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

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(Continued)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,698,423 A 10/1987 Honda et al.
6,018,046 A 1/2000 Ohashi et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 101126020 A * 2/2008
CN 101139317 A * 3/2008
(Continued)

OTHER PUBLICATIONS

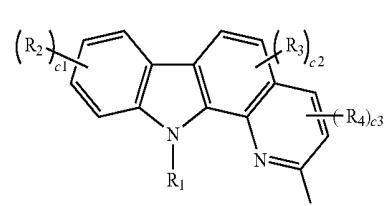
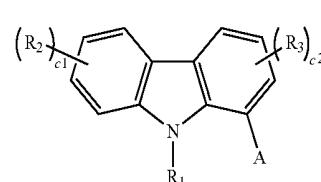
Huang et al. (Chem. Eur. J. 2013, 19, p. 1828).*
(Continued)

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(57) **ABSTRACT**

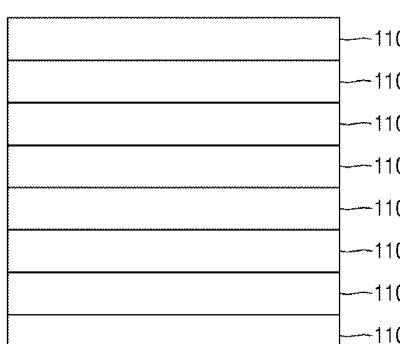
A carbazole compound represented by Formulae 1A or 1B:



wherein in Formulae 1A and 1B, A, R₁ to R₄, and c1 to c3 are described in the specification.

22 Claims, 1 Drawing Sheet

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(56) **References Cited**

U.S. PATENT DOCUMENTS

7,745,988 B2 6/2010 Sasaki et al.
8,604,048 B2 12/2013 Lafanechere et al.
8,795,848 B2 8/2014 Kaei et al.
8,986,858 B2 3/2015 Tada et al.
9,199,966 B2 12/2015 Kim et al.
9,331,290 B2 5/2016 Stoessel et al.
9,461,250 B2 10/2016 Ogawa et al.
2011/0204333 A1 * 8/2011 Xia C07F 15/0033
257/40
2012/0041017 A1 2/2012 Lafanechere et al.
2013/0161603 A1 6/2013 Chung et al.
2015/0214489 A1 7/2015 Parham et al.
2016/0260906 A1 * 9/2016 Shin H01L 51/0072

FOREIGN PATENT DOCUMENTS

CN 102312696 A 3/2012
JP 1994-080668 A 3/1995
JP 2003-335753 A 11/2003
JP 2004-319305 A 11/2004
JP 2005-154412 A 6/2005
JP 2012-062450 A 3/2012
JP 2012089777 A * 5/2012
JP 2012-518626 A 8/2012
JP 2012-174901 A 9/2012
JP 2013-526014 A 6/2013
JP 2013-149880 A 8/2013
JP 5304653 B2 * 10/2013
KR 10-2014-0006711 A 1/2014
WO 1997-045427 A1 12/1997
WO 1999-026946 A1 6/1999
WO 2000-032195 A1 6/2000
WO 2009-136595 A1 11/2009
WO 2010-074422 A1 7/2010
WO 2010-114264 A2 10/2010
WO 2011-081061 A1 7/2011
WO 2011-105161 A1 9/2011
WO 2011-126224 A1 10/2011
WO 2012-007086 A1 1/2012
WO 2013-012298 A1 1/2013
WO 2014-015931 A1 1/2014
WO 2015/053575 A1 * 4/2015
WO 2015076035 A1 5/2015

OTHER PUBLICATIONS

Kato et al. (J. Org. Chem. 2012, 77, p. 9120).*
Machine English translation of Oshiyama et al. (JP 5304653 B2).*
Machine English translation of Huang et al. 2 (CN 101139317 A). dated Apr. 29, 2017.*

Machine English translation of JP 2012-089777 A. dated Nov. 9, 2017.*

Charles B. de Koning, et al., "A versatile and convenient method for the synthesis of substituted benzo[a]carbazoles and pyrido[2,3-a]carbazoles", J. Chem. Soc., Perkin Trans. 1, 2000, 1705-1713.

Anna Caruso et al. "A rapid and versatile synthesis of novel pyrimido [5,4-b]carbazoles", Tetrahedron 2009, 65 (50), 10400-10405.

Bo Li et al. "Design and synthesis of pyrido[3,2-a]carbazole derivatives and their analogues as potent antitumour agents", European Journal of Medicinal Chemistry 2013, 66, 531-539.

Chih-Hao Chang et al. "A dicarbazole-triazine hybrid bipolar host material for highly efficient green phosphorescent OLEDs", Journal of Materials Chemistry 2012, 22, 3832.

D.R.A. Marks "Femtosecond Studies of Excited-state Proton Transfer Reactions in Solutions", Chapter 7, "(Sub) picosecond fluorescence upconversion studies of intermolecular proton transfer of dipyrido [2,3-a: 3', 2'-i] carbazole and related compounds", Downloaded from UvA-DARE, the institutional repository of the University of Amsterdam (UvA), 2000—also published in Journal of Physical Chemistry A (2000), 104(31), 7167-7175.

Thangavel Indumathi et al. "Synthesis of 2-amino-8-chloro-4-phenyl-5,11-dihydro-6H-pyrido[2,3-a]carbazole-3-carbonitrile: Structural and biological evaluation", Journal of Molecular Structure 2012, 1016, 134-139.

Salah A. Al-Trawneh et al. "Synthesis and biological evaluation of tetracyclic fluoroquinolones as antibacterial and anticancer agents", Bioorganic & Medicinal Chemistry 2010, 18 (16), 5873-5884.

Scheila F. Braga et al. "Semiempirical study on the electronic structure of antitumor drugs ellipticines, olivacines and isoellipticines", Journal of Molecular Structure: THEOCHEM 2004, 710, 51-59.

Office Action issued by the Japanese Patent Office dated Oct. 3, 2017, with English Translation.

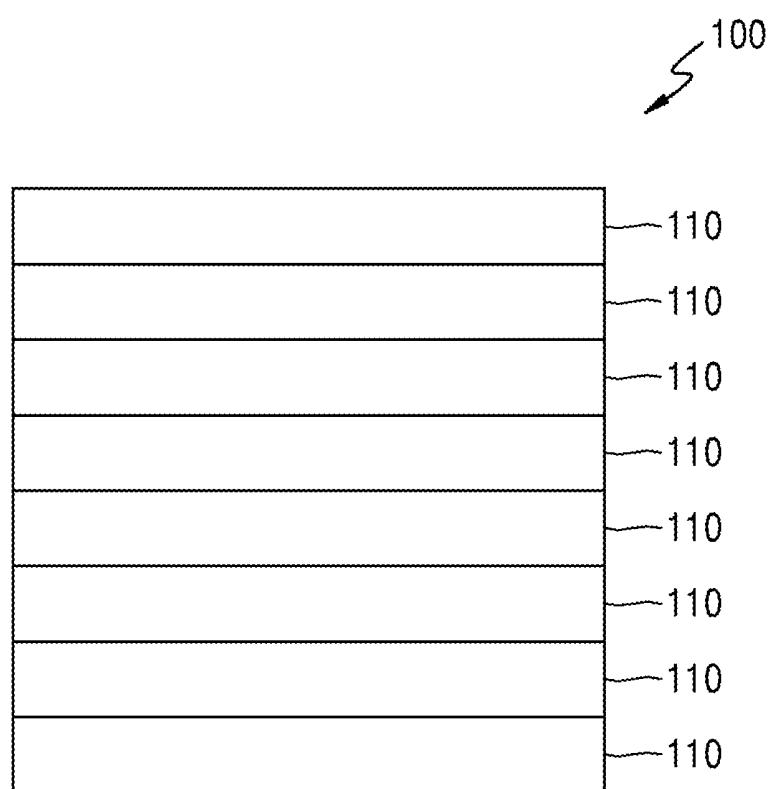
Shin-ichiro Kato et al. "Bicarbazoles: Systematic Structure-Property Investigations on a Series of Conjugated Carbazole Dimers", J. Org. Chem., 2012, 77(20), 9120-9133.

Wei Lu et al. "Polycondensation of Dibromofluorene Analogues with Tetrafluorobenzene via Direct Arylation", ACS Publications, Macromolecules 2011, 1252-1255.

Wen-Liang Gong et al. "Carbazole oligomers revisited: new additions at the carbazole 1- and 8-positions", RSC Advances, 2012, 2(29), 10821-10828.

Office Action issued by the Japanese Patent Office dated Apr. 3, 2018 in the examination of the Japanese Patent Application No. 2013-273385.

* cited by examiner



**CARBAZOLE COMPOUND AND ORGANIC
LIGHT-EMITTING DEVICE INCLUDING
THE SAME**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

This application claims priority to Korean Patent Application No. 10-2014-0162851, filed on Nov. 20, 2014, in the Korean Intellectual Property Office, and Japanese Patent Application No. 2013-273385, filed on Dec. 27, 2013, in the Japanese Patent Office, and all the benefits accruing therefrom under 35 U.S.C. § 119, the contents of which are incorporated herein in their entirety by reference.

BACKGROUND

1. Field

The present disclosure relates to a carbazole compound and an organic light-emitting device including the same.

2. Description of the Related Art

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

A typical organic light-emitting device may include an anode, a cathode, and an organic layer that is disposed between the anode and the cathode and includes an emission layer. In an organic light-emitting device, a hole transport region may be formed between the anode and the emission layer, and an electron transport region may be formed between the emission layer and the cathode. Holes provided from the anode may move toward the emission layer through the hole transport region, and electrons provided from the cathode may move toward the emission layer through the electron transport region. The holes and electrons may be recombined in the emission layer to produce excitons. These excitons may change from an excited state to a ground state, thereby generating light.

In order to improve emission efficiency of the organic light-emitting device, the emission layer may include a host. As a host material, a carbazole compound having hole-transporting capability and a large energy band gap in a triplet state can be used. Particularly, a carbazole compound, such as 4,4'-N,N'-dicarbazole-biphenyl (CBP) or 1,3-bis (carbazole-9-yl)benzene (mCP), is known to be used as a host material of the organic light-emitting device.

JP 2003-335753 A discloses a carbazole compound having electron-transport capability provided by substituents introduced to the N-, 2-, and 3-positions of the carbazole moiety.

However, the carbazole compound including a functional group for electric charge transport introduced to the N-, 2-, and 3-positions of the carbazole moiety as disclosed in JP 2003-335753 A has problems with decreasing energy band gap values in a triplet state.

Thus, there remains a need in a carbazole host having electric charge transporting capability and a large energy band gap in a triplet state to ensure its optimal performance in an organic light-emitting device.

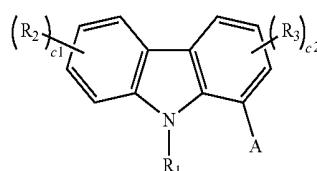
SUMMARY

Provided are a new carbazole compound having electric charge transporting capability and a large energy band gap

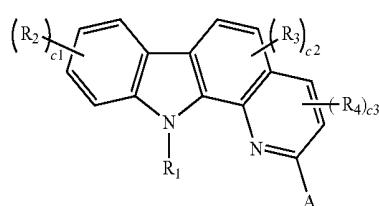
in a triplet state to solve the problems, and an organic light-emitting device including the carbazole compound.

Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented exemplary embodiments.

According to an aspect of an exemplary embodiment, there is provided a carbazole compound represented by Formulae 1A or 1B below:



Formula 1A



Formula 1B

In Formulae 1A and 1B,

A is $-(L_1)_{a1}-(E_1)_{b1}$,

L_1 is selected from a substituted or unsubstituted C_6-C_{60} arylene group, and a substituted or unsubstituted C_1-C_{60} heteroarylene group;

E_1 is a substituted or unsubstituted electron transporting-cyclic group or a substituted or unsubstituted carbazolyl group, each of which includes at least one N as a ring-forming atom;

a_1 is selected from integers of 1 to 3;

b_1 is 1 or 2, provided that when b_1 is 2, two groups E_1 are identical to or different from each other;

R_1 is selected from a deuterium atom, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{20} alkyl group, a substituted or unsubstituted C_2-C_{20} alkenyl group, a substituted or unsubstituted C_2-C_{20} alkynyl group, and a substituted or unsubstituted C_1-C_{20} alkoxy group;

R_2 to R_4 are each independently selected from a deuterium atom, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{20} alkyl group, a substituted or unsubstituted C_2-C_{20} alkenyl group, a substituted or unsubstituted C_2-C_{20} alkynyl group, a substituted or unsubstituted C_1-C_{20} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsub-

stituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, the substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{11})(Q_{12})$, $—Si(Q_{13})(Q_{14})(Q_{15})$, and $—B(Q_{16})(Q_{17})$;

c1 to c3 are each independently 1 or 2;

at least one of substituents of the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted electron transporting-cyclic group, the substituted carbazolyl group, the substituted C_1 - C_{20} alkyl group, the substituted C_2 - C_{20} alkenyl group, the substituted C_2 - C_{20} alkynyl group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_1 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_1 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from

a deuterium atom, $—F$, $—Cl$, $—Br$, $—I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group;

a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, $—F$, $—Cl$, $—Br$, $—I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{21})(Q_{22})$, $—Si(Q_{23})(Q_{24})(Q_{25})$, and $—B(Q_{26})(Q_{27})$;

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium atom, $—F$, $—Cl$, $—Br$, $—I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group,

group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—N(Q_{31})(Q_{32})$, $—Si(Q_{33})(Q_{34})(Q_{35})$, and $—B(Q_{36})(Q_{37})$; and $—N(Q_{41})(Q_{42})$, $—Si(Q_{43})(Q_{44})(Q_{45})$, and $—B(Q_{46})(Q_{47})$, and

Q_{11} to Q_{17} , Q_{21} to Q_{27} , Q_{31} to Q_{37} , and Q_{41} to Q_{47} are each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

According to an exemplary embodiment, there is provided an organic light-emitting device including:

a first electrode;

a second electrode facing the first electrode; and an organic layer disposed between the first electrode and the second electrode, wherein the organic layer includes an emission layer and at least one carbazole compound represented by Formulae 1A or 1B above.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects will become apparent and more readily appreciated from the following description of the exemplary embodiments, taken in conjunction with the accompanying drawings in which:

the FIGURE is a schematic cross-sectional view illustrating a structure of an organic light-emitting device according to an exemplary embodiment.

DETAILED DESCRIPTION

Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present exemplary embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the exemplary embodiments are merely described below, by referring to the FIGURES, to explain aspects. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

It will be understood that when an element is referred to as being “on” another element, it can be directly in contact with the other element or intervening elements may be present therebetween. In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present.

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer, or section from

another element, component, region, layer, or section. Thus, a first element, component, region, layer, or section discussed below could be termed a second element, component, region, layer, or section without departing from the teachings of the present embodiments.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the FIGURES. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the FIGURES. For example, if the device in the FIGURES is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

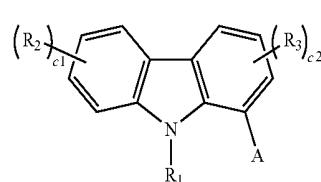
"About" or "approximately" as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). For example, "about" can mean within one or more standard deviations, or within $\pm 30\%$, 20% , 10% , 5% of the stated value.

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

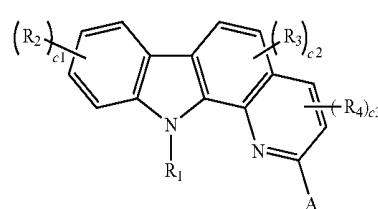
Exemplary embodiments are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present claims.

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According to an aspect, there is provided a carbazole compound represented by Formulae 1A or 1B below:



Formula 1A



Formula 1B

In Formulae 1A and 1B,

A may be $-(L_1)_{a1}-(E_1)_{b1}$,

L_1 may be selected from a substituted or unsubstituted C_6-C_{60} arylene group, and a substituted or unsubstituted C_1-C_{60} heteroarylene group;

E_1 may be a substituted or unsubstituted electron transporting-cyclic group or a substituted or unsubstituted carbazolyl group, each of which includes at least one nitrogen (N) as a ring-forming atom;

a_1 may be selected from integers of 1 to 3;

b_1 may be 1 or 2, provided that when b_1 is 2, two groups E_1 may be each independently connected to L_1 and may be identical to or different from each other;

R_1 may be selected from a deuterium atom, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{20} alkyl group, a substituted or unsubstituted C_2-C_{20} alkenyl group, a substituted or unsubstituted C_2-C_{20} alkynyl group, and a substituted or unsubstituted C_1-C_{20} alkoxy group;

R_2 to R_4 may be each independently selected from a deuterium atom, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{20} alkyl group, a substituted or unsubstituted C_2-C_{20} alkenyl group, a substituted or unsubstituted C_2-C_{20} alkynyl group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_{11})(Q_{12})$, $-Si(Q_{13})(Q_{14})(Q_{15})$, and $-B(Q_{16})(Q_{17})$;

c_1 to c_3 may be each independently 1 or 2;

at least one of substituents of the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted electron transporting-cyclic group, the substituted carbazolyl group, the substituted C_1 - C_{20} alkyl group, the substituted C_2 - C_{20} alkenyl group, the substituted C_2 - C_{20} alkynyl group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_1 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_1 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group; a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), and —B(Q₂₆)(Q₂₇); a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

matic condensed heteropolycyclic group, —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇); and —N(Q₄₁)(Q₄₂), —Si(Q₄₃)(Q₄₄)(Q₄₅) and —B(Q₄₆)(Q₄₇), and Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, Q₃₁ to Q₃₇, and Q₄₁ to Q₄₇ may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

In Formulae 1A and 1B, L₁ may be selected from a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorophenylene group, a spiro-fluorophenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrenylene group, a chryseneylene group, a naphthacenylene group, a picenylene group, a perlenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzoazazolylene group, a benzoimidazolylene group, a furanylene group, a benzofurazolylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofurazolylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group; and a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorophenylene group, a spiro-fluorophenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrenylene group, a chryseneylene group, a naphthacenylene group, a picenylene group, a perlenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzoazazolylene group, a benzoimidazolylene group, a furanylene group, a benzofurazolylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofurazolylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group; and

group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzoazazolylene group, a benzoimidazolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a C_6 - C_{20} aryl group, and a C_1 - C_{60} heteroaryl group.

In some embodiments, L_1 in Formulae 1A and 1B may be selected from

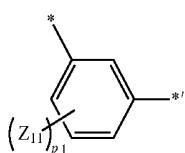
a phenylene group, a naphthylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a pyrrolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, and a triazinylene group; and

a phenylene group, a naphthylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a pyrrolylene group, a pyridinylene group, a pyrazinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, and a triazinylene group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; and

a1 may be 1 or 2.

In some other embodiments, $(L_1)_{a1}$ in Formulae 1A and 1B may be represented by one of Formulae 2A to 2F below:

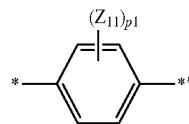
5 2A



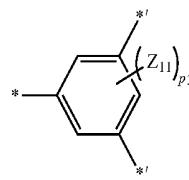
65

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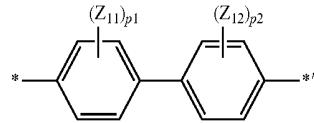
2B



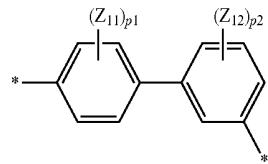
2C



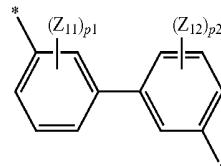
2D



2E



2F



In Formulae 2A to 2F,

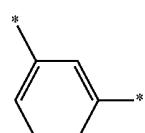
Z_{11} and Z_{12} may be each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; $p1$ and $p2$ may be each independently an integer of 0 to 4;

$p3$ may be an integer of 0 to 3; and

* and *' may each independently indicate a binding site to a neighboring group or atom, wherein *' may indicate a binding site to E_1 .

For example, $(L_1)_{a1}$ in Formulae 1A and 1B may be represented by one of Formulae 3A to 3G below:

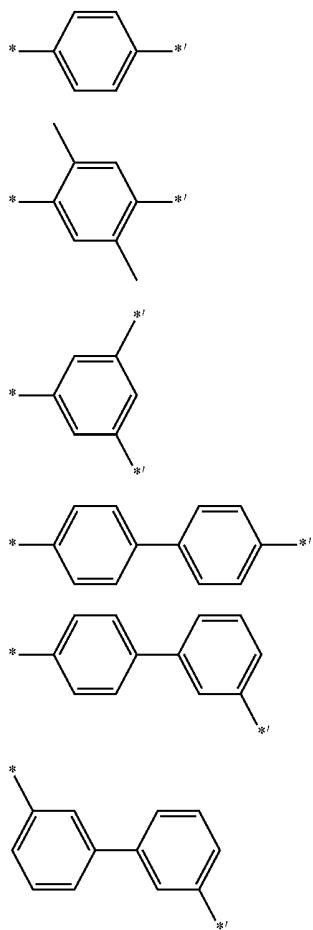
60 2A



3A

11

-continued



In an embodiment, E_1 in Formulae 1A and 1B may be selected from

a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

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bazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one Ar_1 ,

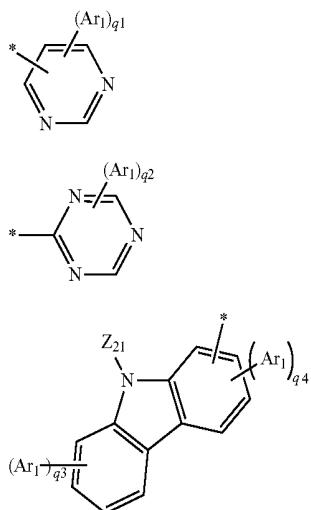
wherein Ar_1 may be selected from

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof and a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl

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group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group.

In an embodiment, E_1 in Formulae 1A and 1B may be represented by one of Formulae 4A to 4C below:



In Formulae 4A to 4C,

Ar_1 may be selected from a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a 35 phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group;

Z_{21} may be selected from a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group;

a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each 45 substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group;

$q1$ may be an integer of 0 to 3;

$q2$ may be an integer of 0 to 2;

$q3$ may be an integer of 0 to 4; and

* may indicate a binding site to a neighboring group or atom.

For example, in Formulae 4A to 4C, Ar_1 may be a phenyl group, $q1$ and $q2$ may be each 2, and $q3$ and $q4$ may be each 0.

In an embodiment, E_1 in Formulae 1A and 1B may be represented by one of Formulae 5A to 5C below:

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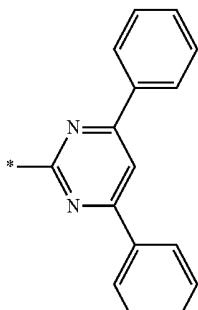
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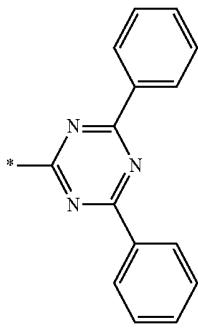
14

5A



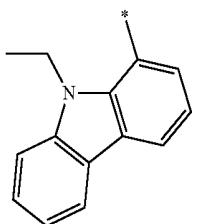
4A

5B



4B

5C



4C

In Formulae 5A to 5C, * may indicate a binding site to a neighboring group or atom.

In Formulae 1A and 1B,

R_1 may be selected from

a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group; a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group.

For example, R_1 may be selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group.

In Formulae 1A and 1B,

R_2 to R_4 may be each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid

oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; and

—N(Q₁₃)(Q₁₄) and —Si(Q₁₅)(Q₁₆)(Q₁₇), and

Q_{13} to Q_{17} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group.

In an exemplary embodiment, R_2 to R_4 may be each independently selected from

a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group;

a phenyl group, a naphthyl group, a pyridinyl group, and a naphthyridinyl group;

a phenyl group, a naphthyl group, a pyridinyl group, and a naphthyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracyenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; and

$$-\mathbf{Si}(Q_{15})(Q_{16})(Q_{17}),$$

wherein Q₁₅ to Q₁₇ may be each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy

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group, a phenyl group, a naphthyl group, an anthracyanyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group.

For example, R₂ may be selected from a methyl group and an ethyl group;

R₃ to R₄ may be each independently selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group; and

optionally, at least one of R₃ to R₄ may be each independently selected from fluorine and a C₁-C₂₀ alkoxy group.

The carbazole compound of Formulae 1A or 1B may include at least one of Compounds 1 to 30 below, but the carbazole compound is not limited thereto:

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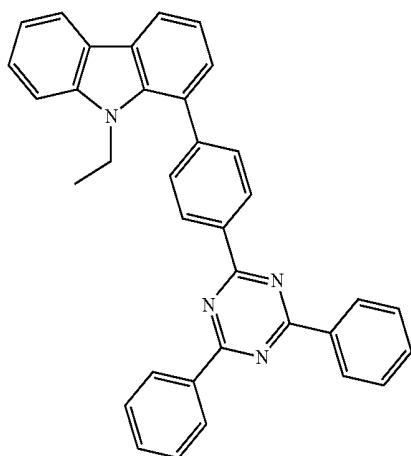
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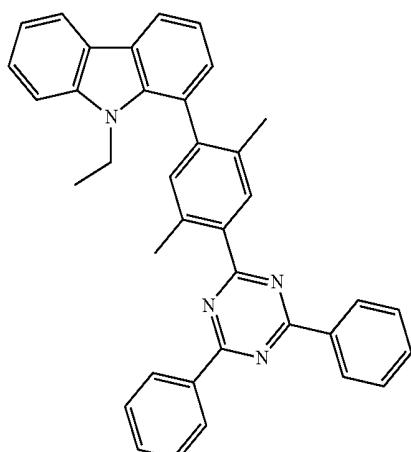
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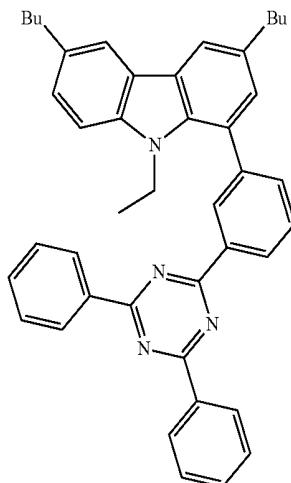
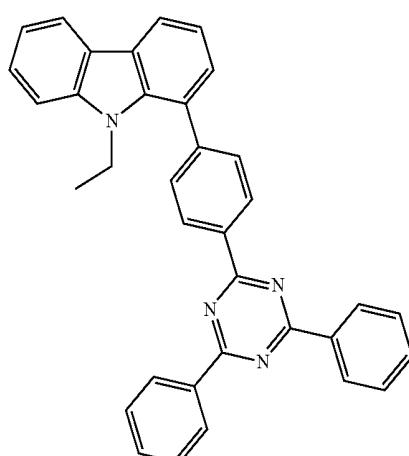
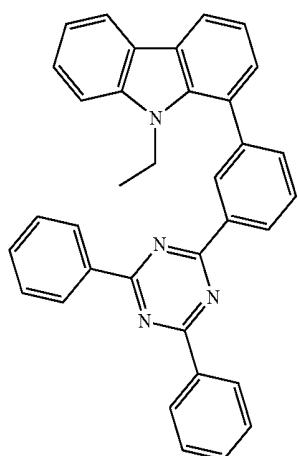
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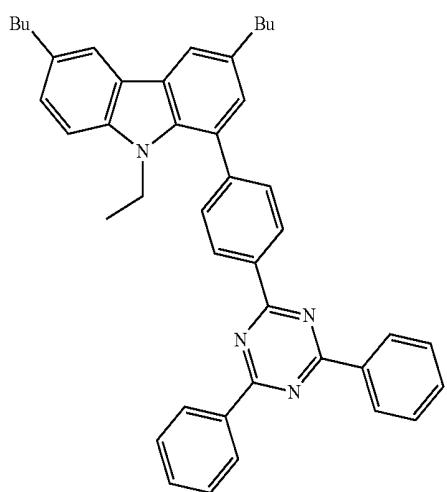
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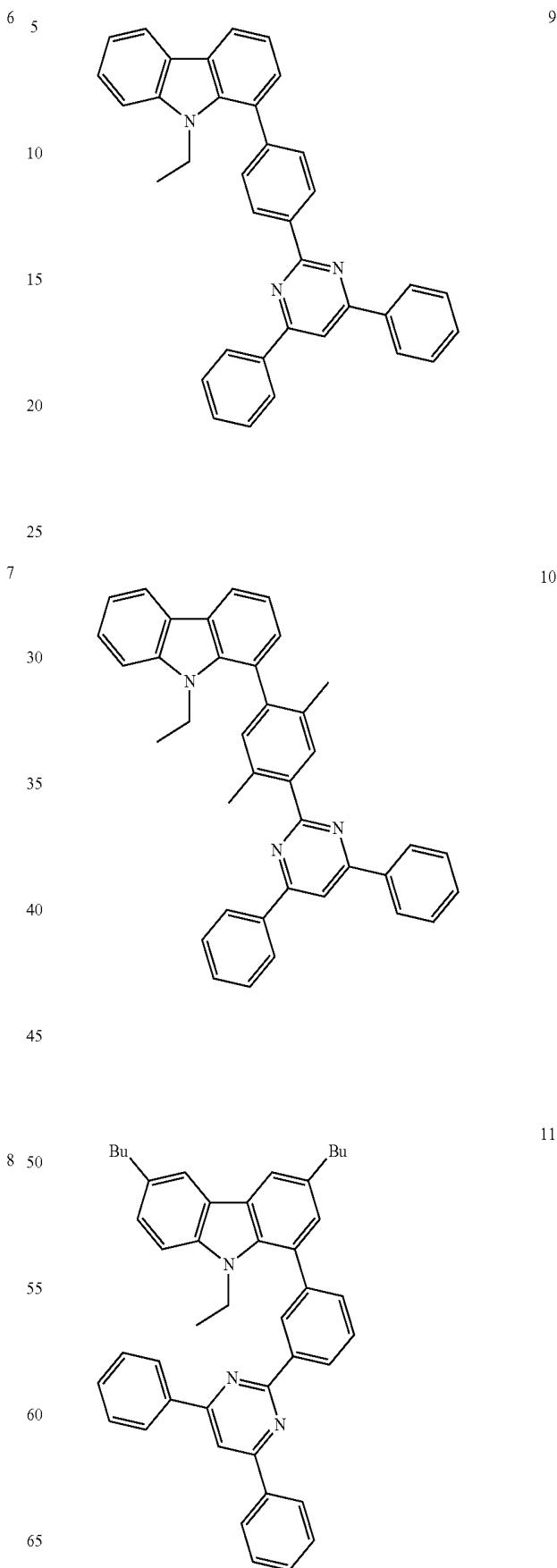


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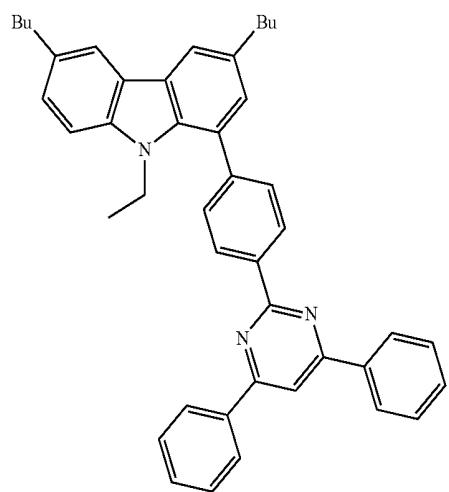
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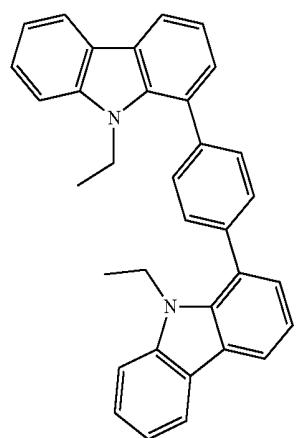


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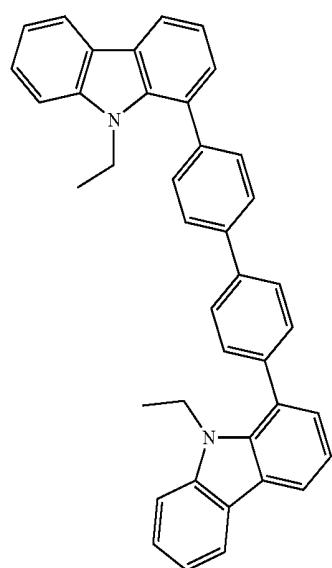
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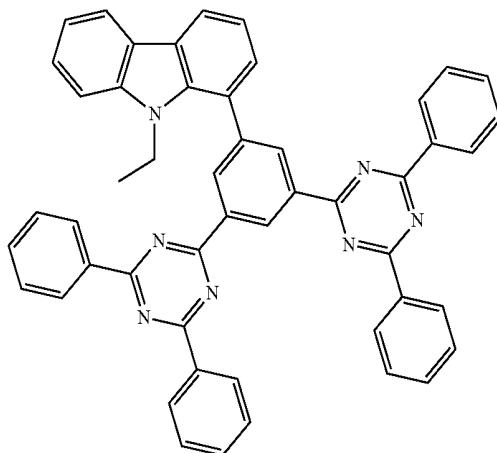
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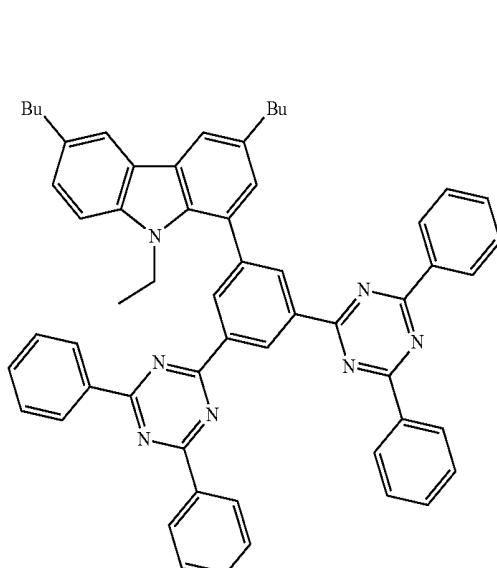
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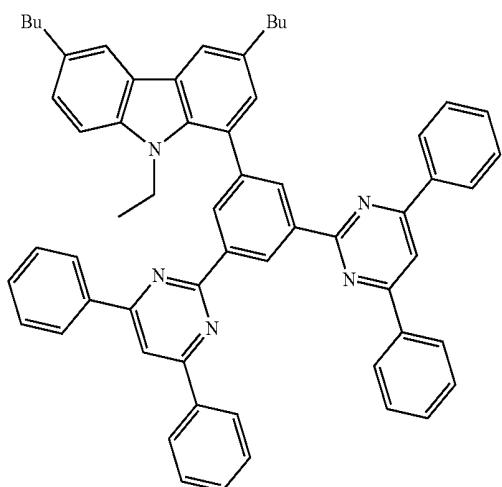
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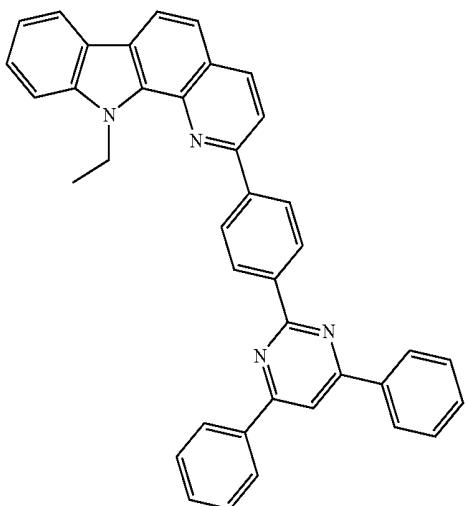


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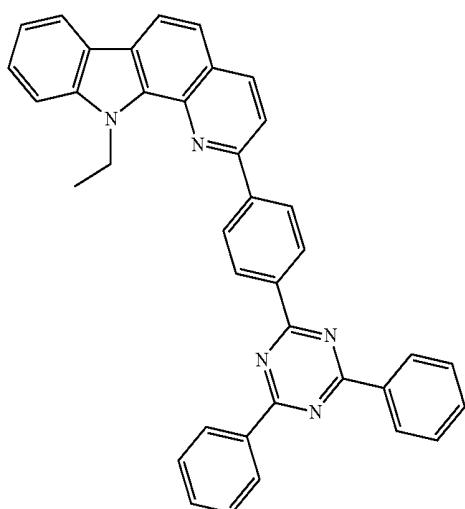
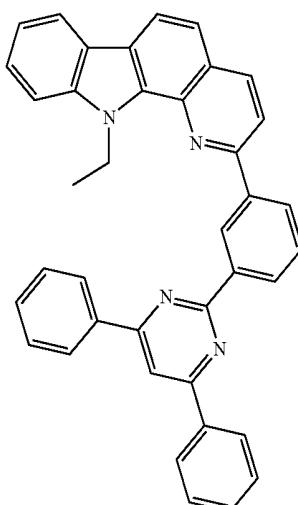
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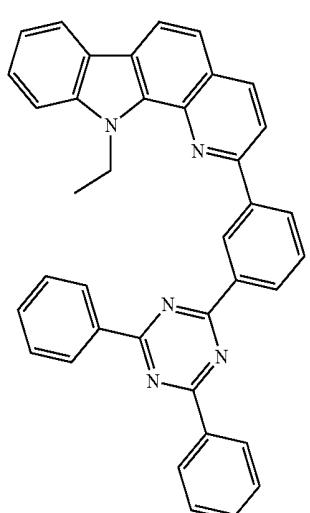
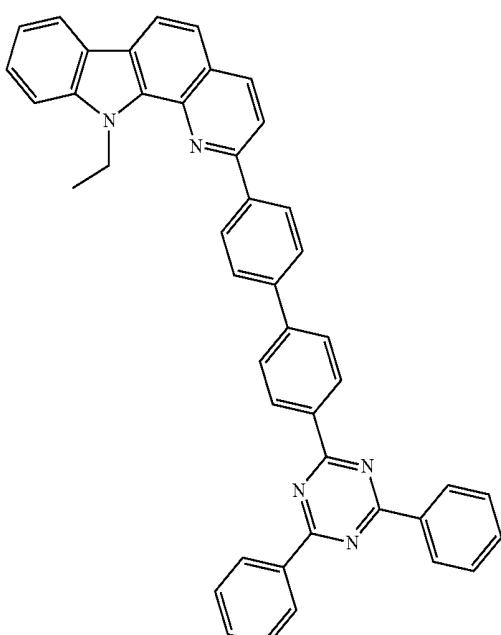
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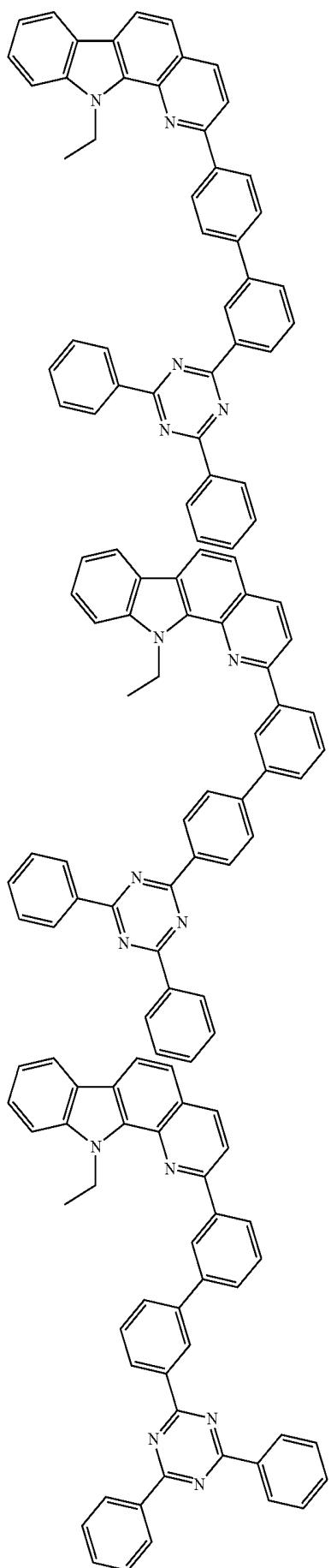
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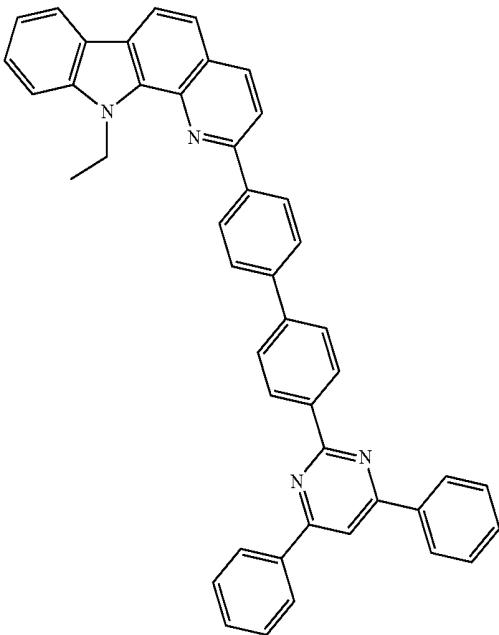
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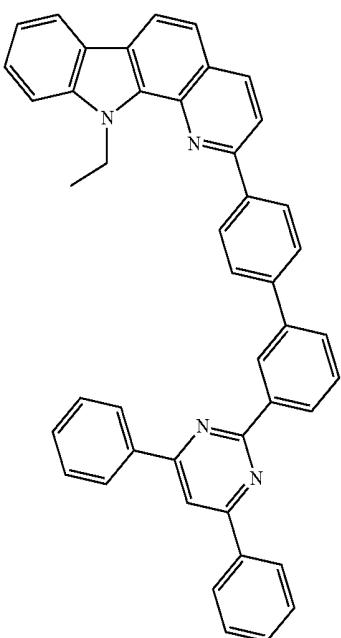
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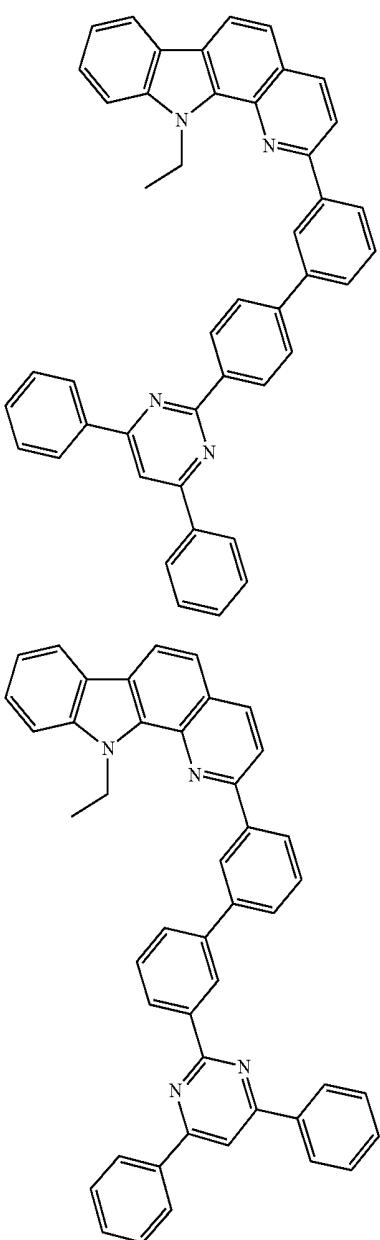


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Optionally, the carbazole compound of an exemplary embodiment of the present inventive concept may include a substituent, e.g., at least one of fluorine and a C₁-C₂₀ alkoxy group. For example, several hydrogens of Compounds of exemplary embodiments above may be substituted with fluorine or an alkoxy group.

The carbazole compound of an exemplary embodiment of the present inventive concept may have charge transport capability provided by a substituent including a charge-transporting group that is introduced to the 1-position of the carbazolyl group (or pyrido-carbazolyl group). In addition, because the position of the substituent including a charge-transporting group which is introduced to the carbazolyl group (or pyrido-carbazolyl group) is the 1-position rather than the N-, 2-, or 3-positions, a large energy band gap in a triplet state may be obtained.

In addition, an organic light-emitting device including the carbazole compound that has both hole-transporting capability and electron-transporting capability may ensure car-

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rier balance between holes and electrons. Thus, due to the presence of the carbazole compound, an organic light-emitting device may have improved emission efficiency and lifespan.

5 A method of synthesizing the carbazole compound of Formula 1 above may be understood by referring to Synthesis Examples that will be provided below.

According to an aspect, there is provided a carbazole compound represented by Formulae 1A or 1B suitable as a host of an organic layer, e.g., an emission layer included in the organic layer, of an organic light-emitting device. According to another aspect, there is provided an organic light-emitting device including:

10 a first electrode;

a second electrode; and

15 an organic layer disposed between the first electrode and the second electrode, wherein the organic layer includes an emission layer and at least one carbazole compound represented by Formulae 1A or 1B.

The organic light-emitting device includes an organic layer that includes the carbazole compound represented by Formulae 1A or 1B, and accordingly, the organic light-emitting device may have low driving voltage, high efficiency, high luminance, and long lifespan characteristics.

20 The carbazole compound represented by Formulae 1A or 1B may be used between a pair of electrodes of the organic light-emitting device. For example, the carbazole compound may be included in at least one of the emission layer, a hole transport region (for example, including at least one of a

25 hole injection layer, a hole transport layer, and an electron blocking layer) formed between the first electrode and the emission layer, and an electron transport region (for example, including at least one of a hole blocking layer, an

30 electron transport layer, and an electron injection layer) formed between the emission layer and the second electrode. For example, the carbazole compound represented by Formulae 1A or 1B may be included in the emission layer. Here, the emission layer may further include a dopant, and the

35 carbazole compound included in the emission layer may function as a host. The emission layer may be a green emission layer emitting green light or a red emission layer emitting red light. The dopant may be a phosphorescent dopant.

40 The expression “(an organic layer) includes at least one of carbazole compounds” used herein refers to “(an organic layer) includes one carbazole compound of Formulae 1A or 1B or two or more different carbazole compounds of Formulae 1A or 1B”.

45 For example, the organic layer may include, as the carbazole compound, only Compound 1. In this regard, Compound 1 may be situated in the emission layer of the organic light-emitting device. Alternatively, the organic layer may include, as the carbazole compound, Compound 1 and

50 Compound 2. In this regard, Compound 1 and Compound 2 may be situated in either an identical layer (for example, Compound 1 and Compound 2 all may be situated in an emission layer), or different layers.

55 The first electrode may be an anode that is a hole injection electrode, and the second electrode may be a cathode that is an electron injection electrode. Alternatively, the first electrode may be a cathode that is an electron injection electrode, and the second electrode may be a anode that is a hole injection electrode.

60 For example, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include:

- i) a hole transport region that is formed between the first electrode (i.e., an anode) and the emission layer, wherein the hole transport region includes at least one of a hole injection layer, a hole transport layer, and an electron blocking layer, and
- ii) an electron transport region that is formed between the emission layer and the second electrode (i.e., a cathode), wherein the electron transport region includes at least one of a hole blocking layer, an electron transport layer, and an electron injection layer.

The term "organic layer" used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the "organic layer" may include a metal-containing organometallic complex in addition to an organic compound.

The FIGURE illustrates a schematic cross-sectional view of an organic light-emitting device **100** according to an exemplary embodiment. Hereinafter, the structure of an organic light-emitting device according to an exemplary embodiment and a method of manufacturing an organic light-emitting device according to an exemplary embodiment will be described in connection with The FIGURE.

The FIGURE, the organic light-emitting device **100** includes a substrate **110**, a first electrode **120** disposed on the substrate **110**, a hole injection layer **130** disposed on the first electrode **120**, a hole transport layer **140** disposed on the hole injection layer **130**, an emission layer **150** disposed on the hole transport layer **140**, an electron transport layer **160** disposed on the emission layer **150**, an electron injection layer **170** disposed on the electron transport layer **160**, and a second electrode **180** disposed on the electron injection layer **170**.

The carbazole compound used herein may be included in one or more layers disposed between the first electrode **120** and the second electrode **180** of the organic light-emitting device **100**. The carbazole compound may be included as a host material in the emission layer **150**.

For use as the substrate **110**, any suitable substrate that is used in general organic light-emitting devices may be used, and the substrate **110** may be a glass substrate, a semiconductor substrate, a transparent plastic substrate.

The first electrode **120** may be, for example, an anode, and may be formed on the **110** by using deposition or sputtering method. In detail, the first electrode **120** may be formed as a transmissive electrode by using materials with a high work function, such as a metal, an alloy, or a conductive compound. The first electrode **120** may be formed as, for example, a reflective electrode by using indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), or zinc oxide (ZnO), each with transparency and excellent conductivity. Alternatively, the first electrode **120** may be formed as a semi-transmissive electrode by using magnesium (Mg), aluminum, or the like.

The hole injection layer **130** is a functional layer that facilitates hole injection from the first electrode **120**, and may be formed on the first electrode **120** by using various methods, such as vacuum deposition, spin coating, ink-jet printing, or the like. In addition, the hole injection layer **130** may be formed to a thickness in a range of about 10 nanometers (nm) to 1,000 nm, and for example, about 10 nm to about 100 nm.

In addition, the hole injection layer **130** may be formed by using a material known in the art, such as $\text{N},\text{N}'\text{-diphenyl-N},\text{N}'\text{-bis-[4-(phenyl-m-tolyl-amino)-phenyl]-biphenyl-4,4'-diamine}$ (DNTPD), a phthalocyanine compound, such as phthalocyanine, $4,4',4''\text{-tris(3-methylphenylphenylamino)}$

triphenyl amine (m-MTDA), $\text{N},\text{N}'\text{-di(1-naphthyl)-N},\text{N}'\text{-diphenylbenzidine}$ (NPB), $4,4',4''\text{-tris\{N,N-diphenyl amino\}triphenyl amine}$ (TDATA), $4,4',4''\text{-tris(N,N-2-naphthylphenylamino)triphenylamine}$ (2-TNATA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxothiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), or polyaniline/camphorsulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate):polyaniline (PANI/PSS).

The hole transport layer **140** is a layer including a hole-transferring material that is capable of transporting a hole, and may be formed on the hole injection layer **130** by using various methods, such as vacuum deposition, spin coating, ink-jet printing, or the like. In addition, the hole transport layer **140** may be formed to a thickness in a range of about 5 nm to about 200 nm, and for example, about 10 nm to about 150 nm. In addition, the hole transport layer **140** may be formed by using a suitable hole-transferring material, such as N-phenylcarbazole , a carbazole derivative, such as polyvinyl carbazole, $\text{N},\text{N}'\text{-bis(3-methylphenyl)-N},\text{N}'\text{-diphenyl-[1,1-biphenyl]-4,4'-diamine}$ (TPD), $4,4',4''\text{-tris(N-carbazolyl)triphenylamine}$ (TCTA), $4,4',4''\text{-tris(N-carbazolyl)triphenylamine}$, $\text{N},\text{N}'\text{-bis(naphthalene-2-yl)-N},\text{N}'\text{-bis(phenyl)-benzidine}$ (NPB), $\text{N},\text{N}'\text{-bis(naphthalene-1-yl)-N},\text{N}'\text{-bis(phenyl)-benzidine}$, or $\text{N},\text{N}'\text{-bis(naphthalen-1-yl)-N},\text{N}'\text{-bis(phenyl)-2,2'-dimethylbenzidine}$ (α -NPD).

The emission layer **150** is a layer emitting phosphorescent or fluorescent light, and may be formed on the hole transport layer **140** by using various methods, such as vacuum deposition, spin coating, ink-jet printing, or the like. In addition, the emission layer **150** may include a host material and a dopant material, and for example, may include, as a host material, the carbazole compound of an exemplary embodiment. In addition, the emission layer **150** may be formed to a thickness in a range of about 10 nm to about 100 nm, and for example, about 20 nm to about 60 nm.

In addition, the emission layer **150** may include other host materials, such as tris(8-quinolinolinate)aluminum (Alq_3), $4,4'\text{-N},\text{N}'\text{-dicarbazole-biphenyl}$ (CBP), poly(n-vinylcarbazole) (PVK), 9,10-di(naphthalene-2-yl)anthracene (ADN), TCTA, 1,3,5-tris(N-phenylbenzimidazole-2-yl)benzene (TPBI), 3-tert-butyl-9,10-di(naphth-2-yl)anthracene (TBADN), distyrylarylene (DSA), or $4,4'\text{-bis(9-carbazole)-2,2'-dimethylbiphenyl}$ (dmCBP).

In addition, the emission layer **150** may be an emission layer emitting a certain light color. For example, the emission layer **150** may be formed as a red emission layer, a green emission layer, and a blue emission layer. In addition, the carbazole compound of an exemplary embodiment may be suitable as a host material of a red emission layer and a green emission layer.

When the emission layer **150** is a blue emission layer, the blue emission layer may be formed by using a material known in the art, such as perylene and a derivative thereof, and an iridium (Ir) complex, e.g., bis[2-(4,6-difluorophenyl)pyridate]picolinateiridium(III) (Flrpic).

When the emission layer **150** is a red emission layer, examples of a material available as a red dopant known in the art may include rubrene and a derivative thereof, 4-(di-cyanomethylene)-2-methyl-6-[p-(dimethylamino)styryl]-4H-pyran (DCM) and a derivative thereof, an Ir complex, such as bis(1-phenylisoquinoline)(acetylacetone)iridium (III) ($\text{Ir}(\text{pic})_2(\text{acac})$), an osmium (Os) complex, and a platinum (Pt) complex.

When the emission layer **150** is a green emission layer, examples of a material available as a green dopant known in

the art may include coumarin and a derivative thereof, and an Ir complex, such as tris(2-phenylpyridine)(iridium(III))(Ir(ppy)₃)).

The electron transport layer 160 is a layer including an electron-transporting material that is capable of transporting an electron, and may be formed on the emission layer 150 by using methods, such as vacuum deposition, spin coating, ink-jet printing, or the like. In addition, the electron transport layer 160 may be formed to a thickness in a range of about 10 nm to about 100 nm, and for example, about 15 nm to about 50 nm. In addition, the electron transport layer 160 may be formed by using an electron-transporting material known in the art, and examples of the electron-transporting material are a lithium (Li) complex, such as lithium quinolate (LiQ), a quinoline derivative, such as tris(8-quinolinate)aluminum (Alq₃), 1,2,4-triazole derivative (TAZ), bis(2-methyl-8-quinolinolato)-(p-phenylphenolato)-aluminum (BAIq), beryllium, and bis(benzoquinoline 10-olate) (BeBq₂).

The electron injection layer 170 is a functional layer that facilitates electron injection from the second electrode 180, and may be formed on the electron transport layer 160 by using vacuum deposition. In addition, the electron injection layer 170 may be formed to a thickness in a range of about 0.1 nm to about 10 nm, and for example, about 0.3 nm to about 9 nm.

In addition, the electron injection layer 170 may be formed by using a material known in the art, and examples of the material are lithium fluoride (LiF), sodium chloride (NaCl), cesium fluoride (CsF), lithium oxide (Li₂O), barium oxide (BaO).

The second electrode 180 may be, for example, a cathode, and may be formed on the electron injection layer 170 by using deposition or sputtering method. In detail, the second electrode 180 may be formed as a reflective electrode by using materials with a low work function, such as a metal, an alloy, or a conductive compound. The second electrode 180 may be formed of, for example, lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag). In addition, the second electrode 180 may be formed as a transmissive electrode by using indium tin oxide (ITO) or indium zinc oxide (IZO).

The structure of the organic light-emitting device 100 according to an exemplary embodiment is described, but the structure is not limited thereto. The organic light-emitting device 100 according to an exemplary embodiment may be fabricated by using other structures of organic light-emitting devices known in the art. For example, the organic light-emitting device 100 may not include one or more of the hole injection layer 130, the hole transport layer 140, the electron transport layer 160, and the electron injection layer 170. The layers of the organic light-emitting device 100 may be each formed in a single-layer structure or a multi-layer structure including a plurality of layers.

Furthermore, the organic light-emitting device 100 may include a hole blocking layer between the hole transport layer 140 and the emission layer 150 to help prevent diffusion of triplet excitons or holes into the electron transport layer 160. The hole blocking layer may be formed of, for example, an oxadiazole derivative, a triazole derivative, or a phenanthroline derivative.

A C₁-C₂₀ alkyl group as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 20 carbon atoms. Detailed examples thereof are a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an

iso-amyl group, and a hexyl group. A C₁-C₂₀ alkylene group as used herein refers to a divalent group having the same structure as the C₁-C₂₀ alkyl group.

A C₁-C₂₀ alkoxy group as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl). Detailed examples thereof are a methoxy group, an ethoxy group, and an isopropoxy group.

A C₂-C₂₀ alkenyl group as used herein refers to a hydrocarbon group formed by substituting at least one carbon double bond in the middle or at the terminal of the C₂-C₂₀ alkyl group. Detailed examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C₂-C₂₀ alkylene group as used herein refers to a divalent group having the same structure as the C₂-C₂₀ alkenyl group.

A C₂-C₂₀ alkynyl group as used herein refers to a hydrocarbon group formed by substituting at least one carbon triple bond in the middle or at the terminal of the C₂-C₂₀ alkyl group. Detailed examples thereof are an ethynyl group and a propynyl group. A C₂-C₂₀ alkynylene group as used herein refers to a divalent group having the same structure as the C₂-C₂₀ alkynyl group.

A C₃-C₁₀ cycloalkyl group as used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms. Detailed examples thereof are a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C₃-C₁₀ cycloalkylene group as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

A C₁-C₁₀ heterocycloalkyl group as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 1 to 10 carbon atoms. Detailed examples thereof are a tetrahydrofuran group and a tetrahydrothiophenyl group. A C₁-C₁₀ heterocycloalkylene group as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

A C₃-C₁₀ cycloalkenyl group as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in the ring thereof, and which is not aromatic. Detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C₃-C₁₀ cycloalkenylene group as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

A C₁-C₁₀ heterocycloalkenyl group as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Detailed examples of the C₁-C₁₀ heterocycloalkenyl group are a 2,3-dihydrofuran group and a 2,3-dihydrothiophenyl group. A C₁-C₁₀ heterocycloalkenylene group as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

A C₆-C₆₀ aryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C₆-C₆₀ arylene group used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C₆-C₆₀ aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysene group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

A C₁-C₆₀ heteroaryl group as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. A C₁-C₆₀

heteroarylene group as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. Detailed examples of the C_1 - C_{60} heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_1 - C_{60} heteroaryl group and the C_1 - C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other.

A C_6 - C_{60} aryloxy group as used herein indicates $—OA_{102}$ (wherein A_{102} is the C_6 - C_{60} aryl group), and a C_6 - C_{60} arylthio group as used herein indicates $—SA_{103}$ (wherein A_{103} is the C_6 - C_{60} aryl group).

A monovalent non-aromatic condensed polycyclic group (e.g., a group having 8 to 60 carbon atoms) as used herein refers to a monovalent group that has two or more rings condensed to each other, has carbon atoms only as a ring-forming atom, and which is non-aromatic in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenol group. A divalent non-aromatic condensed polycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

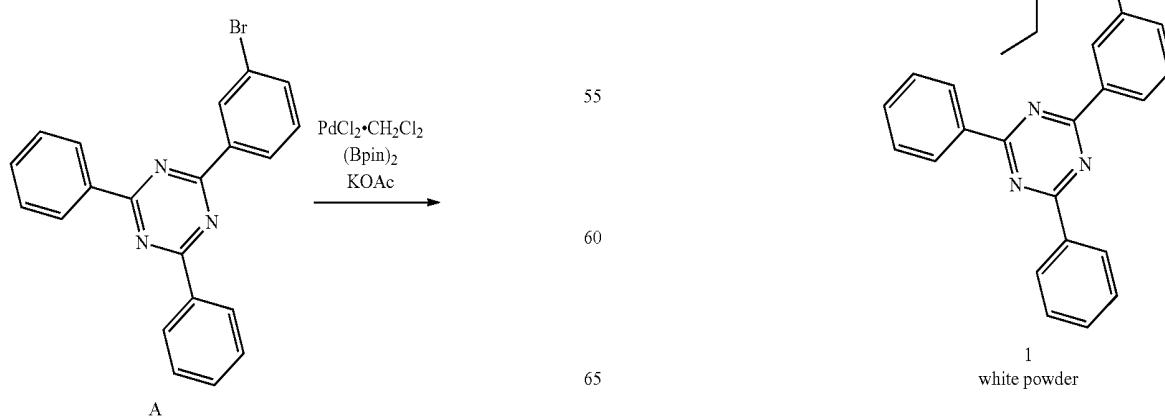
A monovalent non-aromatic condensed heteropolycyclic group (e.g., a group having 2 to 60 carbon atoms) as used herein refers to a monovalent group that has two or more rings condensed to each other, has heteroatoms as a ring-forming atom selected from N, O, P, and S, in addition to C, and which is non-aromatic in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. A divalent non-aromatic condensed heteropolycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

Hereinafter, the compounds and the organic light-emitting device according to exemplary embodiments are described in detail with reference to Synthesis Examples and Examples, but are not limited thereto. The wording “‘B’ was used instead of ‘A’” used in describing Synthesis Examples means that a molar equivalent of ‘A’ was identical to a molar equivalent of ‘B’.

SYNTHESIS EXAMPLE

Compound 1 and Compound 19 were synthesized by a Suzuki-Miyaura cross-coupling reaction.

Synthesis Example 1: Synthesis of Compound 1



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In a reaction container, 500 milligrams (mg) (1.29 millimoles (mmol)) of Compound A, 326 mg (1.3 mmol) of bis(pinacolato)diboron ((Bpin)₂), 252 mg (2.6 mmol) of potassium acetate (KOAc), and 105 mg (0.13 mmol) of [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium (II).dichloromethane (Pd(Dppf)Cl₂·CH₂Cl₂) were dissolved in 10 milliliters (mL) of 1,4-dioxane. The mixed solution was heated and stirred at a temperature of 90° C. The reaction solution was extracted with ethyl acetate (EtOAc). The extracted material was purified by column chromatography, thereby obtaining 486 mg of Compound B.

In a reaction container, 100 mg (0.55 mmol) of Compound C was dissolved in 5 mL of dimethyl sulfoxide (DMSO), and 24 mg (0.60 mmol) of sodium hydride (NaH) was added thereto. The mixed solution was stirred at room temperature. 0.05 mL (0.66 mmol) of ethyl bromide (EtBr) was further added thereto and the resulting mixture was stirred at room temperature. The reaction solution was extracted with chloroform. The extracted material was purified by column chromatography, thereby obtaining 80 mg of Compound D.

In a reaction container, 75 mg of Compound D was dissolved in 5 mL of hydrochloric acid solution. 1 mL (0.5 moles per liter (mol/L)) of a sodium nitrite (NaNO₂) solution (0.5 mol/L, 1 mL) was added dropwise to the mixed solution at a temperature of 5° C. or less. After 1 hour, 100 mg (0.60 mmol) of potassium iodide (KI) was added to the reaction solution for a reaction, thereby obtaining 100 mg of Compound E.

85 mg of Compound E, 112 mg (0.26 mmol) of diphenyl triazine derivative (Compound B), 28 mg (24 µmol) of tetrakis(triphenylphosphine)palladium (Pd(PPh₃)₄), and 0.40 mL (40 mass %, 1.0 mmol) of potassium tetraethyl ammonium (Et₄NOH) were added to 3 mL of toluene. The mixed solution was heated and stirred at a temperature of 100° C., thereby obtaining 90 mg of Compound 1. Compound 1 was extracted with chloroform, purified by using column chromatography, and subjected to structural analysis using nuclear magnetic resonance spectrum (NMR).

Compound B

NMR (300 MHz, CDCl₃): δ 1.42 (12H, s), 7.61 (7H, m), 8.06 (1H, m), 8.80 (4H, m), 8.87 (1H, m), 9.14 (1H, m).

Compound C

NMR (300 MHz, CDCl₃): δ 1.48 (3H, t, J=7.2 Hz), 3.68 (2H, br, s), 4.74 (2H, q, J=7.2 Hz), 6.83 (1H, m), 7.12 (1H, m), 7.23 (1H, m), 7.43 (2H, m), 7.63 (1H, m), 8.04 (1H, m).

Compound D

NMR (300 MHz, CDCl₃): δ 1.48 (3H, t, J=7.2 Hz), 3.78 (2H, br, s), 4.62 (2H, q, J=7.2 Hz), 6.80 (1H, m), 7.05 (1H, m), 7.20 (1H, m), 7.42 (2H, m), 7.62 (1H, m), 8.04 (1H, m).

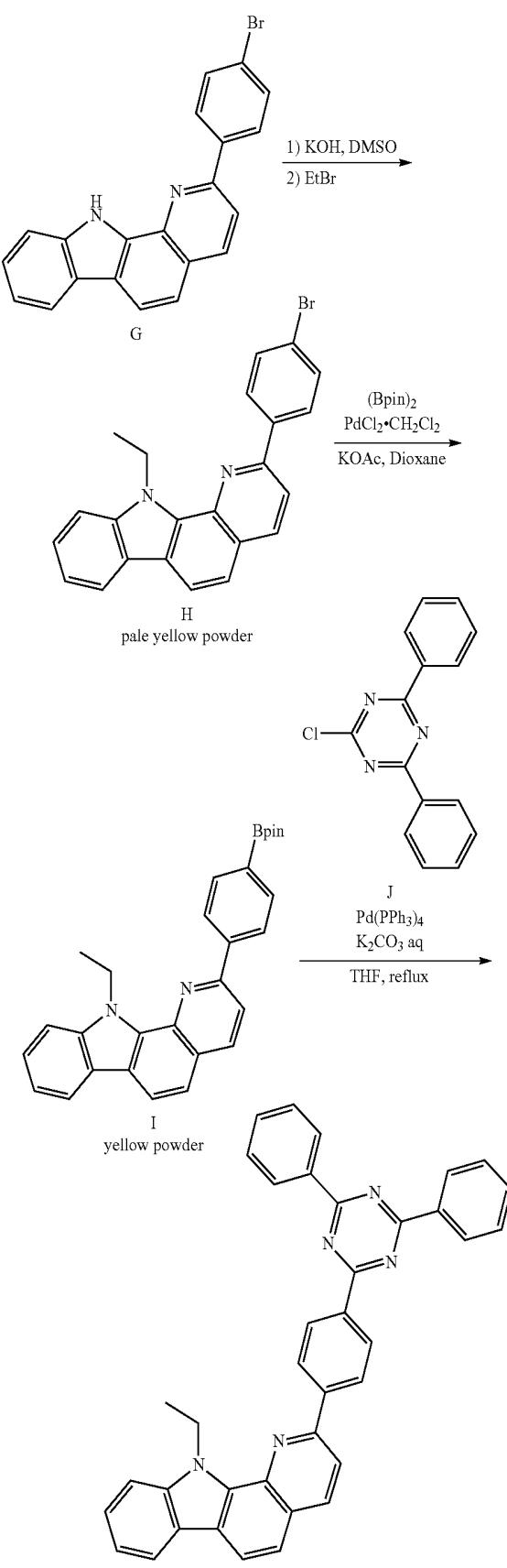
Compound E

NMR (300 MHz, CDCl₃): δ 1.45 (3H, t, J=7.2 Hz), 4.83 (2H, q, J=7.2 Hz), 6.92 (1H, m), 7.29 (1H, m), 7.53 (2H, m), 7.68 (1H, m), 7.92 (1H, m), 8.07 (1H, m).

Compound 1

NMR (300 MHz, CDCl₃): δ 0.96 (3H, t, J=7.2 Hz), 3.89 (2H, q, J=7.2 Hz), 6.92 (1H, m), 7.20-7.32 (3H, m), 7.28-7.52 (7H, m), 7.68-7.71 (2H, m), 8.11 (2H, m), 8.68 (4H, m), 8.84 (2H, m); LC-MS: m/z 502 (M⁺).

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Synthesis Example 2: Synthesis of Compound 19

19
yellow powder

1) Synthesis of Compound H

In a 50 mL Schlenk tube, 221 mg (0.67 mmol) of Compound G and 13.65 mL of DMSO were added, and air in the tube was replaced by argon gas. 68.5 mg (1.04 mmol) of KOH was added to the Schlenk tube, and the mixed solution was heated and stirred at a temperature of 60° C. in an oil bath. After 2 hours of the heating and stirring the Schlenk tube, the reaction solution was cooled to room temperature. 0.25 mL (3.36 mmol) of ethyl bromide (EtBr) was added to the Schlenk tube. The mixed solution was stirred again for 2 hours at room temperature, and kept overnight.

45 mL of water was added to the reaction solution. An organic layer was extracted twice therefrom with 150 mL of chloroform. The organic layer obtained thereby was collected, washed out with 200 mL of NaCl, and dried with magnesium sulfate. The concentrate obtained by filtering the dry matter was purified by silica gel column chromatography (using hexane-ethyl acetate as a development solvent), thereby obtaining 156 mg (0.39 mmol, yield: 66%) of Compound H.

2) Synthesis of Compound 19

In a 100 mL 3-necked flask, 144 mg (0.36 mmol) of Compound H, 24 mL of 1,4-dioxane, 28.9 mg (0.035 mmol) of $\text{Pd}(\text{dppf})_2\text{Cl}_2 \cdot \text{CH}_2\text{Cl}_2$, 135 mg (0.531 mmol) of $(\text{Bpin})_2$ (bis(pinacolato)diboron, and 74.8 mg (0.762 mmol) of potassium acetate (KOAc) were added. The air in the flask was replaced by argon gas, and the mixed solution was heated and stirred at a temperature of 100° C. for 7 hours. After the completion of the reaction, the reaction solution was cooled to room temperature, and diluted by 30 mL of chloroform. The diluted mixture was washed out with 20 mL of water and 50 mL of saturated sodium chloride aqueous solution. An organic layer was collected therefrom, dried with magnesium sulfate, filtered, and concentrated. The concentrate was purified by silica gel column chromatography (using hexane-ethyl acetate as a development solvent), thereby obtaining 164.8 mg of Compound I.

In a 100 mL 3-necked flask, 164.8 mg (0.36 mmol) of Compound I, 165 mg (0.616 mmol) of Compound J, 50 mg (0.43 mmol) of $\text{Pd}(\text{PPh}_3)_4$, 38.5 mL of tetrahydrofuran (THF), and 16.4 mL of 0.34 molar (M) potassium carbonate solution (K_2CO_3) were added, and the mixture was heat-refluxed for 3 hours. The reaction solution was cooled in an ethanol-ice bath (at a temperature of -10° C.), and filtered to separate powder from the precipitate. The powder obtained therefrom was passed through a silica gel column (using chloroform as a development solvent). The filtered solution was concentrated. The solid obtained therefrom was recrystallized from a toluene-ethanol solvent mixture. The obtained concentrate was subjected to filtration to obtain 126 mg (0.228 mmol, yield: 55%) of Compound 19. The compound obtained therefrom was identified by NMR.

Compound H

NMR (300 MHz, CDCl_3): δ 1.56 (3H, t, $J=6.9$ Hz), 5.39 (2H, q, $J=6.9$ Hz), 7.33 (2H, m), 7.45 (2H, m), 7.58 (2H, m), 7.69 (3H, m), 8.19 (2H, m), 8.88 (1H, m).

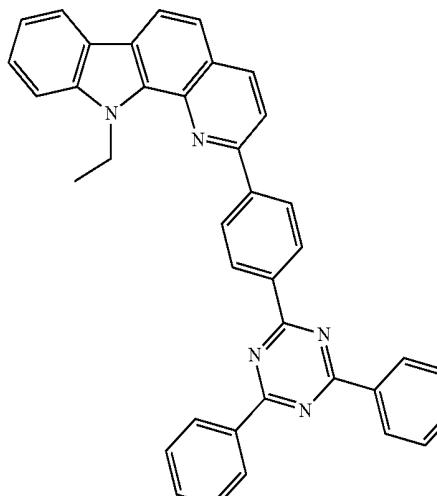
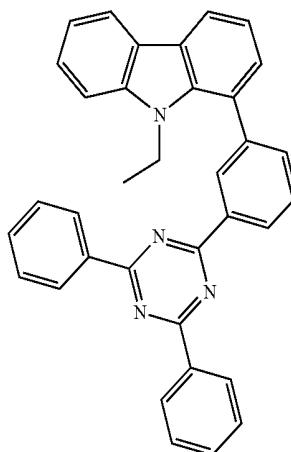
Compound 19

NMR (300 MHz, CDCl_3): δ 1.52 (3H, t, $J=7.2$ Hz), 5.42 (2H, q, $J=7.2$ Hz), 7.33 (1H, m), 7.47 (1H, m), 7.52-7.72 (9H, m), 7.82 (2H, m), 8.20 (2H, m), 8.83 (4H, m), 8.97 (2H, m), 9.03 (1H, m); LC-MS: m/z 553 (M+).

Evaluation of Physical Property

Highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) of Compound 1 of Synthesis Example 1 and Compound 19 of Synthesis Example 2 were simulated in structural optimization using Gausian 09 software (Gausian company) with basis function B3LYP/6-31G*. In addition, the triplet energy levels (i.e., energy levels T1 in a triplet state) of Compound 1 and Compound 19 were calculated based on time-dependent density functional theory (TD-DFT) further using basis function B3LYP/6-31G**.

In addition, in the same manner as described above, HOMO, LUMO, and T1 of a carbazole compound (Comparative Example Compounds 1, 2, and 3 below) and 4,4'-N,N'-d carbazole biphenyl (CBP) in which charge-transporting groups were substituted in at least one of N-, 2-, and 3-positions in carbazolyl group were simulated. Here, Comparative Compound 1 included a charge-transporting group introduced to the N-position, Comparative Compound 2 included a charge-transporting group introduced to the 2-position, and Comparative Compound 3 included a charge-transporting group introduced to the 3-position.



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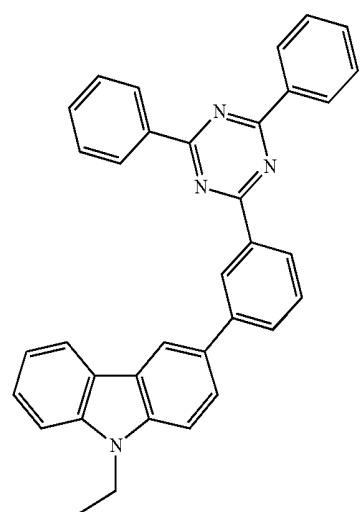
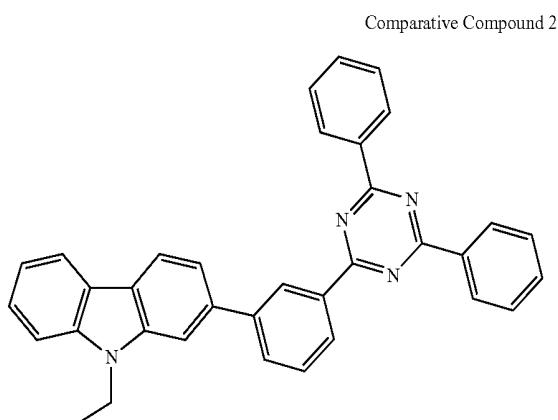
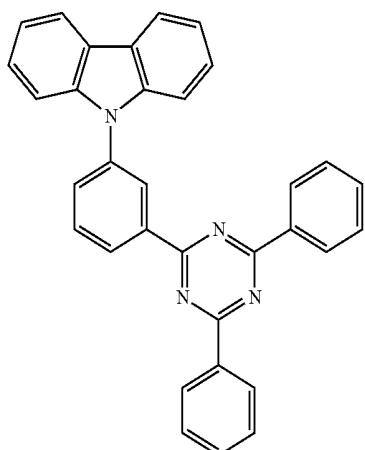


TABLE 1

| 5 | Comparative Compound 1 | Comparative Compound 1 | Comparative Compound 2 | Comparative Compound 3 | CBP |
|----|------------------------|------------------------|------------------------|------------------------|-------|
| | | HOMO [eV] | LUMO [eV] | T ₁ [eV] | |
| 10 | | -5.59 | -5.66 | -5.66 | -5.55 |
| | | -2.24 | -2.35 | -2.17 | -2.11 |
| | | 2.88 | 2.72 | 2.81 | 2.79 |
| | | | | | 2.56 |

Referring to Table 1, Compound 1 was found to have HOMO and LUMO energy levels in a similar range as compared with those of Comparative Compounds 1 to 3 and CBP. This indicates that Compound 1 is suitable as a host material of the organic light-emitting device. In addition, Compound 1 had a greater triplet energy level T₁ than Comparative Compounds 1 to 3 and CBP. Thus, it is appreciated that the carbazole compound according to exemplary embodiments has a larger energy band gap in a triplet state than carbazole compounds to which a charge-transporting group was introduced in at least one of N-, 2-, and 3-positions. Therefore, Compound 1 may be used as a host for green light emission.

The material property examination results of Compound 19 and Comparative Compound 4 used as a red dopant are shown in Table 2 below.

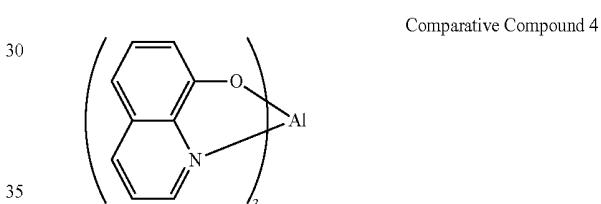


TABLE 2

| 40 | HOMO [eV] | LUMO [eV] | T ₁ [eV] | Egg [eV] |
|------------------------|-----------|-----------|---------------------|----------|
| Compound 19 | -5.82 | -3.12 | 2.23 | 2.70 |
| Comparative Compound 4 | -6.11 | -3.38 | 2.03 | 2.73 |
| 45 | | | | |

Referring to Table 2, it was confirmed that Compound 19 had capability of good charge transport based on HOMO and LUMO energy levels. In addition, Compound 19 had a triplet energy level T₁ that is greater than that of Compound 4 served as a red dopant, and that is, Compound 19 was found to be suitable as a red light emission host.

Accordingly, as described above, the carbazole compound according to exemplary embodiments had capability of charge transport by a substituent introduced to the 1-position of a carbazolyl group (or pyrido-carbazolyl group), resulting in a greater energy band gap in a triplet state.

Therefore, the organic light-emitting device including the carbazole compound of exemplary embodiments controls the balance of the charge carriers and enhances emission efficiency and lifespan.

As described above, according to the one or more of the above exemplary embodiments, a carbazole compound is well capable of transporting a charge and has a large energy gap in a triplet state. In this regard, an organic light-emitting device employing the carbazole compound may have low driving voltage, high efficiency, high luminance, and long lifespan characteristics.

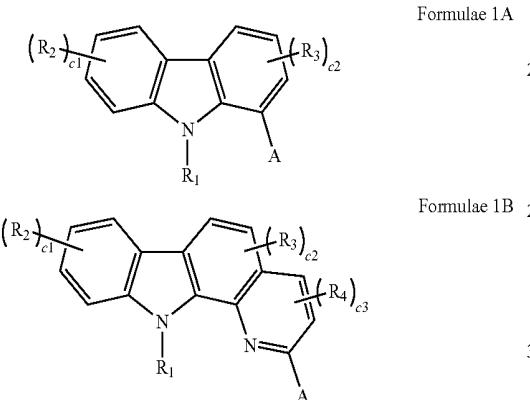
The material property examination results (HOMO, LUMO, T₁) of Compound 1 and Comparative Compounds 1 to 3 are shown in Table 1 below. Here, T₁ represents energy levels in a triplet state, and all energy levels were shown with respect to a vacuum level.

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

While one or more exemplary embodiments have been described with reference to the FIGURES, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

What is claimed is:

1. A carbazole compound represented by Formulae 1A or 1B



wherein in Formulae 1A and 1B,

A is $-(L_1)_{a1}-(E_1)_{b1}$;

L_1 is selected from a substituted or unsubstituted C_6-C_{60} arylene group, and a substituted or unsubstituted C_6-C_{60} heteroarylene group:

in Formula 1A, E_1 is selected from:

a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a

a pyridyl group, an indazolyl group, a pyrazinyl group, a pyridinyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a car-

bazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one Ar_1 , wherein Ar_1 is selected from a phenyl group, a pentenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and a phenyl group, a pentenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof and a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl

group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; in Formula 1B, E_1 is a substituted or unsubstituted electron transporting-cyclic group or a substituted or unsubstituted carbazolyl group, each of which includes at least one N as a ring-forming atom; wherein in Formulae 1A and 1B, a1 is selected from integers of 1 to 5; b1 is 1 or 2, provided that when b1 is 2, two groups E_1 are identical to or different from each other; R_1 is selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{20} alkenyl group, a substituted or unsubstituted C_2 - C_{20} alkynyl group, and a substituted or unsubstituted C_1 - C_{20} alkoxy group; R_2 to R_4 are each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{20} alkenyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{11})(Q_{12}), —Si(Q_{13})(Q_{14})(Q_{15}), and —B(Q_{16})(Q_{17}); c1 to c3 are each independently 0 to 2; at least one of substituents of the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted electron transporting-cyclic group, the substituted carbazolyl group, the substituted C_1 - C_{20} alkyl group, the substituted C_2 - C_{20} alkenyl group, the substituted C_2 - C_{20} alkynyl group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_1 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_1 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group are selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid

group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group; a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{21})(Q_{22}), —Si(Q_{23})(Q_{24})(Q_{25}), and —B(Q_{26})(Q_{27}); a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{31})(Q_{32}), —Si(Q_{33})(Q_{34})(Q_{35}), and —B(Q_{36})(Q_{37}); and —N(Q_{41})(Q_{42}), —Si(Q_{43})(Q_{44})(Q_{45}) and —B(Q_{46})(Q_{47}), wherein Q_{11} to Q_{17} , Q_{21} to Q_{27} , Q_{31} to Q_{37} , and Q_{41} to Q_{47} are each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, provided that, in Formula 1A, R_2 in the number of c1 are all different from A.

2. The carbazole compound of claim 1, wherein L_1 is selected from a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an ace-naphthylene group, a fluorenylene group, a spiro-flu-

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renylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chryseneylene group, a naphthaceneylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzooxazolylene group, a benzimidazolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an ace-naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysene group, a naphthacenylene group, a picenylene group, a perylene group, a pentaphenylene group, a hexacenylene group, 40 a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, an indazolylene group, a purinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzoxazolylene group, a benzoimidazolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, a thiazolylene group, an isothiazolylene group, 55 a benzothiazolylene group, an isoxazolylene group, an oxazolylene group, a triazolylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, an imidazopyrimidinylene group, and an imidazopyridinylene group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 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406090 406095 406100 406105 406110 406115 406120 406125 406130 406135 406140 406145 406150 406155 406160 406165 406170 406175 406180 406185 406190 406195 406200 406205 406210 406215 406220 406225 406230 406235 406240 406245 406250 406255 406260 406265 406270 406275 406280 406285 406290 406295 406300 406305 406310 406315 406320 406325 406330 406335 406340 406345 406350 406355 406360 406365 406370 406375 406380 406385 406390 406395 406400 406405 406410 406415 406420 406425 406430 406435 406440 406445 406450 406455 406460 406465 406470 406475 406480 406485 406490 406495 406500 406505 406510 406515 406520 406525 406530 406535 406540 406545 406550 406555 406560 406565 406570 406575 406580 406585 406590 406595 406600 406605 406610 406615 406620 406625 406630 406635 406640 406645 406650 406655 406660 406665 406670 406675 406680 406685 406690 406695 406700 406705 406710 406715 406720 406725 406730 406735 406740 406745 406750 406755 406760 406765 406770 406775 406780 406785 406790 406795 406800 406805 406810 406815 406820 406825 406830 406835 406840 406845 406850 406855 406860 406865 406870 406875 406880 406885 406890 406895 406900 406905 406910 406915 406920 406925 406930 406935 406940 406945 406950 406955 406960 406965 406970 406975 406980 406985 406990 406995 407000 407005 407010 407015 407020 407025 407030 407035 407040 407045 407050 407055 407060 407065 407070 407075 407080 407085 407090 407095 407100 407105 407110 407115 407120 407125 407130 407135 407140 407145 407150 407155 407160 407165 407170 407175 407180 407185 407190 407195 407200 407205 407210 407215 407220 407225 407230 407235 407240 407245 407250 407255 407260 407265 407270 407275 407280 407285 407290 407295 407300 407305 407310 407315 407320 407325 407330 407335 407340 407345 407350 407355 407360 407365 407370 407375 407380 407385 407390 407395 407400 407405 407410 407415 407420 407425 407430 407435 407440 407445 407450 407455 407460 407465 407470 407475 407480 407485 407490 407495 407500 407505 407510 407515 407520 407525 407530 407535 407540 407545 407550 407555 407560 407565 407570 407575 407580 407585 407590 407595 407600 407605 407610 407615 407620 407625 407630 407635 407640 407645 407650 407655 407660 407665 407670 407675 407680 407685 407690 407695 407700 407705 407710 407715 407720 407725 407730 407735 407740 407745 407750 407755 407760 407765 407770 407775 407780 407785 407790 407795 407800 407805 407810 407815 407820 407825 407830 407835 407840 407845 407850 407855 407860 407865 407870 407875 407880 407885 407890 407895 407900 407905 407910 407915 407920 407925 407930 407935 407940 407945 407950 407955 407960 407965 407970 407975 407980 407985 407990 407995 408000 408005 408010 408015 408020 408025 408030 408035 408040 408045 408050 408055 408060 408065 408070 408075 408080 408085 408090 408095 408100 408105 408110 408115 408120 408125 408130 408135 408140 408145 408150 408155 408160 408165 408170 408175 408180 408185 408190 408195 408200 408205 408210 408215 408220 408225 408230 408235 408240 408245 408250 408255 408260 408265 408270 408275 408280 408285 408290 408295 408300 408305 408310 408315 408320 408325 408330 408335 408340 408345 408350 408355 408360 408365 408370 408375 408380 408385 408390 408395 408400 408405 408410 408415 408420 408425 408430 408435 408440 408445 408450 408455 408460 408465 408470 408475 408480 408485 408490 408495 408500 408505 408510 408515 408520 408525 408530 408535 408540 408545 408550 408555 408560 408565 408570 408575 408580 408585 408590 408595 408600 408605 408610 408615 408620 408625 408630 408635 408640 408645 408650 408655 408660 408665 408670 408675 408680 408685 408690 408695 408700 408705 408710 408715 408720 408725 408730 408735 408740 408745 408750 408755 408760 408765 408770 408775 408780 408785 408790 408795 408800 408805 408810 408815 408820 408825 408830 408835 408840 408845 408850 408855 408860 408865 408870 408875 408880 408885 408890 408895 408900 408905 408910 408915 408920 408925 408930 408935 408940 408945 408950 408955 408960 408965 408970 408975 408980 408985 408990 408995 409000 409005 409010 409015 409020 409025 409030 409035 409040 409045 409050 409055 409060 409065 409070 409075 409080 409085 409090 409095 409100 409105 409110 409115 409120 409125 409130 409135 409140 409145 409150 409155 409160 409165 409170 409175 409180 409185 409190 409195 409200 409205 409210 409215 409220 409225 409230 409235 409240 409245 409250 409255 409260 409265 409270 409275 409280 409285 409290 409295 409300 409305 409310 409315 409320 409325 409330 409335 409340 409345 409350 409355 409360 409365 409370 409375 409380 409385 409390 409395 409400 409405 409410 409415 409

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group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a C_6 - C_{20} aryl group, and a C_1 - C_{60} heteroaryl group.

3. The carbazole compound of claim 1, wherein L_1 is selected from

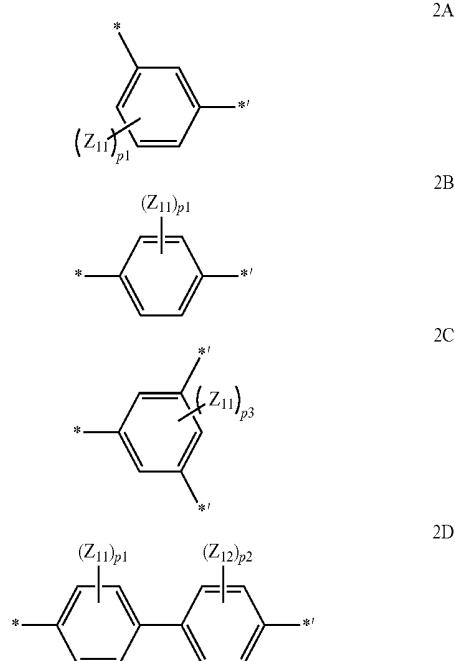
a phenylene group, a naphthylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a pyrrolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, and a triazinylene group; and

a phenylene group, a naphthylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a pyrrolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, and a triazinylene group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenly group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group.

4. The carbazole compound of claim 1, wherein a1 is 1 or

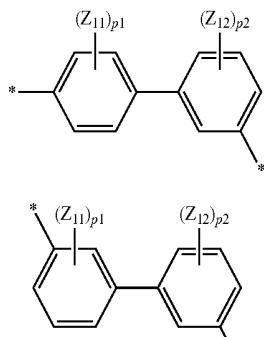
2.

5. The carbazole compound of claim 1, wherein $(L_1)_{\alpha 1}$ is represented by one of Formulae 2A to 2F:



47

-continued



2E

5

2F

10

15

48

-continued



3E

3F

3G

wherein in Formulae 2A to 2F,

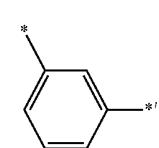
Z_{11} and Z_{12} are each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; p1 and p2 are each independently an integer of 0 to 4; p3 is an integer of 0 to 3; and

* and *' are each independently indicate a binding site to a neighboring group or atom, wherein *' indicates a binding site to E_1 .

6. The carbazole compound of claim 1, wherein $(L_1)_{a1}$ is represented by one of Formulae 3A to 3G:

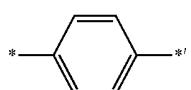
3A

45



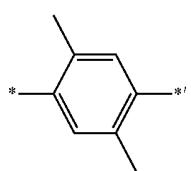
3B

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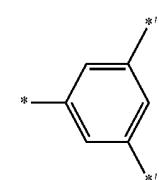
3C

55



3D

60



wherein in Formulae 3A to 3G,

* and *' are each independently indicate a binding site to a neighboring group or atom, wherein *' indicates a binding site to E_1 .

7. The carbazole compound of claim 1, wherein E_1 is selected from

a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

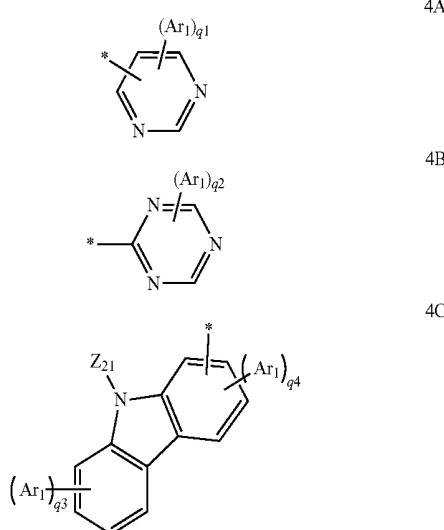
a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one Ar_1 ,

wherein Ar_1 is selected from

a phenyl group, a pentenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perlenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, a pentaphenyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl

group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and a phenyl group, a pentenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenly group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof and a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenly group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxaliny group, a cinnolinyl group, and a quinazolinyl group.

8. The carbazole compound of claim 1, wherein E_1 is represented by one of Formulae 4A to 4C:



wherein in Formulae 4A to 4C,

Ar_1 is selected from a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenly group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxaliny group, a cinnolinyl group, and a quinazolinyl group;

Z_{21} is selected from a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group;

a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenly group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxaliny group, a cinnolinyl group, and a quinazolinyl group;

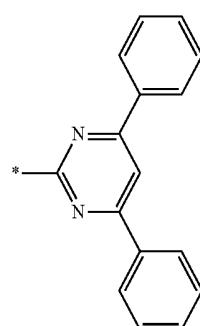
$q1$ is an integer of 0 to 3;

$q2$ is an integer of 0 to 2;

$q3$ is an integer of 0 to 4; and

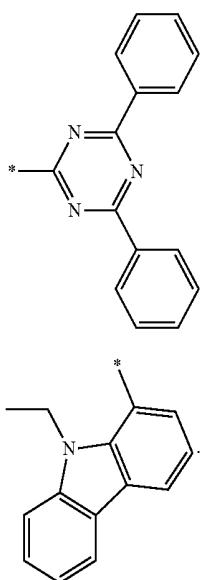
* indicates a binding site to a neighboring group or atom.

9. The carbazole compound of claim 1, wherein E_1 is represented by one of Formulae 5A to 5C:



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-continued



10. The carbazole compound of claim 1, wherein R₁ is selected from a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group; and

a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group.

11. The carbazole compound of claim 1, wherein R₁ is selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group.

12. The carbazole compound of claim 1, wherein R₂ to R₄ are each independently selected from

a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, and C₁-C₂₀ alkoxy group;

a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, and a C₁-C₂₀ alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group;

a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, and a C₁-C₂₀ alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group;

5B

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5C

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dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group;

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perlenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, an imidazopyridinyl group, and an imidazopyridinyl group;

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perlenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, an imidazopyridinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group;

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carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group; and —N(Q₁₃)(Q₁₄) and —Si(Q₁₅)(Q₁₆)(Q₁₇), wherein Q₁₃ to Q₁₇ are each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group.

13. The carbazole compound of claim 1, wherein R₂ to R₄ are each independently selected from

a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, and C₁-C₂₀ alkoxy group; a phenyl group, a naphthyl group, a pyridinyl group, and a naphthyridinyl group;

a phenyl group, a naphthyl group, a pyridinyl group, and a naphthyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group;

and —Si(Q₁₅)(Q₁₆)(Q₁₇), wherein Q₁₅ to Q₁₇ are each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group.

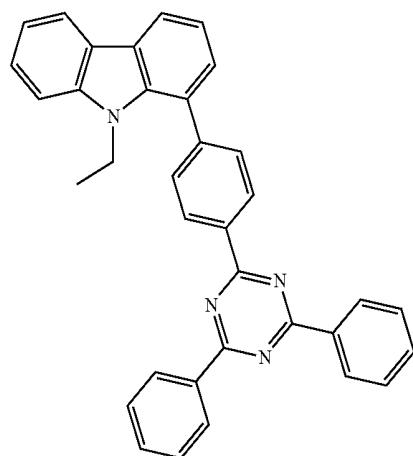
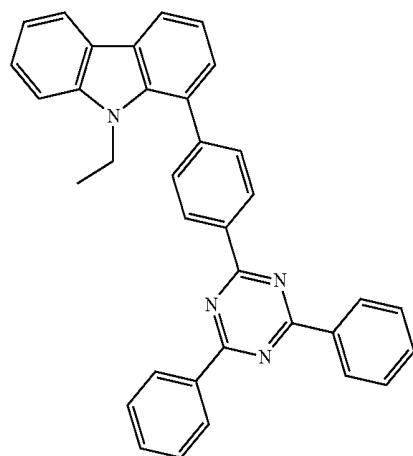
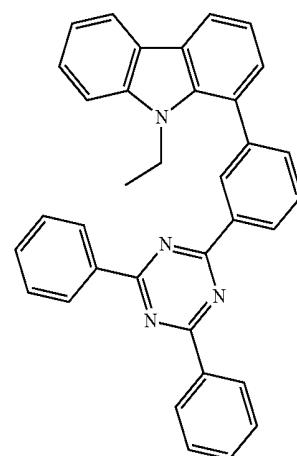
14. The carbazole compound of claim 1, wherein R₁ is selected from a methyl group and an ethyl group; and R₂ to R₄ are each independently selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl

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group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group.

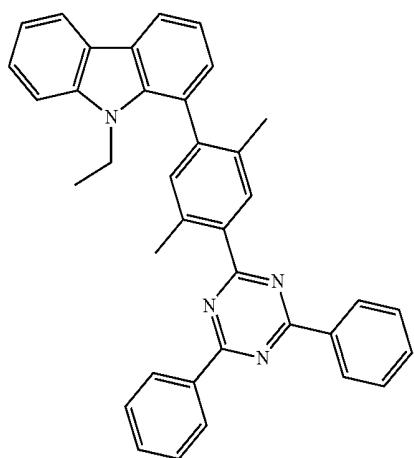
15. The carbazole compound of claim 1, wherein at least one of R₂ to R₄ is each independently selected from fluorine and a C₁-C₂₀ alkoxy group.

16. The carbazole compound of claim 1, comprising at least one of Compounds 1 to 30:



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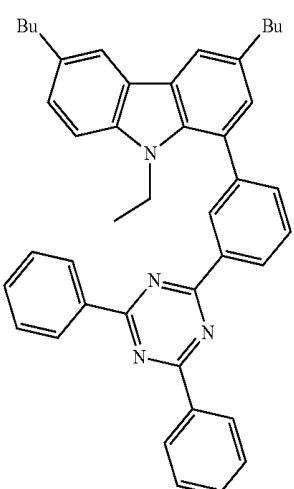
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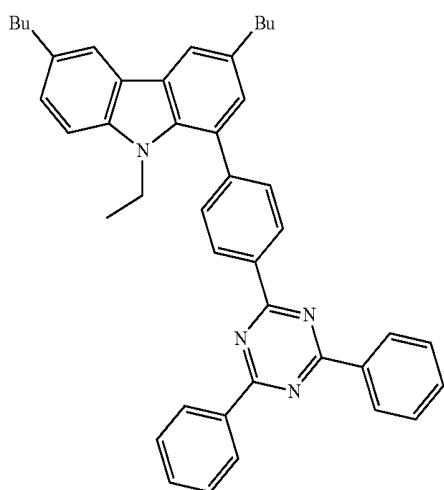
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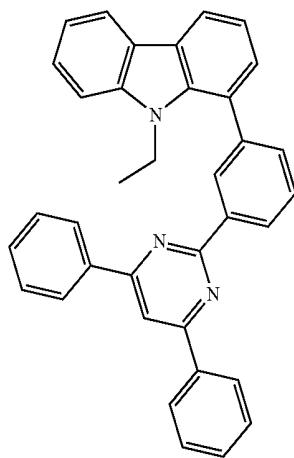
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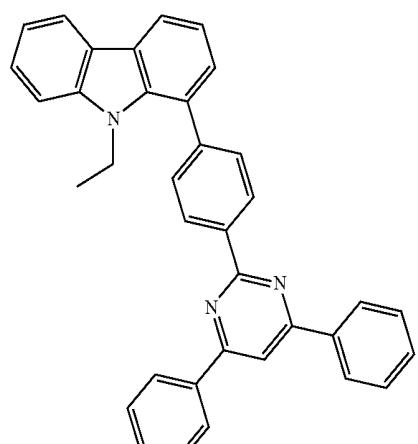
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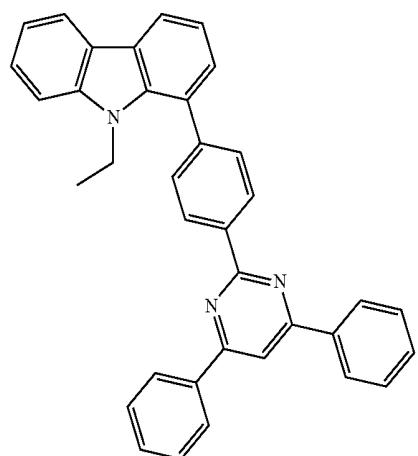
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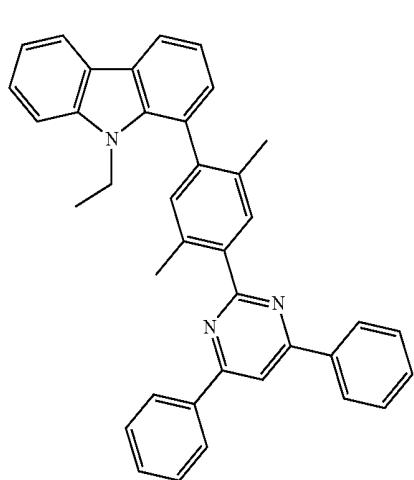
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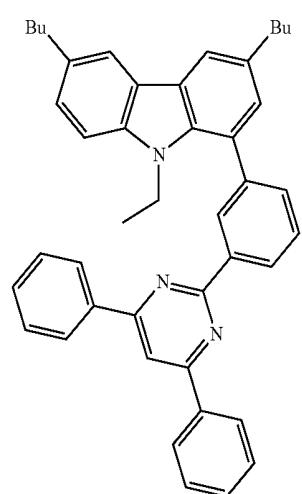
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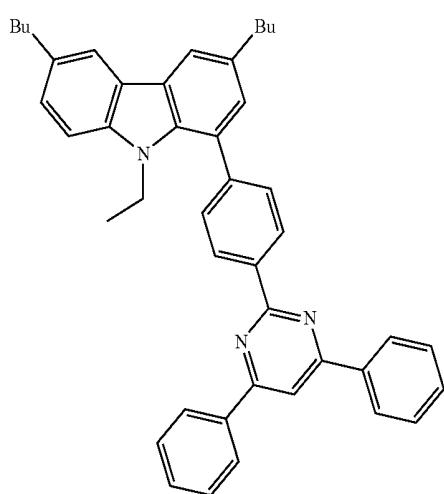
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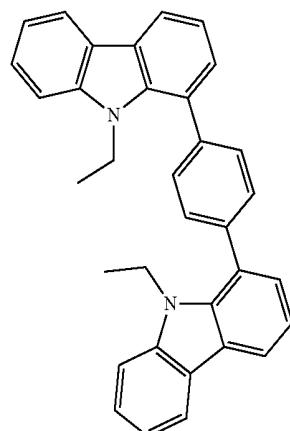
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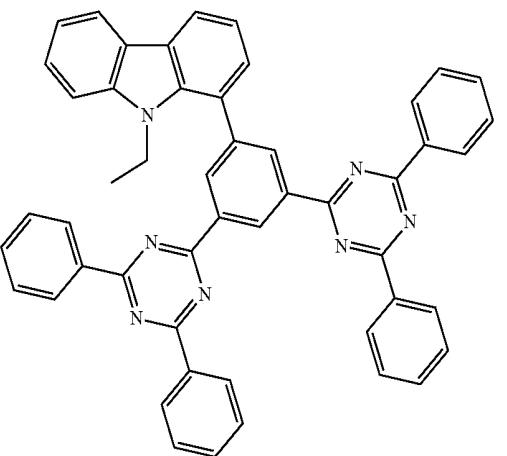
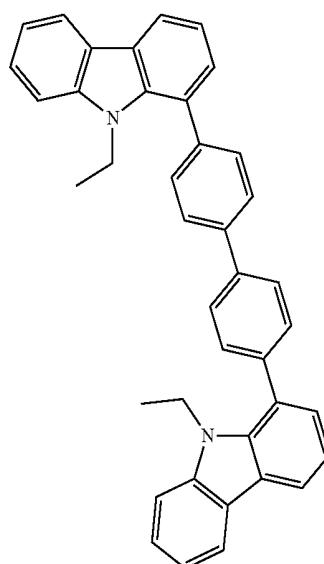
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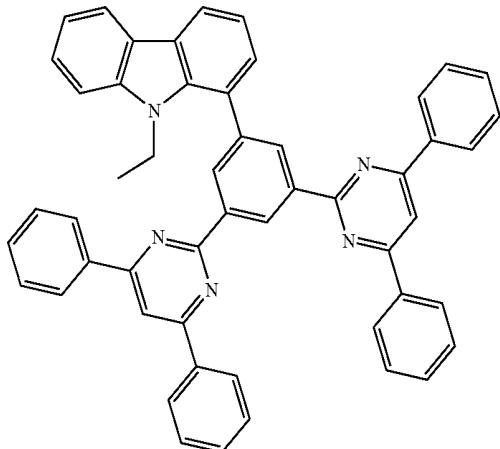
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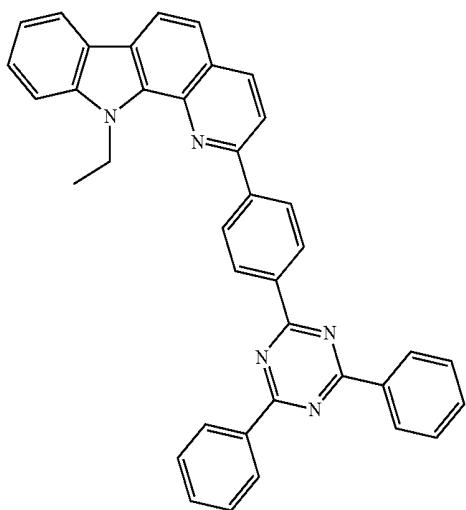
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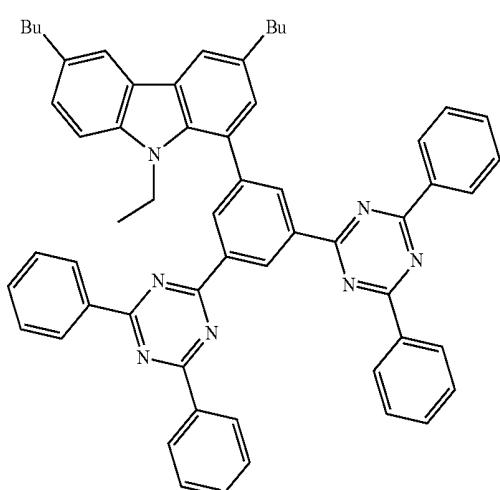
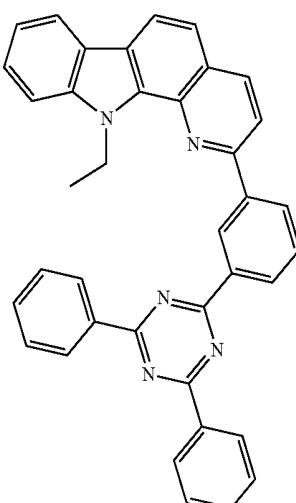
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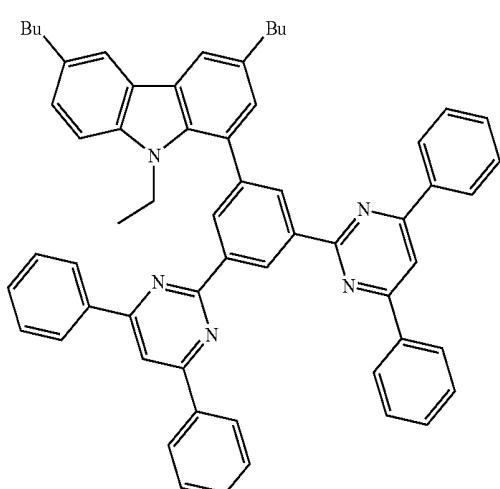
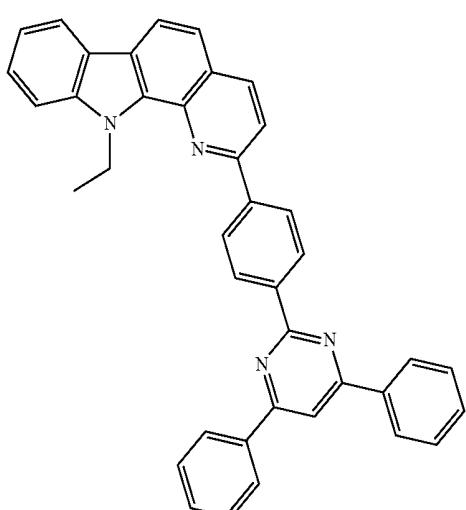
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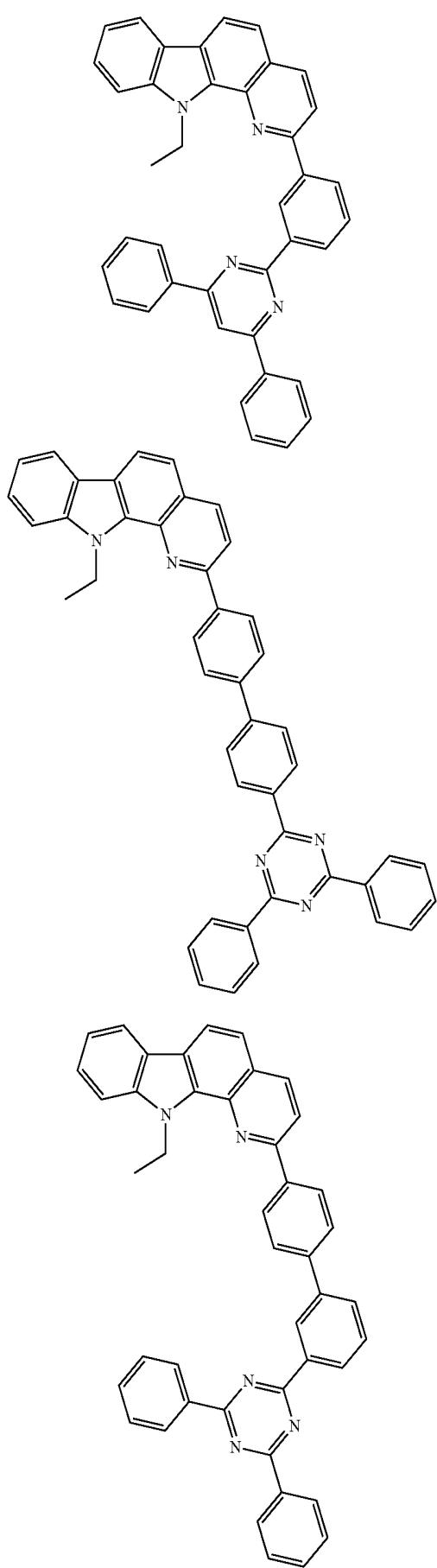
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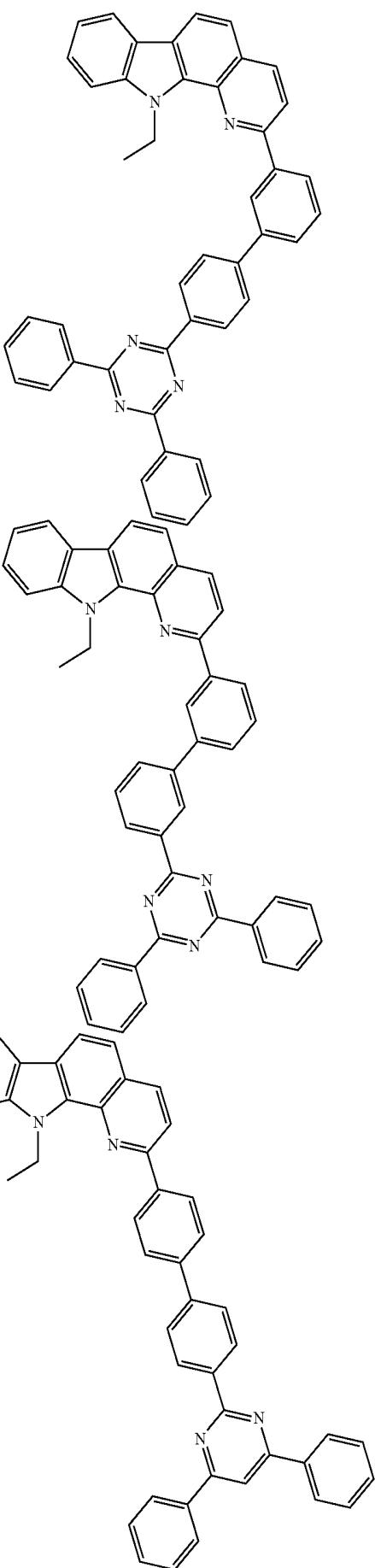
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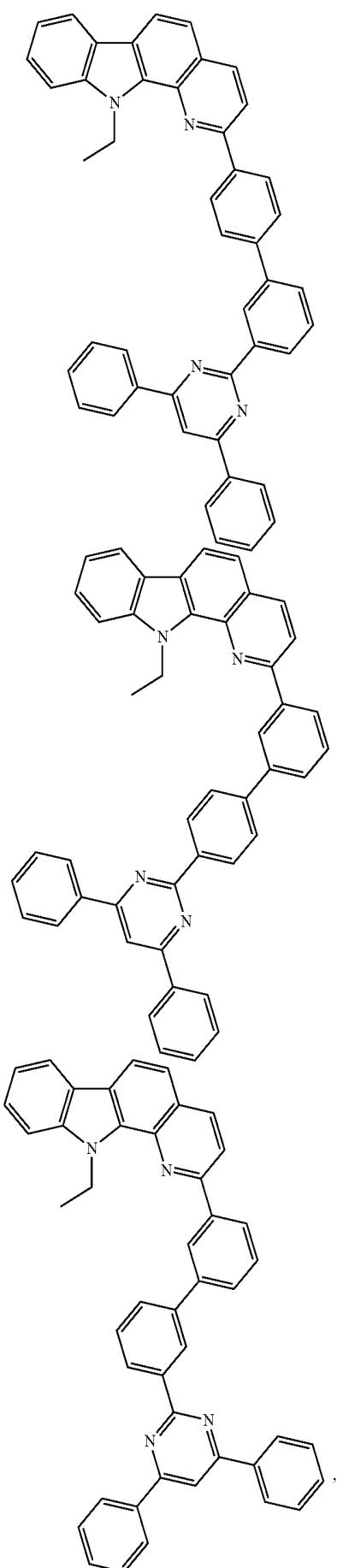
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wherein, in Compounds 5, 6, 11, 12, 17, and 18, "Bu" refers to an n-butyl group.

17. An organic light-emitting device comprising a first electrode;

a second electrode facing the first electrode; and an organic layer disposed between the first electrode and the second electrode, wherein the organic layer comprises an emission layer and at least one carbazole compound of claim 1.

18. The organic light-emitting device of claim 17, wherein the first electrode is an anode, the second electrode is a cathode, and the organic layer comprises

i) a hole transport region formed between the first electrode and the emission layer, wherein the hole transport region comprises at least one of a hole injection layer, a hole transport layer, and an electron blocking layer, and

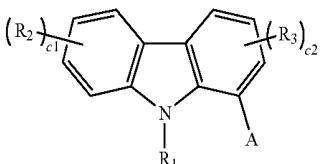
ii) an electron transport region formed between the emission layer and the second electrode, wherein the electron transport region comprises at least one of a hole blocking layer, an electron transport layer, and an electron injection layer.

19. The organic light-emitting device of claim 17, wherein the emission layer comprises the carbazole compound of claim 1.

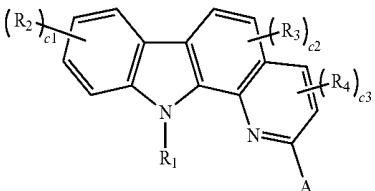
20. The organic light-emitting device of claim 17, wherein the emission layer comprises a phosphorescent dopant.

21. A carbazole compound represented by Formulae 1A or 1B:

Formulae 1A



Formulae 1B



50 wherein in Formulae 1A and 1B, A is $-(L_1)_{a1}-(E_1)_{b1}$,

55 L_1 is selected from a substituted or unsubstituted C_6-C_{60} arylene group, and a substituted or unsubstituted C_1-C_{60} heteroarylene group;

in Formula 1A, E_1 is selected from:

a pyrrolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a

tetrazolyl group, an oxadiazolyl group, a triazinyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

a pyrrolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one Ar_1 ,

wherein Ar_1 is selected from

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenly group, a spiro-fluorenly group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenly group, a spiro-fluorenly group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

olyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof and a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenly group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxaliny group, a cinnolinyl group, and a quinazolinyl group;

in Formula 1B, E_1 is a substituted or unsubstituted electron transporting-cyclic group including at least one N as a ring-forming atom, except a substituted or unsubstituted carbazolyl group;

wherein in Formulae 1A and 1B,

a_1 is 0;

b_1 is 1 or 2, provided that when b_1 is 2, two groups E_1 are identical to or different from each other;

R_1 is selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{20} alkenyl group, a substituted or unsubstituted C_2 - C_{20} alkynyl group, and a substituted or unsubstituted C_1 - C_{20} alkoxy group;

R_2 to R_4 are each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{20} alkenyl group, a substituted or unsubstituted C_2 - C_{20} alkynyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{11})(Q_{12}), —Si(Q_{13})(Q_{14})(Q_{15}), and —B(Q_{16})(Q_{17});

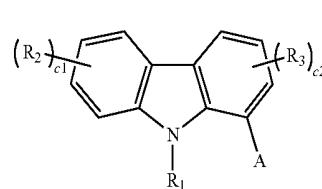
c_1 to c_3 are each independently 0 to 2;

at least one of substituents of the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted electron transporting-cyclic group, the substituted carbazolyl group, the substituted C_1 - C_{20} alkyl group, the substituted C_2 - C_{20} alkenyl group, the substituted C_2 - C_{20} alkynyl group, the substituted C_3 - C_{10} cycloalkyl group, the substituted

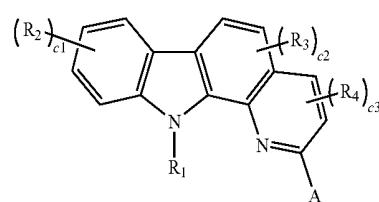
C_1 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_1 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group are selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, 10 a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, 15 a C_2 - C_{20} alkynyl group, and C_1 - C_{20} alkoxy group; a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, —F, 20 —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl 25 group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed 30 polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{21})(Q_{22}), —Si(Q_{23})(Q_{24})(Q_{25}), and —B(Q_{26})(Q_{27}); a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed 35 polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed 40 polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, 45 a C_2 - C_{20} alkynyl group, and C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed 50 polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, 55 a C_2 - C_{20} alkynyl group, and C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed 60 polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{31})(Q_{32}), —Si(Q_{33})(Q_{34})(Q_{35}), and —B(Q_{36})(Q_{37}); and —N(Q_{41})(Q_{42}), —Si(Q_{43})(Q_{44})(Q_{45}) and —B(Q_{46})(Q_{47}), wherein Q_{11} to Q_{17} , Q_{21} to Q_{27} , Q_{31} to Q_{37} , and Q_{41} to Q_{47} are each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a 65

C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

22. An organic light-emitting device comprising a first electrode; a second electrode facing the first electrode; and an organic layer disposed between the first electrode and the second electrode, wherein the organic layer comprises an emission layer and at least one carbazole compound represented by Formulae 1A or 1B:



Formulae 1A



Formulae 1B

wherein in Formulae 1A and 1B, A is $-(L_1)_{a1}-(E_1)_{b1}$,

L_1 is selected from a substituted or unsubstituted C_6 - C_{60} arylene group, and a substituted or unsubstituted C_1 - C_{60} heteroarylene group;

in Formula 1A, E_1 is selected from:

a pyrrolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

a pyrrolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one Ar_1 ,

wherein Ar_1 is selected from

wherein R_1 is selected from a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perylene group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group; and

a phenyl group, a pentenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysanyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof and a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a

triazinyl group, a quinoliny group, an isoquinoliny group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group;

in Formula 1B, E_1 is a substituted or unsubstituted electron transporting-cyclic group including at least one N as a ring-forming atom, except a substituted or unsubstituted carbazolyl group;

wherein in Formulae 1A and 1B,

a1 is 0;

b1 is 1 or 2, provided that when b1 is 2, two groups E_1 are identical to or different from each other;

R_1 is selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{20} alkenyl group, a substituted or unsubstituted C_2 - C_{20} alkynyl group, and a substituted or unsubstituted C_1 - C_{20} alkoxy group;

R_2 to R_4 are each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_2 - C_{20} alkynyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, — $N(Q_{11})(Q_{12})$, — $Si(Q_{13})(Q_{14})(Q_{15})$, and — $B(Q_{16})(Q_{17})$;

c1 to c3 are each independently 0 to 2;

at least one of substituents of the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted electron transporting-cyclic group, the substituted carbazolyl group, the substituted C_1 - C_{20} alkyl group, the substituted C_2 - C_{20} alkenyl group, the substituted C_2 - C_{20} alkynyl group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_1 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_1 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group are selected from

a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, and C₁-C₂₀ alkoxy group;

a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a 5 hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{21})(Q_{22}), —Si 15 (Q_{23})(Q_{24})(Q_{25}), and —B(Q_{26})(Q_{27});
 a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;
 a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; 20
 a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; 25

ensed heteropolycyclic group, each substituted with at least one of a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{31})(Q_{32}), —Si(Q_{33})(Q_{34})(Q_{35}), and —B(Q_{36})(Q_{37}); and —N(Q_{41})(Q_{42}), —Si(Q_{43})(Q_{44})(Q_{45}) and —B(Q_{46})(Q_{47}), wherein Q_{11} to Q_{17} , Q_{21} to Q_{27} , Q_{31} to Q_{37} , and Q_{41} to Q_{47} are each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

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|----------------|---|---------|------------|
| 专利名称(译) | 咔唑化合物和包括其的有机发光器件 | | |
| 公开(公告)号 | US10396294 | 公开(公告)日 | 2019-08-27 |
| 申请号 | US14/584142 | 申请日 | 2014-12-29 |
| [标]申请(专利权)人(译) | 三星电子株式会社 | | |
| 申请(专利权)人(译) | SAMSUNG ELECTRONICS CO. , LTD. | | |
| 当前申请(专利权)人(译) | SAMSUNG ELECTRONICS CO. , LTD. | | |
| [标]发明人 | MIYAZAKI EIGO KAZUSHIGE HORI TANI KEITA ISHII NORIHITO | | |
| 发明人 | MIYAZAKI, EIGO KAZUSHIGE, HORI TANI, KEITA ISHII, NORIHITO | | |
| IPC分类号 | H01L51/00 C07D403/14 H01L51/50 C07D403/10 C07D209/86 C07D471/04 | | |
| 代理机构(译) | 康托科尔伯恩LLP | | |
| 审查员(译) | 杨 , JAY | | |
| 优先权 | 2013273385 2013-12-27 JP 1020140162851 2014-11-20 KR | | |
| 其他公开文献 | US20150188058A1 | | |
| 外部链接 | Espacenet | | |

摘要(译)

由式1A或1B表示的咔唑化合物：其中在公式1A和1B中，A，R 1 到R 4 , c1到c3在说明书中描述。

