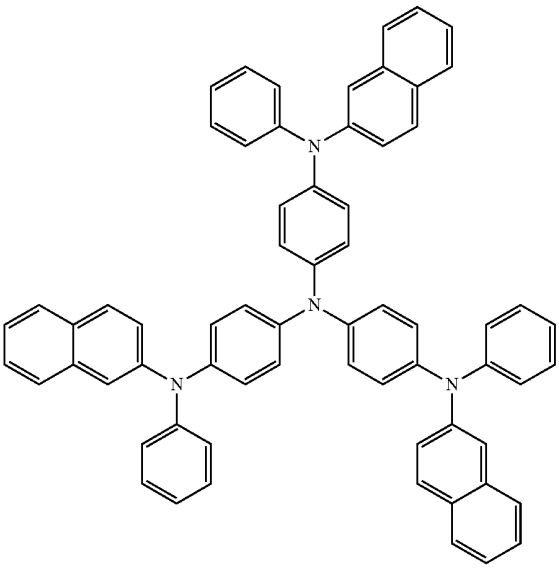
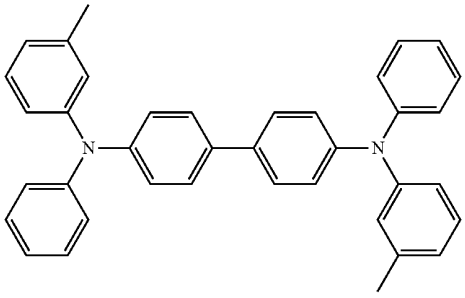


[0068] A thickness of the hole injection layer **13** may be about 100 Å to about 10000 Å, for example, about 100 Å to about 1000 Å. When the thickness of the hole injection layer **13** is within these ranges, satisfactory hole injection characteristics may be obtained without a substantial increase in the driving voltage.

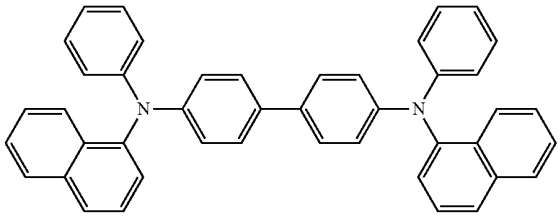
[0069] The hole transport layer **14** is formed on the hole injection layer **13** by vacuum deposition, a wet process, or laser transferring. When the hole transport layer **14** is formed by vacuum deposition or spin coating, the deposition conditions and coating conditions may vary according to the compound used. However, in general, the conditions may be similar to the conditions described above for forming the hole injection layer **13**.

[0070] The hole transport layer **14** may include any known material for the hole transport layer, for example, TPD (refer to Formula below) or NPB (refer to Formula below).

TPD



NPB



[0071] A thickness of the hole transport layer **14** may be about 50 Å to about 1000 Å, for example, about 100 Å to about 800 Å. When the thickness of the hole transport layer **14** is in these ranges, satisfactory hole transport characteristics may be obtained without a substantial increase in driving voltage.

[0072] Instead of the hole injection layer **13** and the hole transport layer **14**, a functional layer (not illustrated) simultaneously having hole injection and hole transport functions may be formed. A material for forming the functional layer having both hole injection and hole transport functions may be selected from known materials.

[0073] At least one of the hole injection layer **13**, the hole transport layer **14**, and the functional layer simultaneously having hole injection and hole transport functions may further include a charge-generation material for improving the conductivity of the layer, in addition to the condensed-cyclic compound represented by Formula 1, a known hole injection material, and/or a known hole transport material.

[0074] Nonlimiting examples of the charge-generation material include p-dopants. Nonlimiting examples of the p-dopant include quinone derivatives such as tetracyanoquinonedimethan (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzonquinonedimethane (F4TCNQ); metal oxides such as tungsten oxides or molybdenum oxides; and cyano group containing compounds such as hexanitrile hexaazatriphenylene.

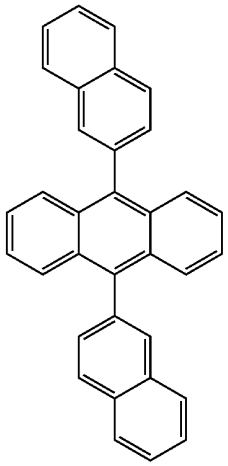
[0075] When the hole injection layer **13**, the hole transport layer **14**, or the functional layer simultaneously having hole injection and hole transport functions further includes the charge-generation material, the charge-generation material is homogeneously or non-homogeneously dispersed in the layer.

[0076] The emission layer **15** may be formed on the hole transport layer **14** or the functional layer simultaneously having hole injection and hole transport functions by using vacuum deposition, a wet process, or laser transferring. When the emission layer **15** is formed by vacuum deposition or spin coating, the deposition conditions may vary according to the compound used. However, in general, the conditions may be similar to the conditions described above for forming the hole injection layer **13**.

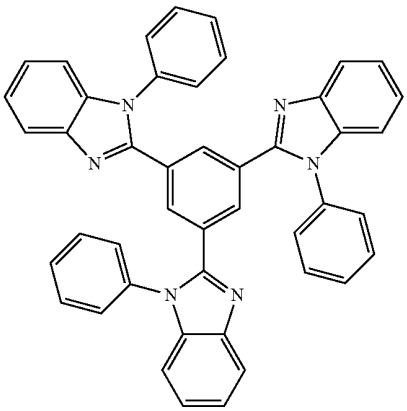
[0077] The emission layer **15** may include at least one of the condensed-cyclic compound of Formula 1 and a known phosphorescent host, fluorescent host, phosphorescent dopant, or fluorescent dopant. When the emission layer **15** includes the condensed-cyclic compound represented by Formula 1, the condensed-cyclic compound may function as a phosphorescent host, a fluorescent host, a phosphorescent dopant, or a fluorescent dopant.

[0078] Nonlimiting examples of known hosts may include 4,4'-N,N'-dicarbazole-biphenyl (CBP), 9,10-di-naphthalene-2-yl-anthracene (AND) (refer to Formula below), TPBI (refer to Formula below), TBADN (refer to Formula below), E3 (refer to Formula below).

ADN



TPBI



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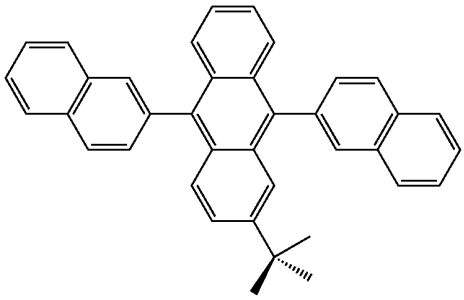
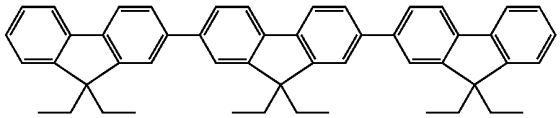
TBADN

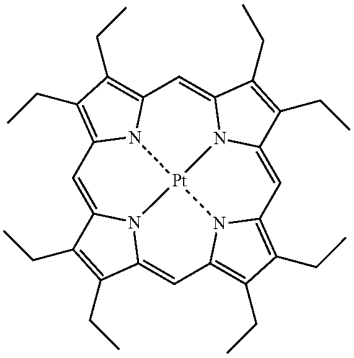


E3

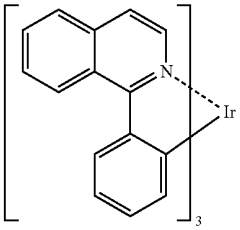


[0079] At least one of the fluorescent dopant and the phosphorescent dopant may be used as a dopant. The phosphorescent dopant may be an organic metal complex including Ir, Pt, Os, Re, Ti, Zr, Hf, or combinations including at least two of Ir, Pt, Os, Re, Ti, Zr, and Hf. However, the present invention is not limited thereto.

[0080] As a red dopant, PtOEP (refer to Formula below), $Ir(piq)_3$ (refer to Formula below), or $Btp_2Ir(acac)$ (refer to Formula below) may be used. However, the present invention is not limited thereto.



PtOEp



$Ir(piq)_3$

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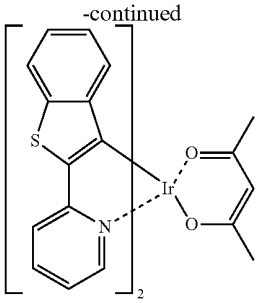
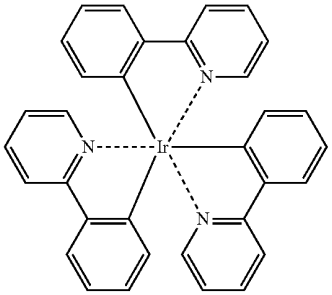
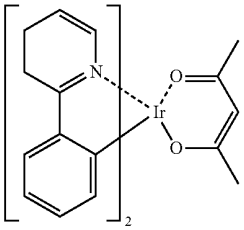


$Btp_2Ir(acac)$

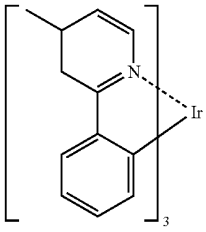
[0081] As a green dopant, $Ir(ppy)_3$(ppy=phenyl-pyridines, refer to Formula below), $Ir(ppy)_2(acac)$ (refer to Formula below), or $Ir(mpyp)_3$ (refer to Formula below) may be used. However, the present invention is not limited thereto.



$Ir(ppy)_3$

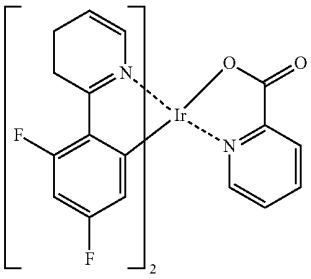


$Ir(ppy)_2(acac)$

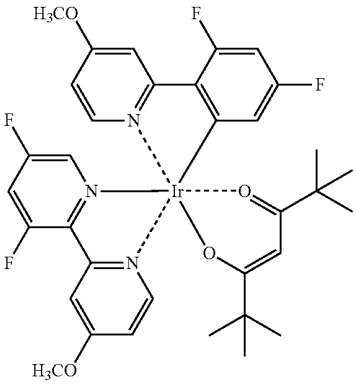


$Ir(mpyp)_3$

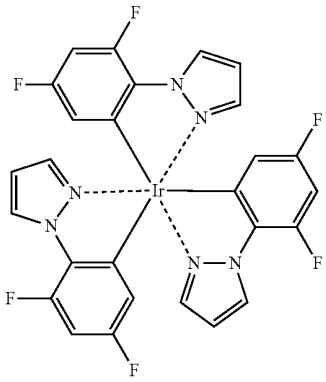
[0082] As a blue dopant, F_2Irpic (refer to Formula below), $(F_2ppy)_2Ir(tmd)$ (refer to Formula below), $Ir(dfppz)_3$ (refer to Formula below), DPVBi (refer to Formula below), 4,4'-bis(4-diphenylaminosteril)biphenyl (DPAVBi, refer to Formula below), or 2,5,8,11-tetra-tert-butylpherylene (TBPe) (refer to Formula below) may be used. However, the present invention is not limited thereto.



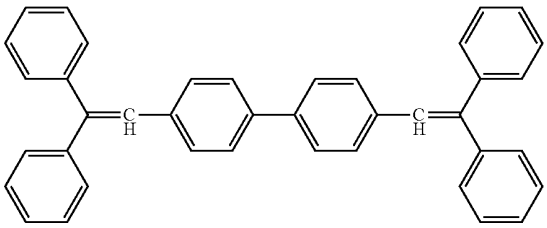
F_2Irpic



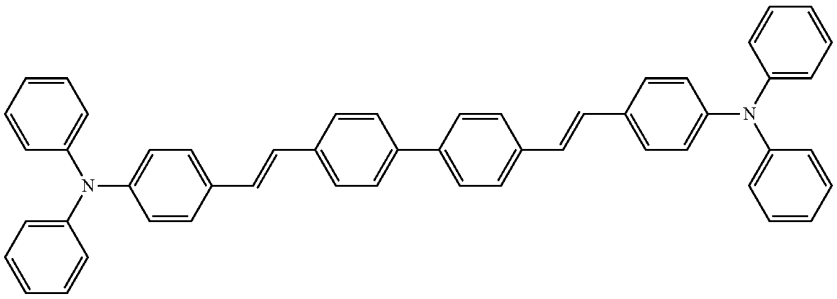
$(F_2ppy)_2Ir(tmd)$



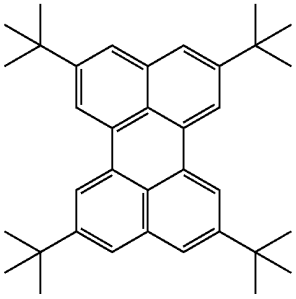
$Ir(dfppz)_3$



DPVBi



DPAVBi



TBPe

[0083] When the emission layer **15** includes a host and a dopant, an amount of the dopant 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. However, the present invention is not limited thereto.

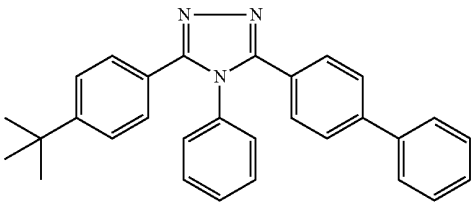
[0084] A thickness of the emission layer **15** may be about 100 Å to about 1000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer **15** is in these ranges, good emission characteristics may be obtained without a substantial increase in driving voltage.

[0085] When the phosphorescent dopant is included in the emission layer **15**, a hole blocking layer (not illustrated) may be formed between the emission layer **15** and the hole transport layer **16** by vacuum deposition, a wet process, or laser transferring so as to prevent triplet excitons or holes from being diffused to the electron transport layer **16**. When the hole blocking layer is formed by vacuum deposition or spin

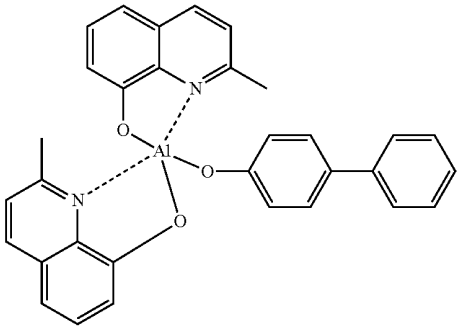
coating, the conditions thereof may vary according to the compound used. However, in general, the conditions may be similar to the conditions described above for forming the hole injection layer **13**. Any known hole blocking material may be used. Nonlimiting examples of known hole blocking materials include oxadiazole derivatives, triazole derivatives, and phenanthroline derivatives.

[0086] A thickness of the hole blocking layer may be about 50 Å to about 1000 Å, for example, about 100 Å to about 300 Å. When the thickness of the hole blocking layer is in these ranges, good hole blocking characteristics may be obtained without a substantial increase in driving voltage.

[0087] The electron transport layer **16** my be formed by vacuum deposition, a wet process, or laser transferring. When the electron transport layer **16** is formed by vacuum deposition or spin coating, the conditions thereof may vary according to the compound used. However, in general, the conditions may be similar to the conditions described above for forming the hole injection layer **13**. The condensed-cyclic compound represented by Formula 1 may be used as a material for forming the electron transport layer **16**. Also, the electron transport layer **16** may further include a known electron transport material to stably transport electrons injected from the cathode. Nonlimiting examples of known transport materials include quinoline derivatives, in particular, tris(8-quinolinolate)aluminum (Alq_3), TAZ (refer to Formula below), Balq (refer to Formula below), beryllium bis benzoquinolin-10-olate ($Bebq_2$). However, the present invention is not limited thereto.



TAZ

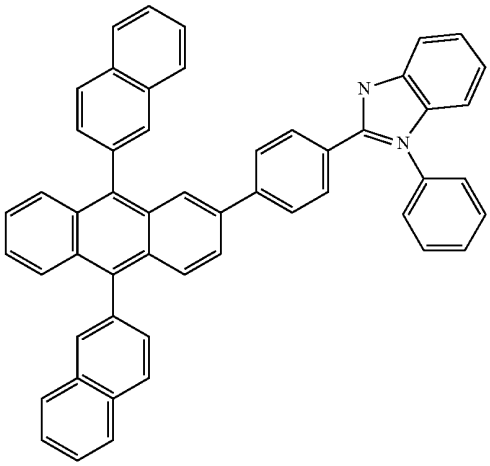


BAlq

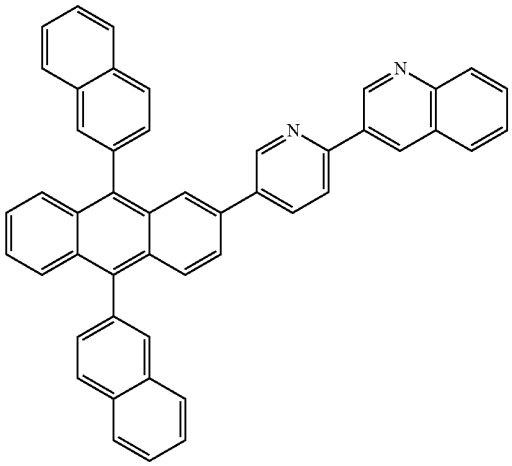
[0088] A thickness of the electron transport layer **16** may be about 100 Å to about 1000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer **16** is in these ranges, good electron transport characteristics may be obtained without a substantial increase in driving voltage.

[0089] Also, the electron transport layer **16** may include an organic electron transport compound and a metal-containing material. Nonlimiting examples of the organic electron transport compound include 9,10-di(naphthalene-2-yl)anthracene (AND); and anthracene-based compounds such as a compound 301 or 302 below:

Compound 301

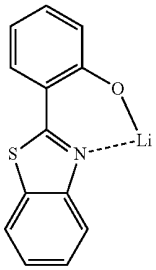


Compound 302



[0090] The metal-containing material may include a Li complex. Nonlimiting examples of the Li complex include lithium quinolate (LiQ) or compound 303 below:

Compound 303



[0091] Also, the electron injection layer **17**, which facilitates electron injection from a cathode, may be formed on the

electron transport layer **16**. A material for forming the electron injection layer **17** may include any known material for forming an electron injection layer, such as LiF, NaCl, CsF, Li_2O, or BaO. The deposition conditions of the electron injection layer **17** may vary according the compound used. However, in general, the conditions may be similar to the conditions described above for forming the hole injection layer **13**.

[0092] A thickness of the electron injection layer **17** may be about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer **17** is in these ranges, satisfactory hole injection characteristics may be obtained without a substantial increase in driving voltage.

[0093] The second electrode **18** may be a transparent electrode and may be formed on the electron injection layer **17**. The second electrode **18** may be a cathode, which is an electrode injection electrode. Here, a metal for forming the second electrode **18** may include a metal having a low work function, an alloy, an electric conducting compound, and mixtures thereof. More specifically, the transparent electrode may be a thin film of lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag). In order to obtain a top-emission light-emitting device, the transparent electrode may be formed of ITO or IZO.

[0094] The organic light-emitting device may be used in a flat panel display apparatus including a transistor.

[0095] According to an embodiment of the present invention, a flat panel display apparatus includes an organic light-emitting device including a transistor including a source electrode, a drain electrode, a gate, and an active layer, and an organic layer including the condensed-cyclic compound represented by Formula 1 above. In the organic light-emitting device, the first electrode is electrically connected to the source electrode or the drain electrode. The active layer of the transistor may vary and may be, for example, an amorphous silicon layer, a crystallized silicon layer, an organic semiconductor layer, or an oxide semiconductor layer.

[0096] Hereinafter, an organic light-emitting device according to the present invention will be described more specifically with reference to the following Synthesis Examples and Examples. The following Synthesis Examples and Examples are presented for illustrative purposes only and are not intended to limit the scope of the invention.

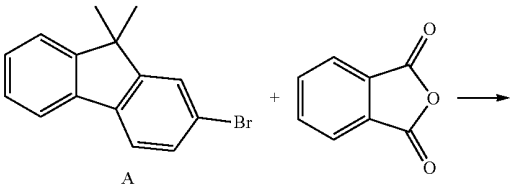
EXAMPLES

Synthesis Example 1

Synthesis of Compound 1

[0097] Compound 1 was synthesized according to Reaction Formula 1 below:

Reaction Formula 1



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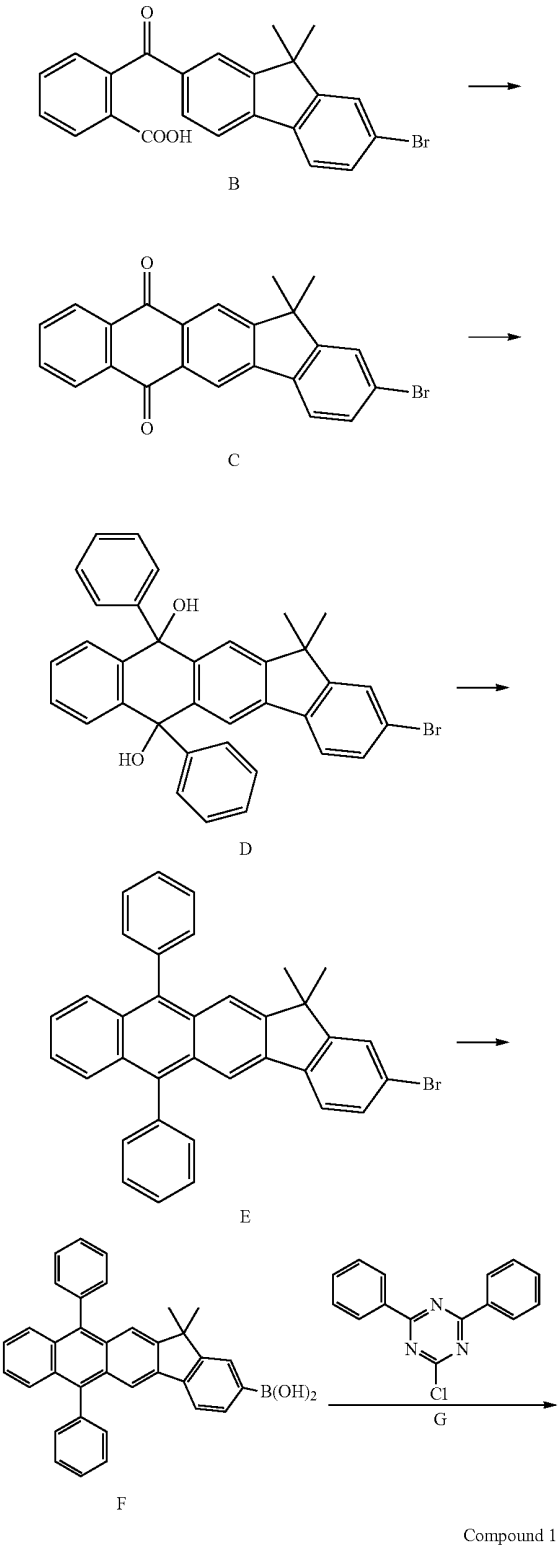


1) Synthesis of Intermediate B

[0098] 27.3 g (0.1 mol) of intermediate A and 16.3 g (0.11 mol) of phthalic anhydride were put in a flask and dichloromethane was added to the flask. 20 g (0.15 mol) of aluminum chloride was gradually added to the flask at 0° C. and then was stirred for 12 hours at room temperature so as to obtain a reaction mixture. After the reaction was completed, distilled water was slowly added to the reaction mixture and the mixture was extracted using dichloromethane. Then, the solvent was removed and a solid was obtained. The obtained solid was washed using hexane, filtered, and dried, thereby obtaining 33.7 g (yield 80%) of intermediate B. 1H-NMR (400 MHz, CDCl3) 8.23 (1H), 7.99 (1H), 7.93 (2H), 7.83 (1H), 7.75 (3H), 7.66 (1H), 7.53 (1H), 1.67 (6H)

2) Synthesis of Intermediate C

[0099] 33.7 g (80.0 mmol) of intermediate B was put in a flask and polyphosphoric acid was added to the flask. Then, the flask was stirred for 2 hours at 130° C. so as to obtain a mixture. The mixture was cooled down to room temperature and distilled water was gradually added to the mixture, thereby obtaining a solid. The obtained solid was filtered and washed using a small amount of methanol, thereby obtaining 26.8 g (yield 83%) of intermediate C. 1H-NMR (400 MHz, CDCl3) 8.84 (1H), 8.12 (1H), 7.78-7.75 (4H), 7.56 (3H), 1.67 (6H)

3) Synthesis of Intermediate E

[0100] 10 g (24.8 mmol) of intermediate C was put in 250 ml of THF, which was dried under a nitrogen atmosphere, so as to obtain a mixture. Then, the temperature was lowered to −78° C. and then 50.0 mL (0.5 M) of 2-naphthylmagnesiumbromide was slowly added to the mixture so as to obtain a reaction mixture. The temperature was increased to room temperature and then the reaction mixture was stirred for 3 hours. An ammonium chloride aqueous solution was added to the reaction mixture and the mixture was then extracted using dichloromethane, thereby obtaining an organic layer. The organic layer was dried using anhydrous magnesium sulfate and the solvent was removed so as to obtain a mixture. The mixture was dissolved using a small amount of ethyl ether, petroleum ether was added to the mixture, and the mixture was stirred for a few hours, thereby obtaining a solid compound. The solid compound was vacuum dried and a solid product was obtained. Then, in a nitrogen atmosphere, the solid product was dispersed in 200 ml of acetic acid so as to form a mixture. Then, 41 g (250 mmol) of potassium iodide and 44 g (500 mmol) of sodium hypophosphate hydrate were added to the mixture and then stirred and refluxed for 3 hours so as to form a reaction mixture. After the reaction was completed, an excessive amount of distilled water was added to the reaction mixture so as to form a solid. Then, the solid was filtered, washed using water and methanol, and vacuum dried, thereby obtaining 11.3 g of light-yellow intermediate E (yield 73%). 1H-NMR (400 MHz, CDCl3) 8.10 (1H), 7.95 (1H), 7.91 (2H), 7.70 (2H), 7.73-7.78 (4H), 7.66-7.61 (5H), 7.51 (2H), 7.35 (4H), 7.26 (2H), 1.67 (6H)

4) Synthesis of Intermediate F

[0101] 6.3 g (10 mmol) of intermediate E was dissolved in 70 ml of THF, which was dried under a nitrogen atmosphere, so as to obtain a mixture. Then, 4.8 ml (2.5 M) of butyllithium was added to the mixture at −78° C. so as to form a mixture solution. The mixture solution was stirred for 1 hour at the same temperature and 1.7 ml (15 mmol) of trimethyl borate was added to the mixture solution. The temperature was increased to room temperature. After 1 hour, 2 N aqueous hydrochloric acid was added to the mixture solution and was stirred for 3 hours, thereby obtaining a solid compound. The obtained solid compound was washed using toluene and filtered, thereby obtaining 4.7 g of light-yellow intermediate F (yield 81%).

5) Synthesis of Intermediate G

[0102] 20 g (108.5 mmol) of 2,4,6-trichloro-1,3,5-triazine was dissolved in 50 ml of anhydrous tetrahydrofuran, so as to obtain a mixture. Then, 228 mL (227.8 mmol) of 1M phenylmagnesiumbromide was gradually added to the mixture at 0° C., so as to obtain a mixture solution. The temperature was increased to room temperature and the mixture solution was stirred for 4 hours. The remaining grignard reagent was removed using 200 ml of an aqueous ammonium chloride solution, the mixture solution was neutralized using 300 ml of an aqueous sodium hydrogen carbonate solution, and then extracted using 3×50 mL of tetrahydrofuran. Moisture was removed using anhydrous magnesium sulfate, the resulting solid was filtered, and excess solvent was removed using vacuum distillation and the solid was recrystallized using hexane, thereby obtaining 15 g of the compound of Formula G (52%)(MS: [M+H]=268).

6) Synthesis of Compound 1

[0103] 3.2 g (8.0 mmol) of the compound of Intermediate F and 1.7 g (6.3 mmol) of the compound of Intermediate G were completely dissolved in 100 ml of tetrahydrofuran, so as to obtain a mixture. Then, a 2M aqueous potassium carbonate solution was added to the mixture and then, 155 mg (0.013 mmol) of tetrakis(triphenylphosphine)palladium was added to the mixture, thereby heating and stirring for 5 hours to obtain a mixture solution. The temperature was lowered to room temperature, a material layer of the mixture solution was removed, the mixture solution was dried using anhydrous magnesium sulfate, was vacuum evaporated, and was slowly separated using column chromatography (tetrahydrofuran: hexane=1:6), thereby obtaining 1.5 g of compound 1 (36%) (MS: [M+H]=677).

Synthesis Example 2

Synthesis of Compound 4

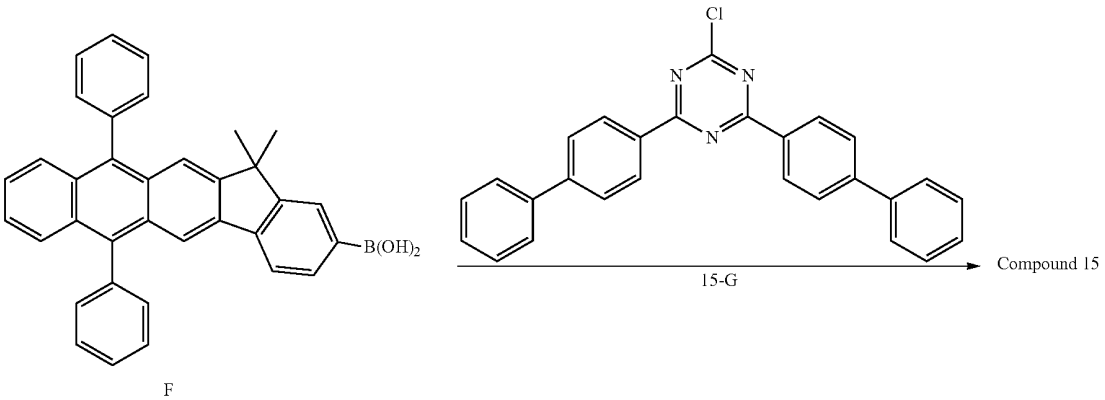
[0104] Compound 4 was obtained in the same manner as in the Synthesis Example of Compound 1, except that 50.0 ml of 0.5 M 2-phenylmagnesiumbromide was used instead of 50.0 ml of 0.5 M 2-naphthylmagnesiumbromide when synthesizing intermediate E (MS: [M+H]=778).

Synthesis Example 3

Synthesis of Compound 15

[0105] Compound 15 was synthesized according to Reaction Formula 2 below:

Reaction Formula 2



Synthesis of Intermediate 15-G

[0106] 20 g (108.5 mmol) of 2,4,6-trichloro-1,3,5-triazine was dissolved in 50 ml of anhydrous tetrahydrofuran, so as to obtain a mixture. Then, 228 mL (227.8 mmol) of 1M biphenylmagnesiumbromide was gradually added to the mixture at 0° C., so as to obtain a mixture solution. The temperature was increased to room temperature and the mixture solution was stirred for 4 hours. The remaining grignard reagent was removed using 200 ml of an aqueous ammonium chloride solution, the mixture solution was neutralized using 300 ml of an aqueous sodium hydrogen carbonate solution, and then extracted using 3×50 mL of tetrahydrofuran. Moisture was removed using anhydrous magnesium sulfate and the solid was filtered, and excess solvent was removed using vacuum distillation and the solid was recrystallized using hexane, thereby obtaining 16.5 g of the compound in Formula 15-G (53%) (MS: [M+H]=420).

Synthesis of Compound 15

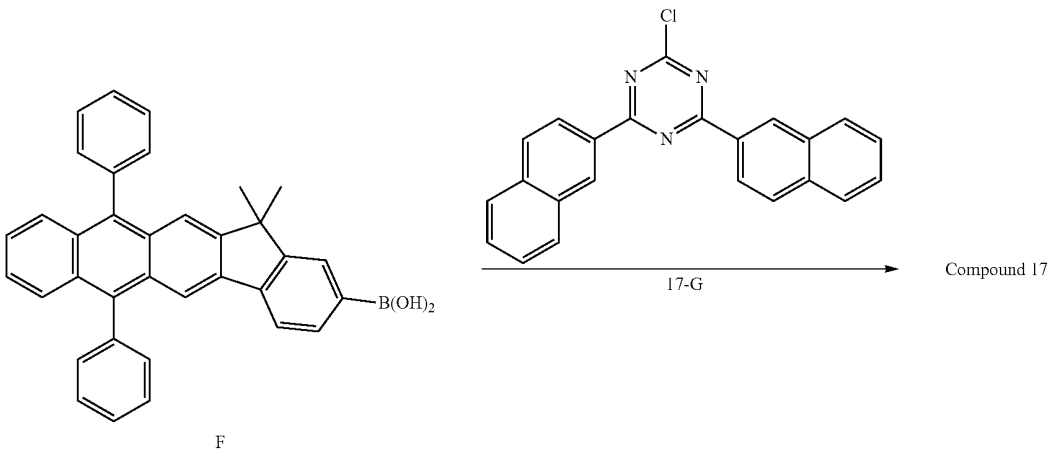
[0107] 3.2 g (8.0 mmol) of the compound of Intermediate F and 1.7 g (6.3 mmol) of the compound of Intermediate 15-G were completely dissolved in 100 ml of tetrahydrofuran, so as to obtain a mixture. Then, a 2M aqueous potassium carbonate solution was added to the mixture and then, 155 mg (0.013 mmol) of tetrakis(triphenylphosphine)palladium was added to the mixture, and the mixture was heated and stirred for 5 hours to obtain a mixture solution. The temperature was lowered to room temperature, the material layer of the mixture solution was removed, the mixture solution was dried using anhydrous magnesium sulfate, vacuum evaporated, and slowly separated using column chromatography (tetrahydrofuran:hexane=1:7), thereby obtaining 15 g of compound 15 (36%) (MS: [M+H]=930).

Synthesis Example 4

Synthesis of Compound 17

[0108] Compound 17 was synthesized according to Reaction Formula 3 below:

Reaction Formula 3



Synthesis of Intermediate 17-G

[0109] 20 g (108.5 mmol) of 2,4,6-trichloro-1,3,5-triazine was dissolved in 50 ml of anhydrous tetrahydrofuran, so as to obtain a mixture. Then, 233 mL (227.8 mmol) of 1M 2-naphthylmagnesiumbromide was gradually added to the mixture at 0° C., so as to obtain a mixture solution. The temperature was increased to room temperature and the mixture solution was stirred for 5 hours. The remaining grignard reagent was removed using 200 ml of an aqueous ammonium chloride solution, the mixture was neutralized using 300 ml of an aqueous sodium hydrogen carbonate solution, and then extracted using 3×50 mL of tetrahydrofuran. Moisture was removed using anhydrous magnesium sulfate and the solid was filtered, and excess solvent was removed using vacuum distillation and the solid was recrystallized using hexane, thereby obtaining 15.2 g of the compound in Formula 17-G (49%)(MS: [M+H]=368).

Synthesis of Compound 17

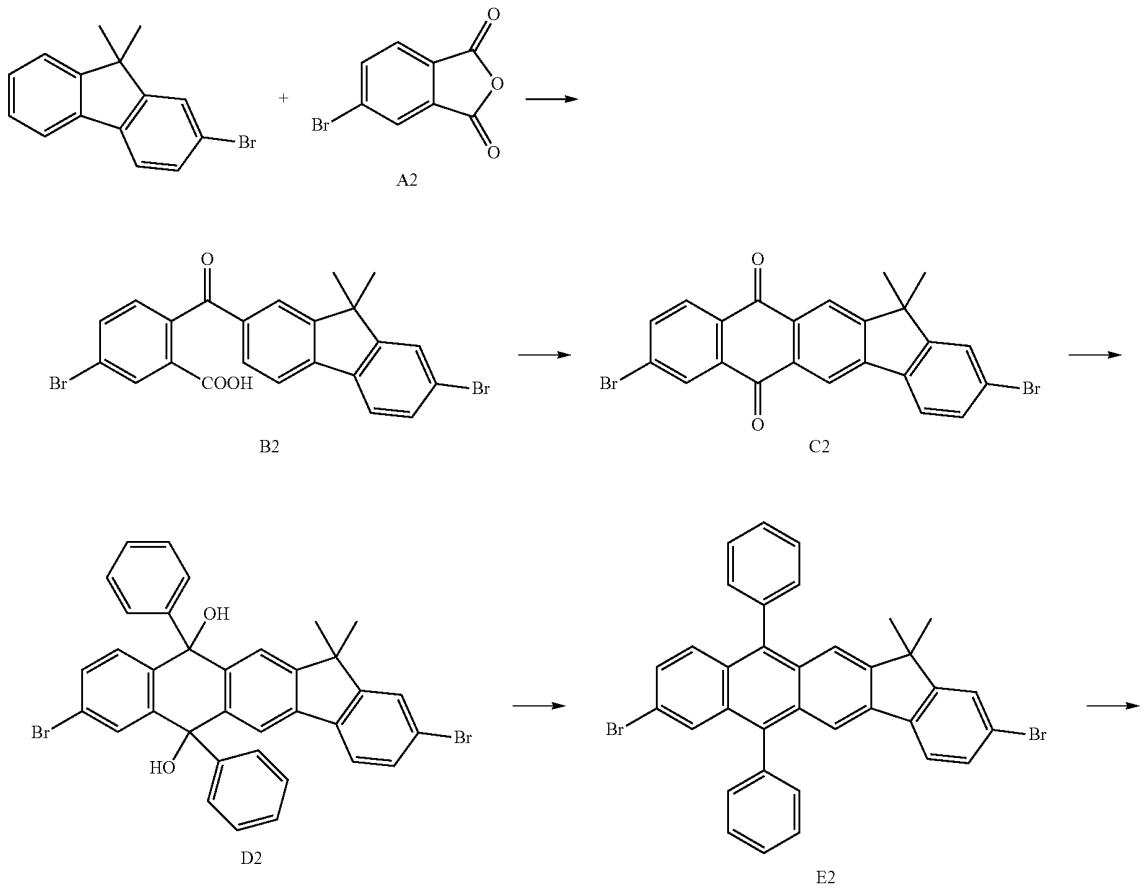
[0110] 3.2 g (8.0 mmol) of the compound of Intermediate F and 1.7 g (6.3 mmol) of the compound of Intermediate 17-G were completely dissolved in 100 ml of tetrahydrofuran, so as to obtain a mixture. Then, a 2M aqueous potassium carbonate solution was added to the mixture and then, 155 mg (0.013 mmol) of tetrakis(triphenylphosphine)palladium was added to the mixture, and the mixture was heated and stirred for 5 hours to obtain a mixture solution. The temperature was lowered to room temperature, the material layer of the mixture solution was removed, the mixture solution was dried using anhydrous magnesium sulfate, vacuum evaporated, and slowly separated using column chromatography (tetrahydrofuran:hexane=1:5), thereby obtaining 1.0 g of compound 17 (31%) (MS: [M+H]=778).

Synthesis Example 5

Synthesis of Compound 25

[0111] Compound 25 was synthesized according to Reaction Formula 4 below:

Reaction Formula 4



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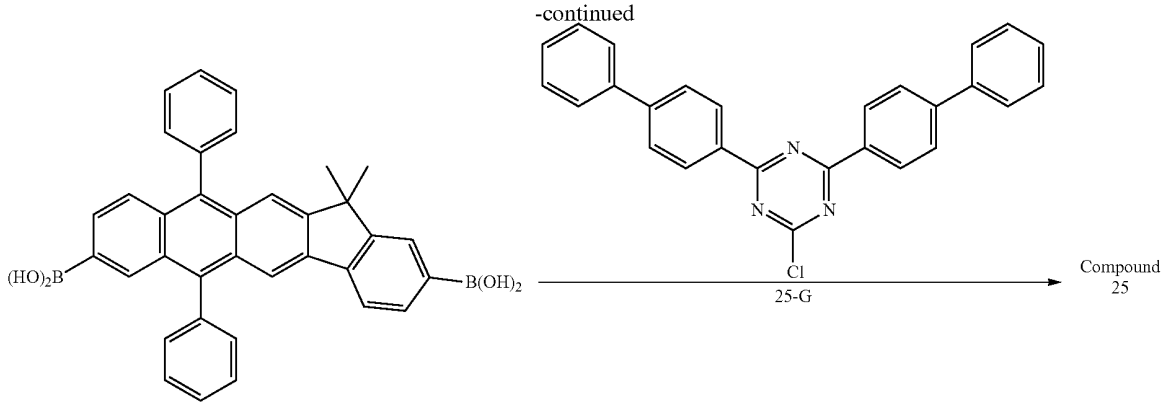


F2

Synthesis of Intermediate B2

[0112] 27.3 g (0.1 mol) of 2-bromo dimethyl fluorene and 16.3 g (0.11 mol) of 2-bromo-phthalic anhydride were put in a flask and dichloromethane was added to the flask. 20 g (0.15 mol) of aluminum chloride was gradually added to the flask at 0° C. and then was stirred for 12 hours at room temperature so as to obtain a reaction mixture. After the reaction was completed, distilled water was slowly added to the reaction mixture and the mixture was extracted using dichloromethane. Then, the solvent was removed and a solid was obtained. The obtained solid was washed using hexane, filtered, and dried, thereby obtaining 29.6 g (yield 77%) of intermediate B2. 1H-NMR (400 MHz, CDCl3) 8.23 (1H), 7.99 (1H), 7.93 (2H), 7.83 (1H), 7.75 (3H), 7.66 (1H), 7.53 (1H), 1.67 (6H)

Synthesis of Intermediate C2

[0113] 29.6 g (80.0 mmol) of intermediate B2 was put in a flask and polyphosphate was added to the flask. Then, the flask was stirred for 2 hours at 130° C. so as to obtain a mixture. The mixture was cooled down to room temperature and distilled water was gradually added to the mixture, thereby obtaining a solid. The obtained solid was filtered and washed using a small amount of methanol, thereby obtaining 25.6 g (yield 81%) of intermediate C2. 1H-NMR (400 MHz, CDCl3) 8.84 (1H), 8.12 (1H), 7.78-7.75 (4H), 7.56 (3H), 1.67 (6H)

Synthesis of Intermediate E2

[0114] 10 g (24.8 mmol) of intermediate C was put in 250 ml of THF, which was dried under a nitrogen atmosphere, so as to obtain a mixture. Then, the temperature was lowered to −78° C. and then 50.0 mL (0.5 M) of 2-naphthylmagnesium-bromide was slowly added to the mixture so as to obtain a reaction mixture. The temperature was increased to room temperature and then the reaction mixture was stirred for 3 hours. An ammonium chloride aqueous solution was added to the reaction mixture and the mixture was then extracted using dichloromethane, thereby obtaining an organic layer. The organic layer was dried using anhydrous magnesium sulfate and the solvent was removed so as to obtain a mixture. The mixture was dissolved using a small amount of ethyl ether, petroleum ether was added to the mixture, and the mixture was stirred for a few hours, thereby obtaining a solid compound. The solid compound was vacuum dried and a solid product was obtained. Then, in a nitrogen atmosphere, the solid product was dispersed in 200 ml of acetic acid so as to form a mixture. Then, 41 g (250 mmol) of potassium iodide and 44 g (500 mmol) of sodium hypophosphate hydrate were added to the mixture and then stirred and refluxed for 3 hours so as to form a reaction mixture. After the reaction was completed, an excess amount of distilled water was added to the reaction mixture so as to form a solid. Then, the solid was filtered, washed using water and methanol, and vacuum dried, thereby obtaining 11.3 g of light-yellow intermediate E (yield 73%). 1H-NMR (400 MHz, CDCl3) 8.10 (1H), 7.95 (1H), 7.91 (2H), 7.70 (2H), 7.73-7.78 (4H), 7.66-7.61 (5H), 7.51 (2H), 7.35 (4H), 7.26 (2H), 1.67 (6H)

Synthesis of Intermediate F2

[0115] 6.3 g (10 mmol) of intermediate E2 was dissolved in 70 ml of THF, which was dried under a nitrogen atmosphere, so as to obtain a mixture. Then, 7.2 ml (2.5 M) of butyllithium was added to the mixture at −78° C. so as to form a mixture solution. The mixture solution was stirred for 1 hour at the same temperature and 5.0 ml (15 mmol) of trimethyl borate was added to the mixture solution. The temperature was increased to room temperature. After 1 hour, 2 N of aqueous hydrochloric acid was added to the mixture solution and was stirred for 3 hours, thereby obtaining a solid compound. The obtained solid compound was washed using toluene and filtered, thereby obtaining 4.7 g of light-yellow intermediate F (yield 81%).

Synthesis of Intermediate 25-G

[0116] 20 g (108.5 mmol) of 2,4,6-trichloro-1,3,5-triazine was dissolved in 50 ml of anhydrous tetrahydrofuran, so as to obtain a mixture. Then, 228 mL (227.8 mmol) of 1M biphenylmagnesiumbromide was gradually added to the mixture at 0° C., so as to obtain a mixture solution. The temperature was increased to room temperature and the mixture solution was stirred for 4 hours. The remaining grignard reagent was removed using 200 ml of an aqueous ammonium chloride solution, was neutralized using 300 ml of an aqueous sodium hydrogen carbonate solution, and the mixture solution was then extracted using 3×50 mL of tetrahydrofuran. Moisture was removed using anhydrous magnesium sulfate and the

solid was filtered, and excess solvent was removed using vacuum distillation and the solid was recrystallized using hexane, thereby obtaining 17 g of compound in Formula 25-G (52%) (MS: [M+H]=420).

Synthesis of Compound 25

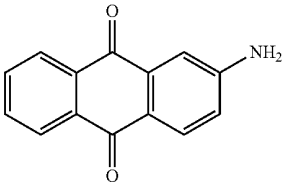
[0117] 3.2 g (8.0 mmol) of Intermediate F2 and 5.1 g (18.9 mmol) of Intermediate 25-G were completely dissolved in 100 ml of tetrahydrofuran, so as to obtain a mixture. Then, a 2M aqueous potassium carbonate solution was added to the mixture and then, 200 mg (0.018 mmol) of tetrakistriphenylphosphinopaladium was added to the mixture, and the mixture was heated and stirred for 15 hours to obtain a mixture solution. Temperature was lowered to room temperature, the material layer of the mixture solution was removed, the mixture solution was dried using anhydrous magnesium sulfate, vacuum evaporated, and slowly separated using column chromatography once (tetrahydrofuran:hexane=1:3), thereby obtaining 1.5 g of compound 25 (32%) (MS: [M+H]=1214).

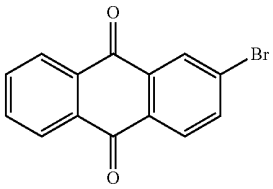
Comparative Synthesis Example 1

Synthesis of Compound 201

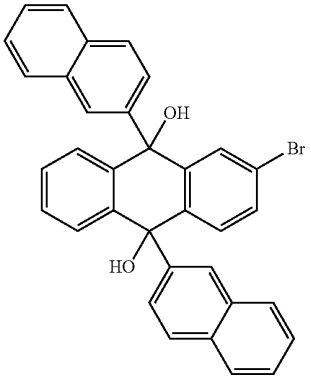
[0118] Compound 201 was manufactured according to Reaction Formula 5 below:

Reaction Formula 5





1a



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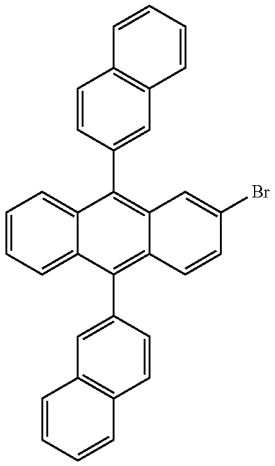
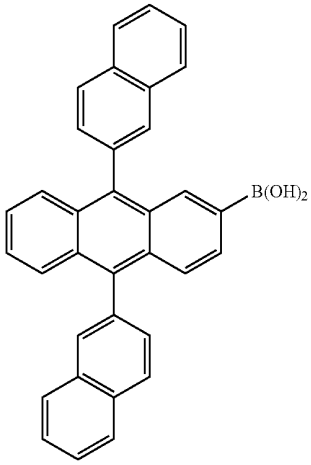
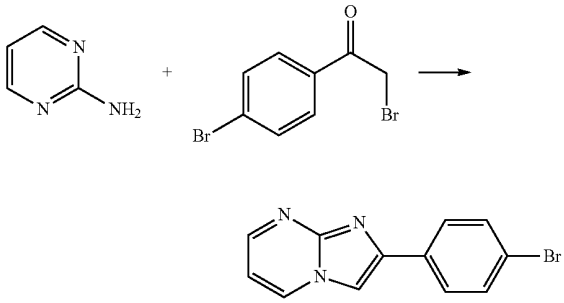


1b



1c



1d

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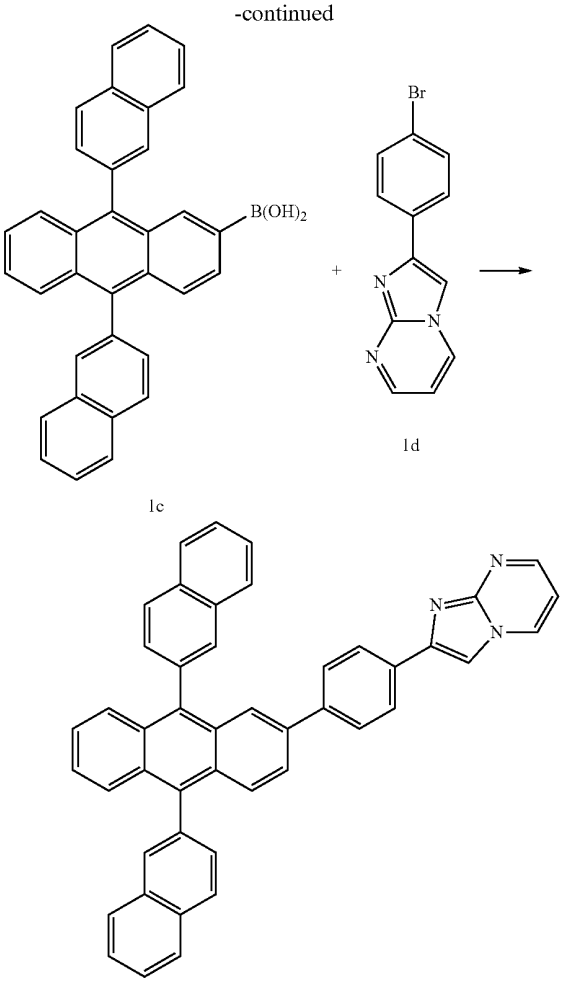


Synthesis of Intermediate 1a

[0119] 10 g (44 mmol) of copper bromide and 8 g (35.8 mmol) of 2-amino-anthraquinone were put in 250 ml of bromic acid so as to form a mixture. The mixture was heated to 65° C. When gas generation was completed, the mixture was cooled down to room temperature so as to form a reaction solution. The reaction solution was added to 1000 ml of 20% aqueous hydrochloric acid and was extracted using dichloromethane, thereby obtaining an organic layer. The remaining moisture of the organic layer was removed using anhydrous magnesium sulfate and vacuum dried, thereby obtaining a product. The product was separated using column chromatography (dichloromethane:normal hexane=4:1), thereby obtaining 7.7 g of intermediate 1a.

2) Synthesis of Intermediate 1b

[0120] 10 g (34.8 mmol) of intermediate 1a was put in 100 ml of THF, which was dried under a nitrogen atmosphere, so as to obtain a mixture. Then, the temperature was lowered to −78° C. and then 0.5 M 2-naphthylmagnesiumbromide (10 mmol) was slowly added to the mixture so as to obtain a reaction mixture. The temperature was increased to room temperature and then the reaction mixture was stirred for 3 hours. An ammonium chloride aqueous solution was added to the reaction mixture and the mixture was then extracted using dichloromethane, thereby obtaining an organic layer. The organic layer was dried using anhydrous magnesium sulfate and the solvent was removed so as to obtain a mixture. The mixture was dissolved using a small amount of ethyl ether, petroleum ether was added to the mixture, and the mixture was stirred for a few hours, thereby obtaining a solid compound. The solid compound was filtered and vacuum dried, thereby obtaining 17.6 g of dinaphthyldialcohol.

[0121] Then, in a nitrogen atmosphere, 17.6 g (32.4 mmol) of dinaphthyldialcohol was dispersed in 200 ml of acetic acid so as to form a mixture. Then, 53.4 g (330 mmol) of potassium iodide and 58 g (660 mmol) of sodium hypophosphate hydrate were added to the mixture and then stirred and refluxed for 3 hours so as to form a reaction mixture. The mixture was cooled down to room temperature, filtered, and washed using water and methanol, and vacuum dried, thereby obtaining 11.3 g of light-yellow intermediate 1b.

3) Synthesis of Intermediate 1c

[0122] 5 g (9.81 mmol) of intermediate 1b was dissolved in 70 ml of THF, which was dried under a nitrogen atmosphere, so as to obtain a mixture. Then, 4.7 ml (11.8 mmol) of butyllithium was added to the mixture at −78° C. so as to form a mixture solution. The mixture solution was stirred for 1 hour at the same temperature and 2.20 ml (29.4 mmol) of trimethyl borate was added to the mixture solution. The temperature was increased to room temperature. After 1 hour, 2 N aqueous hydrochloric acid was added to the mixture solution and was stirred for 3 hours, thereby obtaining a solid compound. The obtained solid compound was washed using toluene and filtered, thereby obtaining 3.27 g of light-yellow intermediate 1c (yield 70%).

4) Synthesis of Intermediate 1d

[0123] 3.39 g (35.98 mmol) of 2-aminopyridine and 10 g (35.98 mmol) of 2,4'-dibromoacetophenone were dissolved in 150 ml of ethanol so as to form a mixture. Then, the mixture was refluxed for 12 hours. When the mixture was cooled down to room temperature, a white solid was generated and was filtered while washing using a saturated $NaHCO_3$ solution, thereby obtaining an organic layer. The remaining moisture of the organic layer was removed using anhydrous magnesium sulfate, and the resultant was vacuum dried, and recrystallized (dichloromethane/normal hexane), thereby obtaining 8.02 g of intermediate 1d having a crystal form of a panel (yield 82%).

5) Synthesis of Compound 201

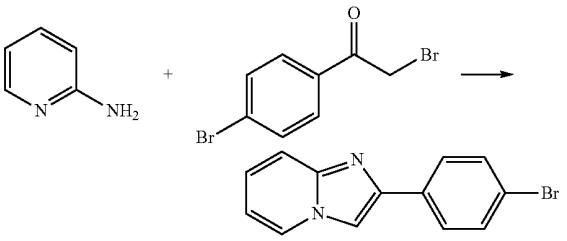
[0124] 1.85 g (3.90 mmol) of intermediate 1c and 1 g (3.90 mmol) of intermediate 1d were put in a mixed solvent of 2.7 g (19.5 mmol) of potassium carbonate aqueous solution and THF so as to form a mixture. Then, 225 mg (0.196 mmol) of $Pd(PPh_3)_4$ was put in the mixture while stirring, and the mixture was refluxed for 6 hours so as to form a mixture solution. The mixture solution was cooled down to room temperature and then a solid compound was generated. The solid compound was filtered while washing using water, ethanol, and toluene, thereby obtaining 1.73 g (71%) of com-

pound 201. 1H NMR (400 MHz, CDCl3) 8.51 (1H), 8.40 (1H), 8.12 (1H), 8.06-7.99 (5H), 7.96 (2H), 7.85 (1H), 7.78-7.59 (15H), 7.32 (2H), 6.84 (1H)

Comparative Synthesis Example 2

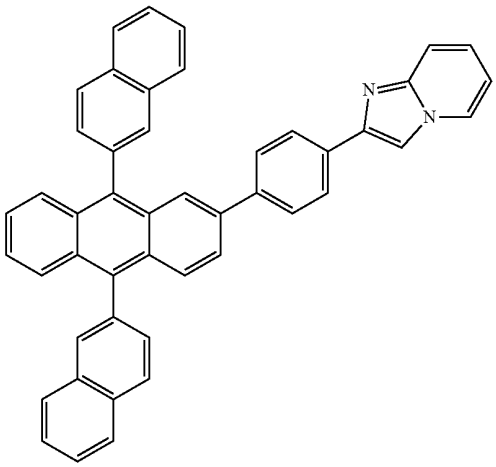
Synthesis of Compound 202

[0125] 1.73 g (71%) of compound 202 was obtained in the same manner as in Comparative Synthesis Example 1, except that intermediate 2d below was used instead of intermediate 1d when synthesizing. 1H NMR (400 MHz, $CDCl_3$) 8.13-8.04 (7H), 8.01 (1H), 7.97-7.92 (4H), 7.86-7.82 (2H), 7.75 (2H), 7.71-7.58 (10H), 7.32 (2H), 7.15 (1H), 6.75 (1H)



2d

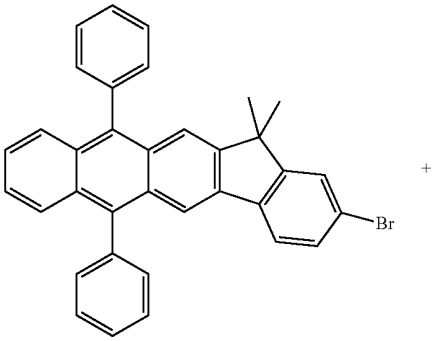
Compound 202



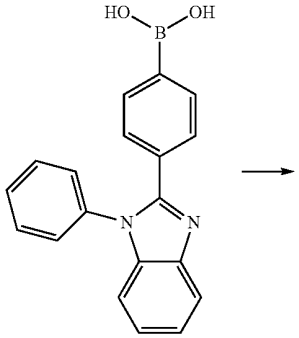
Comparative Synthesis Example 3

Synthesis of Compound 203

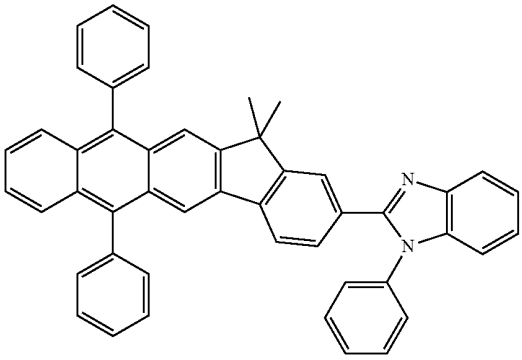
[0126] Intermediate E-1 was synthesized in the same manner as in Synthesis Example 1, except that a phenyl group was used instead of a naphthyl group when synthesizing intermediate E. 2.05 g (3.90 mmol) of intermediate E-1 and 1.23 g (3.90 mmol) of intermediate H were put in a mixed solvent of 2.7 g (19.5 mmol) of potassium carbonate aqueous solution and toluene so as to form a mixture. Then, 225 mg (0.196 mmol) of $Pd(PPh_3)_4$ was put in the mixture while stirring, and the mixture was refluxed for 6 hours so as to form a mixture solution. The mixture solution was cooled down to room temperature and then a solid compound was generated. The solid compound was filtered while washing using water, ethanol, and toluene, thereby obtaining 1.74 g (70%) of compound 203. ^{1}H-NMR (400 MHz, $CDCl_3$) 8.52 (1H), 8.27 (1H), 8.10 (1H), 7.83 (2H), 7.74 (1H), 7.68 (4H), 7.59-7.42 (16H), 7.22 (2H), 1.67 (6H)



E-1



H



Compound 203

Example 1

[0127] As an anode, a 15 Ω/cm^2 (1200 Å) ITO glass substrate from Corning Co., Ltd. was cut into 50 mm×50 mm×0.7 mm and was ultrasonically washed for 5 minutes each with isopropyl alcohol and purified water. Then, ultraviolet rays were irradiated to the washed ITO glass substrate for 15 minutes and the substrate was washed by exposure to ozone. Then, the ITO glass substrate was deposited in a vacuum deposition device. m-MTDATA was vacuum deposited on the ITO glass substrate so as to form a hole injection layer having a thickness of 600 Å. Then, NPB was vacuum deposited on the hole injection layer, forming a hole transport layer having

a thickness of 300 Å. 98% of Alq_3, as a green emission host, and 2% of C545T, as a green dopant, were used to form an emission layer having a thickness of 300 Å on the hole transport layer. Compound 1 was vacuum deposited on the emission layer so as to form an electron transport layer having a thickness of 300 Å. LiF was vacuum deposited on the electron transport layer so as to form an electron injection layer having a thickness of 10 Å and then Al was vacuum deposited on the electron injection layer so as to form a cathode having a thickness of 3000 Å. Therefore, an organic light-emitting device was completely manufactured.

Example 2

[0128] An organic light-emitting device was manufactured as in Example 1, except that compound 4 was used instead of compound 1 when forming the electron transport layer.

Example 3

[0129] An organic light-emitting device was manufactured as in Example 1, except that compound 15 was used instead of compound 1 when forming the electron transport layer.

Example 4

[0130] An organic light-emitting device was manufactured as in Example 1, except that compound 17 was used instead of compound 1 when forming the electron transport layer.

Example 5

[0131] An organic light-emitting device was manufactured as in Example 1, except that compound 25 was used instead of compound 1 when forming the electron transport layer.

Comparative Example 1

[0132] An organic light-emitting device was manufactured as in Example 1, except that Alq_3 (aluminum tris(8-hydroxyquinoline)) was used instead of compound 1 when forming the electron transport layer.

Comparative Example 2

[0133] An organic light-emitting device was manufactured as in Example 1, except that compound 201 was used instead of compound 1 when forming the electron transport layer.

Comparative Example 3

[0134] An organic light-emitting device was manufactured as in Example 1, except that compound 202 was used instead of compound 1 when forming the electron transport layer.

Comparative Example 4

[0135] An organic light-emitting device was manufactured as in Example 1, except that compound 203 was used instead of compound 1 when forming the electron transport layer.

Evaluation Example

[0136] The organic light-emitting devices of Examples 1 through 5 and the organic light-emitting devices of Comparative Examples 1 through 4 were evaluated in terms of current density, driving voltage, efficiency, color coordinates, and lifetime (T_50%: time used for brightness to reduce below 50%) using PR650 (Spectroscan) Source Measurement Unit (PhotoResearch Co. LTD.). The results are shown in Table 1 below.

TABLE 1

	Electron transport layer material	Driving voltage (V)	Current density (mA/cm^2)	Emission Efficiency (cd/A)	Lifetime (h)	Color Coordinates
Example 1	Compound 1	6.38	50	15.3	75	(0.309, 0.642)
Example 2	Compound 4	6.44	50	15.8	89	(0.309, 0.641)
Example 3	Compound 15	5.81	50	13.9	63	(0.310, 0.643)
Example 4	Compound 17	5.36	50	12.5	44	(0.309, 0.641)
Example 5	Compound 25	6.74	50	14.9	112	(0.310, 0.642)
Comparative Example 1	Alq_3	7.52	50	11.9	38	(0.309, 0.641)
Comparative Example 2	Compound 201	7.23	50	10.8	40	(0.309, 0.639)
Comparative Example 3	Compound 202	7.03	50	9.7	45	(0.309, 0.640)
Comparative Example 4	Compound 203	7.34	50	10.3	29	(0.309, 0.641)

[0137] According to Table 1, the organic light-emitting devices of Examples 1 through 5 have improved performance, for example, low driving voltages, high emission efficiencies, and long lifetime, as compared to the organic light-emitting devices of Comparative Examples 1 through 4.

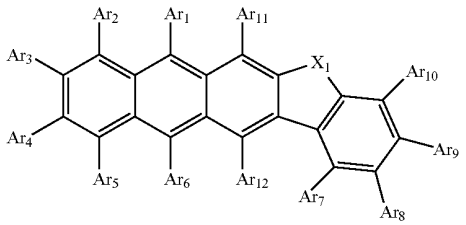
[0138] The organic light-emitting devices including the condensed-cyclic compound represented by Formula 1 have low driving voltages, high emission efficiencies, and long lifetimes, and thus flat panel display apparatuses have good performance.

[0139] While the present invention has been illustrated and described with respect to certain exemplary embodiments, those of ordinary skill in the art will understand that various changes made be made to the described embodiments without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. A condensed-cyclic compound represented by Formula 1:

Formula 1



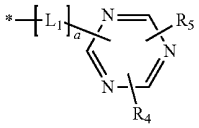
wherein X_1 is CR_1R_2, NR_3, O, or S;

each of Ar_1 through Ar_{12} is independently selected from the group consisting of hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, substituted C_1-C_{30} alkyl groups, unsubstituted C_1-C_{30} alkyl groups, substituted C_2-C_{30} alkenyl groups, unsubstituted C_2-C_{30} alkenyl groups, substituted C_2-C_{30} alkynyl groups, unsubstituted C_2-C_{30} alkynyl groups, substituted C_1-C_{30} alkoxy groups, unsubstituted C_1-C_{30} alkoxy groups, substituted C_3-C_{30} cycloalkyl groups, unsubstituted C_3-C_{30} cycloalkyl groups, substituted C_3-C_{30} cycloalkenyl groups, unsubstituted C_3-C_{30} cycloalkenyl groups, substituted C_5-C_{30} aryl groups, unsubstituted C_5-C_{30} aryl groups, substituted C_5-C_{30} aryloxy groups, unsubstituted C_5-C_{30} aryloxy groups, substituted C_5-C_{30} arylthio groups, unsubstituted C_5-C_{30} arylthio groups, substituted C_2-C_{30} heterocyclic groups, unsubstituted C_2-C_{30} heterocyclic groups, groups represented by Formula 2, groups represented by $N(Q_1)(Q_2)$, and groups represented by $Si(Q_3)(Q_4)(Q_5)$;

wherein each of Q_1 through Q_5 is independently selected from the group consisting of hydrogen atoms, deuterium, halogen atoms, hydroxyl groups, cyano groups, amino groups, nitro groups, carboxyl groups, substituted C_1-C_{30}alkyl groups, unsubstituted C_1-C_{30}alkyl groups, substituted C_2-C_{30} alkenyl groups, unsubstituted C_2-C_{30} alkenyl group, substituted C_2-C_{30} alkynyl groups, unsubstituted C_2-C_{30} alkynyl groups, substituted C_1-C_{30} alkoxy groups, unsubstituted C_1-C_{30} alkoxy groups, substituted C_3-C_{30} cycloalkyl groups, unsubstituted C_3-C_{30} cycloalkyl groups, substituted C_3-C_{30} cycloalkenyl groups, unsubstituted C_3-C_{30} cycloalkenyl groups, substituted C_5-C_{30} aryl groups, unsubstituted C_5-C_{30} aryl groups, substituted C_5-C_{30} aryloxy groups, unsubstituted C_5-C_{30} aryloxy groups, substituted C_5-C_{30} arylthio groups, unsubstituted C_5-C_{30} arylthio groups, substituted C_2-C_{30} heterocyclic groups and unsubstituted C_2-C_{30} heterocyclic groups,

wherein at least one of Ar_1 through Ar_{12} is a group represented by Formula 2;

Formula 2



wherein L_1 is a substituted or unsubstituted C_1-C_{30} alkylene group, a substituted or unsubstituted C_5-C_{30} arylene group, or a substituted or unsubstituted divalent C_2-C_{30} heterocyclic group;

a is an integer from 0 to 5;

each of R_1 through R_5 is independently a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a substituted or unsubstituted C_1-C_{30}alkyl group, a substituted or unsubstituted C_2-C_{30} alkenyl group, a substituted or unsubstituted C_2-C_{30} alkynyl group, a substituted or unsubstituted C_1-C_{30} alkoxy group, a substituted or unsubstituted C_3-C_{30} cycloalkyl group, a substituted or unsubstituted C_3-C_{30} cycloalkenyl group, a substituted or unsubstituted C_5-C_{30} aryl group, a substituted or unsubstituted C_5-C_{30} aryloxy group, a substituted or unsubstituted C_5-C_{30} arylthio group, or a substituted or unsubstituted C_2-C_{30} heterocyclic group, wherein plural numbers in R_4 and R_5 are the same as each other or different from each other.

2. The condensed-cyclic compound of claim **1**, wherein X_1 is CR_1R_2.

3. The condensed-cyclic compound of claim **1**, wherein X_1 is $C(CH_3)(CH_3)$.

4. The condensed-cyclic compound of claim **1**, wherein each of R_1 through R_3 is independently a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, or a substituted or unsubstituted pyridazinyl group.

5. The condensed-cyclic compound of claim **1**, wherein at least one of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 is a group represented by Formula 2.

6. The condensed-cyclic compound of claim **1**, wherein each of Ar_2, Ar_5, Ar_7, Ar_8, Ar_{10}, Ar_{11}, and Ar_{12} is a hydrogen atom, and each of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 is independently deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, a carboxyl group, a substituted or unsubstituted C_1-C_{30}alkyl group, a substituted or unsubstituted C_2-C_{30} alkenyl group, a substituted or unsubstituted C_2-C_{30} alkynyl group, a substituted or unsubstituted C_1-C_{30} alkoxy group, a substituted or unsubstituted C_3-C_{30} cycloalkyl group, a substituted or unsubstituted C_3-C_{30} cycloalkenyl group, a substi-

tuted or unsubstituted C_5-C_{30} aryl group, a substituted or unsubstituted C_5-C_{30} aryloxy group, a substituted or unsubstituted C_5-C_{30} arylthio group, a substituted or unsubstituted C_2-C_{30} heterocyclic group, a group represented by Formula 2 above, a group represented by $N(Q_1)(Q_2)$, or a group represented by $Si(Q_3)(Q_4)(Q_5)$,

wherein at least one of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 is a group represented by Formula 2.

7. The condensed-cyclic compound of claim **1**, wherein each of Ar_2, Ar_5, Ar_7, Ar_8, Ar_{10}, Ar_{11}, and Ar_{12} is a hydrogen atom, and each of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 is independently a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, a carboxyl group, a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted biphenyl group, a substituted or unsubstituted pentalenyl group, a substituted or unsubstituted indenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted azulenyl group, a substituted or unsubstituted heptalenyl group, a substituted or unsubstituted indacenyl group, a substituted or unsubstituted acenaphthyl 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 imidazolyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted isoindolyl group, a substituted or unsubstituted indolyl group, a substituted or unsubstituted indazolyl group, a substituted or unsubstituted purinyl group, a substituted or unsubstituted quinolinyl group, a substituted or unsubstituted benzoquinolinyl group, a substituted or unsubstituted phthalazinyl group, a substituted or unsubstituted naphthyridinyl group, a substituted or unsubstituted quinoxalinyl group, a substituted or unsubstituted quinazolinyl group, a substituted or unsubstituted cinnolinyl group, a substituted or unsubstituted carbazolyl group, a substituted or unsubstituted phenanthridinyl group, a substituted or unsubstituted acridinyl group, a substituted or unsubstituted phenanthrolinyl group, a substituted or unsubstituted phenazinyl group, a substituted or unsubstituted benzooxazolyl group, a substituted or unsubstituted benzoimidazolyl group, a substituted or unsubstituted furanyl, a substituted or unsubstituted benzofuranyl group, a substituted or unsubstituted thiophenyl group, a substituted or unsubstituted benzothiophenyl group, a substituted or unsubstituted thiazolyl group, a substituted or unsubstituted isothiazolyl group, a substituted or unsubstituted benzothiazolyl group, a substituted or unsubstituted isoxazolyl group, a substituted or unsubstituted oxazolyl group, a substituted or unsubstituted triazolyl group, a substituted or unsubstituted tetrazolyl group, a substituted or unsubstituted oxadiazolyl group, a substituted or unsubstituted triazinyl group, a substituted or unsubstituted benzooxazolyl group, a substituted or unsubstituted dibenzofuranyl group, a substituted or unsubstituted dibenzothiophenyl group, or a group represented by Formula 2 above,

wherein at least one of Ar_1, Ar_3, Ar_4, Ar_6, and Ar_9 is a group represented by Formula 2.

8. The condensed-cyclic compound of claim **1**, wherein L_1 in Formula 2 is a substituted or unsubstituted phenylene group, a substituted or unsubstituted pentalenylene group, a substituted or unsubstituted indenylene group, a substituted or unsubstituted naphthylene group, a substituted or unsubstituted azulenylene group, a substituted or unsubstituted heptalenylene group, a substituted or unsubstituted indacenylene group, a substituted or unsubstituted acenaphthylene group, a substituted or unsubstituted fluorenylene group, a substituted or unsubstituted spiro-fluorenyl 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 chrysenyl group, a substituted or unsubstituted naphthacenyl group, a substituted or unsubstituted picenyl group, a substituted or unsubstituted perylenylene group, a substituted or unsubstituted pentaphenylene group, or a substituted or unsubstituted hexylenylene group.

9. The condensed-cyclic compound of claim **1**, wherein a in Formula 2 is 0 or 1.

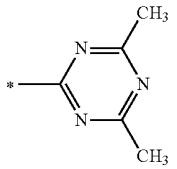
10. The condensed-cyclic compound of claim **1**, wherein each of R_4 and R_5 in Formula 2 is independently a hydrogen atom, deuterium, a halogen atom, a hydroxyl group, a cyano group, an amino group, a nitro group, a carboxyl group, a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted biphenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted indenoanthracenyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted bipyridinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted quinolinyl group, or a substituted or unsubstituted phenanthrolinyl group.

11. The condensed-cyclic compound of claim **1**, wherein R_4 and R_5 are the same as each other and each of R_4 and R_5 is a substituted or unsubstituted methyl group, a substituted or unsubstituted ethyl group, a substituted or unsubstituted propyl group, a substituted or unsubstituted butyl group, a substituted or unsubstituted pentyl group, a substituted or unsubstituted phenyl group, a substituted or unsubstituted biphenyl group, a substituted or unsubstituted naphthyl group, a substituted or unsubstituted fluorenyl group, a substituted or unsubstituted spiro-fluorenyl group, a substituted or unsubstituted anthryl group, a substituted or unsubstituted inde-

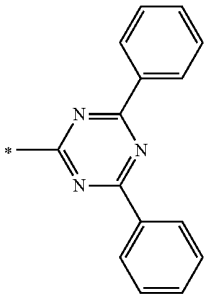
noanthracenyl group, a substituted or unsubstituted pyrazolyl group, a substituted or unsubstituted pyridinyl group, a substituted or unsubstituted bipyridinyl group, a substituted or unsubstituted pyridazinyl group, a substituted or unsubstituted pyrimidinyl group, a substituted or unsubstituted pyrazinyl group, a substituted or unsubstituted quinolinyl group, or a substituted or unsubstituted phenanthrolinyl group.

12. The condensed-cyclic compound of claim **1**, wherein the group represented by Formula 2 is selected from the group consisting of groups represented by Formulas 2A through 2U:

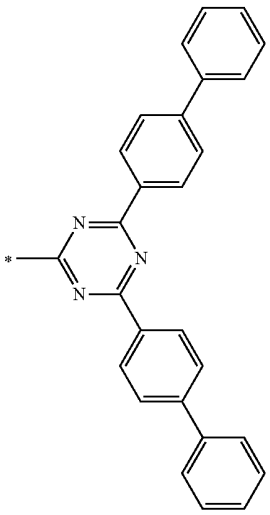
Formula 2A



Formula 2B



Formula 2C



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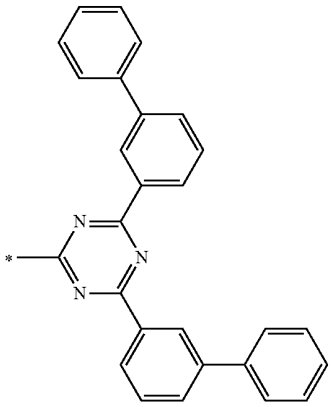
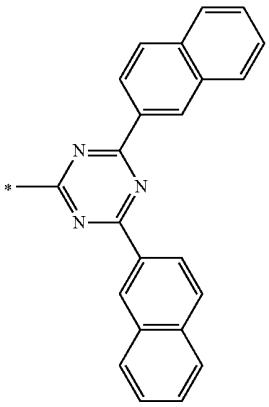
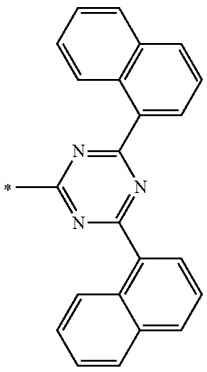
Formula 2D



Formula 2E



Formula 2F



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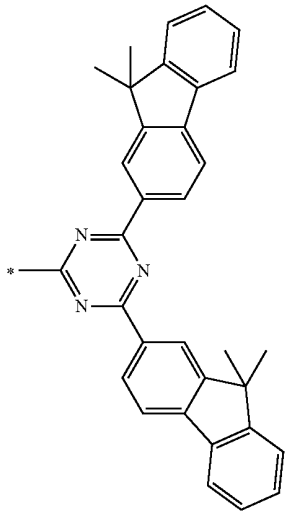
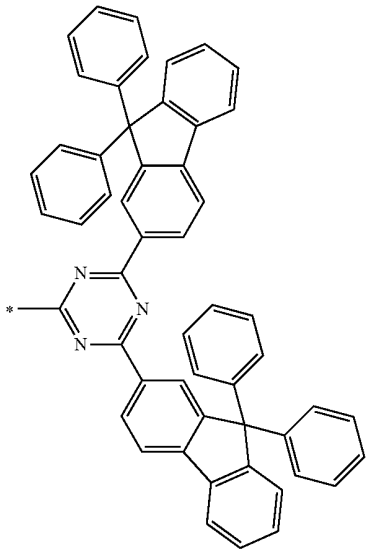
Formula 2G



Formula 2H



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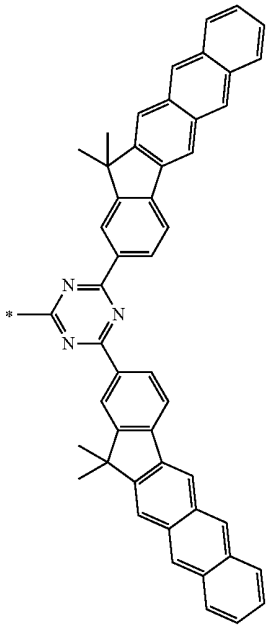
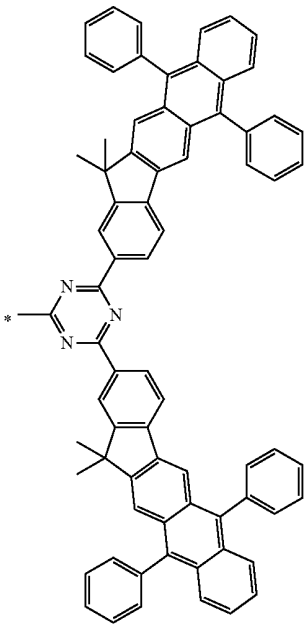
Formula 2I



Formula 2J



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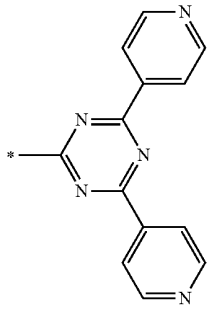
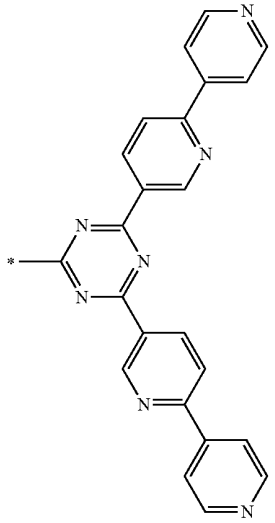
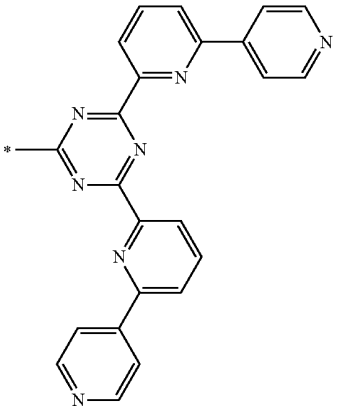
Formula 2K



Formula 2L



Formula 2M



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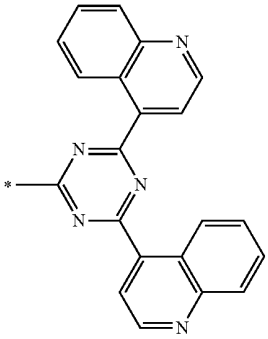
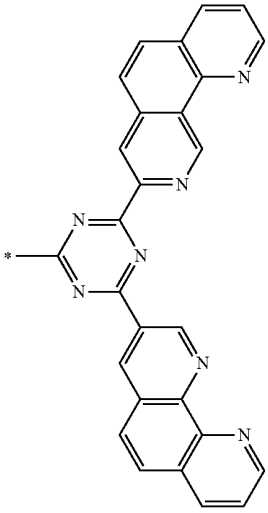
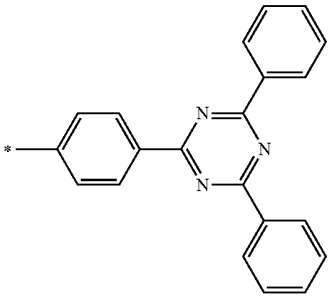
Formula 2N



Formula 2O



Formula 2P



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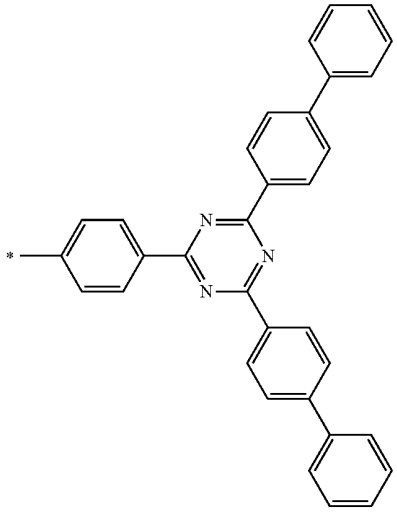
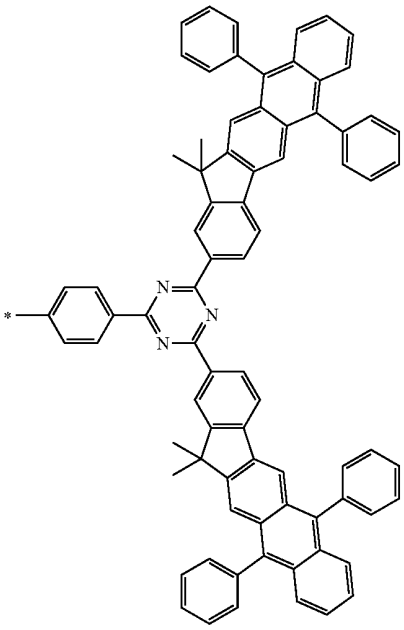
Formula 2Q



Formula 2R



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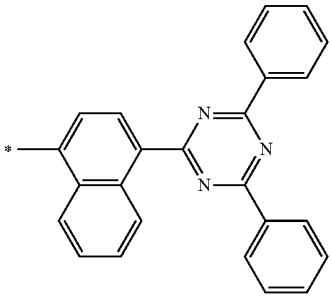
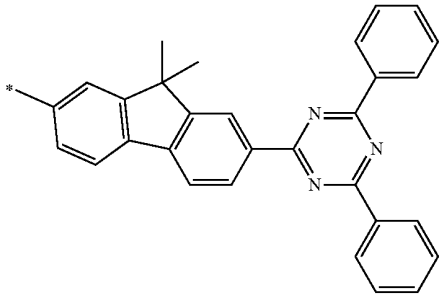
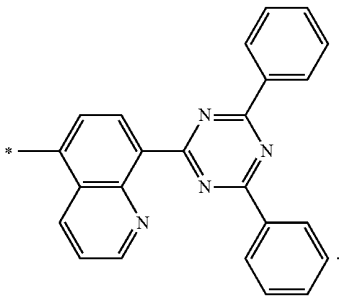
Formula 2S



Formula 2T

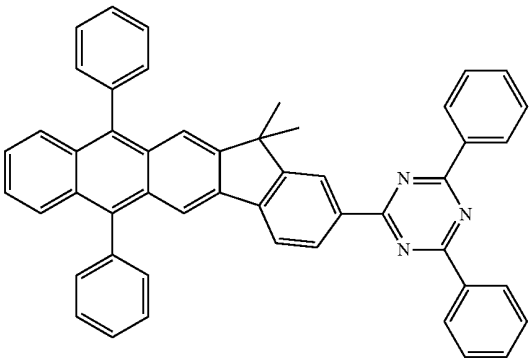


Formula 2U

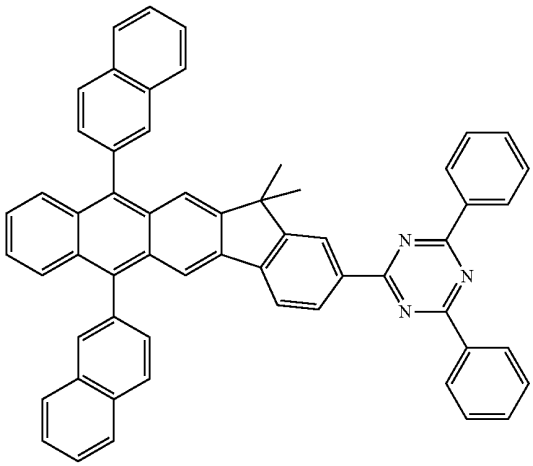


13. The condensed-cyclic compound of claim **1**, wherein the condensed-cyclic compound represented by Formula 1 is selected from the group consisting of compounds represented by Compounds 1, 4, 15, 17, and 25:

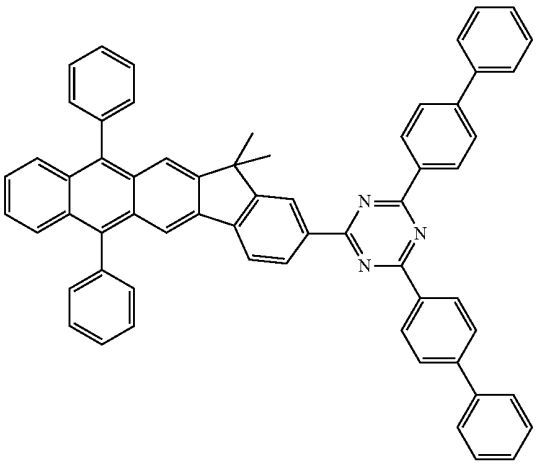
Compound 1



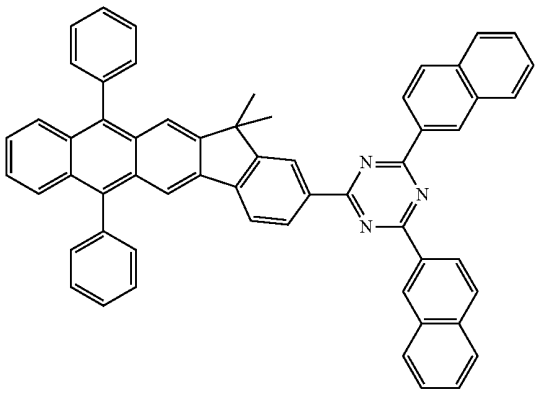
Compound 4



Compound 15



Compound 17



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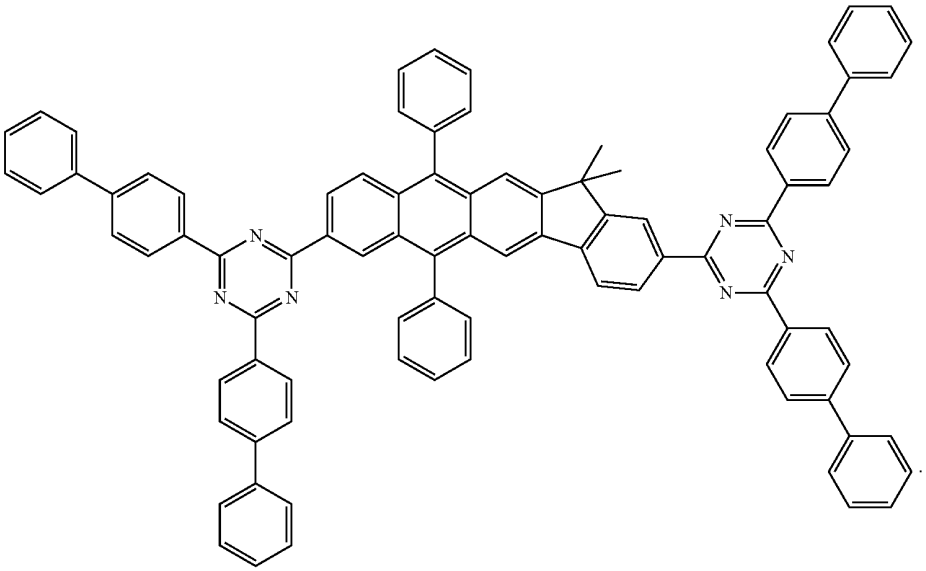
Compound 25



14. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

an organic light-emitting device comprising at least one organic layer between the first electrode and the second electrode,

wherein the at least one organic layer comprises the condensed-cyclic compound of claim **1**.

15. The organic light-emitting device of claim **14**, wherein the organic layer comprises an electron injection layer, an electron transport layer, or a single layer having both electron injection and electron transport functions.

16. The organic light-emitting device of claim **14**, wherein the at least one organic layer is an emission layer.

17. The organic light-emitting device of claim **14**, wherein the at least one organic layer is an emission layer, the condensed-cyclic compound is a fluorescent host or a phosphorescent host, and the emission layer further comprises a fluorescent dopant or a phosphorescent dopant.

18. The organic light-emitting device of claim **14**, further comprising at least one layer selected from the group consisting of a hole injection layer, a hole transport layer, an electron blocking layer, a hole blocking layer, an electron transport layer, and an electron injection layer between the first electrode and the second electrode.

19. The organic light-emitting device of claim **14**, wherein the organic light-emitting device has a first electrode/hole injection layer/emission layer/electron transport layer/electron injection layer/second electrode structure, a first electrode/hole injection layer/hole transport layer/emission layer/electron transport layer/electron injection layer/second electrode structure, or a first electrode/hole injection layer/hole transport layer/emission layer/hole blocking layer/electron transport layer/electron injection layer/second electrode structure.

20. A flat panel display apparatus comprising:

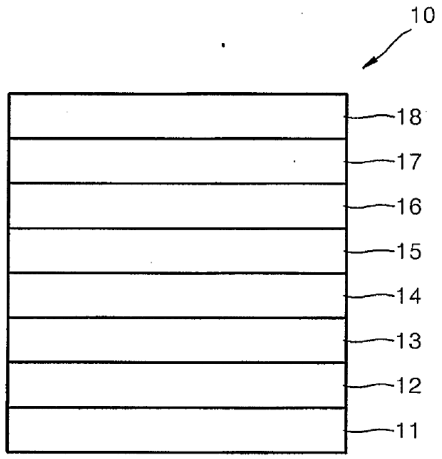
a transistor comprising a source electrode, a drain electrode, a gate, and an active layer, and

the organic light-emitting device of claim **14**,

wherein the first electrode of the organic light-emitting device is electrically connected to the source electrode or the drain electrode of the transistor.

* * * * *

专利名称(译)	缩合环状化合物，包含该化合物的有机发光装置，以及包括该装置的平板显示装置		
公开(公告)号	US20120286249A1	公开(公告)日	2012-11-15
申请号	US13/333674	申请日	2011-12-21
[标]申请(专利权)人(译)	李在镕 杨SEUNG珏 金喜善YEON 易JEOUNG IN		
申请(专利权)人(译)	李在镕 杨升GAK 金喜善妍 易JEOUNG-IN		
当前申请(专利权)人(译)	李在镕 杨升GAK 金喜善妍 易JEOUNG-IN		
[标]发明人	LEE JAE YONG YANG SEUNG GAK KIM HEE YEON YI JEOUNG IN		
发明人	LEE, JAE-YONG YANG, SEUNG-GAK KIM, HEE-YEON YI, JEOUNG-IN		
IPC分类号	H01L51/54 C07D403/10 C07D251/24		
CPC分类号	C07D401/14 C07D401/04 C07D235/14 C07D251/24 H01L51/5056 C07D487/04 C07D519/00 H01L51/0055 H01L51/0067 C07D471/04 Y10S428/917 C09K11/06		
优先权	1020110045118 2011-05-13 KR		
其他公开文献	US8999525		
外部链接	Espacenet USPTO		

摘要(译)

稠环化合物由下面的式1表示。有机发光装置包括缩合环化合物。平板显示装置包括有机发光装置。 有机发光装置包括含有式1化合物的有机层，并且具有低驱动电压，高发射效率和长寿命。