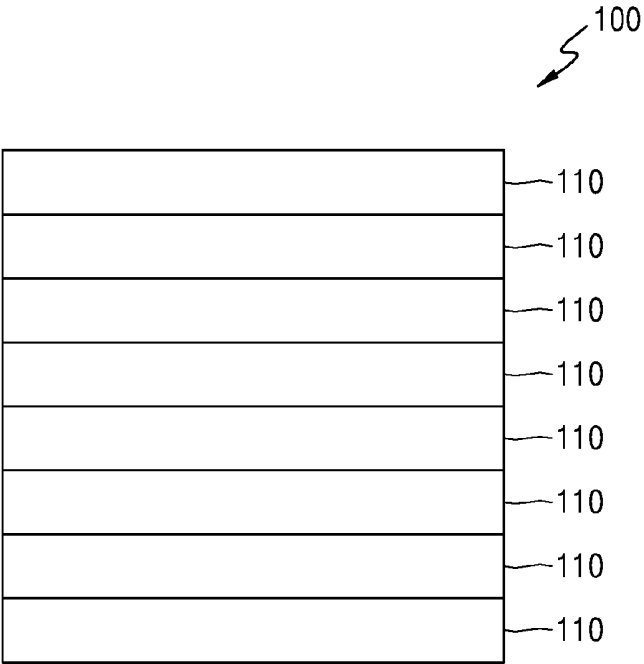


(43) **Pub. Date:** **Jul. 2, 2015**

[illegible]

FIG. 1



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

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] 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

[0002] 1. Field

[0003] The present disclosure relates to a carbazole compound and an organic light-emitting device including the same.

[0004] 2. Description of the Related Art

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

[0006] 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.

[0007] 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.

[0008] 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.

[0009] 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.

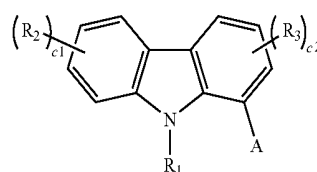
[0010] Thus, there remains a need in a carbazole host having electric charge transporting capability and a large energy band gap in a triplet state to ensure its optimal performance in an organic light-emitting device.

## SUMMARY

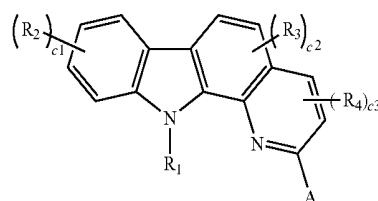
[0011] Provided are a new carbazole compound having electric charge transporting capability and a large energy band gap in a triplet state to solve the problems, and an organic light-emitting device including the carbazole compound.

[0012] 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.

[0013] 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

[0014] In Formulae 1A and 1B,

[0015] A is  $-(L_1)_{a1}-(E_1)_{b1}$ ,

[0016]  $L_1$  is selected from a substituted or unsubstituted  $C_6-C_{60}$  arylene group, and a substituted or unsubstituted  $C_1-C_{60}$  heteroarylene group;

[0017]  $E_1$  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;

[0018]  $a1$  is selected from integers of 1 to 3;

[0019]  $b1$  is 1 or 2, provided that when  $b1$  is 2, two groups  $E_1$  are identical to or different from each other;

[0020]  $R_1$  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;

[0021]  $R_2$  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 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<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylthio group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, the substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —N(Q<sub>11</sub>)(Q<sub>12</sub>), —Si(Q<sub>13</sub>)(Q<sub>14</sub>)(Q<sub>15</sub>), and —B(Q<sub>16</sub>)(Q<sub>17</sub>);

[0022] c1 to c3 are each independently 1 or 2;

[0023] at least one of substituents of the substituted C<sub>6</sub>-C<sub>60</sub> arylene group, the substituted C<sub>1</sub>-C<sub>60</sub> heteroarylene group, the substituted electron transporting-cyclic group, the substituted carbazolyl group, the substituted C<sub>1</sub>-C<sub>20</sub> alkyl group, the substituted C<sub>2</sub>-C<sub>20</sub> alkenyl group, the substituted C<sub>2</sub>-C<sub>20</sub> alkynyl group, the substituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, the substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, the substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, the substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, the substituted C<sub>6</sub>-C<sub>60</sub> aryl group, the substituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, the substituted C<sub>6</sub>-C<sub>60</sub> arylthio group, the substituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from

[0024] 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, and a C<sub>1</sub>-C<sub>20</sub> alkoxy group;

[0025] a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, and a C<sub>1</sub>-C<sub>20</sub> 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<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q<sub>21</sub>)(Q<sub>22</sub>), —Si(Q<sub>23</sub>)(Q<sub>24</sub>)(Q<sub>25</sub>), and —B(Q<sub>26</sub>)(Q<sub>27</sub>);

[0026] a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>2</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0027] a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub>

aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q<sub>31</sub>)(Q<sub>32</sub>), —Si(Q<sub>33</sub>)(Q<sub>34</sub>)(Q<sub>35</sub>), and —B(Q<sub>36</sub>)(Q<sub>37</sub>); and —N(Q<sub>41</sub>)(Q<sub>42</sub>), —Si(Q<sub>43</sub>)(Q<sub>44</sub>)(Q<sub>45</sub>), and —B(Q<sub>46</sub>)(Q<sub>47</sub>), and

[0028] Q<sub>11</sub> to Q<sub>17</sub>, Q<sub>21</sub> to Q<sub>27</sub>, Q<sub>31</sub> to Q<sub>37</sub>, and Q<sub>41</sub> to Q<sub>47</sub> are each independently selected from a hydrogen, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0029] According to an exemplary embodiment, there is provided an organic light-emitting device including:

[0030] a first electrode;

[0031] a second electrode facing the first electrode; and

[0032] 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

[0033] 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:

[0034] FIG. 1 is a schematic cross-sectional view illustrating a structure of an organic light-emitting device according to an exemplary embodiment.

#### DETAILED DESCRIPTION

[0035] 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.

**[0036]** 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.

**[0037]** 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.

**[0038]** 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.

**[0039]** 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.

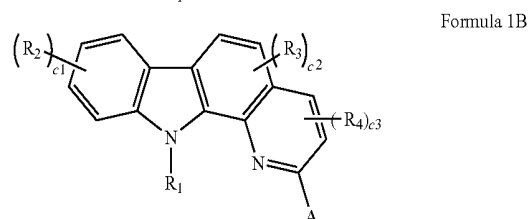
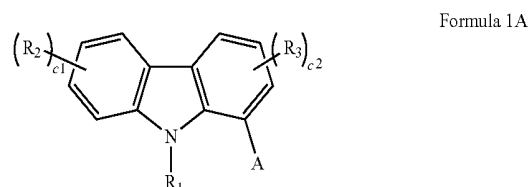
**[0040]** Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially 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.

**[0041]** “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.

**[0042]** 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.

**[0043]** 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.

**[0044]** According to an aspect, there is provided a carbazole compound represented by Formulae 1A or 1B below:



**[0045]** In Formulae 1A and 1B,

**[0046]** A may be  $-(L_1)_{a1}-(E_1)_{b1}$ ,

**[0047]**  $L_1$  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;

**[0048]**  $E_1$  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;

**[0049]**  $a1$  may be selected from integers of 1 to 3;

**[0050]**  $b1$  may be 1 or 2, provided that when  $b1$  is 2, two groups  $E_1$  may be each independently connected to  $L_1$  and may be identical to or different from each other;

**[0051]**  $R_1$  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;

**[0052]**  $R_2$  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,

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  $-B(Q_{16})(Q_{17})$ ;

[0053] c1 to c3 may be each independently 1 or 2;

**[0054]** 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

**[0055]** 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, and a C<sub>1</sub>-C<sub>20</sub> alkoxy group;

**[0056]** a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, and a C<sub>1</sub>-C<sub>20</sub> 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<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q<sub>21</sub>)(Q<sub>22</sub>), —Si(Q<sub>23</sub>)(Q<sub>24</sub>)(Q<sub>25</sub>), and —B(Q<sub>26</sub>)(Q<sub>27</sub>);

**[0057]** a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>2</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed

polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

**[0058]** a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q<sub>31</sub>)(Q<sub>32</sub>), —Si(Q<sub>33</sub>)(Q<sub>34</sub>)(Q<sub>35</sub>), and —Br(Q<sub>36</sub>)(Q<sub>37</sub>); and

[0059] —N(Q<sub>41</sub>)(Q<sub>42</sub>), —Si(Q<sub>43</sub>)(Q<sub>44</sub>)(Q<sub>45</sub>) and —B(Q<sub>46</sub>)(Q<sub>47</sub>), and

**[0060]** Q<sub>11</sub> to Q<sub>17</sub>, Q<sub>21</sub> to Q<sub>27</sub>, Q<sub>31</sub> to Q<sub>37</sub>, and Q<sub>41</sub> to Q<sub>47</sub> may be each independently selected from a hydrogen, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

**[0061]** In Formulae 1A and 1B,

[0062] L<sub>1</sub> 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 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 chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylenylene group, a pyrazolylenylene group, a pyridinylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, an isoindolylenylene group, an indolylenylene group, an indazolylenylene group, a purinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a carbazolylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzooxazolylenylene group, a benzimidazolylenylene group, a furanylenylene group, a benzofuranylenylene group, a thiophenylenylene group, a benzothiophenylenylene group, a thiazolylenylene group, an isothiazolylenylene group, a benzothiazolylenylene group, an isoxazolylenylene group, an oxazolylenylene group, a triaz-

olylene group, a tetrazolylene group, an oxadiazolylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylenegroup, a dibenzocarbazolylenegroup, an imidazopyrimidinylene group, and an imidazopyridinylene group; and

[0063] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spirofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylenegroup, 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 carbazolylenegroup, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzooxazolylene 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 benzocarbazolylenegroup, a dibenzocarbazolylenegroup, 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a C<sub>6</sub>-C<sub>20</sub> aryl group, and a C<sub>1</sub>-C<sub>60</sub> heteroaryl group.

[0064] In some embodiments, L<sub>1</sub> in Formulae 1A and 1B may be selected from

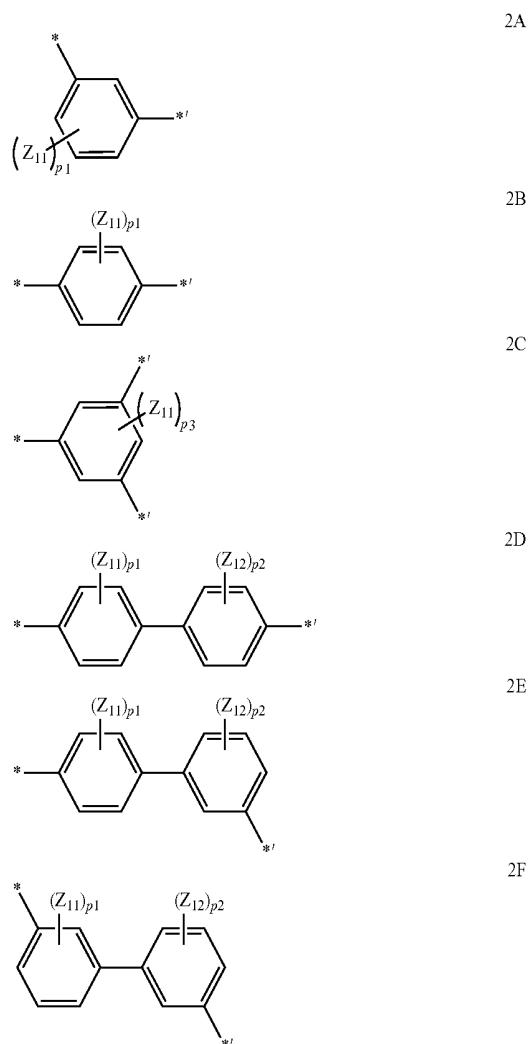
[0065] a phenylene group, a naphthylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a pyrrolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoindolylene group, an indolylene group, a furanylene group, a benzofuranylene group, a thiophenylene group, a benzothiophenylene group, and a triazinylene group; and

[0066] 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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

[0067] a<sub>1</sub> may be 1 or 2.

[0068] In some other embodiments, (L<sub>1</sub>)<sub>a1</sub> in Formulae 1A and 1B may be represented by one of Formulae 2A to 2F below:



[0069] In Formulae 2A to 2F,

[0070] Z<sub>11</sub> and Z<sub>12</sub> 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

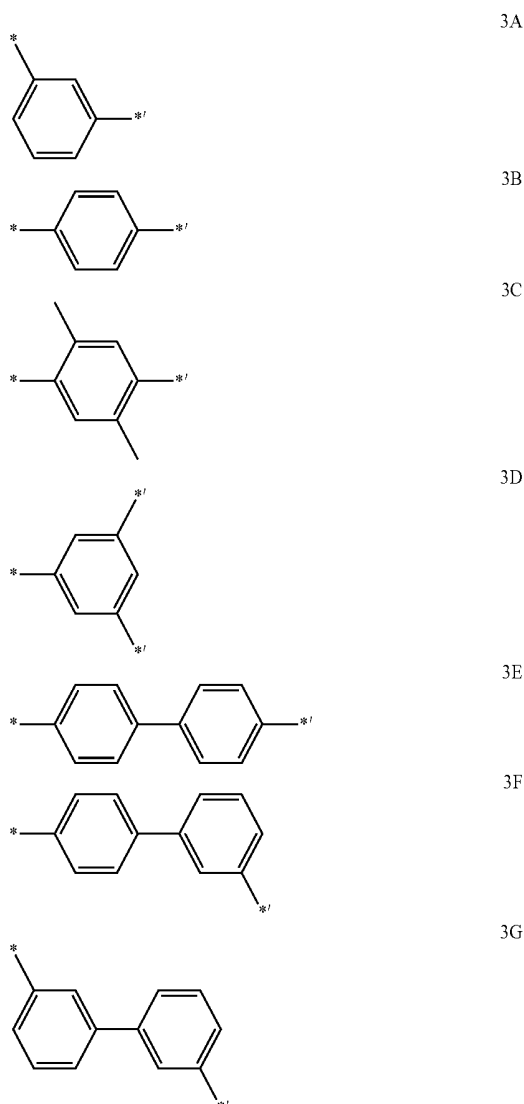
group or a salt thereof, a phosphoric acid group or a salt thereof, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl 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;

[0071] p1 and p2 may be each independently an integer of 0 to 4;

[0072] p3 may be an integer of 0 to 3; and

[0073] \* and \*' may each independently indicate a binding site to a neighboring group or atom, wherein \*' may indicate a binding site to  $E_1$ .

[0074] For example,  $(L_1)_{a1}$  in Formulae 1A and 1B may be represented by one of Formulae 3A to 3G below:



[0075] 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 pyri-

midinyl 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

[0076] 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  $Ar_1$ ,

[0077] wherein  $Ar_1$  may be selected from

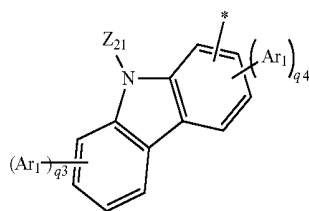
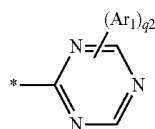
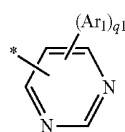
[0078] a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a 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

[0079] 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 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 quinoliny group, an isoquinoliny group, a benzoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazoliny group, a cinnoliny group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzimidazolyl 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 benzothiophenyl 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 quinoliny group, an isoquinoliny group, a phthalazinyl group, a quinoxaliny group, a cinnoliny group, and a quinazoliny group.

[0080] In an embodiment,  $E_1$  in Formulae 1A and 1B may be represented by one of Formulae 4A to 4C below:



[0081] In Formulae 4A to 4C,

[0082]  $Ar^1$  may be selected from 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 pyrazi-

nyl group, a pyridazinyl group, a triazinyl group, a quinoliny group, an isoquinoliny group, a phthalazinyl group, a quinoxaliny group, a cinnoliny group, and a quinazoliny group;

[0083]  $Z_{21}$  may be selected from a  $C_1$ - $C_{20}$  alkyl group and a  $C_1$ - $C_{20}$  alkoxy group;

[0084] 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 fluorenyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinoliny group, an isoquinoliny group, and a quinazoliny group;

[0085]  $q_1$  may be an integer of 0 to 3;

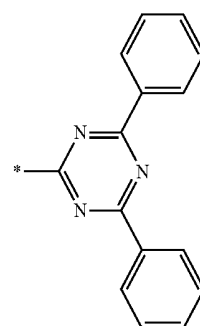
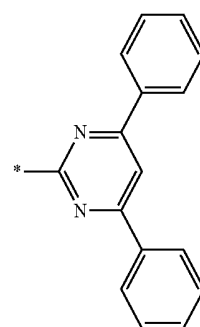
[0086]  $q_2$  may be an integer of 0 to 2;

[0087]  $q_3$  may be an integer of 0 to 4; and

[0088] \* may indicate a binding site to a neighboring group or atom.

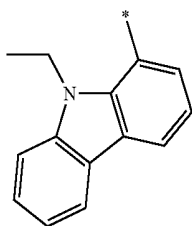
[0089] For example, in Formulae 4A to 4C,  $Ar^1$  may be a phenyl group,  $q_1$  and  $q_2$  may be each 2, and  $q_3$  and  $q_4$  may be each 0.

[0090] In an embodiment,  $E_1$  in Formulae 1A and 1B may be represented by one of Formulae 5A to 5C below:



-continued

5C



[0091] In Formulae 5A to 5C, \* may indicate a binding site to a neighboring group or atom.

[0092] In Formulae 1A and 1B,

[0093]  $R_1$  may be selected from

[0094] a  $C_1$ - $C_{20}$  alkyl group and a  $C_1$ - $C_{20}$  alkoxy group;

[0095] 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 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.

[0096] 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.

[0097] In Formulae 1A and 1B,

[0098]  $R_2$  to  $R_4$  may be each independently selected from

[0099] 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;

[0100] 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 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;

[0101] 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 fluo-

renyl 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 pice-nyl 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 imidazopyridinyl group, and an imidazopyridinyl group;

[0102] 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 chrysenyl group, a naphthacenyl group, a pice-nyl 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, 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 isoquino-

linyl group, a phthalazinyl group, a quinoxalinylnyl group, a cinnolinyl group, and a quinazolinyl group; and

[0103]  $-\text{N}(\text{Q}_{13})(\text{Q}_{14})$  and  $-\text{Si}(\text{Q}_{15})(\text{Q}_{16})(\text{Q}_{17})$ , and

[0104]  $\text{Q}_{13}$  to  $\text{Q}_{17}$  may be each independently selected from a hydrogen, a  $\text{C}_1$ - $\text{C}_{20}$  alkyl group, a  $\text{C}_1$ - $\text{C}_{20}$  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 quinoxalinylnyl group, a cinnolinyl group, and a quinazolinyl group.

[0105] In an exemplary embodiment,  $\text{R}_2$  to  $\text{R}_4$  may be each independently selected from

[0106] a deuterium atom,  $-\text{F}$ ,  $-\text{Cl}$ ,  $-\text{Br}$ ,  $-\text{I}$ , 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  $\text{C}_1$ - $\text{C}_{20}$  alkyl group, a  $\text{C}_2$ - $\text{C}_{20}$  alkenyl group, a  $\text{C}_2$ - $\text{C}_{20}$  alkynyl group, and a  $\text{C}_1$ - $\text{C}_{20}$  alkoxy group;

[0107] a phenyl group, a naphthyl group, a pyridinyl group, and a naphthyridinyl group;

[0108] a phenyl group, a naphthyl group, a pyridinyl group, and a naphthyridinyl group, each substituted with at least one of a deuterium atom,  $-\text{F}$ ,  $-\text{Cl}$ ,  $-\text{Br}$ ,  $-\text{I}$ , 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  $\text{C}_1$ - $\text{C}_{20}$  alkyl group, a  $\text{C}_2$ - $\text{C}_{20}$  alkenyl group, a  $\text{C}_2$ - $\text{C}_{20}$  alkynyl group, a  $\text{C}_1$ - $\text{C}_{20}$  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 quinoxalinylnyl group, a cinnolinyl group, and a quinazolinyl group; and

[0109]  $-\text{Si}(\text{Q}_{15})(\text{Q}_{16})(\text{Q}_{17})$ .

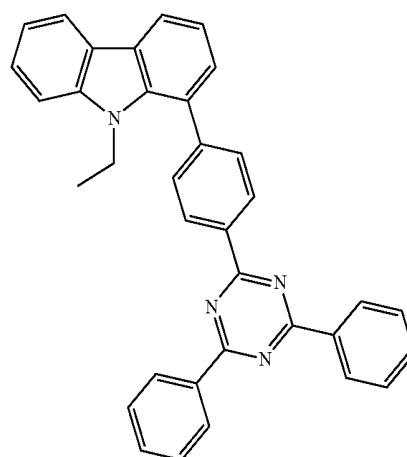
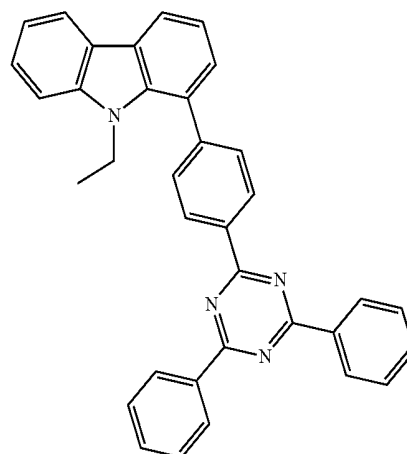
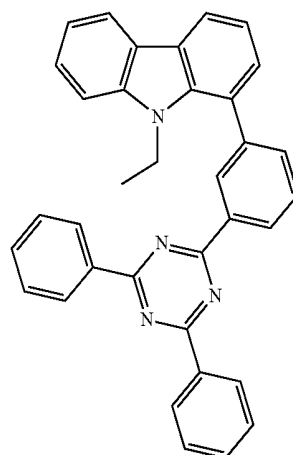
[0110] wherein  $\text{Q}_{15}$  to  $\text{Q}_{17}$  may be each independently selected from a hydrogen, a  $\text{C}_1$ - $\text{C}_{20}$  alkyl group, a  $\text{C}_1$ - $\text{C}_{20}$  alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a 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 quinoxalinylnyl group, a cinnolinyl group, and a quinazolinyl group.

[0111] For example,  $\text{R}_2$  may be selected from a methyl group and an ethyl group;

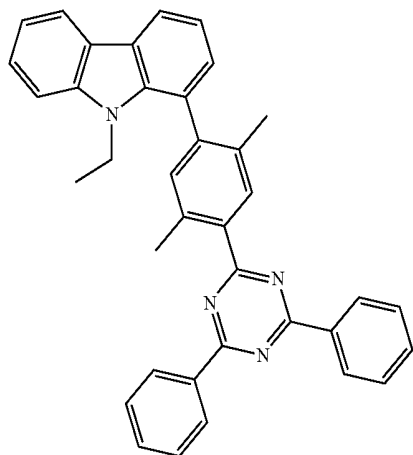
[0112]  $\text{R}_3$  to  $\text{R}_4$  may be each independently selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group; and

[0113] optionally, at least one of  $\text{R}_3$  to  $\text{R}_4$  may be each independently selected from fluorine and a  $\text{C}_1$ - $\text{C}_{20}$  alkoxy group.

[0114] 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:

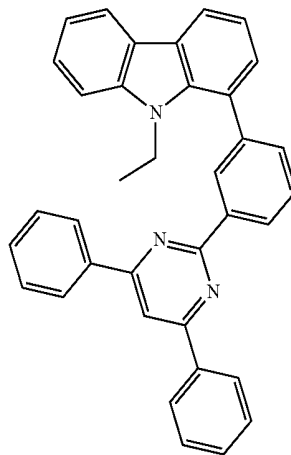


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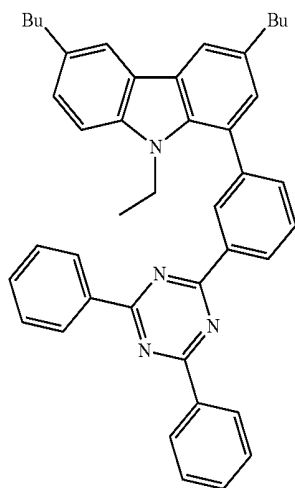


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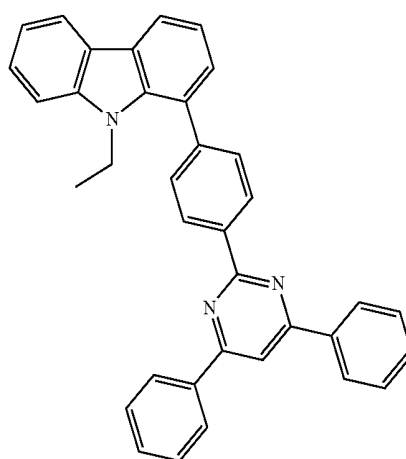
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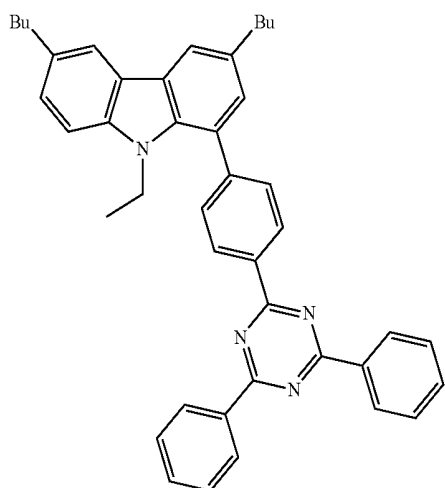
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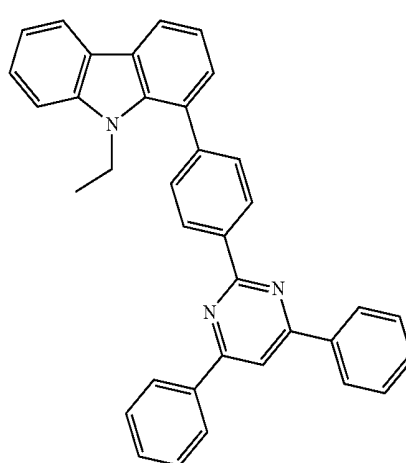
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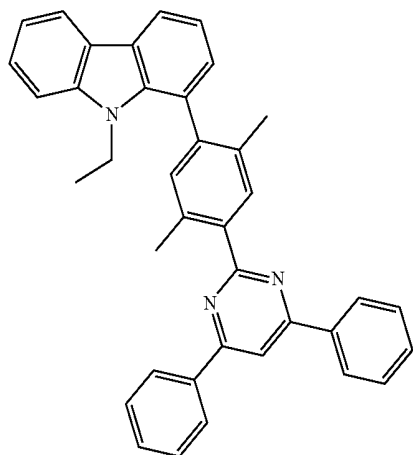


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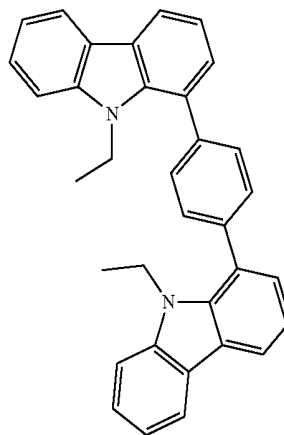
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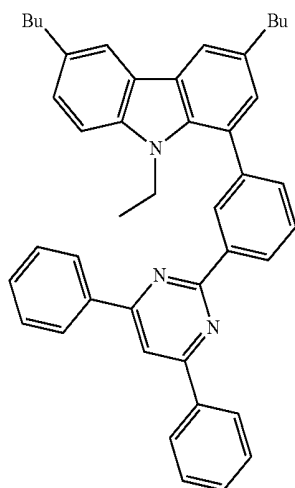


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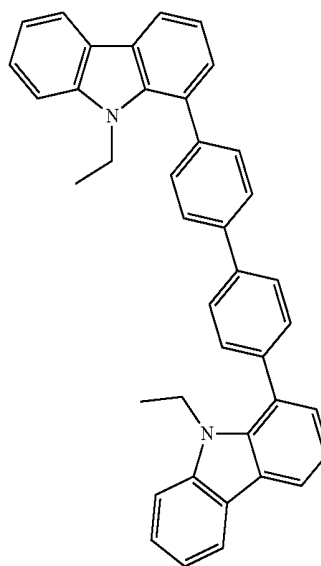
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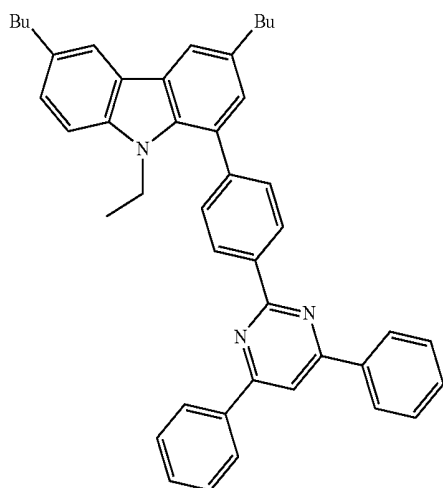
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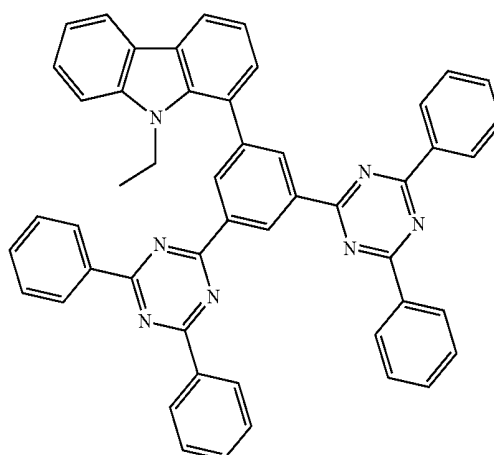
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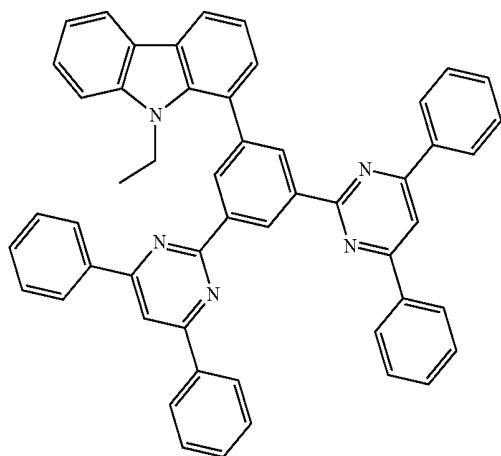


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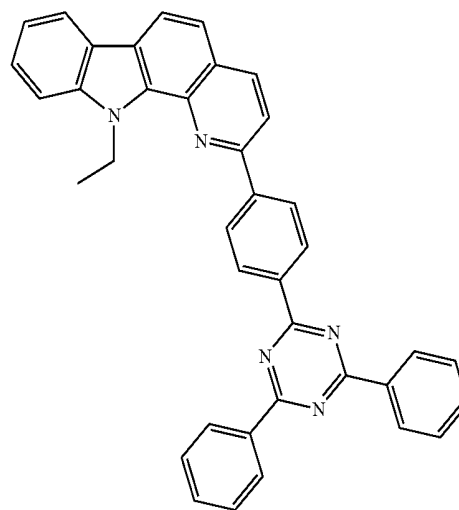
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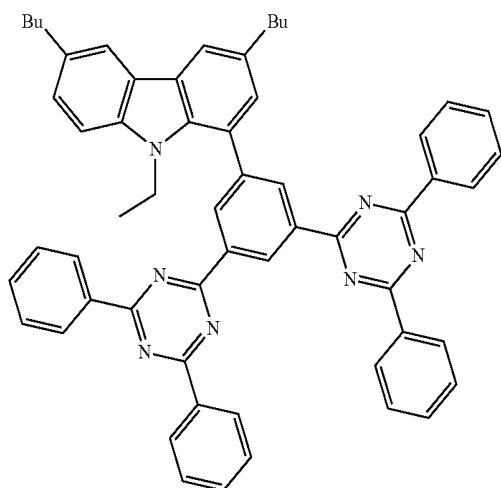


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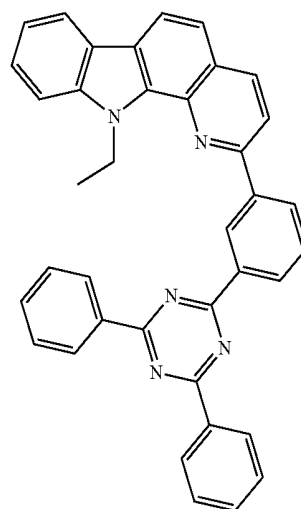
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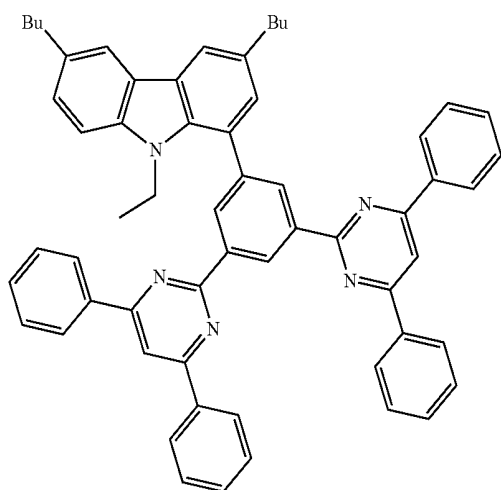
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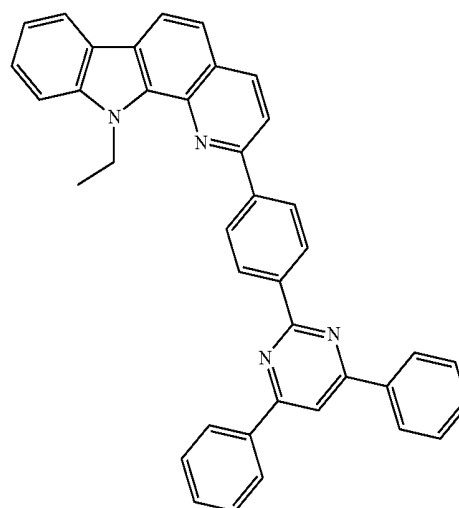
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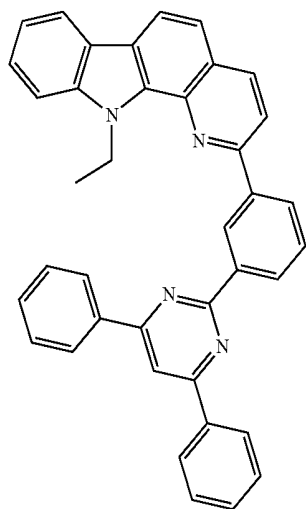


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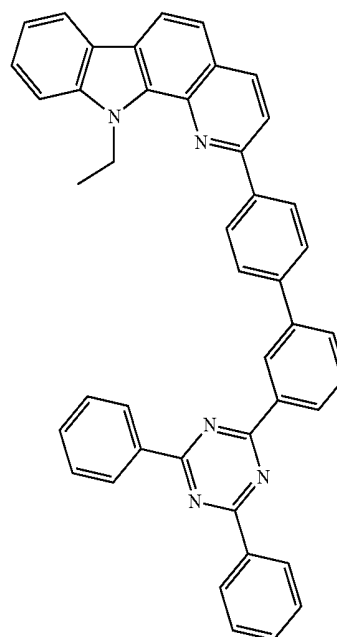
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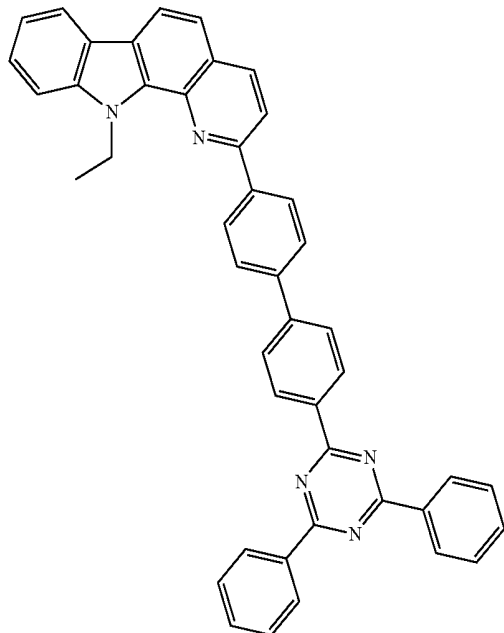
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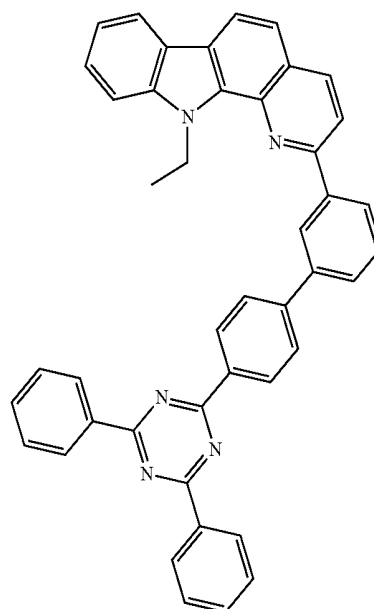


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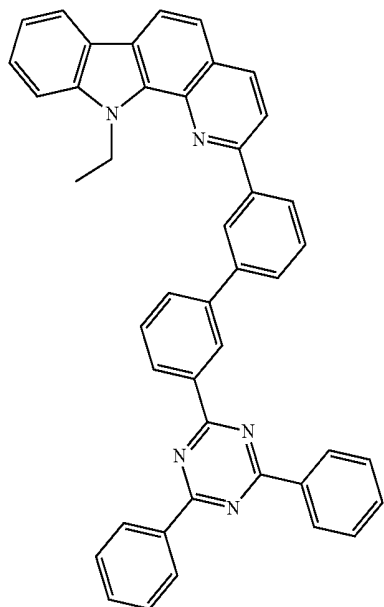


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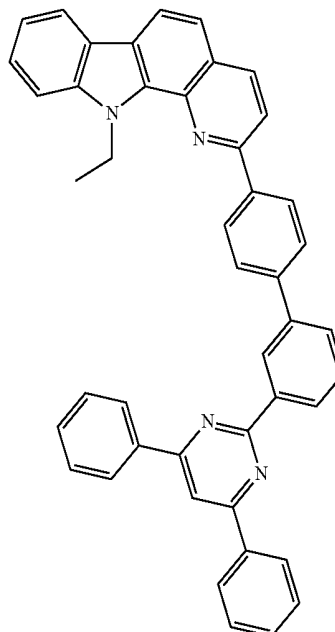
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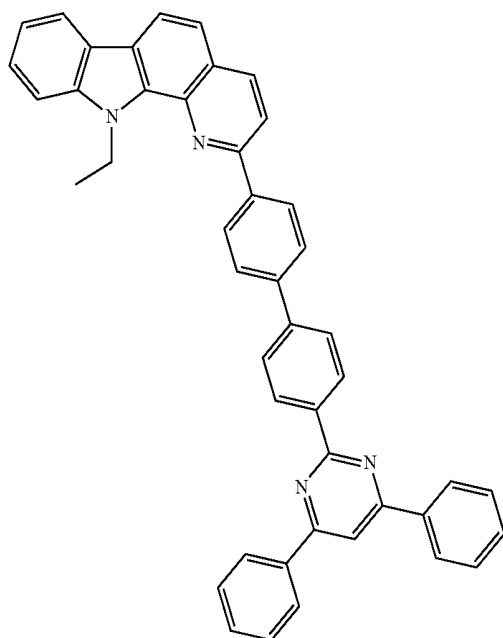


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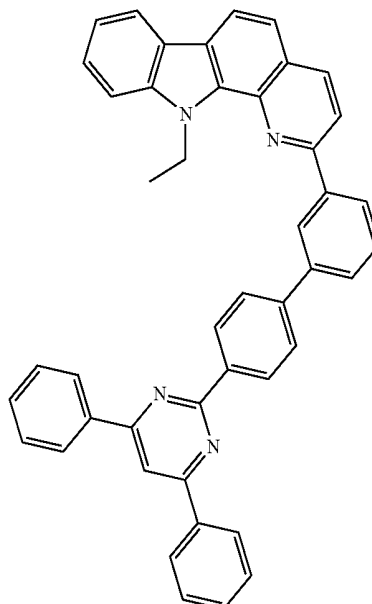
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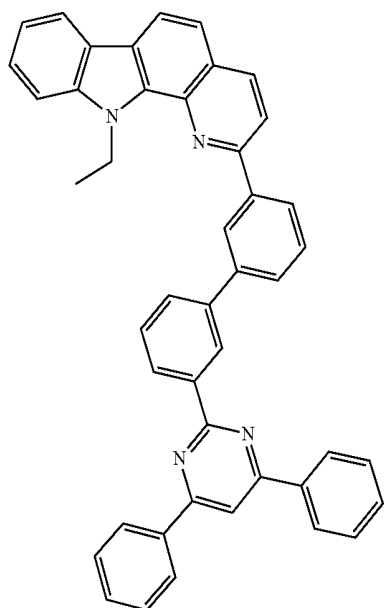


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[0115] Optionally, the carbazole compound of an exemplary embodiment of the present inventive concept may include a substituent, e.g., at least one of fluorine and a  $C_1$ - $C_{20}$  alkoxy group. For example, several hydrogens of Compounds of exemplary embodiments above may be substituted with fluorine or an alkoxy group.

[0116] 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.

[0117] In addition, an organic light-emitting device including the carbazole compound that has both hole-transporting capability and electron-transporting capability may ensure carrier 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.

[0118] A method of synthesizing the carbazole compound of Formula 1 above may be understood by referring to Synthesis Examples that will be provided below.

[0119] 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:

[0120] a first electrode;

[0121] a second electrode; and

[0122] 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.

[0123] 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.

[0124] 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 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 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 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.

[0125] 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”.

[0126] 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 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.

[0127] 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 an anode that is a hole injection electrode.

[0128] For example, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include:

[0129] 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

[0130] 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.

[0131] 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.

[0132] FIG. 1 illustrates a schematic cross-sectional view of an organic light-emitting device 100 according to an exem-

plary 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 FIG. 1.

[0133] In FIG. 1, 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.

[0134] 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.

[0135] 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.

[0136] 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 ( $\text{SnO}_2$ ), 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.

[0137] 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.

[0138] In addition, the hole injection layer 130 may be formed by using a material known in the art, such as N,N'-diphenyl-N,N'-bis-[4-(phenyl-m-tolyl-amino)-phenyl]-biphenyl-4,4'-diamine (DNTPD), a phthalocyanine compound, such as phthalocyanine, 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (m-MTDATA), N,N'-di(1-naphthyl)-N,N'-diphenylbenzidine (NPB), 4,4',4''-tris{N,N'-diphenyl amino}triphenylamine (TDATA), 4,4',4''-tris(N,N'-2-naphthylphenylamino)triphenylamine (2-TNATA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), or polyaniline/camphorsulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate):polyaniline (PANI/PSS).

[0139] The hole transport layer 140 is a layer including a hole-transporting 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-transporting material, such as N-phenylcarbazole, a carbazole derivative, such as polyvinyl carbazole, N,N'-bis(3-methylphenyl)-N,N'-diphenyl-[1,1-biphenyl]-4,4'-diamine (TPD), 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), 4,4',4''-tris(N-carbazolyl)triphenylamine), N,N'-bis(naphthalene-2-yl)-N,N'-bis(phenyl)-benzidine (NPB), N,N'-bis(naphthalene-1-yl)-N,N'-bis(phenyl)-benzidine), or N,N'-bis(naphthalene-1-yl)-N,N'-bis(phenyl)-2,2'-dimethylbenzidine ( $\alpha$ -NPD).

[0140] 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.

[0141] In addition, the emission layer 150 may include other host materials, such as tris(8-quinolinolate)aluminum ( $\text{Alq}_3$ ), 4,4'-N,N'-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'-bis(9-carbazole)-2,2'-dimethylbiphenyl (dmCBP).

[0142] 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.

[0143] 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).

[0144] 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-(dicyanomethylene)-2-methyl-6-[p-(dimethylamino)styryl]-4H-pyran (DCM) and a derivative thereof, an Ir complex, such as bis(1-phenylisoquinoline)(acetylacetonate)iridium(III) ( $\text{Ir}(\text{piq})_2(\text{acac})$ ), an osmium (Os) complex, and a platinum (Pt) complex.

[0145] 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)<sub>3</sub>).

[0146] 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-quinolinato)aluminum

(Alq<sub>3</sub>), 1,2,4-triazole derivative (TAZ), bis(2-methyl-8-quinolinolato)-(p-phenylphenolato)-aluminum(BAlq), beryllium, and bis(benzoquinoline 10-olate) (BeBq<sub>2</sub>).

[0147] 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.

[0148] 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 (Li<sub>2</sub>O), barium oxide (BaO).

[0149] 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).

[0150] 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.

[0151] 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.

[0152] A C<sub>1</sub>-C<sub>20</sub> 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 isopentyl group, and a hexyl group. A C<sub>1</sub>-C<sub>20</sub> alkylene group as used herein refers to a divalent group having the same structure as the C<sub>1</sub>-C<sub>20</sub> alkyl group.

[0153] A C<sub>1</sub>-C<sub>20</sub> alkoxy group as used herein refers to a monovalent group represented by —OA<sub>101</sub> (wherein A<sub>101</sub> is the C<sub>1</sub>-C<sub>60</sub> alkyl). Detailed examples thereof are a methoxy group, an ethoxy group, and an isopropoxy group.

[0154] A C<sub>2</sub>-C<sub>20</sub> 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 C<sub>2</sub>-C<sub>20</sub> alkyl group. Detailed examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C<sub>2</sub>-C<sub>20</sub> alkenylene

group as used herein refers to a divalent group having the same structure as the C<sub>2</sub>-C<sub>20</sub> alkenyl group.

[0155] A C<sub>2</sub>-C<sub>20</sub> 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 C<sub>2</sub>-C<sub>20</sub> alkyl group. Detailed examples thereof are an ethynyl group and a propynyl group. A C<sub>2</sub>-C<sub>20</sub> alkynylene group as used herein refers to a divalent group having the same structure as the C<sub>2</sub>-C<sub>20</sub> alkynyl group.

[0156] A C<sub>3</sub>-C<sub>10</sub> 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 C<sub>3</sub>-C<sub>10</sub> cycloalkylene group as used herein refers to a divalent group having the same structure as the C<sub>3</sub>-C<sub>10</sub> cycloalkyl group.

[0157] A C<sub>1</sub>-C<sub>10</sub> 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 tetrahydrofuranlyl group and a tetrahydrothiophenyl group. A C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group as used herein refers to a divalent group having the same structure as the C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group.

[0158] A C<sub>3</sub>-C<sub>10</sub> 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 C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group as used herein refers to a divalent group having the same structure as the C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group.

[0159] A C<sub>1</sub>-C<sub>10</sub> 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 C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group are a 2,3-dihydrofuranlyl group and a 2,3-dihydrothiophenyl group. A C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group as used herein refers to a divalent group having the same structure as the C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group.

[0160] A C<sub>6</sub>-C<sub>60</sub> aryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C<sub>6</sub>-C<sub>60</sub> arylene group as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C<sub>6</sub>-C<sub>60</sub> aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C<sub>6</sub>-C<sub>60</sub> aryl group and the C<sub>6</sub>-C<sub>60</sub> arylene group each include two or more rings, the rings may be fused to each other.

[0161] A C<sub>1</sub>-C<sub>60</sub> 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 C<sub>1</sub>-C<sub>60</sub> 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<sub>1</sub>-C<sub>60</sub> 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<sub>1</sub>-C<sub>60</sub> heteroaryl group and the C<sub>1</sub>-C<sub>60</sub> heteroarylene group each include two or more rings, the rings may be fused to each other.

[0162] A C<sub>6</sub>-C<sub>60</sub> aryloxy group as used herein indicates —OA<sub>102</sub> (wherein A<sub>102</sub> is the C<sub>6</sub>-C<sub>60</sub> aryl group), and a C<sub>6</sub>-C<sub>60</sub> arylthio group as used herein indicates —SA<sub>103</sub> (wherein A<sub>103</sub> is the C<sub>6</sub>-C<sub>60</sub> aryl group).

[0163] 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 fluorenyl 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.

[0164] 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.

[0165] 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’.

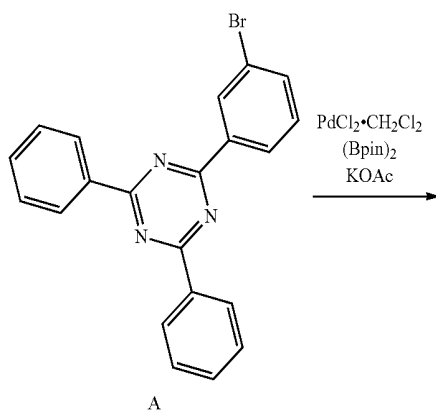
#### Synthesis Example

[0166] Compound 1 and Compound 19 were synthesized by a Suzuki-Miyaura cross-coupling reaction.

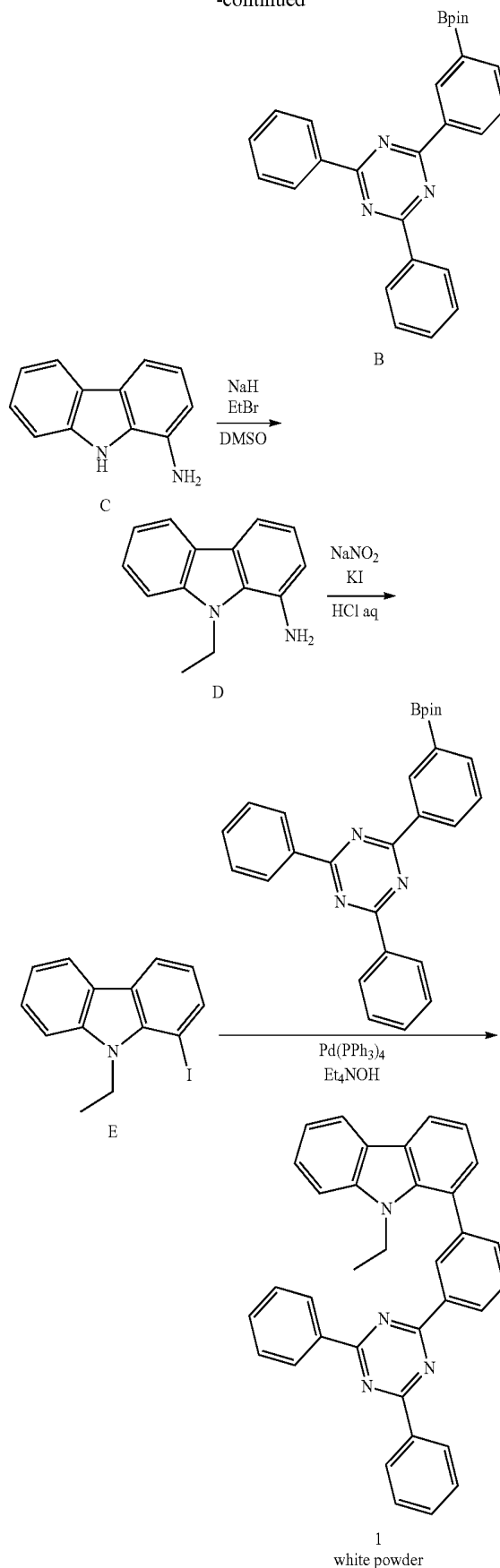
#### Synthesis Example 1

#### Synthesis of Compound 1

[0167]



-continued



**[0168]** In a reaction container, 500 milligrams (mg) (1.29 millimoles (mmol)) of Compound A, 326 mg (1.3 mmol) of bis(pinacolato)diboron ((Bpin)<sub>2</sub>), 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)Cl<sub>2</sub>·CH<sub>2</sub>Cl<sub>2</sub>) 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.

**[0169]** 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.

**[0170]** 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 (NaNO<sub>2</sub>) 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.

**[0171]** 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(PPh<sub>3</sub>)<sub>4</sub>), and 0.40 mL (40 mass %, 1.0 mmol) of potassium tetraethyl ammonium (Et<sub>4</sub>NOH) 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).

**[0172]** Compound B

**[0173]** NMR (300 MHz, CDCl<sub>3</sub>): 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).

**[0174]** Compound C

**[0175]** NMR (300 MHz, CDCl<sub>3</sub>): 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).

**[0176]** Compound D

**[0177]** NMR (300 MHz, CDCl<sub>3</sub>): 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).

**[0178]** Compound E

**[0179]** NMR (300 MHz, CDCl<sub>3</sub>): 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).

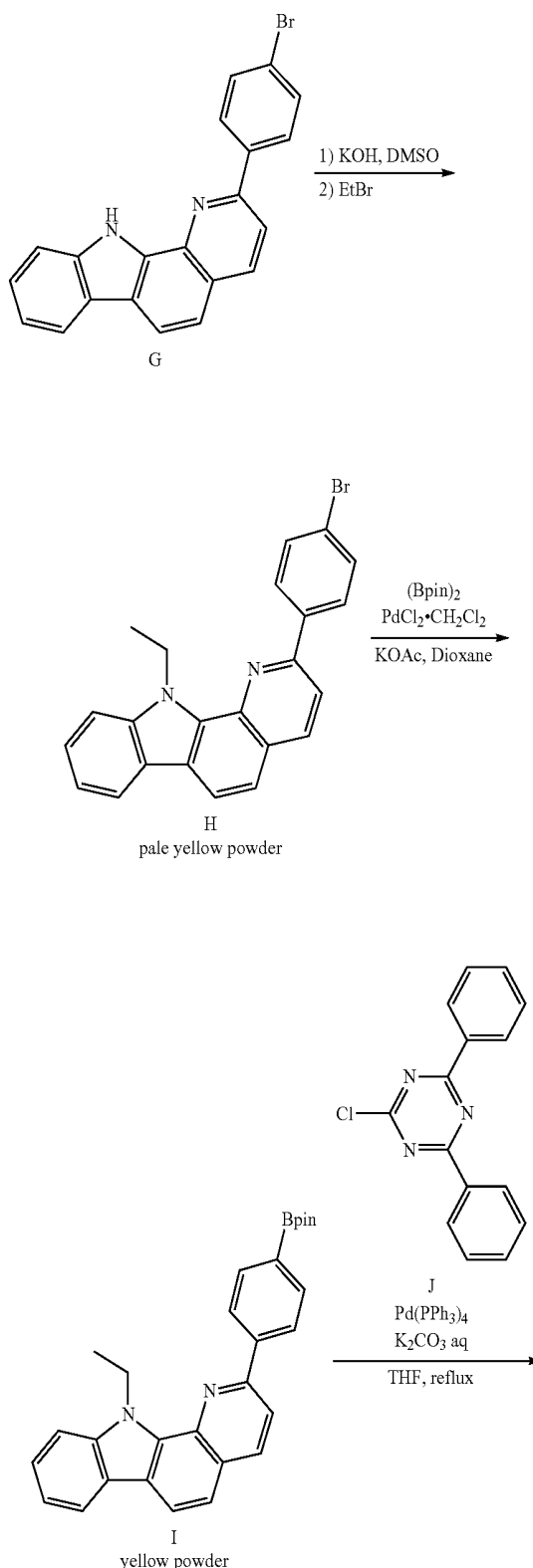
**[0180]** Compound 1

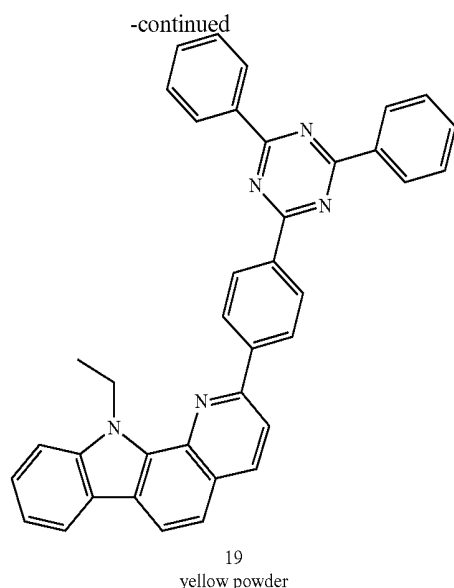
**[0181]** NMR (300 MHz, CDCl<sub>3</sub>): δ 0.96 (3H, t, J=7.2 Hz), 3.89 (2H, q, J=7.2 Hz), 6.92 (1H, m), 7.20-7.32 (3H, m), 7.28-7.52 (7H, m), 7.68-7.71 (2H, m), 8.11 (2H, m), 8.68 (4H, m), 8.84 (2H, m); LC-MS: m/z 502 (M<sup>+</sup>).

## Synthesis Example 2

### Synthesis of Compound 19

**[0182]**



**[0183]** 1) Synthesis of Compound H

**[0184]** 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.

**[0185]** 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.

**[0186]** 2) Synthesis of Compound 19

**[0187]** 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 Pd(dppf)<sub>2</sub>Cl<sub>2</sub>CH<sub>2</sub>Cl<sub>2</sub>, 135 mg (0.531 mmol) of (Bpin)<sub>2</sub> (bis (pinacolate)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.

**[0188]** 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 Pd(PPh<sub>3</sub>)<sub>4</sub>, 38.5 mL of tetrahydrofuran (THF), and 16.4 mL of 0.34 molar (M) potassium carbonate solution (K<sub>2</sub>CO<sub>3</sub>) 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.

**[0189]** Compound H

**[0190]** NMR (300 MHz, CDCl<sub>3</sub>): 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).

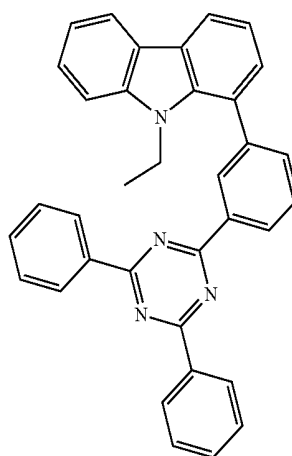
**[0191]** Compound 19

**[0192]** NMR (300 MHz, CDCl<sub>3</sub>): 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<sup>+</sup>).

**[0193]** Evaluation of Physical Property

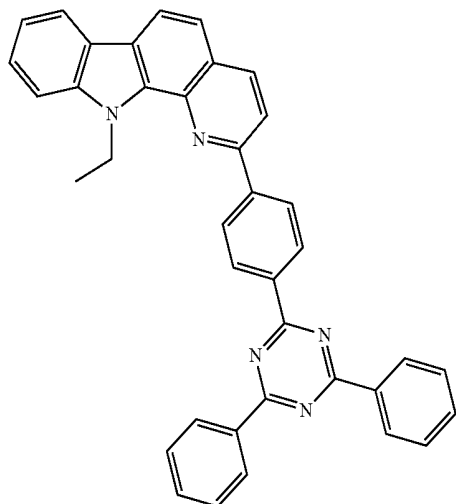
**[0194]** Highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) of Compound 1 of Synthesis Example 1 and Compound 19 of Synthesis Example 2 were simulated in structural optimization using Gaussian 09 software (Gaussian company) with basis function B3LYP/6-31G\*. In 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\*\*.

**[0195]** 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'-dicarbazole 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.

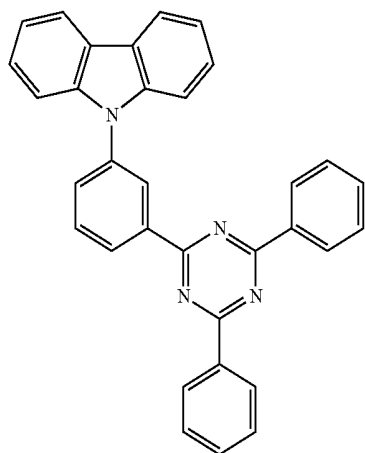


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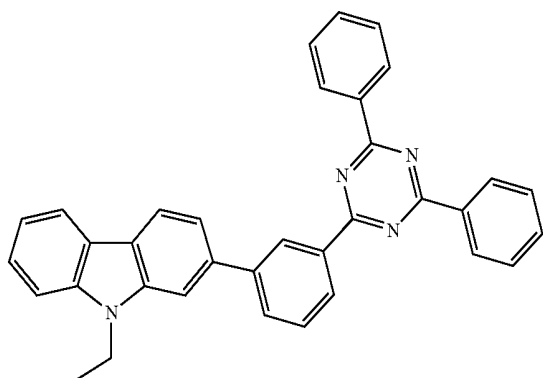
19



Comparative Compound 1

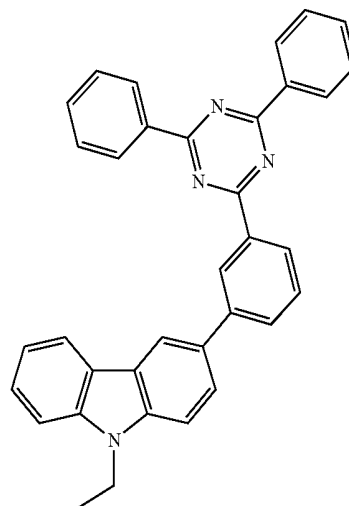


Comparative Compound 2



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Comparative Compound 3



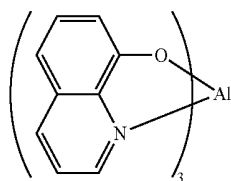
**[0196]** The material property examination results (HOMO, LUMO, T<sub>1</sub>) of Compound 1 and Comparative Compounds 1 to 3 are shown in Table 1 below. Here, T<sub>1</sub> represents energy levels in a triplet state, and all energy levels were shown with respect to a vacuum level.

TABLE 1

	Com- pound 1	Compar- ative Com- pound 1	Compar- ative Com- pound 2	Compar- ative Com- pound 3	CBP
HOMO [eV]	-5.59	-5.66	-5.66	-5.55	-6.3
LUMO [eV]	-2.24	-2.35	-2.17	-2.11	-3
T <sub>1</sub> [eV]	2.88	2.72	2.81	2.79	2.56

**[0197]** 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 T<sub>1</sub> 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.

**[0198]** The material property examination results of Compound 19 and Comparative Compound 4 used as a red dopant are shown in Table 2 below.



Comparative Compound 4

TABLE 2

	HOMO [eV]	LUMO [eV]	T1 [eV]	E <sub>gg</sub> [eV]
Compound 19	-5.82	-3.12	2.23	2.70
Comparative Compound 4	-6.11	-3.38	2.03	2.73

[0199] 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.

[0200] 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.

[0201] 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.

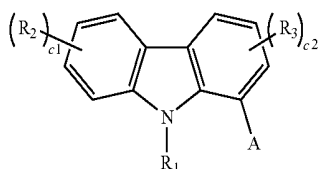
[0202] As described above, according to the one or more of the above exemplary embodiments, a carbazole compound is well capable of transporting a charge and has a large energy gap in a triplet state. In this regard, an organic light-emitting device employing the carbazole compound may have low driving voltage, high efficiency, high luminance, and long lifespan characteristics.

[0203] 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.

[0204] 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:

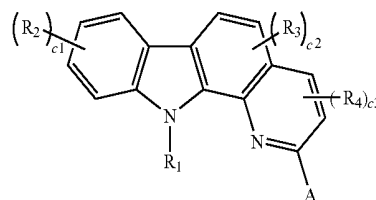
1. A carbazole compound represented by Formulae 1A or 1B:



Formulae 1A

-continued

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;

$E_1$  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 0 to 5;

$b_1$  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  $C_3-C_{10}$  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  $C_6-C_{60}$  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, 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 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 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  $C_1$ - $C_{20}$  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  $C_2$ - $C_{10}$  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.
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 acenaphthylene group, a fluorenylene group, a spirofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoidolylene 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 cinolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzooxazolylene 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; 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 fluorenylene group, a spirofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pyrrolylene group, an imidazolylene group, a pyrazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an isoidolylene 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 cinolinylene group, a carbazolylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzooxazolylene group, a benzoimidazolylene group, a furanylene group, a benzofuranylene group, a thiophe-

nylene group, a benzothiophenylene group, a thiazolylylene group, an isothiazolylylene group, a benzothiazolylylene group, an isoxazolylylene group, an oxazolylylene group, a triazolylylene group, a tetrazolylylene group, an oxadiazolylylene group, a triazinylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene 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.

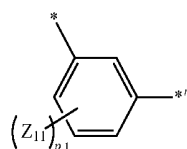
3. The carbazole compound of claim 1, wherein  $L_1$  is selected from

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 isoindolylylene group, an indolylylene 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 isoindolylylene group, an indolylylene 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 carbazoyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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.

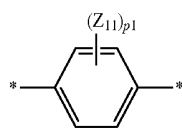
4. The carbazole compound of claim 1, wherein  $a_1$  is 1 or 2.

5. The carbazole compound of claim 1, wherein  $(L_1)_{a_1}$  is represented by one of Formulae 2A to 2F:

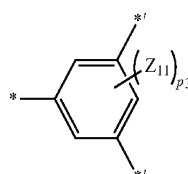


2A

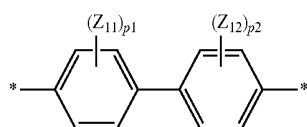
-continued



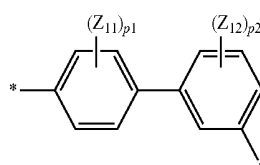
2B



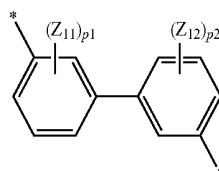
2C



2D



2E



2F

wherein in Formulae 2A to 2F,

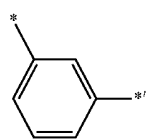
$Z_{11}$  and  $Z_{12}$  are each independently selected from a deuterium atom, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, 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 carbazoyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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;

$p_1$  and  $p_2$  are each independently an integer of 0 to 4;

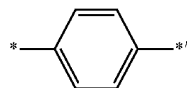
$p_3$  is an integer of 0 to 3; and

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

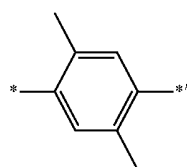
6. The carbazole compound of claim 1, wherein  $(L_1)_{a1}$  is represented by one of Formulae 3A to 3G:



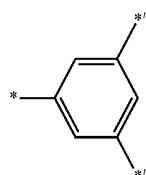
3A



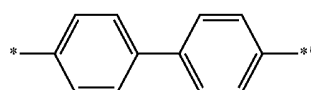
3B



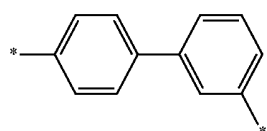
3C



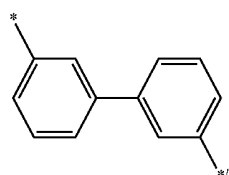
3D



3E



3F



3G

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 oxadiaz-

olyl 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  $Ar_1$ ,

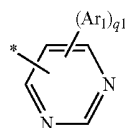
wherein  $Ar_1$  is selected from

a phenyl group, a 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 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

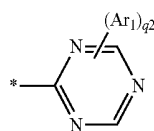
a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a 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 ben-

zoimidazolyl 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, a C<sub>1</sub>-C<sub>20</sub> 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.

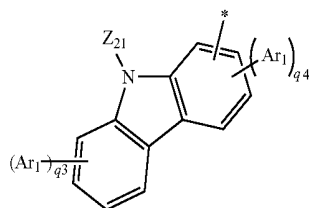
8. The carbazole compound of claim 1, wherein E<sub>1</sub> is represented by one of Formulae 4A to 4C:



4A



4B



4C

wherein in Formulae 4A to 4C,

Ar<sub>1</sub> is selected from 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;

Z<sub>21</sub> is selected from a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> alkoxy group;

a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> 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 benzocarbazolyl group, a dibenzocarbazolyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a quinazolinyl group;

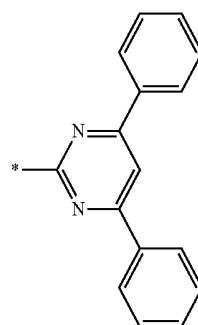
q<sub>1</sub> is an integer of 0 to 3;

q<sub>2</sub> is an integer of 0 to 2;

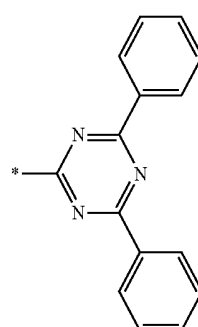
q<sub>3</sub> is an integer of 0 to 4; and

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

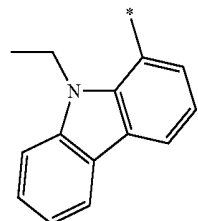
9. The carbazole compound of claim 1, wherein E<sub>1</sub> is represented by one of Formulae 5A to 5C:



5A



5B



5C

10. The carbazole compound of claim 1, wherein R<sub>1</sub> is selected from a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> alkoxy group; and

a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> 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 carbazoyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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  $R_1$  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  $R_2$  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  $C_1$ - $C_{20}$  alkyl group, a  $C_2$ - $C_{20}$  alkenyl group, 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, —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 carbazoyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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 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 carbazoyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzimidazolyl 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 benzocarbazoyl group, a dibenzocarbazoyl 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 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 carbazoyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzimidazolyl 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 benzocarbazoyl group, a dibenzocarbazoyl 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 carbazoyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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( $Q_{13}$ )( $Q_{14}$ ) and —Si( $Q_{15}$ )( $Q_{16}$ )( $Q_{17}$ ),

wherein  $Q_{13}$  to  $Q_{17}$  are 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 carbazoyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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  $R_2$  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  $C_1$ - $C_{20}$  alkyl group, a  $C_2$ - $C_{20}$  alkenyl group, a  $C_2$ - $C_{20}$  alkynyl group, and  $C_1$ - $C_{20}$  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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>2</sub>-C<sub>20</sub> alkenyl group, a C<sub>2</sub>-C<sub>20</sub> alkynyl group, a C<sub>1</sub>-C<sub>20</sub> 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(Q<sub>15</sub>)(Q<sub>16</sub>)(Q<sub>17</sub>),

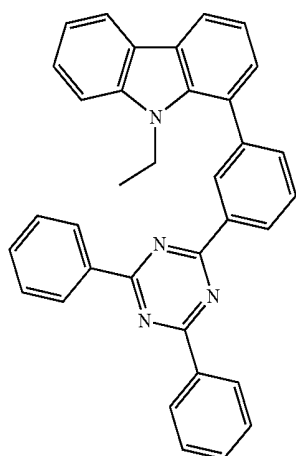
wherein Q<sub>15</sub> to Q<sub>17</sub> are each independently selected from a hydrogen, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, a fluorenyl group, a carbazolyl 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 R<sub>1</sub> is selected from a methyl group and an ethyl group; and

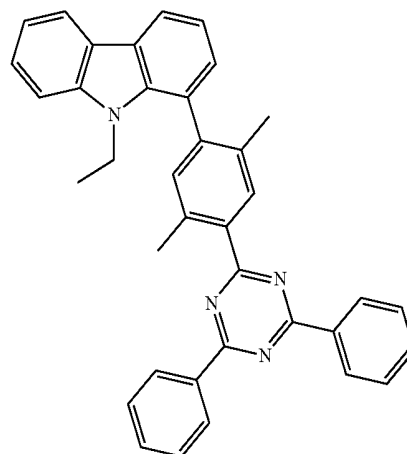
R<sub>2</sub> to R<sub>4</sub> are each independently selected from a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group.

**15.** The carbazole compound of claim 1, wherein at least one of R<sub>2</sub> to R<sub>4</sub> is each independently selected from fluorine and a C<sub>1</sub>-C<sub>20</sub> alkoxy group.

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



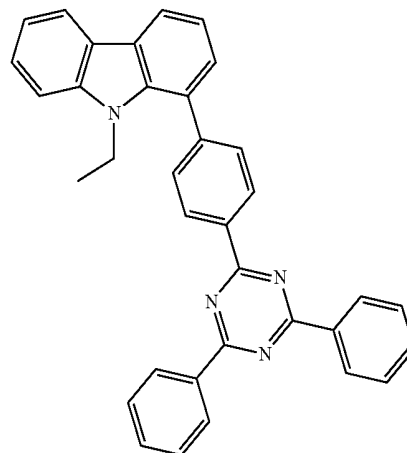
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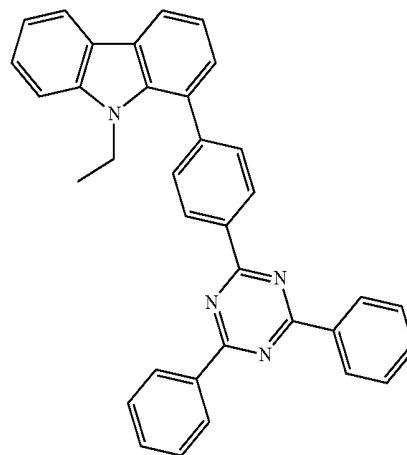
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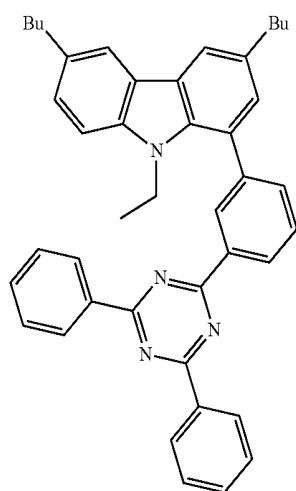
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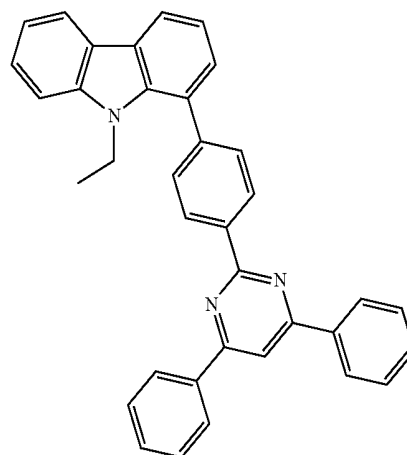


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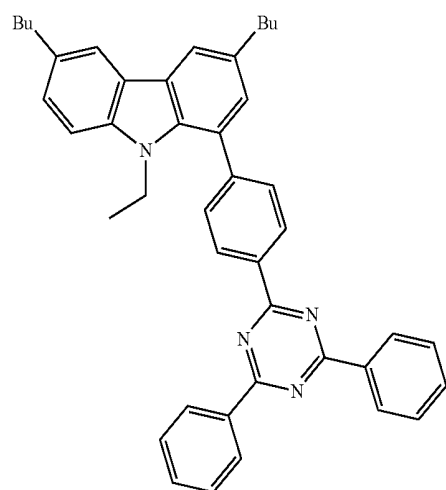


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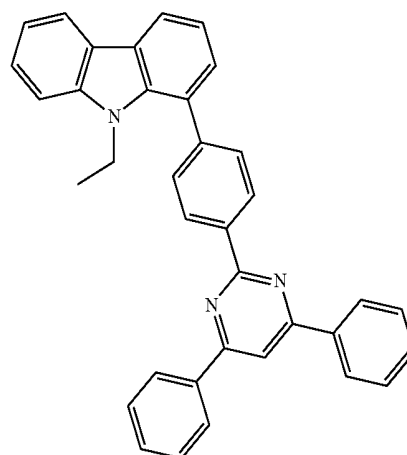
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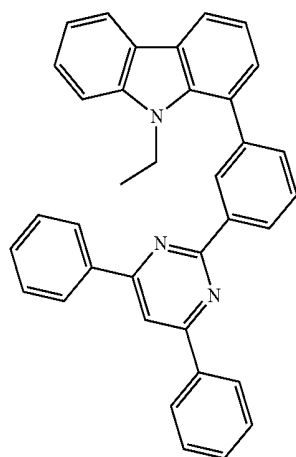
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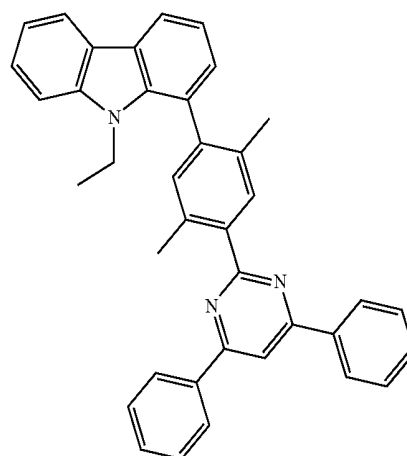
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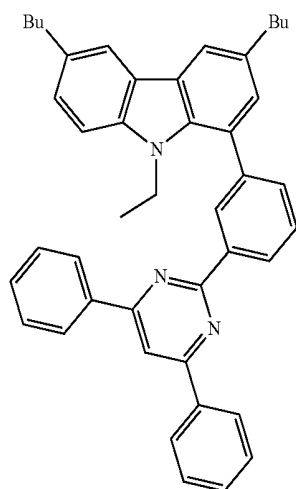


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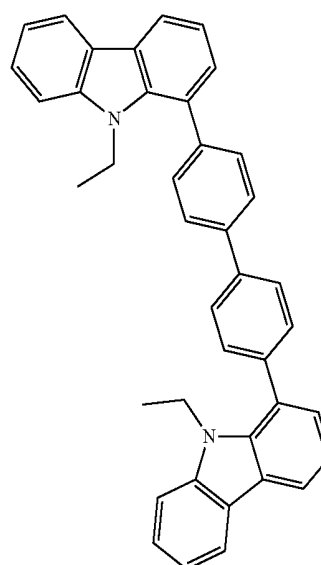
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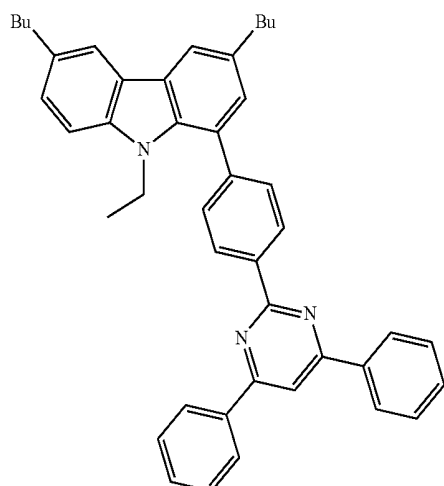
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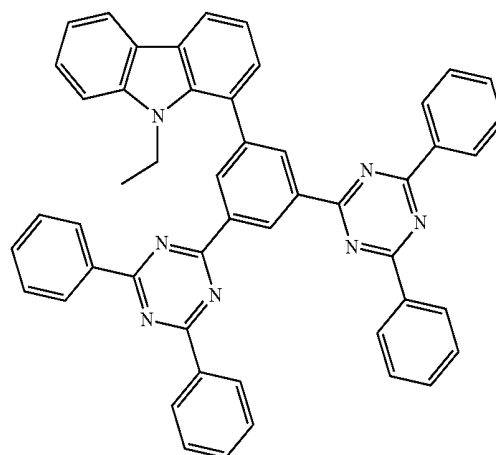
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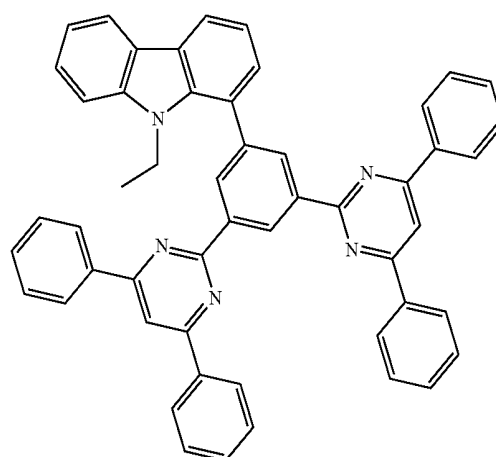
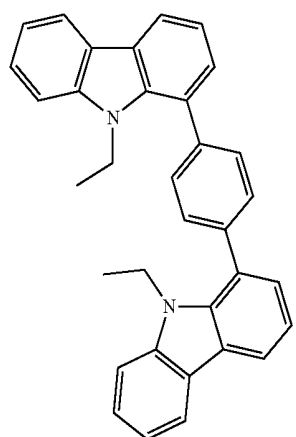


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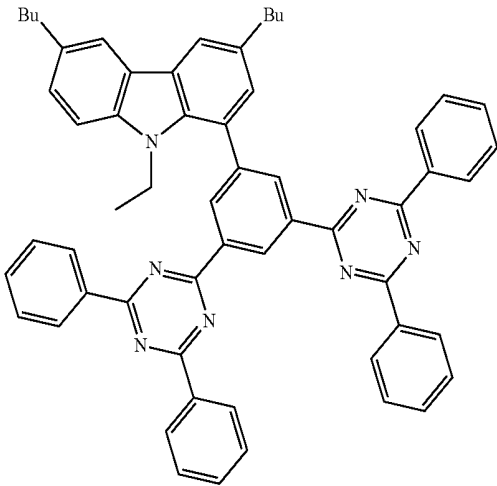


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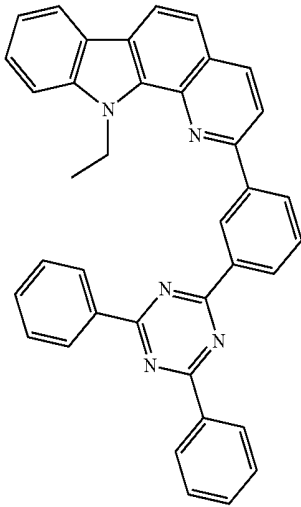


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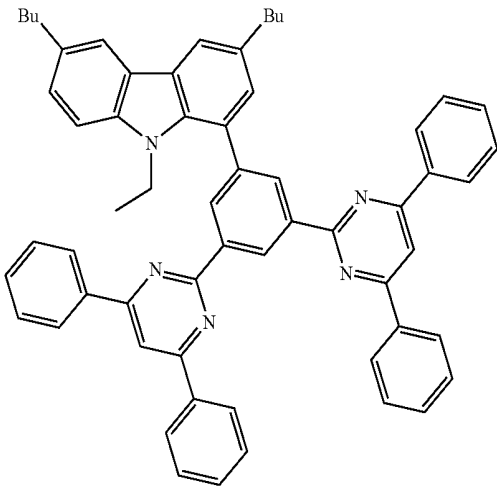
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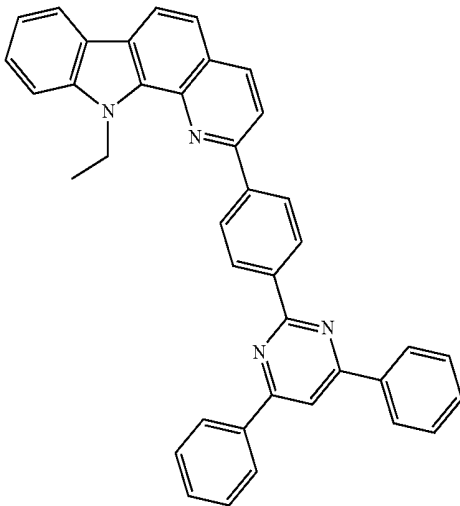


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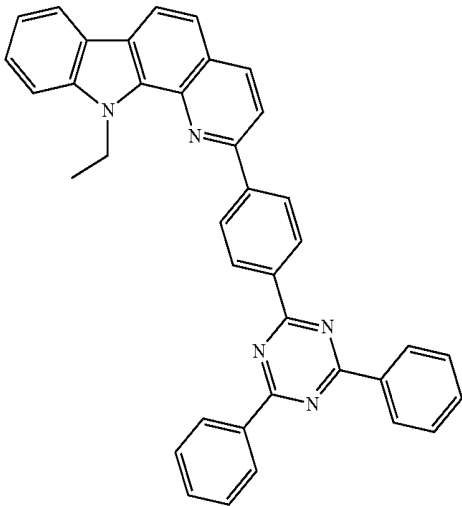
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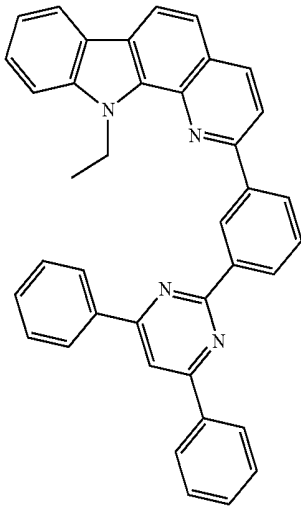
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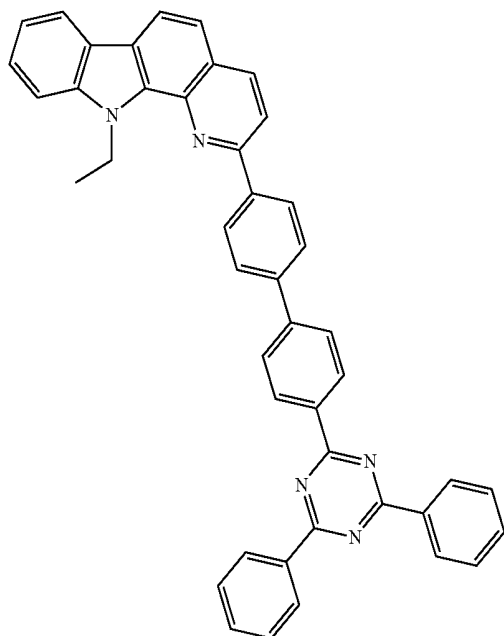


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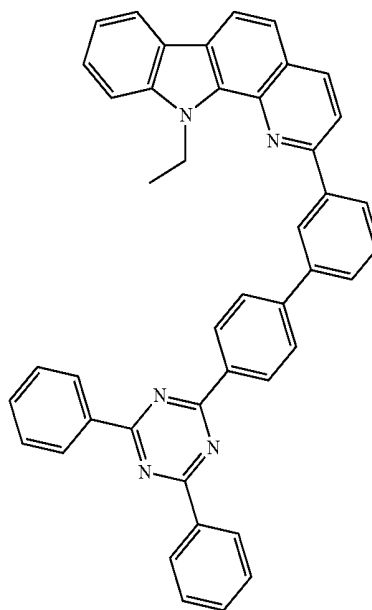
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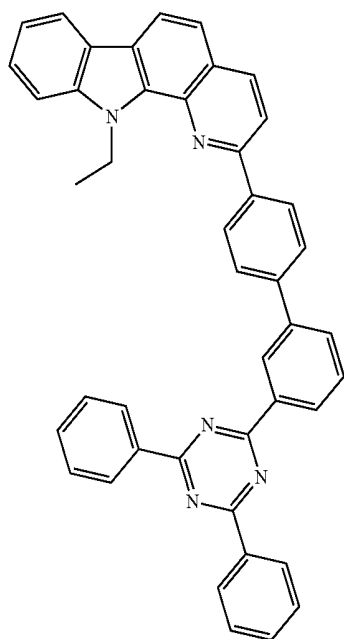


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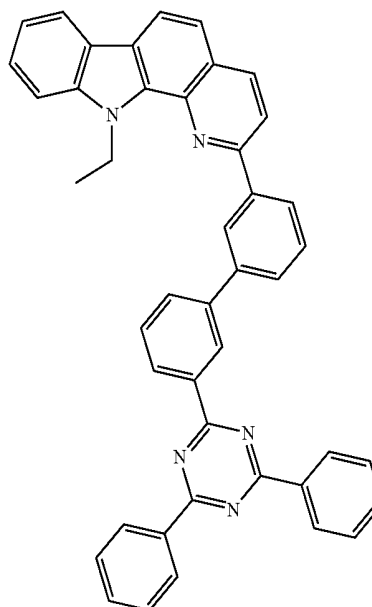
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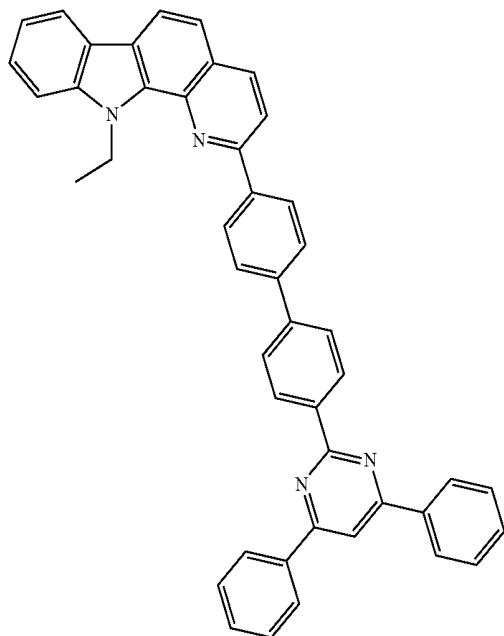


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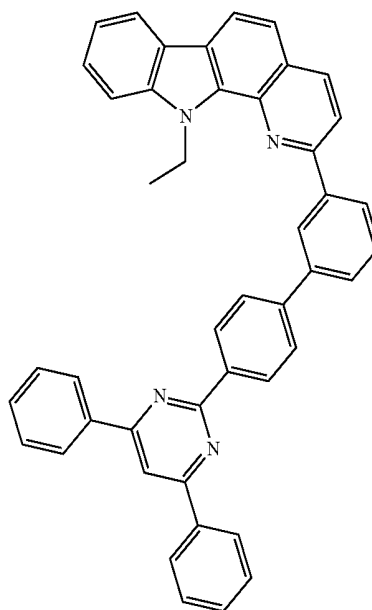
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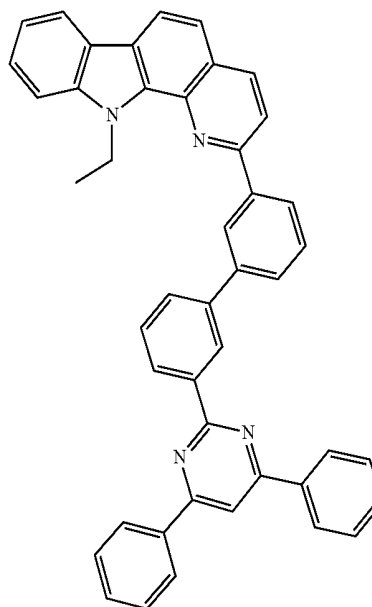


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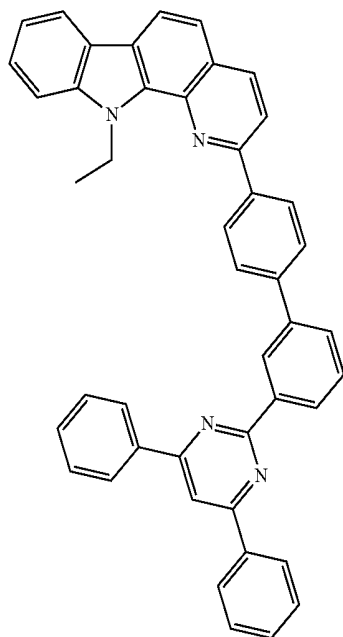
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**17.** An organic light-emitting device comprising  
a first electrode;  
a second electrode facing the first electrode; and  
an organic layer disposed between the first electrode and  
the second electrode, wherein the organic layer comprises an 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.

\* \* \* \* \*

专利名称(译)	唑唑化合物和包括其的有机发光器件		
公开(公告)号	<a href="#">US20150188058A1</a>	公开(公告)日	2015-07-02
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 H01L51/50 C07D403/14 C07D471/04 C07D403/10 C07D209/86		
CPC分类号	H01L51/0072 C07D403/10 C07D209/86 C07D403/14 C07D471/04 H01L51/5012 H01L51/5056 H01L51/5088 H01L51/5096 H01L51/5072 H01L51/5092 H01L51/0067		
优先权	2013273385 2013-12-27 JP 1020140162851 2014-11-20 KR		
其他公开文献	US10396294		
外部链接	<a href="#">Espacenet</a> <a href="#">USPTO</a>		

### 摘要(译)

由式1A或1B表示的唑啉化合物：其中在公式1A和1B中，A，R<sup>1</sup>到R<sup>4</sup>，c<sub>1</sub>到c<sub>3</sub>在说明书中描述。

[illegible]