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(54) **MATERIAL FOR ORGANIC ELECTROLUMINESCENCE DEVICE AND ORGANIC ELECTROLUMINESCENCE DEVICE**

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(57) **ABSTRACT**

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**Related U.S. Application Data**

(60) Provisional application No. 61/582,694, filed on Jan. 3, 2012, provisional application No. 61/669,406, filed on Jul. 9, 2012.

An organic electroluminescence device employing a specific biscarbazole derivative having a cyano group as a first host and a compound having both a carbazole structure and a nitrogen-containing aromatic heteroring as a second host. The organic electroluminescence device has a prolonged life-time.

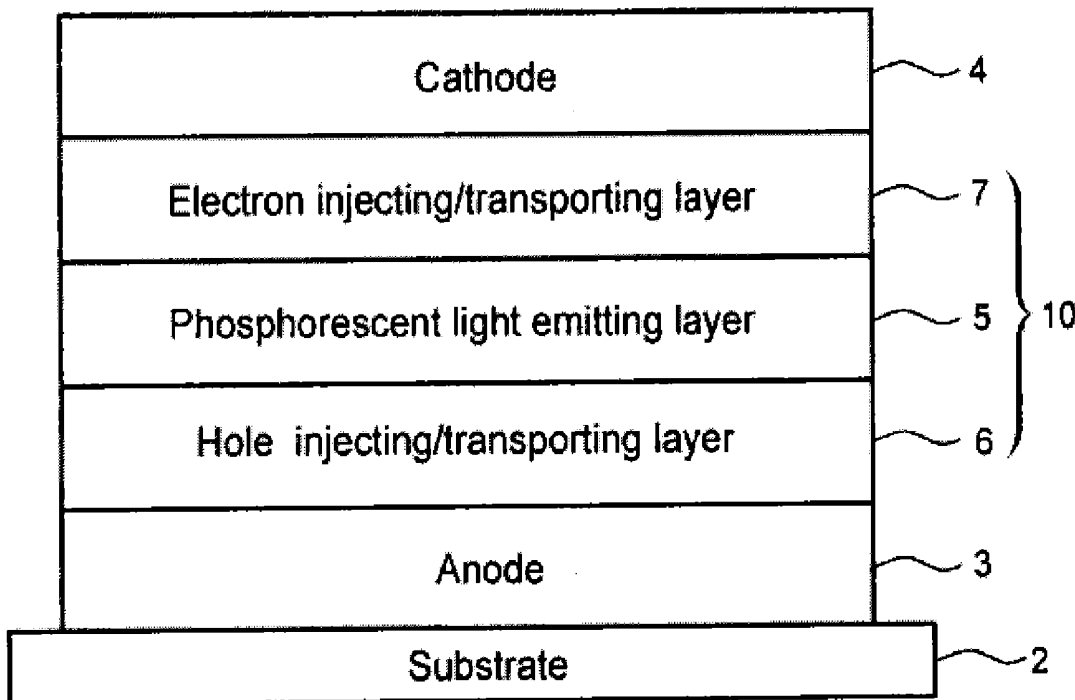
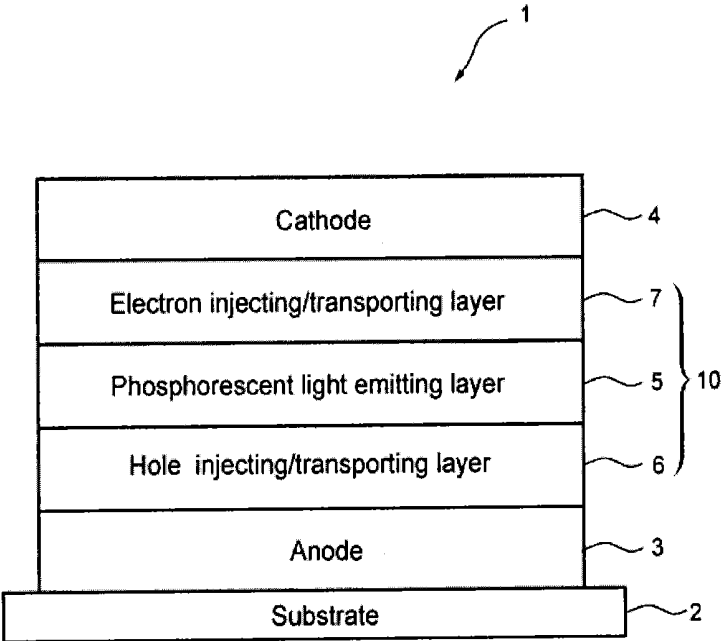


Fig. 1



**MATERIAL FOR ORGANIC  
ELECTROLUMINESCENCE DEVICE AND  
ORGANIC ELECTROLUMINESCENCE  
DEVICE**

TECHNICAL FIELD

**[0001]** The present invention relates to organic electroluminescence devices.

BACKGROUND ART

**[0002]** By applying voltage to an organic electroluminescence device (also referred to as "organic EL device"), holes from an anode and electrons from a cathode are injected into a light emitting layer. The holes and electrons injected into the light emitting layer recombine to form excitons. The singlet exciton and the triplet exciton are formed at a ratio of 25%:75% according to spin-statistics theorem. Since the fluorescence utilizes the emission from singlet excitons, it has been known that the internal quantum efficiency of a fluorescent organic EL device is limited to 25%. In contrast, since the phosphorescence utilizes the emission from triplet excitons, it has been known that the internal quantum efficiency of a phosphorescent organic EL device can be increased to 100% if the intersystem crossing occurs efficiently.

**[0003]** In the development of known organic EL devices, an optimum device design has been made depending upon the emission mechanism such as fluorescence and phosphorescence. It has been known in the art that a high-performance phosphorescent organic EL device cannot be obtained by a mere application of the fluorescent technique to the phosphorescent device, because the emission mechanisms are different from each other. This may be generally because the following reasons.

**[0004]** Since the phosphorescence utilizes the emission from triplet excitons, a compound with larger energy gap is required to be used in the light emitting layer. This is because that the singlet energy (energy difference between the lowest excited singlet state and the ground state) of a compound is generally larger than its triplet energy (energy difference between the lowest excited triplet state and the ground state).

**[0005]** Therefore, to effectively confine the triplet energy of a phosphorescent dopant material within a device, a host material having triplet energy larger than that of the phosphorescent dopant material should be used in the light emitting layer. In addition, if an electron transporting layer and a hole transporting layer is formed adjacent to the light emitting layer, a compound having triplet energy larger than that of the phosphorescent dopant material should be used also in the electron transporting layer and the hole transporting layer. Thus, the device design conventionally employed for developing a phosphorescent organic EL device results in the use of a compound having an energy gap larger than that of a compound for use in a fluorescent organic EL device, thereby increasing the voltage for driving an organic EL device.

**[0006]** A hydrocarbon compound highly resistant to oxidation and reduction, which has been known as a useful compound for a fluorescent device, has a small energy gap because of a broad distribution  $\pi$ -electron cloud. Therefore, such a hydrocarbon compound is not suitable for use in a phosphorescent organic EL device and, instead, an organic compound having a heteroatom, such as oxygen and nitrogen, has been selected. However, a phosphorescent organic EL

device employing such an organic compound having a heteroatom has a shorter lifetime as compared with a fluorescent organic EL device.

**[0007]** In addition, a phosphorescent dopant material has an extremely longer relaxation time of triplet excitons as compared with that of its singlet excitons, this largely affecting the device performance. Namely, in the emission from singlet excitons, since the relaxation speed which leads to emission is high, the diffusion of excitons into a layer adjacent to the light emitting layer (for example, a hole transporting layer and an electron transporting layer) is difficult to occur and efficient emission is expected. In contrast, the emission from triplet excitons is a spin-forbidden transition and the relaxation speed is low. Therefore, the diffusion of excitons into adjacent layers occurs easily and the thermal energy deactivation occurs in most compounds other than the specific phosphorescent compound. Thus, as compared with a fluorescent organic EL device, it is more important for a phosphorescent organic EL device to control the region for recombining electrons and holes.

**[0008]** For the above reasons, the development of a high performance phosphorescent organic EL device requires the selection of materials and the consideration of device design which are different from those for a fluorescent organic EL device.

**[0009]** A carbazole derivative having a high triplet energy known as a hole transporting material has been used as a useful host material of phosphorescent organic EL device.

**[0010]** Patent Documents 1 and 2 describes to use a compound in which a nitrogen-containing heterocyclic group is introduced into a biscarbazole skeleton which includes two carbazole structures connected to each other in the light emitting layer of phosphorescent organic EL device as the host material. The compounds described in Patent Documents 1 and 2 are molecularly designed to balance the charge transport by introducing an electron-deficient nitrogen-containing heterocyclic group to a hole transporting carbazole skeleton. However, organic EL devices employing the compounds described in Patent Documents 1 and 2 have been required to improve their lifetime.

**[0011]** Patent Document 3 discloses that the lifetime is prolonged by combinedly using two or more kinds of host materials in the light emitting layer and many studies have been made on the combination of host materials.

**[0012]** However, an organic EL device having a further prolonged lifetime has been demanded.

PRIOR ART

Patent Documents

Patent Document 1: WO2011/132683

Patent Document 2: WO2011/132684

Patent Document 3: WO2011/155507

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

**[0013]** An object of the invention is to provide an organic electroluminescence having a long lifetime.

## Means for Solving Problem

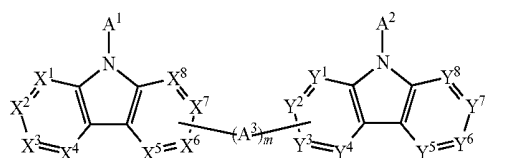
[0014] As a results of extensive research for achieving the above object, the inventors have found that the lifetime of organic EL device can be further increased by using a specific biscarbazole derivative having a cyano group as a first host and a compound having both a carbazole structure and a nitrogen-containing aromatic heteroring as a second host in a light emitting layer. The present invention is based on this finding.

[0015] The present invention provides:

[0016] 1. An organic electroluminescence device which comprises a light emitting layer which is disposed between a cathode and an anode and comprises a first host material, a second host material and a light emitting material,

[0017] wherein

[0018] the first host material is represented by formula (A):



wherein

[0019] each of A<sup>1</sup> and A<sup>2</sup> independently represents a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms;

[0020] A<sup>3</sup> represents a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms

[0021] m represents an integer of 0 to 3;

[0022] each of X<sup>1</sup> to X<sup>8</sup> and Y<sup>1</sup> to Y<sup>8</sup> independently represents N or CR<sup>a</sup>;

[0023] each of R<sup>a</sup> independently represents a hydrogen atom, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted silyl group, a halogen atom, or a cyano group, provided that when two or more R<sup>a</sup> groups exist, the R<sup>a</sup> groups may be the same or different and one of X<sup>5</sup> to X<sup>8</sup> and one of Y<sup>1</sup> to Y<sup>4</sup> are bonded to each other via A<sup>3</sup>; and

[0024] the formula (A) satisfies at least one of the following requirements (i) to (v):

[0025] (i) at least one of A<sup>1</sup> and A<sup>2</sup> represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms;

[0026] (ii) at least one of X<sup>1</sup> to X<sup>4</sup> and Y<sup>5</sup> to Y<sup>8</sup> represents CR<sup>a</sup>, and at least one of R<sup>a</sup> in X<sup>1</sup> to X<sup>4</sup> and Y<sup>5</sup> to Y<sup>8</sup> represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms;

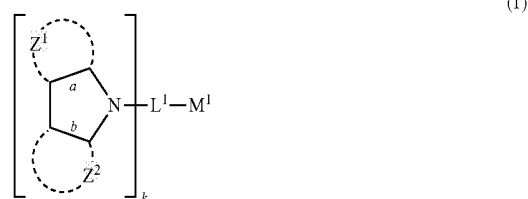
[0027] (iii) m represents an integer of 1 to 3 and at least one of A<sup>3</sup> represents a cyano-substituted divalent aromatic hydro-

carbon group having 6 to 30 ring carbon atoms or a cyano-substituted divalent heterocyclic group having 5 to 30 ring atoms;

[0028] (iv) at least one of X<sup>5</sup> to X<sup>8</sup> and Y<sup>1</sup> to Y<sup>4</sup> represents CR<sup>a</sup>, and at least one of R<sup>a</sup> in X<sup>5</sup> to X<sup>8</sup> and Y<sup>1</sup> to Y<sup>8</sup> represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms; and

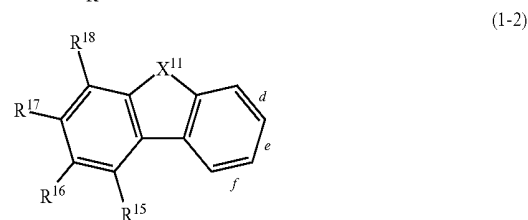
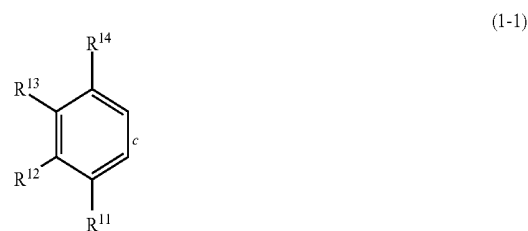
[0029] (v) at least one of X<sup>1</sup> to X<sup>8</sup> and Y<sup>1</sup> to Y<sup>8</sup> represents C—CN; and

[0030] the second host material is represented by formula (1);



wherein

[0031] Z<sup>1</sup> represents a ring structure fused to a side a and represented by formula (1-1) or (1-2), and Z<sup>2</sup> represents a ring structure fused to a side b and represented by formula (1-1) or (1-2), provided that at least one of Z<sup>1</sup> and Z<sup>2</sup> is represented by formula (1-1);



in formula (1-1),

[0032] a side c is fused to the side a or b of formula (1); in formula (1-2),

[0033] any one of sides d, e and f is fused to the side a or b of formula (1);

in formulae (1-1) and (1-2),

[0034] X<sup>11</sup> represents a sulfur atom, an oxygen atom, N—R<sup>19</sup>, or C(R<sup>20</sup>)(R<sup>21</sup>);

[0035] each of R<sup>11</sup> to R<sup>21</sup> independently represents a hydrogen atom, a heavy hydrogen atom, a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl

group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms, provided that adjacent groups of  $R^{11}$  to  $R^{21}$  may be bonded to each other to form a ring;

[0036]  $M^1$  represent a substituted or unsubstituted nitrogen-containing aromatic heteroring having 5 to 30 ring atoms;

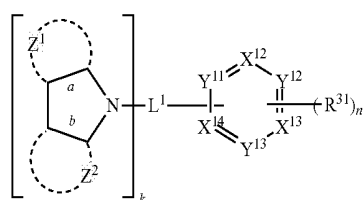
[0037]  $L^1$  represents a single bond, a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms, a cycloalkylene group having 5 to 30 ring atoms, or a group in which the preceding groups are directly linked to each other; and

[0038]  $k$  represents 1 or 2;

[0039] 2. The organic electroluminescence device according to item 1, wherein the first host material satisfies at least one of the requirements (i) and (ii);

[0040] 3. The organic electroluminescence device according to item 1 or 2, wherein  $A^3$  of formula (A) represents a substituted or unsubstituted divalent monocyclic hydrocarbon group having 6 or less ring carbon atoms or a substituted or unsubstituted divalent monocyclic heterocyclic group having 6 or less ring atoms;

[0041] 4. The organic electroluminescence device according to any one of items 1 to 3, wherein the second host material is represented by formula (2):



(2)

wherein

[0042]  $Z^1$  represents a ring structure fused to the side a and represented by formula (1-1) or (1-2), and  $Z^2$  represents a ring structure fused to the side b and represented by formula (1-1) or (1-2), provided that at least one of  $Z^1$  and  $Z^2$  is represented by formula (1-1);

[0043]  $L^1$  is as defined in formula (1);

[0044] each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

[0045] each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

[0046] each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylnyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30

ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

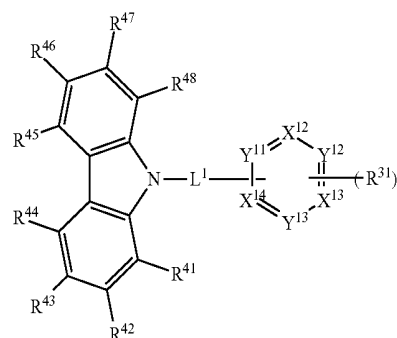
[0047] when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

[0048]  $k$  represents 1 or 2, and  $n$  represents an integer of 0 to 4;

[0049] the side c of formula (1-1) is fused to the side a or b of formula (2); and

[0050] any one of sides d, e and f of formula (1-2) is fused to the side a or b of formula (2);

[0051] 5. The organic electroluminescence device according to any one of items 1 to 4, wherein the second host material is represented by formula (3):



(3)

wherein

[0052]  $L^1$  is as defined in formula (1);

[0053] each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

[0054] each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

[0055] each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylnyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30, ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

[0056] when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

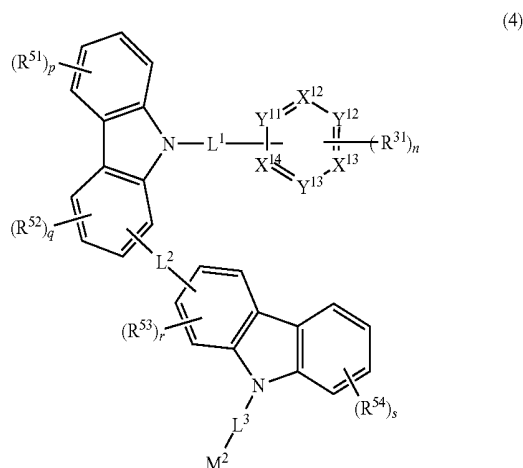
[0057]  $n$  represents an integer of 0 to 4;

[0058] each of  $R^{41}$  to  $R^{48}$  independently represents a hydrogen atom, a heavy hydrogen atom, a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a

substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms; and adjacent groups of  $R^{41}$  to  $R^{48}$  may be bonded to each other to form a ring;

**[0059]** 6. The organic electroluminescence device according to any one of items 1 to 5, wherein the first host material satisfies only the requirement (i);

**[0060]** 7. The organic electroluminescence device according to any one of items 1 to 5, wherein the second host material is represented by formula (4):



wherein

**[0061]**  $L^1$  is as defined in formula (1);

**[0062]** each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

**[0063]** each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

**[0064]** each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

**[0065]** when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

**[0066]**  $n$  represents an integer of 0 to 4;

**[0067]** each of  $L^2$  and  $L^3$  independently represents a single bond, a substituted or unsubstituted divalent aromatic hydro-

carbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms, a cycloalkylene group having 5 to 30 ring atoms, or a group in which the preceding groups are directly linked to each other;

**[0068]** each of  $R^{51}$  to  $R^{54}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

**[0069]** when two or more  $R^{51}$  groups exist, the  $R^{51}$  groups may be the same or different and adjacent  $R^{51}$  groups may be bonded to each other to form a ring;

**[0070]** when two or more  $R^{52}$  groups exist, the  $R^{52}$  groups may be the same or different and adjacent  $R^{52}$  groups may be bonded to each other to form a ring;

**[0071]** when two or more  $R^{53}$  groups exist, the  $R^{53}$  groups may be the same or different and adjacent  $R^{53}$  groups may be bonded to each other to form a ring;

**[0072]** when two or more  $R^{54}$  groups exist, the  $R^{54}$  groups may be the same or different and adjacent  $R^{54}$  groups may be bonded to each other to form a ring;

**[0073]**  $M^2$  represents a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms; and

**[0074]** each of  $p$  and  $s$  independently represents an integer of 0 to 4, and each of  $q$  and  $r$  independently represents an integer of 0 to 3;

**[0075]** 8. The organic electroluminescence device according to any one of items 1 to 7, wherein at least one of  $A^1$  and  $A^2$  represents a cyano-substituted phenyl group, a cyano-substituted naphthyl group, a cyano-substituted phenanthryl group, a cyano-substituted dibenzofuranyl group, a cyano-substituted dibenzothiophenyl group, a cyano-substituted biphenyl group, a cyano-substituted terphenyl group, a cyano-substituted 9,9-diphenylfluorenyl group, a cyano-substituted 9,9'-spirobi[9H-fluorene]-2-yl group, a cyano-substituted 9,9'-dimethylfluorenyl group, or a cyano-substituted triphenylenyl group;

**[0076]** 9. The organic electroluminescence device according to any one of items 1 to 8, wherein the light emitting material comprises a phosphorescent emitting material selected from ortho metallated complexes of a metal selected from iridium (Ir), osmium (Os), and platinum (Pt); and

**[0077]** 10. The organic electroluminescence device according to any one of items 1 to 9, wherein a peak of emission wavelength of the phosphorescent emitting material is 490 nm or longer and 700 nm or shorter.

#### Effect of the Invention

**[0078]** According to the present invention, an organic electroluminescence device having a long lifetime is provided.

## BRIEF DESCRIPTION OF DRAWINGS

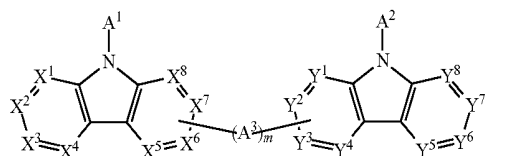
[0079] FIG. 1 is a schematic cross-sectional view of an example of the organic EL device of the invention.

## MODE FOR CARRYING OUT THE INVENTION

[0080] The organic electroluminescence device (hereinafter also referred to as “organic EL device”) of the invention comprises a light emitting layer disposed between a cathode and an anode, wherein the light emitting layer comprises a first host material represented by the following formula (A), a second host material represented by the following formula (1), and a light emitting material.

First Host Material

[0081]



wherein

[0082] each of  $A^1$  and  $A^2$  independently represents a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms;

[0083]  $A^3$  represents a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms

[0084]  $m$  represents an integer of 0 to 3;

[0085] each of  $X^1$  to  $X^8$  and  $Y^1$  to  $Y^8$  independently represents N or  $CR^a$ ;

[0086] each of  $R^a$  independently represents a hydrogen atom, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted silyl group, a halogen atom, or a cyano group, provided that when two or more  $R^a$  groups exist, the  $R^a$  groups may be the same or different and one of  $X^5$  to  $X^8$  and one of  $Y^1$  to  $Y^4$  are bonded to each other via  $A^3$ ; and

[0087] the formula (A) satisfies at least one of the following requirements (i) to (v);

[0088] (i) at least one of  $A^1$  and  $A^2$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms;

[0089] (ii) at least one of  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  represents  $CR^a$ , and at least one of  $R^a$  in  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms;

[0090] (iii)  $m$  represents an integer of 1 to 3 and at least one of  $A^3$  represents a cyano-substituted divalent aromatic hydro-

carbon group having 6 to 30 ring carbon atoms or a cyano-substituted divalent heterocyclic group having 5 to 30 ring atoms;

[0091] (iv) at least one of  $X^5$  to  $X^8$  and  $Y^1$  to  $Y^4$  represents  $CR^a$ , and at least one of  $R^a$  in  $X^5$  to  $X^8$  and  $Y^1$  to  $Y^8$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms; and

[0092] (v) at least one of  $X^1$  to  $X^8$  and  $Y^1$  to  $Y^8$  represents  $C-CN$ .

[0093] The cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms and the cyano-substituted heterocyclic group having 5 to 30 ring atoms may be further substituted by a group other than the cyano group.

[0094] The subscript  $m$  is preferably 0 to 2 and more preferably 0 or 1. When  $m$  is 0, one of  $X^5$  to  $X^8$  and one of  $Y^1$  to  $Y^4$  are bonded to each other via a single bond.

[0095] The aromatic hydrocarbon group having 6 to 30 ring carbon atoms represented by  $A^1$ ,  $A^2$  and  $R^a$  may be a non-condensed aromatic hydrocarbon group or a condensed aromatic hydrocarbon group. Specific examples thereof include phenyl group, naphthyl group, phenanthryl group, biphenyl group, terphenyl group, quaterphenyl group, fluoranthenyl group, triphenylenyl group, phenanthrenyl group, fluorenyl group, spirofluorenyl group, 9,9-diphenylfluorenyl group, 9,9'-spiro[9H-fluorene]-2-yl group, 9,9-dimethylfluorenyl group, benzo[c]phenanthrenyl group, benzo[a]triphenylenyl group, naphtho[1,2-c]phenanthrenyl group, naphtho[1,2-a]triphenylenyl group, dibenzo[a,c]triphenylenyl group, and benzo[b]fluoranthenyl group, with phenyl group, naphthyl group, biphenyl group, terphenyl group, phenanthryl group, triphenylenyl group, fluorenyl group, spirobifluorenyl group, and fluoranthenyl group being preferred, and phenyl group, 1-naphthyl group, 2-naphthyl group, biphenyl-2-yl group, biphenyl-3-yl group, biphenyl-4-yl group, phenanthrene-9-yl group, phenanthrene-3-yl group, phenanthrene-2-yl group, triphenylene-2-yl group, 9,9-dimethylfluorene-2-yl group, fluoranthene-3-yl group being more preferred.

[0096] Examples of the divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms represented by  $A^3$  include divalent residues of the above aromatic hydrocarbon groups having 6 to 30 ring carbon atoms.

[0097] The heterocyclic group having 5 to 30 ring atoms represented by  $A^1$ ,  $A^2$  and  $R^a$  may be a non-condensed heterocyclic group or a condensed heterocyclic group. Specific examples thereof include the residues of pyrrole ring, indole ring, benzofuran ring, isobenzofuran ring, dibenzothiothiophene ring, isoquinoline ring, quinoxaline ring, phenanthridine ring, phenanthroline ring, pyridine ring, pyrazine ring, pyrimidine ring, pyridazine ring, triazine ring, indole ring, quinoline ring, acridine ring, pyrrolidine ring, dioxane ring, piperidine ring, morpholine ring, piperazine ring, carbazole ring, furan ring, thiophene ring, oxazole ring, oxadiazole ring, benzoxazole ring, thiazole ring, thiadiazole ring, benzothiazole ring, triazole ring, imidazole ring, benzimidazole ring, pyran ring, dibenzofuran ring, and benzo[c]dibenzofuran ring, and the residues of derivatives of these rings, with the residues of dibenzofuran ring, carbazole ring, dibenzothiophene ring, and derivatives of these rings being preferred, and the residues of dibenzofuran-2-yl group, dibenzofuran-4-yl group, 9-phenylcarbazole-3-yl group, 9-phenylcarbazole-2-yl group, dibenzothiophene-2-yl group, and dibenzothiophene-4-yl group being more preferred.

**[0098]** Examples of the divalent heterocyclic group having 5 to 30 ring atoms represented by  $A^3$  include divalent residues of the above heterocyclic group having 5 to 30 ring atoms.

**[0099]** Examples of the alkyl group having 1 to 30 carbon atoms represented by  $R^a$  include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group, n-dodecyl group, n-tridecyl group, n-tetradecyl group, n-pentadecyl group, n-hexadecyl group, n-heptadecyl group, n-octadecyl group, neopentyl group, 1-methylpentyl group, cyclopropyl group, cyclobutyl group, cyclopentyl group, cyclohexyl group, cyclooctyl group, and adamantyl group, with methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, cyclopentyl group, and cyclohexyl group being preferred.

**[0100]** Examples of the substituted or unsubstituted silyl group represented by  $R^a$  include trimethylsilyl group, triethylsilyl group, tributylsilyl group, dimethylethylsilyl group, t-butyl dimethylsilyl group, vinyl dimethylsilyl group, propyl dimethylsilyl group, dimethylisopropylsilyl group, dimethylpropylsilyl group, dimethylbutylsilyl group, dimethyltertiarybutylsilyl group, diethylisopropylsilyl group, phenyldimethylsilyl group, diphenylmethylsilyl group, diphenyltertiarybutylsilyl group, and triphenylsilyl group, with trimethylsilyl group, triethylsilyl group, t-butyl dimethylsilyl group, vinyl dimethylsilyl group, and propyl dimethylsilyl group being preferred.

**[0101]** Examples of the halogen atom represented by  $R^a$  include fluorine, chlorine, bromine, and iodine, with fluorine being preferred.

**[0102]** Also preferred as  $R^a$  is a hydrogen atom or a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms.

**[0103]** Examples of the optional substituent indicated by "substituted or unsubstituted" and "may be substituted" referred to above or hereinafter include a halogen atom (fluorine, chlorine, bromine, iodine), a cyano group, an alkyl group having 1 to 20, preferably 1 to 6 carbon atoms, a cycloalkyl group having 3 to 20, preferably 5 to 12 carbon atoms, an alkoxy group having 1 to 20, preferably 1 to 5 carbon atoms, a haloalkyl group having 1 to 20, preferably 1 to 5 carbon atoms, a haloalkoxy group having 1 to 20, preferably 1 to 5 carbon atoms, an alkylsilyl group having 1 to 10, preferably 1 to 5 carbon atoms, an aromatic hydrocarbon group having 6 to 30, preferably 6 to 18 ring carbon atoms, an aryloxy group having 6 to 30, preferably 6 to 18 ring carbon atoms, an arylsilyl group having 6 to 30, preferably 6 to 18 carbon atoms, an aralkyl group having 7 to 30, preferably 7 to 20 carbon atoms, and a heteroaryl group having 5 to 30, preferably 5 to 18 ring atoms.

**[0104]** Examples of the optional alkyl group having 1 to 20 carbon atoms include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group, n-dodecyl group, n-tridecyl group, n-tetradecyl group, n-pentadecyl group, n-hexadecyl group, n-heptadecyl group, n-octadecyl group, neopentyl group, and 1-methylpentyl group.

**[0105]** Examples of the optional cycloalkyl group having 3 to 20 carbon atoms include cyclopropyl group, cyclobutyl group, cyclopentyl group, cyclohexyl group, cyclooctyl group, and adamantyl group.

**[0106]** Examples of the optional alkoxy group having 1 to 20 carbon atoms include those having an alkyl portion selected from the alkyl groups mentioned above.

**[0107]** Examples of the optional haloalkyl group having 1 to 20 carbon atoms include the alkyl groups mentioned above wherein the hydrogen atoms thereof are partly or entirely substituted by halogen atoms.

**[0108]** Examples of the optional haloalkoxy group having 1 to 20 carbon atoms include the alkoxy group mentioned above wherein the hydrogen atoms thereof are partly or entirely substituted by halogen atoms.

**[0109]** Examples of the optional alkylsilyl group having 1 to 10 carbon atoms include trimethylsilyl group, triethylsilyl group, tributylsilyl group, dimethylethylsilyl group, t-butyl dimethylsilyl group, vinyl dimethylsilyl group, propyl dimethylsilyl group, dimethylisopropylsilyl group, dimethylpropylsilyl group, dimethylbutylsilyl group, dimethyltertiarybutylsilyl group, and diethylisopropylsilyl group.

**[0110]** Examples of the optional aromatic hydrocarbon group having 6 to 30 ring carbon atoms include those selected from the aromatic hydrocarbon groups mentioned above with respect to  $A^1$ ,  $A^2$  and  $R^a$ .

**[0111]** Examples of the optional aryloxy group having 6 to 30 ring carbon atoms include those having an aryl portion selected from the aromatic hydrocarbon groups mentioned above.

**[0112]** Examples of the optional arylsilyl group having 6 to 30 carbon atoms include phenyldimethylsilyl group, diphenylmethylsilyl group, diphenyltertiarybutylsilyl group, and triphenylsilyl group.

**[0113]** Examples of the optional aralkyl group having 7 to 30 carbon atoms include benzyl group, 2-phenylpropane-2-yl group, 1-phenylethyl group, 2-phenylethyl group, 1-phenylisopropyl group, 2-phenylisopropyl group, phenyl-t-butyl group,  $\alpha$ -naphthylmethyl group, 1- $\alpha$ -naphthylethyl group, 2- $\alpha$ -naphthylethyl group, 1- $\alpha$ -naphthylisopropyl group, 2- $\alpha$ -naphthylisopropyl group,  $\beta$ -naphthylmethyl group, 1- $\beta$ -naphthylethyl group, 2- $\beta$ -naphthylethyl group, 1- $\beta$ -naphthylisopropyl group, 2- $\beta$ -naphthylisopropyl group, 1-pyrrolylmethyl group, 2-(1-pyrrolyl)ethyl group, p-methylbenzyl group, m-methylbenzyl group, o-methylbenzyl group, p-chlorobenzyl group, m-chlorobenzyl group, o-chlorobenzyl group, p-bromobenzyl group, m-bromobenzyl group, o-bromobenzyl group, p-iodobenzyl group, m-iodobenzyl group, o-iodobenzyl group, p-hydroxybenzyl group, m-hydroxybenzyl group, o-hydroxybenzyl group, p-aminobenzyl group, m-aminobenzyl group, o-aminobenzyl group, p-nitrobenzyl group, m-nitrobenzyl group, o-nitrobenzyl group, p-cyanobenzyl group, m-cyanobenzyl group, o-cyanobenzyl group, 1-hydroxy-2-phenylisopropyl group, and 1-chloro-2-phenylisopropyl group.

**[0114]** Examples of the optional heteroaryl group having 5 to 30 ring atoms include those selected from the heterocyclic groups mentioned above with respect to  $A^1$ ,  $A^2$  and  $R^a$ .

**[0115]** The optional substituent is preferably fluorine atom, cyano group, the alkyl group having 1 to 20 carbon atoms, the aromatic hydrocarbon group having 6 to 30 ring carbon atoms, and the heteroaryl group having 5 to 30 ring atoms, more preferably fluorine atom, phenyl group, naphthyl group,

biphenyl group, terphenyl group, phenanthryl group, triphenylenyl group, fluorenyl group, spirobifluorenyl group, fluo-ranthenyl group, residues of dibenzofuran ring, carbazole ring, dibenzothiophene ring, and their derivatives, methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, cyclopentyl group, and cyclohexyl group.

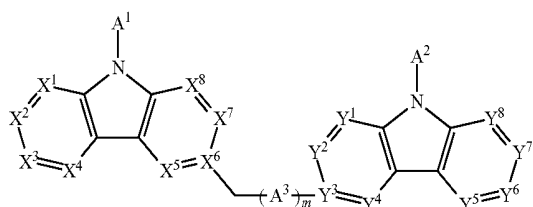
[0116] The optional substituent mentioned above may be further substituted by the optional group mentioned above.

[0117] The “carbon number of a to b” in the expression of “substituted or unsubstituted X group having carbon number of a to b” is the carbon number of the unsubstituted X group and does not include the carbon atom of the optional substituent.

[0118] The hydrogen atom referred to herein includes isotopes different from neutron numbers, i.e., light hydrogen (protium), heavy hydrogen (deuterium) and tritium.

[0119] In the first host material represented by formula (A), the groups represented by formulae (a) and (b) are bonded to each other via  $-(A^3)_m-$  at one of  $X^5$  to  $X^8$  and one of  $Y^1$  to  $Y^4$ . Specific examples of the bonding manner between formulae (a) and (b) are represented by  $X^6-(A^3)_m-Y^3$ ,  $X^6-(A^3)_m-Y^2$ ,  $X^6-(A^3)_m-Y^4$ ,  $X^6-(A^3)_m-Y^1$ ,  $X^7-(A^3)_m-Y^3$ ,  $X^5-(A^3)_m-Y^3$ ,  $X^8-(A^3)_m-Y^3$ ,  $X^7-(A^3)_m-Y^2$ ,  $X^7-(A^3)_m-Y^4$ ,  $X^7-(A^3)_m-Y^1$ ,  $X^5-(A^3)_m-Y^2$ ,  $X^8-(A^3)_m-Y^2$ ,  $X^8-(A^3)_m-Y^4$ ,  $X^8-(A^3)_m-Y^1$ ,  $X^5-(A^3)_m-Y^1$ , and  $X^5-(A^3)_m-Y^4$ .

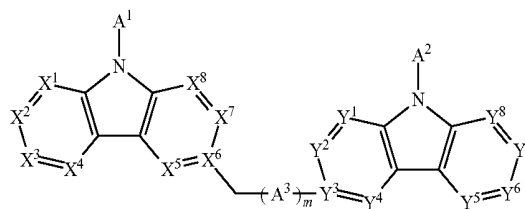
[0120] In preferred embodiments of the first host material represented by formula (A), the bonding manner between formulae (a) and (b) are represented by  $X^6-(A^3)_m-Y^3$ ,  $X^6-(A^3)_m-Y^2$ , or  $X^7-(A^3)_m-Y^3$ , namely the material for organic electroluminescence device is preferably represented by formula (II), (III), or (IV):



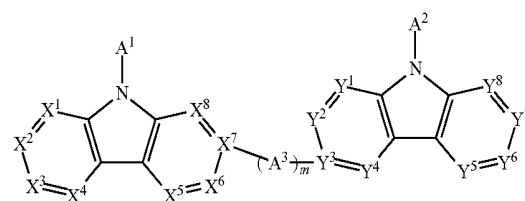
(II)

-continued

(III)



(IV)



wherein  $X^1$  to  $X^8$ ,  $Y^1$  to  $Y^8$ ,  $A^1$  to  $A^3$ , and  $m$  are the same as  $X^1$  to  $X^8$ ,  $Y^1$  to  $Y^8$ ,  $A^1$  to  $A^3$ ,  $m$  in formula (A), and each of formulae (II), (III), and (IV) satisfies at least one of the requirements (1) to (v) as specified in the definition of formula (A).

[0121] The first host material represented by formula (A) satisfies at least one of the requirements (i) to (v), namely, the first host material is a cyano group-introduced biscarbazole derivative having a group represented by formula (a) and a group represented by formula (b) which are linked to each other.

[0122] Since an electron injecting/transporting cyano group is introduced, the first host material has an improved hole resistance. Therefore, the organic EL device comprising the first host material having a cyano group exhibits a prolonged lifetime as compared with a known organic EL device comprising a host material having no cyano group.

[0123]  $A^3$  of formula (A) preferably represents a single bond, a substituted or unsubstituted divalent monocyclic hydrocarbon group having 6 or less ring carbon atoms, or a substituted or unsubstituted divalent monocyclic heterocyclic group having 6 or less ring atoms.

[0124] Examples of the monocyclic hydrocarbon group having 6 or less ring carbon atoms represented by  $A^3$  include phenylene group, cyclopentenylene group, cyclopentadienylene group, cyclohexylene group, and cyclopentylene group, with phenylene group being preferred.

[0125] Examples of the monocyclic heterocyclic group having 6 or less ring atoms represented by  $A^3$  include pyrrolylene group, pyrazinylene group, pyridinylene group, furylene group, and thiophenylene group.

[0126] In a preferred embodiment of formulae (A), (II), (III), and (IV),  $m$  is 0 and one of  $X^5$  to  $X^8$  and one of  $Y^1$  to  $Y^4$  are bonded to each other via a single bond; or  $A^3$  represents the substituted or unsubstituted monocyclic hydrocarbon group having 6 or less ring carbon atoms or the substituted or unsubstituted monocyclic heterocyclic group having 6 or less ring atoms. In such a preferred embodiment, the distortion of the ring (for example, carbazole ring) represented by formula (a) or (b) is minimized to make it easy to retain the conjugation of  $\pi$ -electrons. This allows HOMO (highest occupied molecular orbital) to extend throughout the whole carbazole skeleton, thereby to retain the hole injecting/transporting ability of the carbazole skeleton. In more preferred embodi-

ment,  $m$  is 0 and one of  $X^5$  to  $X^8$  and one of  $Y^1$  to  $Y^4$  are bonded to each other via a single bond; or  $A^3$  represents a substituted or unsubstituted phenylene group.

[0127] The first host material satisfies preferably at least one of the requirements (i) and (ii):

[0128] (i) at least one of  $A^1$  and  $A^2$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms; and

[0129] (ii) at least one of  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  represents  $CR^a$ , and at least one of  $R^a$  in  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms.

[0130] Namely, the first host material is preferably any one of the compounds:

(1) satisfying the requirement (i), but not satisfying the requirements (ii) to (v);

(2) satisfying the requirement (ii), but not satisfying the requirements (i) and (iii) to (v); and

(3) satisfying both the requirements (i) and (ii), but not satisfying the requirements (iii) to (v).

[0131] The first host material satisfying the requirement (i) and/or (ii) has a structure wherein the cyano group-containing aromatic hydrocarbon group or the cyano group-containing heterocyclic group is introduced to the terminal end of the central skeleton comprising the groups represented by formulae (a) and (b).

[0132] The central skeleton comprising the groups represented by formulae (a) and (b) acts as a hole injecting/transporting unit, and each of the cyano group-containing aromatic hydrocarbon group and the cyano group-containing heterocyclic group acts as an electron injecting/transporting unit. Since the first host material satisfying the requirement (i) or (ii) has the cyano group-containing group which acts as an electron injecting/transporting unit outside the central skeleton, the distribution of the electron cloud of HOMO (highest occupied molecular orbital) is retained within the central skeleton, to maintain the hole injecting/transporting ability of the central skeleton good while retaining the electron injecting/transporting ability of the cyano group-containing group. Therefore, the carrier balance in the molecule of the first host material satisfying the requirement (i) or (ii) is good to realize an organic EL device with excellent emission efficiency.

[0133] Thus, the organic EL device having a light emitting layer comprising the first host material satisfying at least one of the requirements (i) and (ii) and the second host material represented by formula (1) also exhibits excellent emission efficiency in addition to a prolonged lifetime.

[0134] When the first host material satisfies the requirement (i), at least one of  $A^1$  and  $A^2$  is preferably a cyano-substituted phenyl group, a cyano-substituted naphthyl group, a cyano-substituted phenanthryl group, a cyano-substituted dibenzofuranyl group, a cyano-substituted dibenzothiophenyl group, a cyano-substituted biphenyl group, a cyano-substituted terphenyl group, a cyano-substituted 9,9-diphenylfluorenyl group, a cyano-substituted 9,9'-spirobi[9H-fluorene]-2-yl group, a cyano-substituted 9,9'-dimethylfluorenyl group, or a cyano-substituted triphenylenyl

group, and more preferably 3'-cyanobiphenyl-2-yl group, 3'-cyanobiphenyl-3-yl group, 3'-cyanobiphenyl-4-yl group, 4'-cyanobiphenyl-3-yl group, 4'-cyanobiphenyl-4-yl group, 4'-cyanobiphenyl-2-yl group, 6-cyanonaphthalene-2-yl group, 4-cyanonaphthalene-1-yl group, 7-cyanonaphthalene-2-yl group, 8-cyanodibenzofuran-2-yl group, 6-cyanodibenzofuran-4-yl group, 8-cyanodibenzothiophene-2-yl group, 6-cyanodibenzothiophene-4-yl group, 7-cyano-9-phenylcarbazole-2-yl group, 6-cyano-9-phenylcarbazole-3-yl group, 7-cyano-9,9-dimethylfluorene-2-yl group, or 7-cyanotriphenylene-2-yl group.

[0135] The first host material wherein  $A^1$  is substituted by a cyano group and  $A^2$  is not substituted by a cyano group is preferred. In this case, the first host material which does not satisfy the requirement (ii) is more preferred.

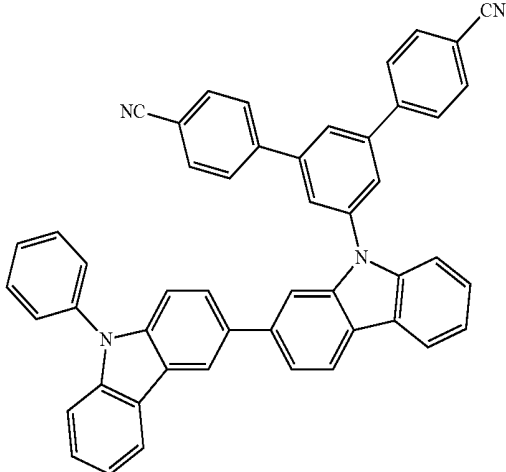
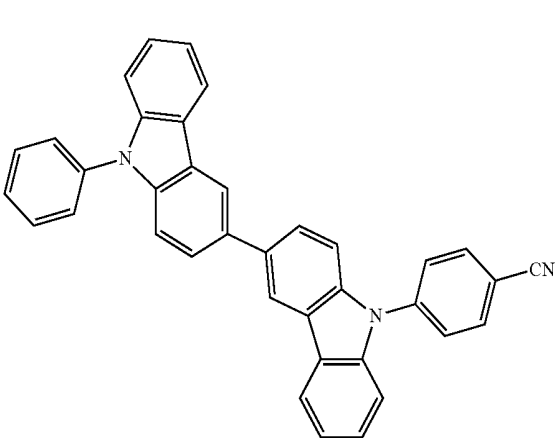
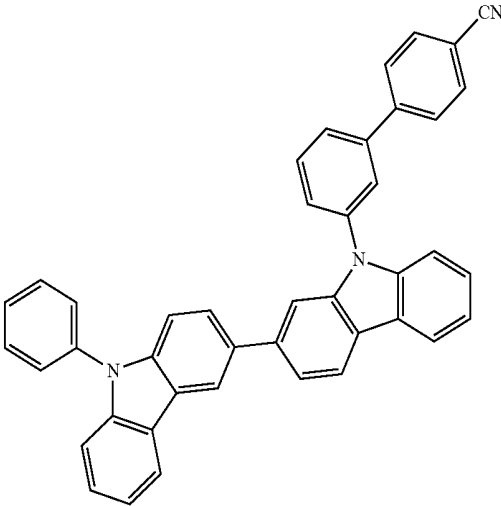
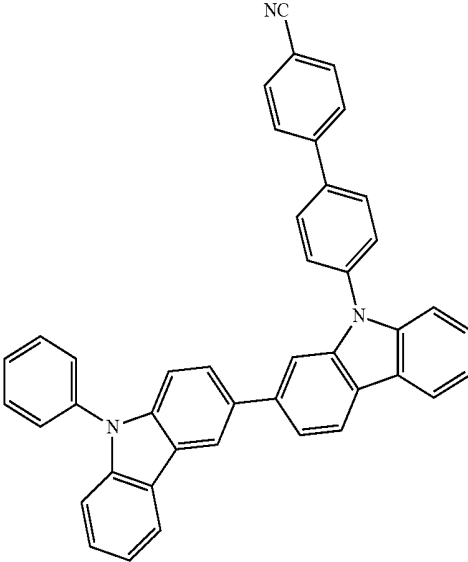
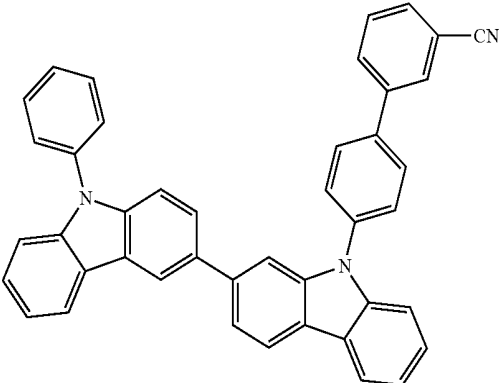
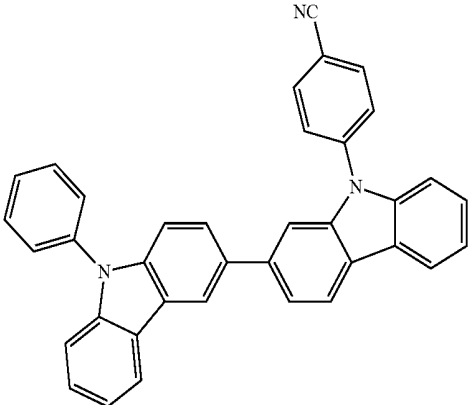
[0136] When the first host material satisfies the requirement (ii), at least one of  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  is preferably  $CR^a$ , and one of  $R^a$  in  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  is preferably a cyano-substituted phenyl group, a cyano-substituted naphthyl group, a cyano-substituted phenanthryl group, a cyano-substituted dibenzofuranyl group, a cyano-substituted dibenzothiophenyl group, a cyano-substituted biphenyl group, a cyano-substituted terphenyl group, a cyano-substituted 9,9-diphenylfluorenyl group, a cyano-substituted 9,9'-spirobi[9H-fluorene]-2-yl group, a cyano-substituted 9,9'-dimethylfluorenyl group, or a cyano-substituted triphenylenyl group, and more preferably 3'-cyanobiphenyl-2-yl group, 3'-cyanobiphenyl-3-yl group, 3'-cyanobiphenyl-4-yl group, 4'-cyanobiphenyl-3-yl group, 4'-cyanobiphenyl-4-yl group, 4'-cyanobiphenyl-2-yl group, 6-cyanonaphthalene-2-yl group, 4-cyanonaphthalene-1-yl group, 7-cyanonaphthalene-2-yl group, 8-cyanodibenzofuran-2-yl group, 6-cyanodibenzofuran-4-yl group, 8-cyanodibenzothiophene-2-yl group, 6-cyanodibenzothiophene-4-yl group, 7-cyano-9-phenylcarbazole-2-yl group, 6-cyano-9-phenylcarbazole-3-yl group, 7-cyano-9,9-dimethylfluorene-2-yl group, or 7-cyanotriphenylene-2-yl group.

[0137] It is preferred for the first host material to satisfy the requirement (ii), but not satisfy the requirement (i).

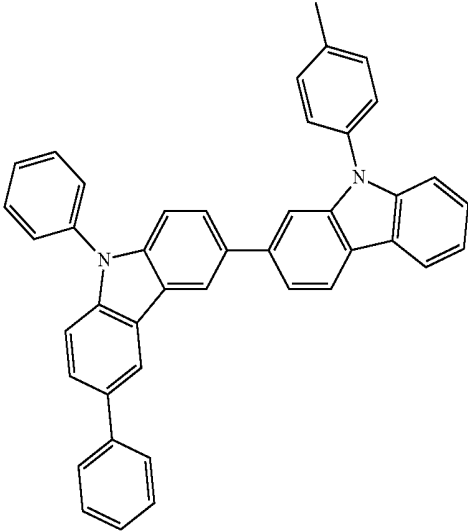
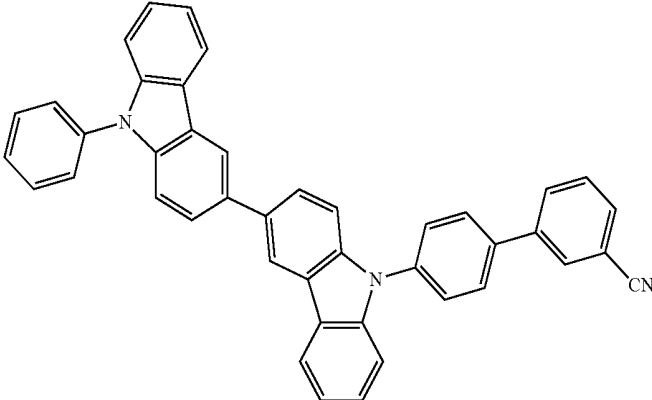
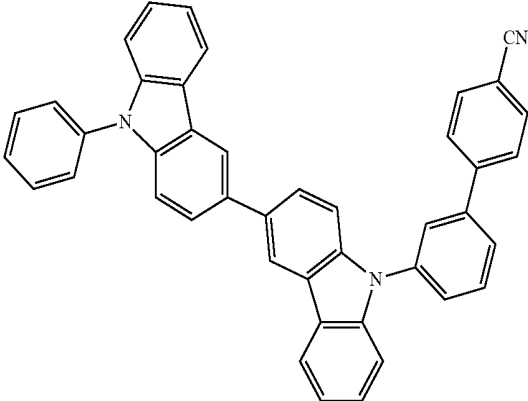
[0138] In formulae (A) and (II) to (IV),  $A^1$  and  $A^2$  are preferably different from each other, and more preferably,  $A^1$  is substituted by a cyano group but  $A^2$  is not substituted by a cyano group. Namely, the first host material is preferably structurally asymmetric. If being asymmetric, the crystallinity and non-crystallinity are good. This enhances the quality of the films of an organic EL device employing the first host material, thereby achieving high performance, for example, organic EL properties, such as current efficiency.

[0139] The production method of the first host material is not particularly limited and it is produced according to a known method, for example, by a coupling reaction of a carbazole derivative and an aromatic halogenated compound in the presence of a copper catalyst described in Tetrahedron 40 (1984) 1435 to 1456 or a palladium catalyst described in Journal of American Chemical Society 123 (2001) 7727 to 7729.

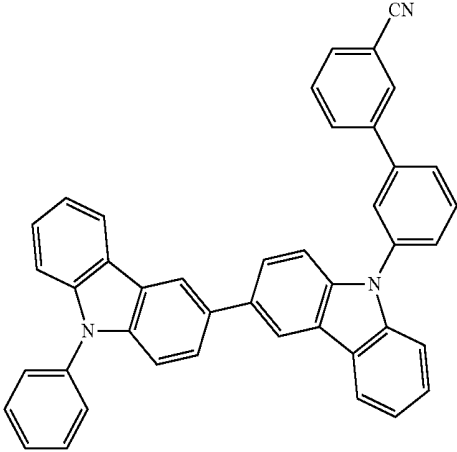
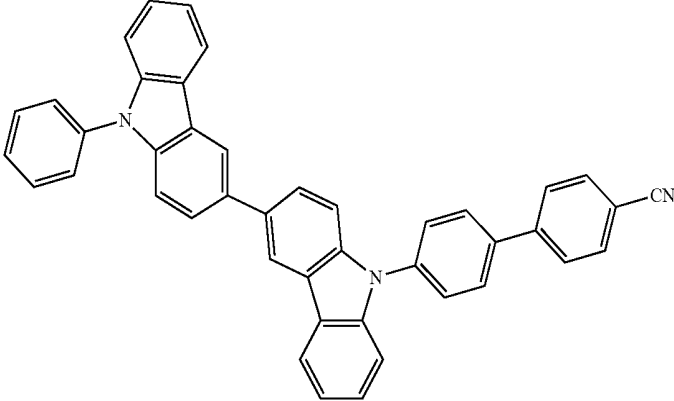
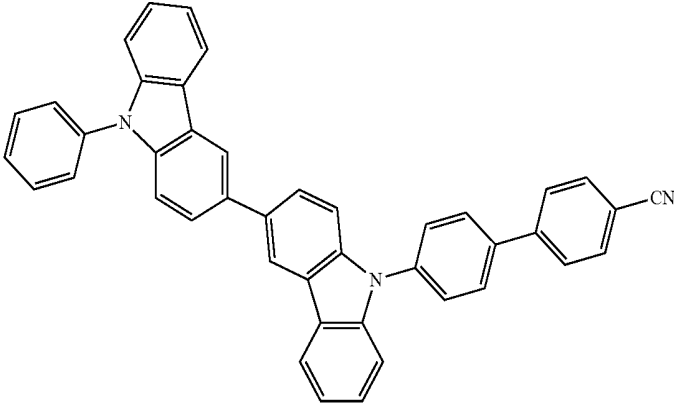
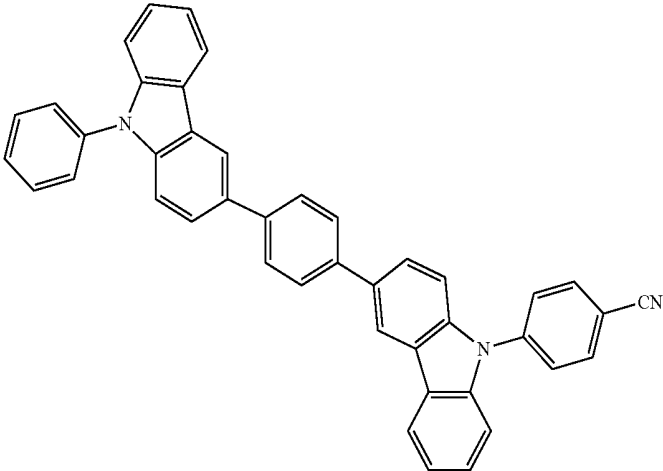
[0140] Specific examples of the first host material are shown below, although not limited thereto.



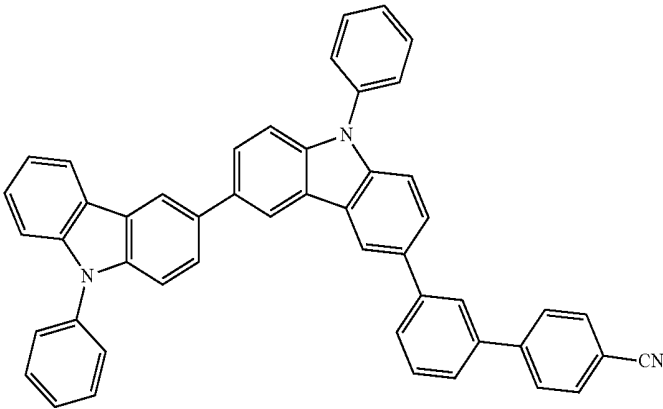
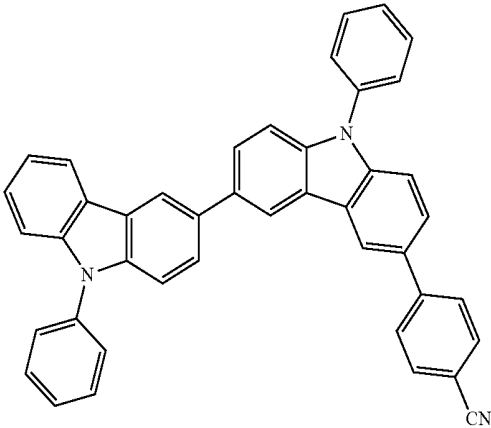
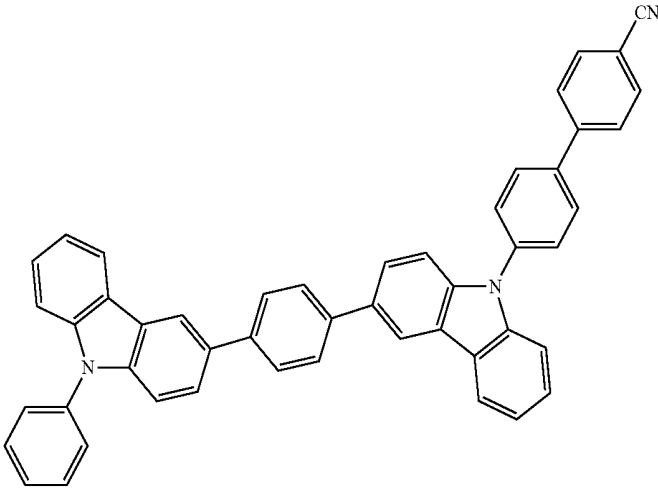
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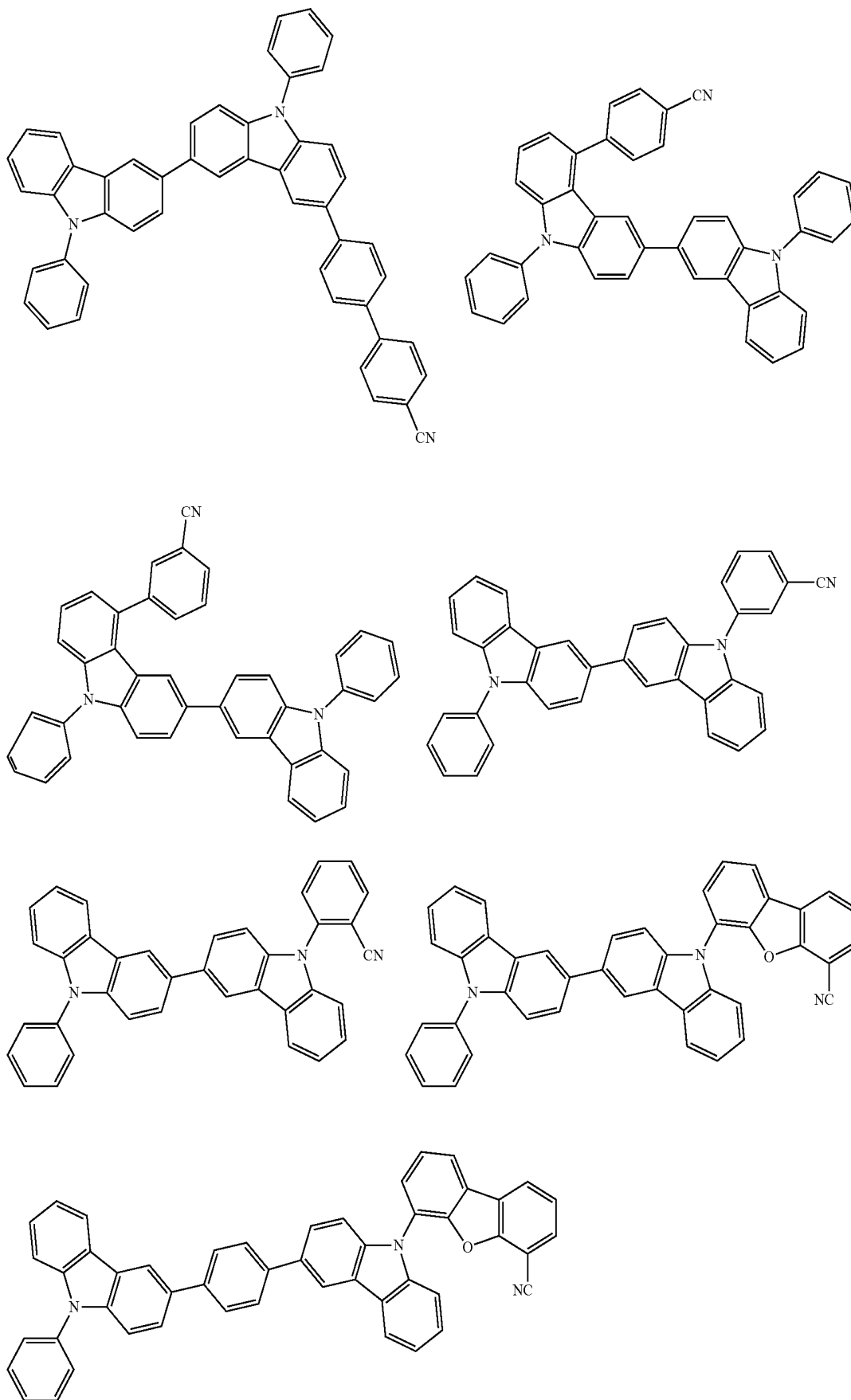
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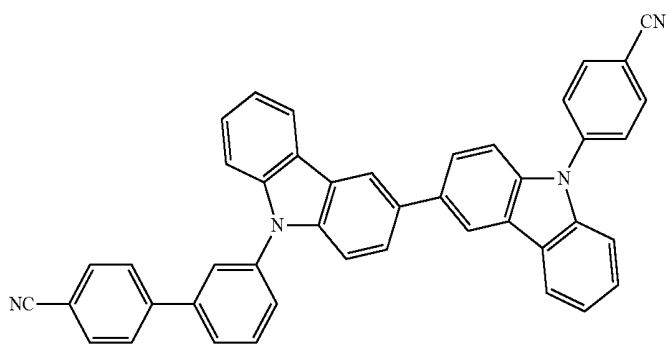
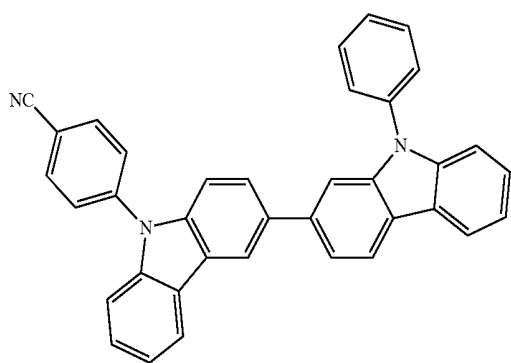
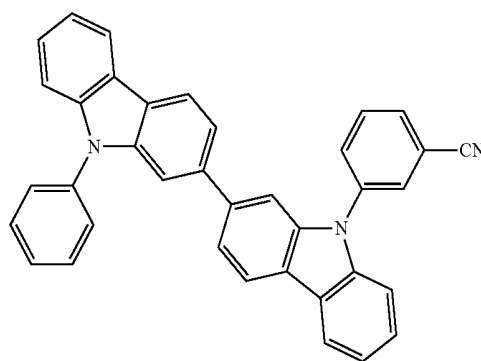
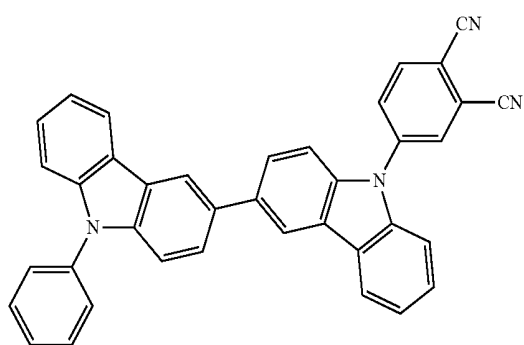
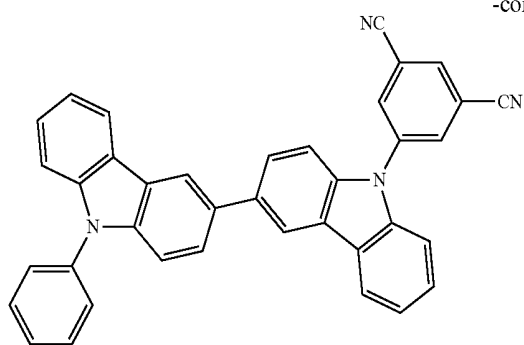
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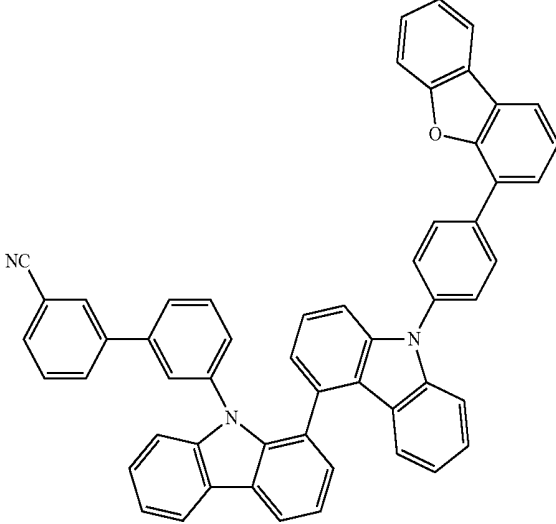
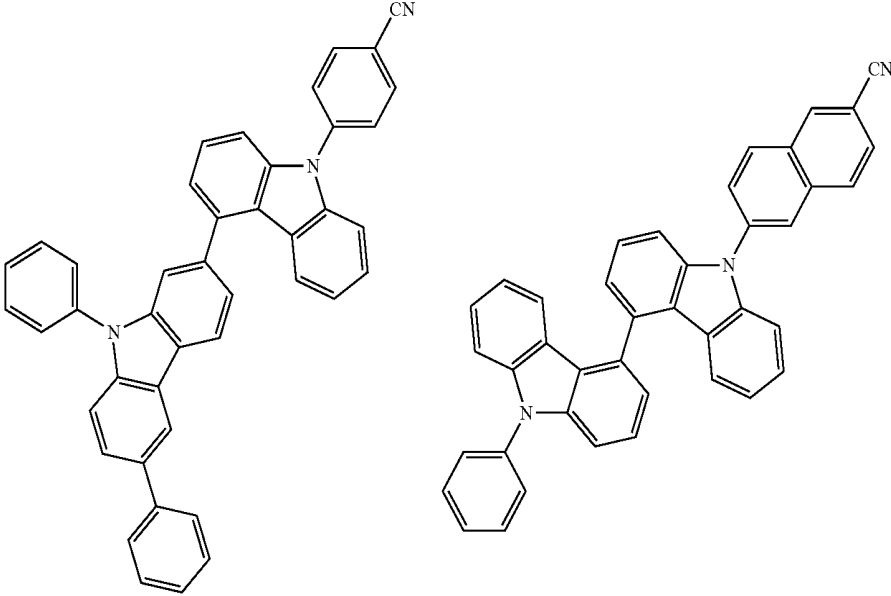
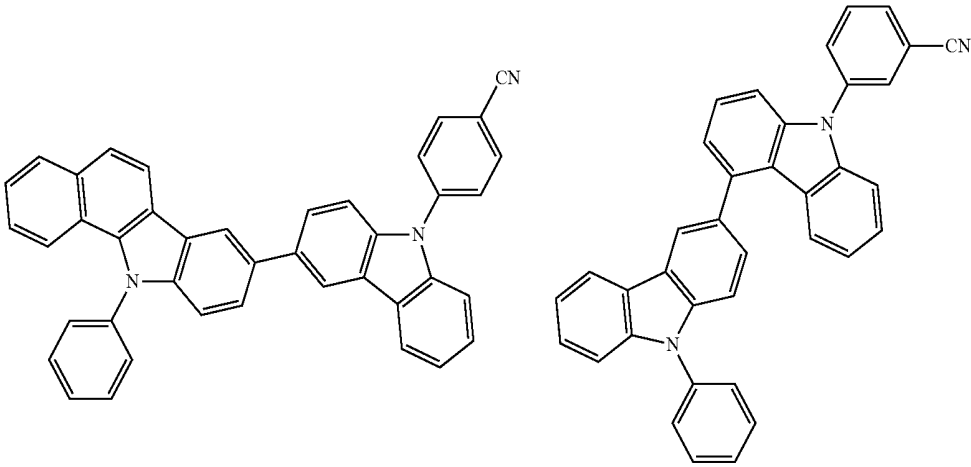
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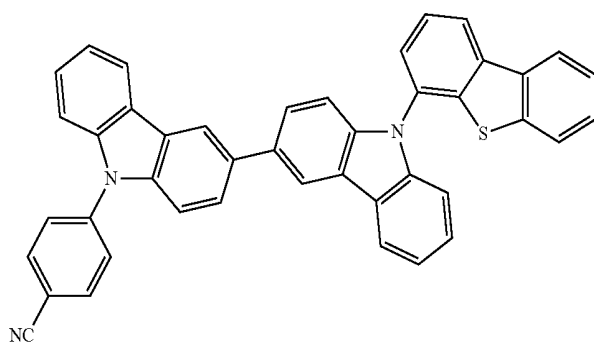
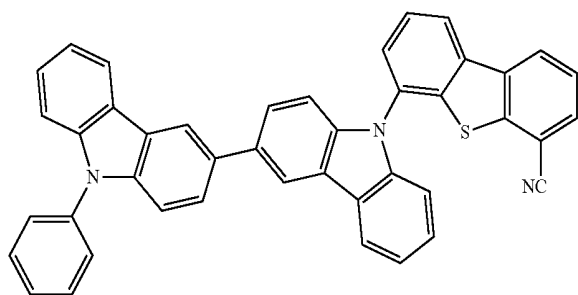
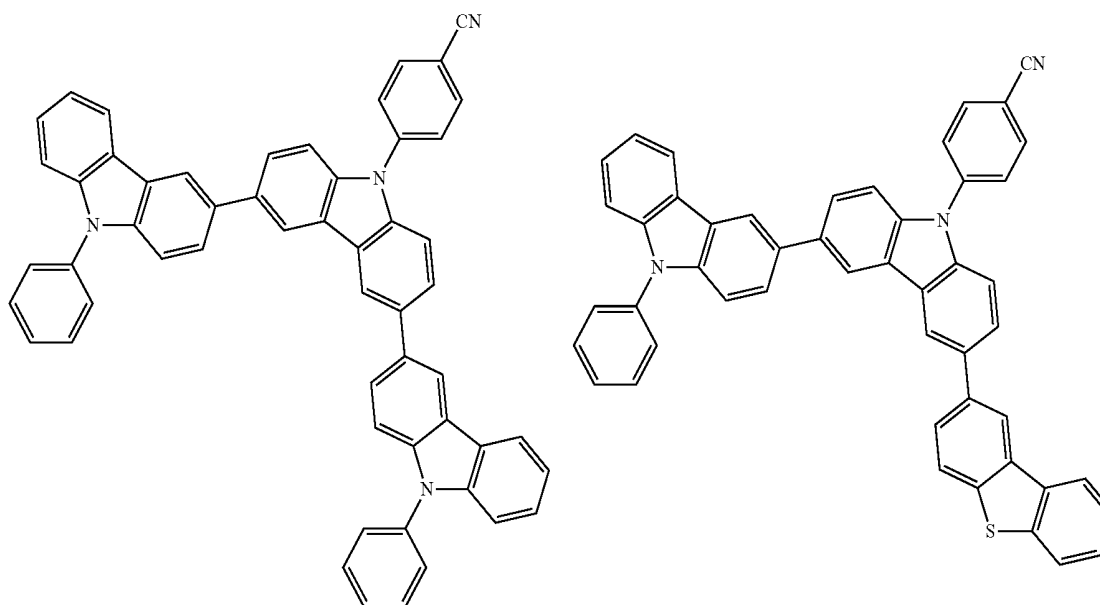
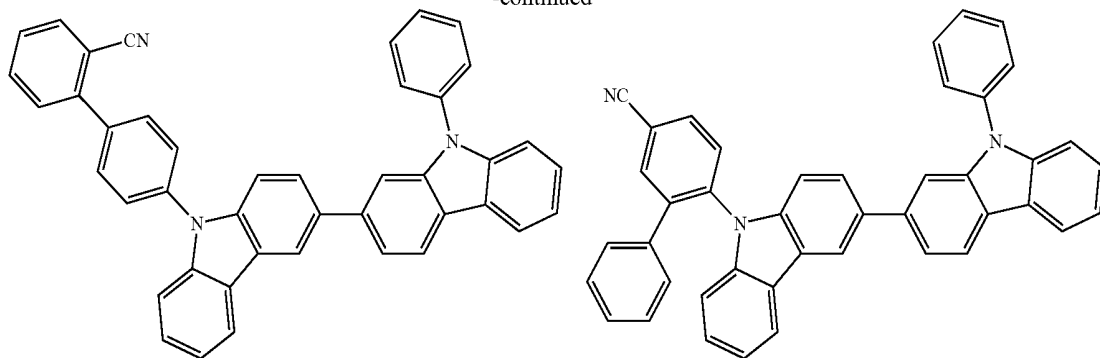
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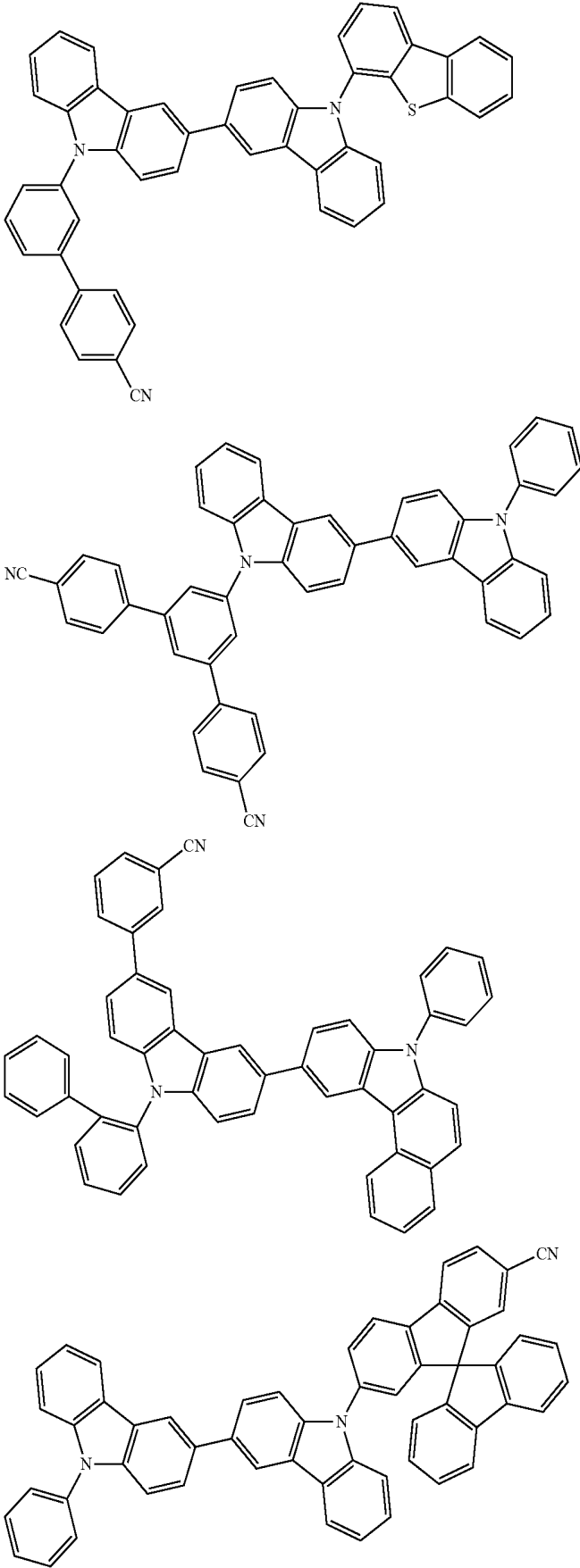
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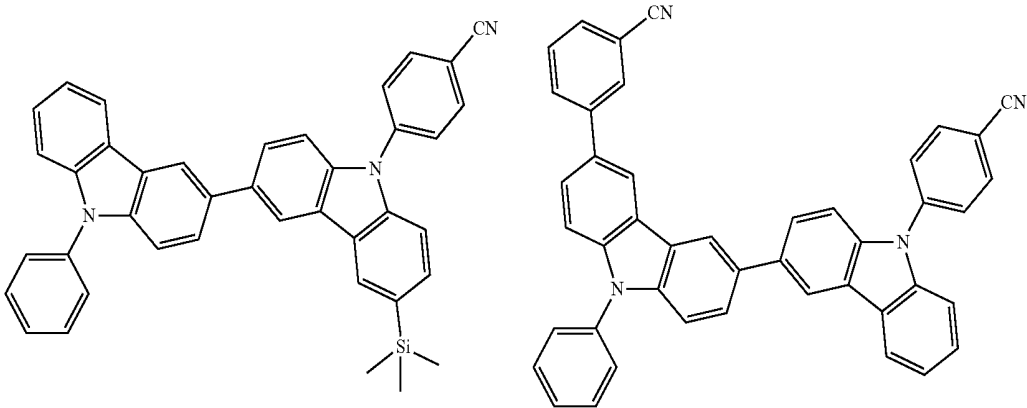
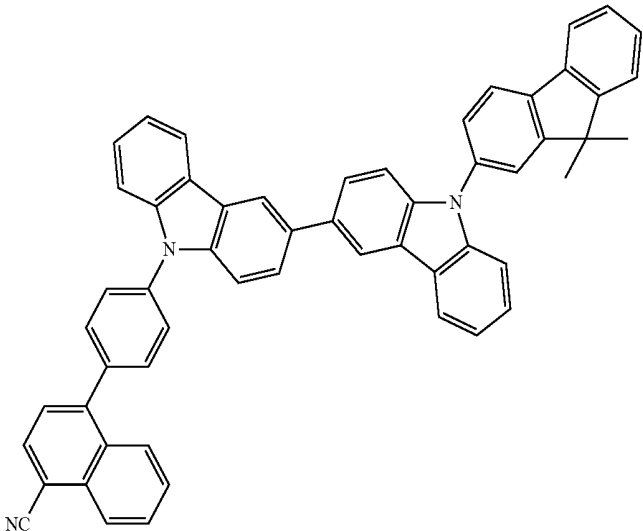
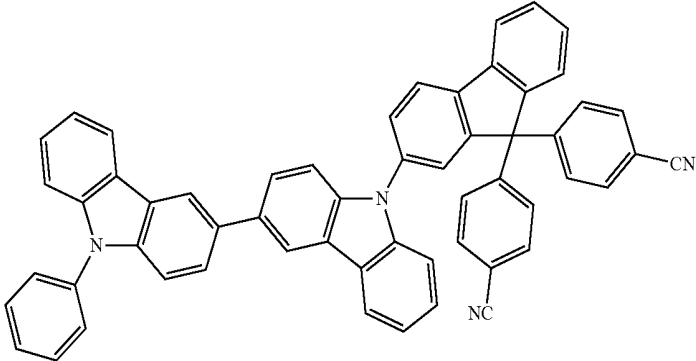
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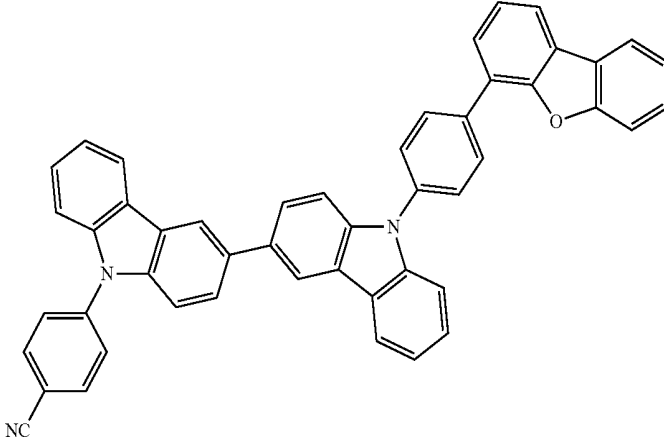
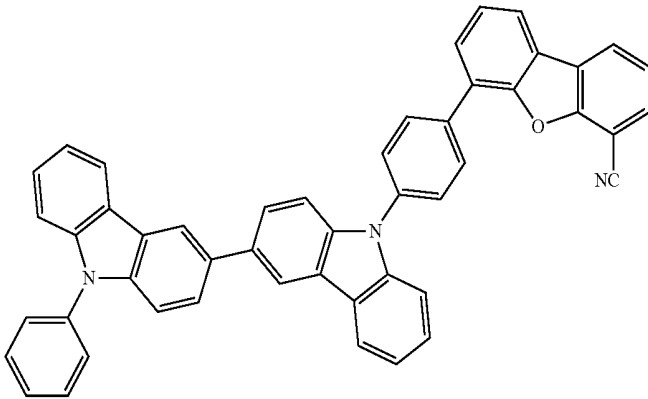
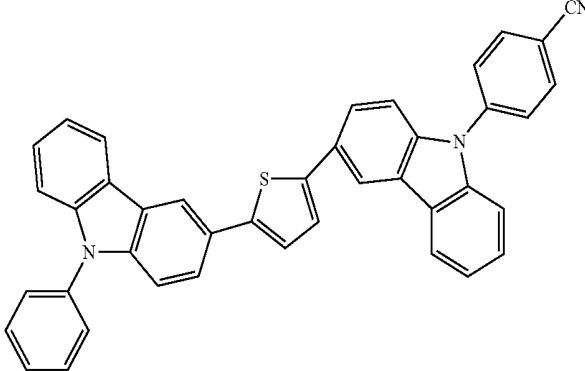
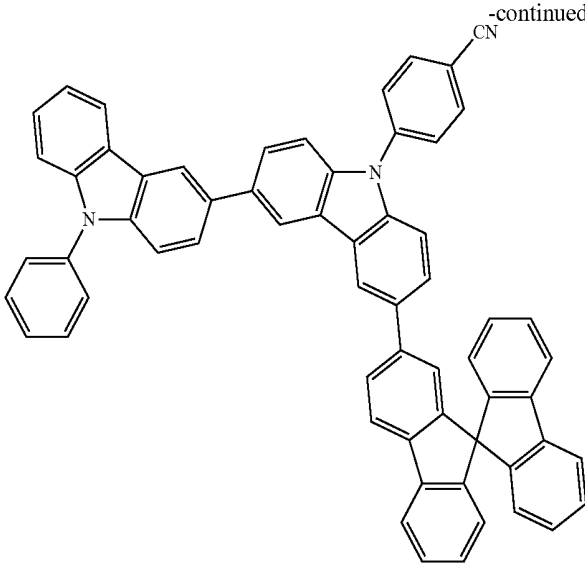


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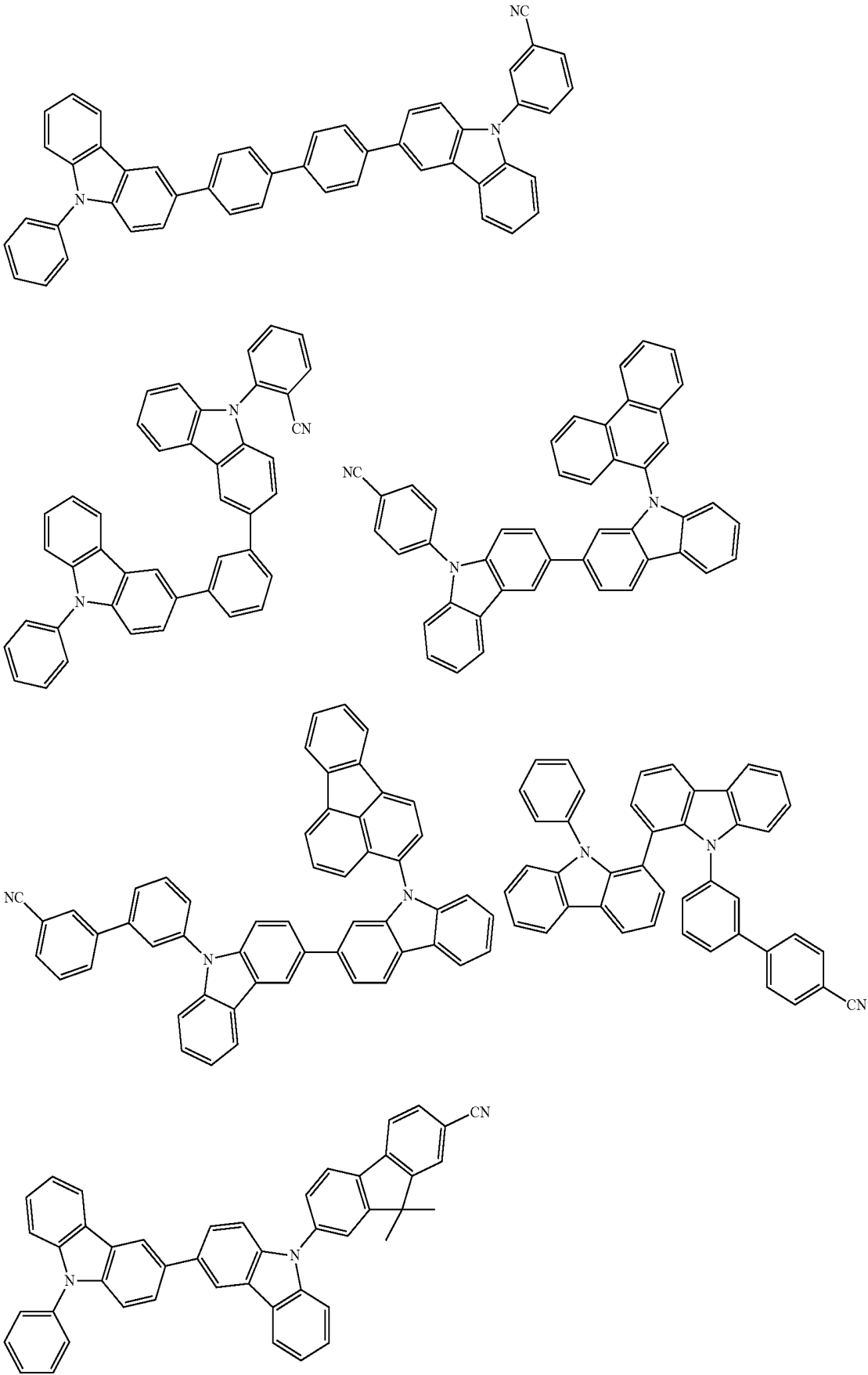


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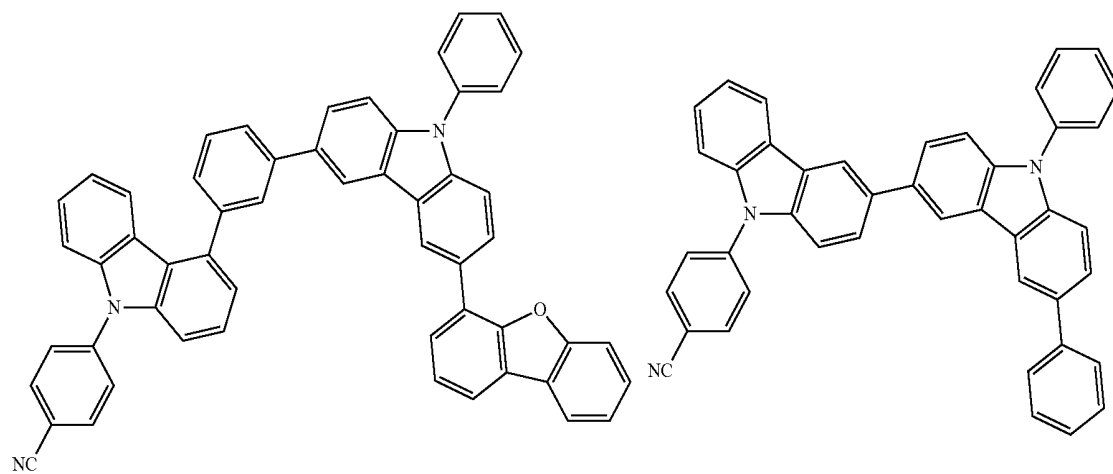
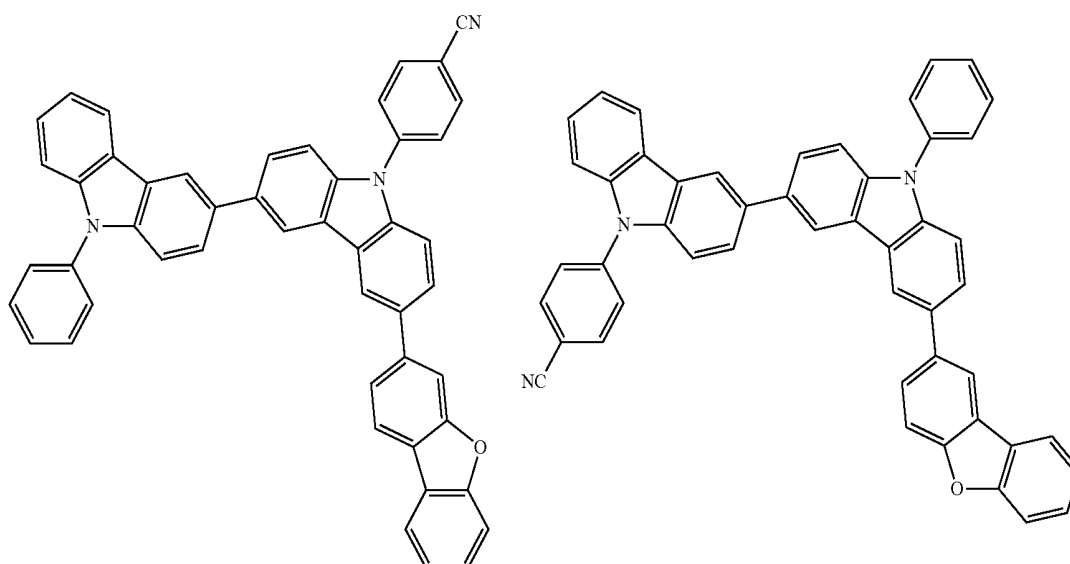
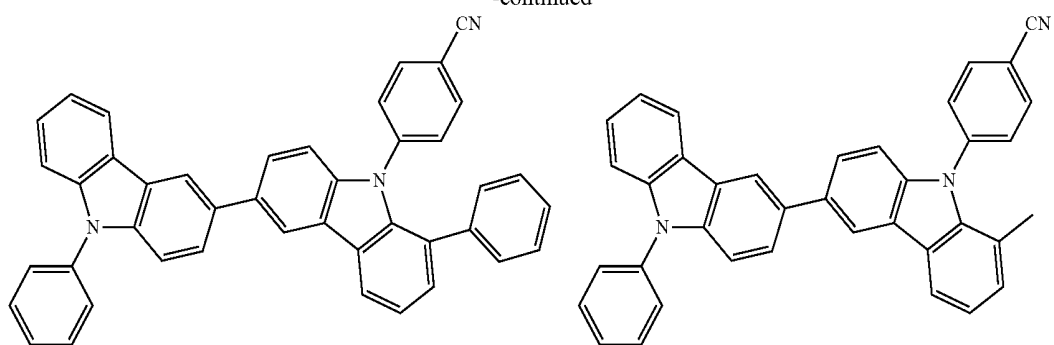




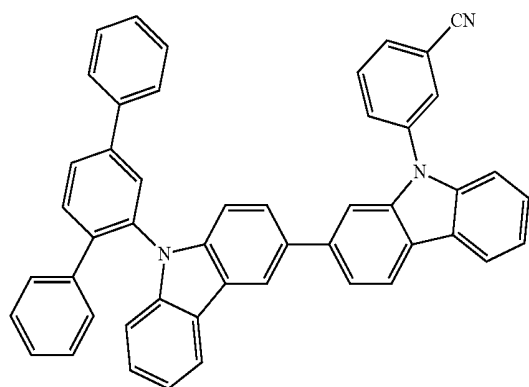
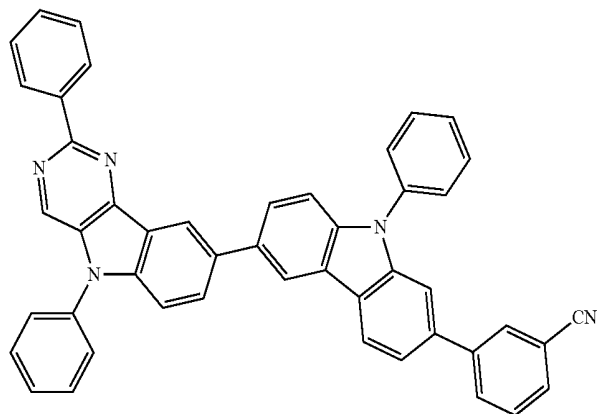
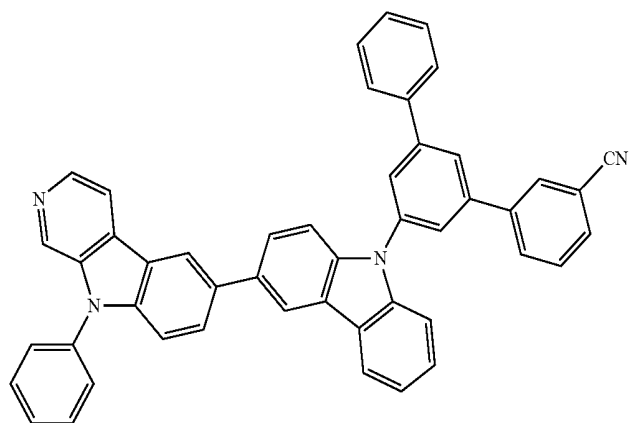
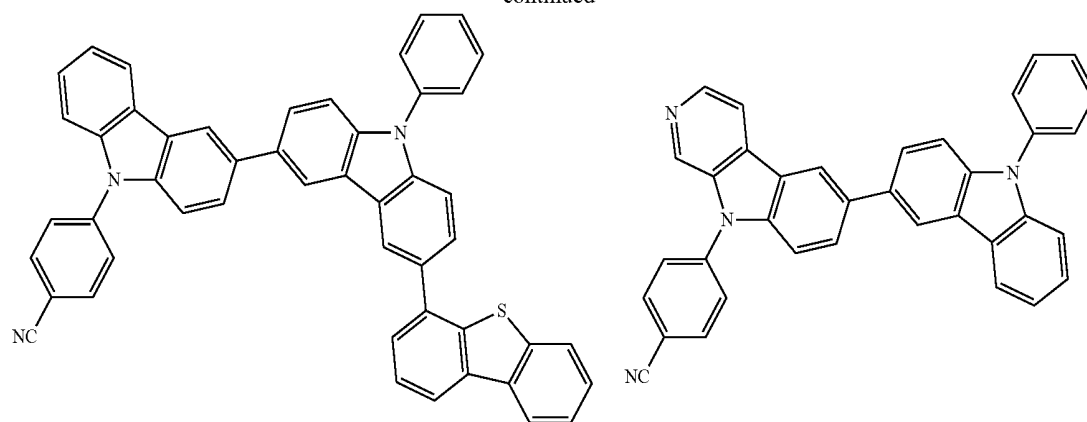
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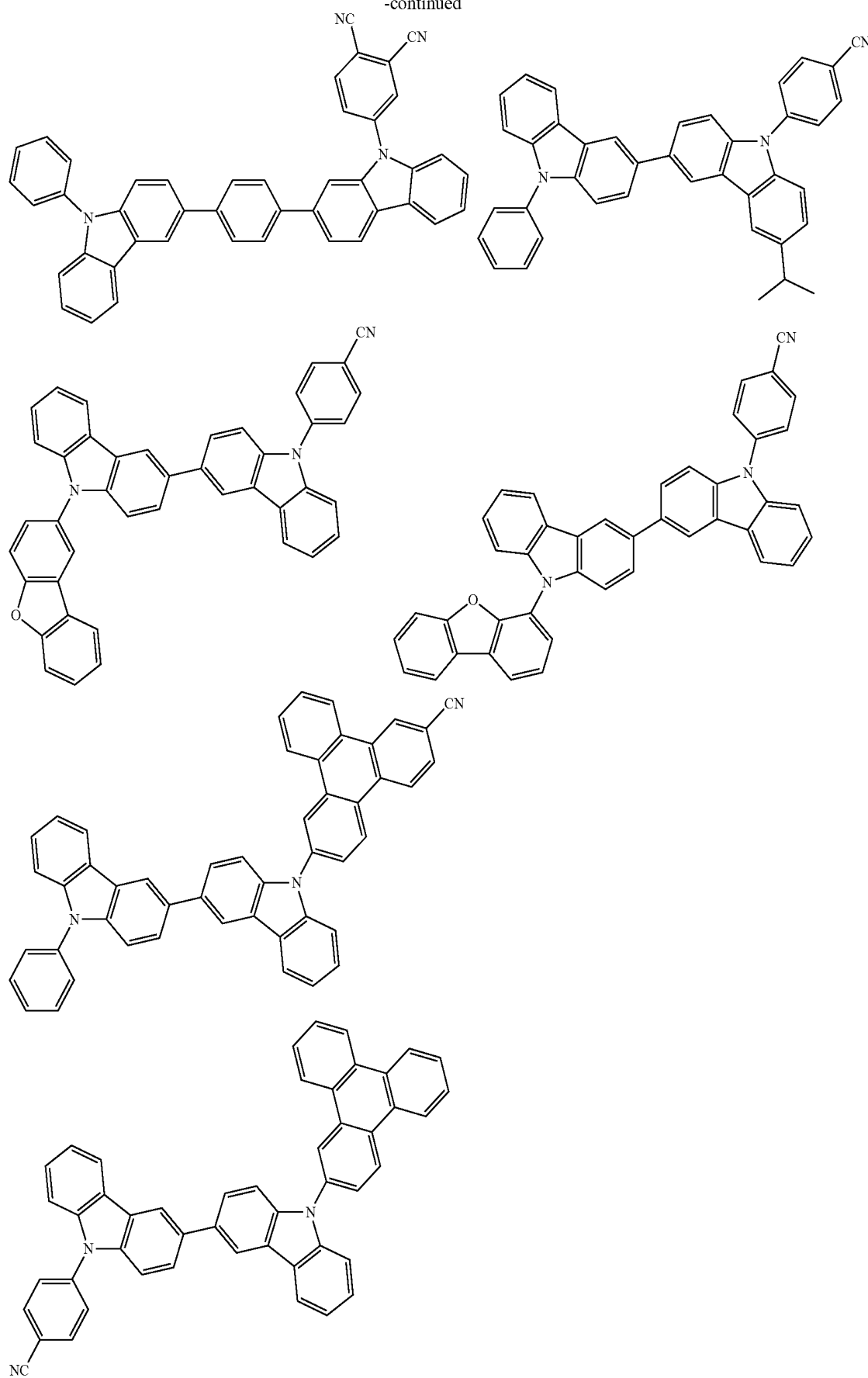
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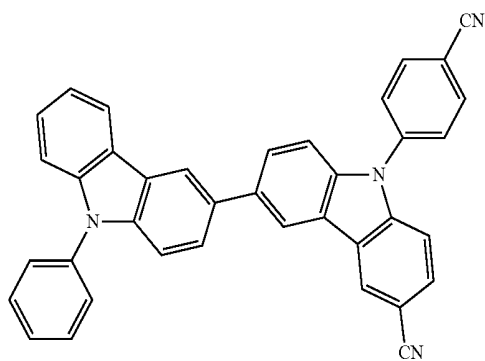
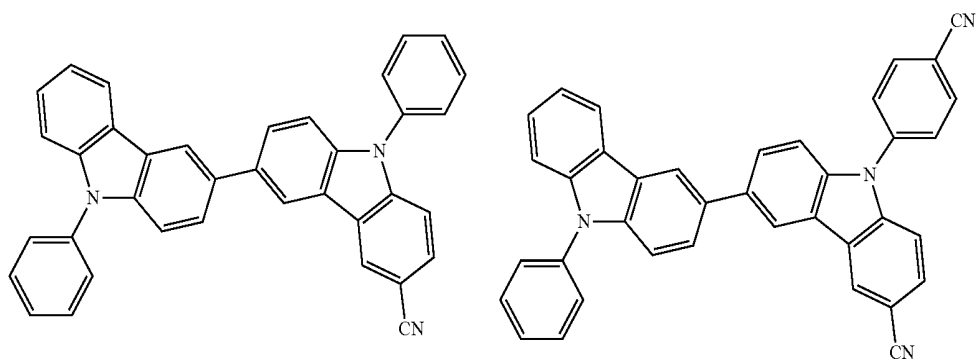
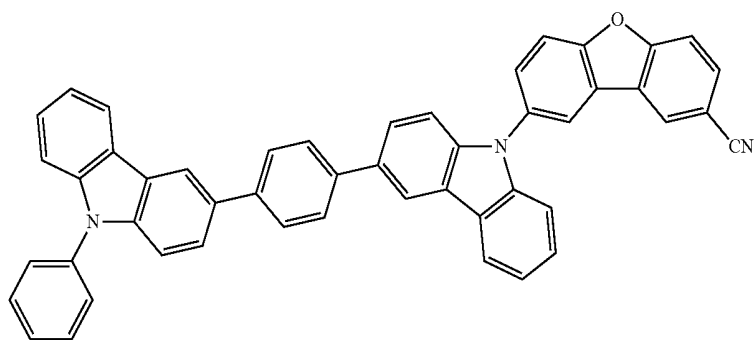
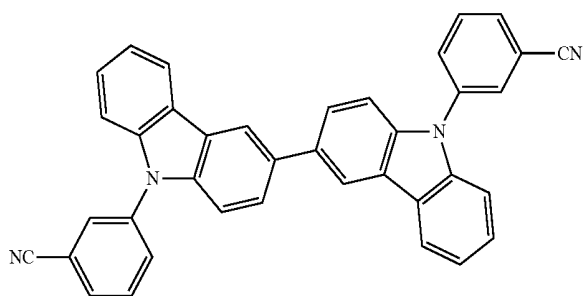
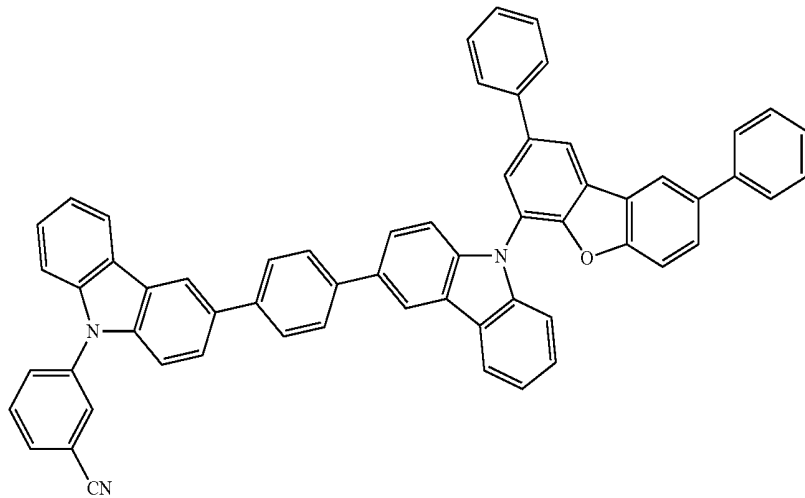
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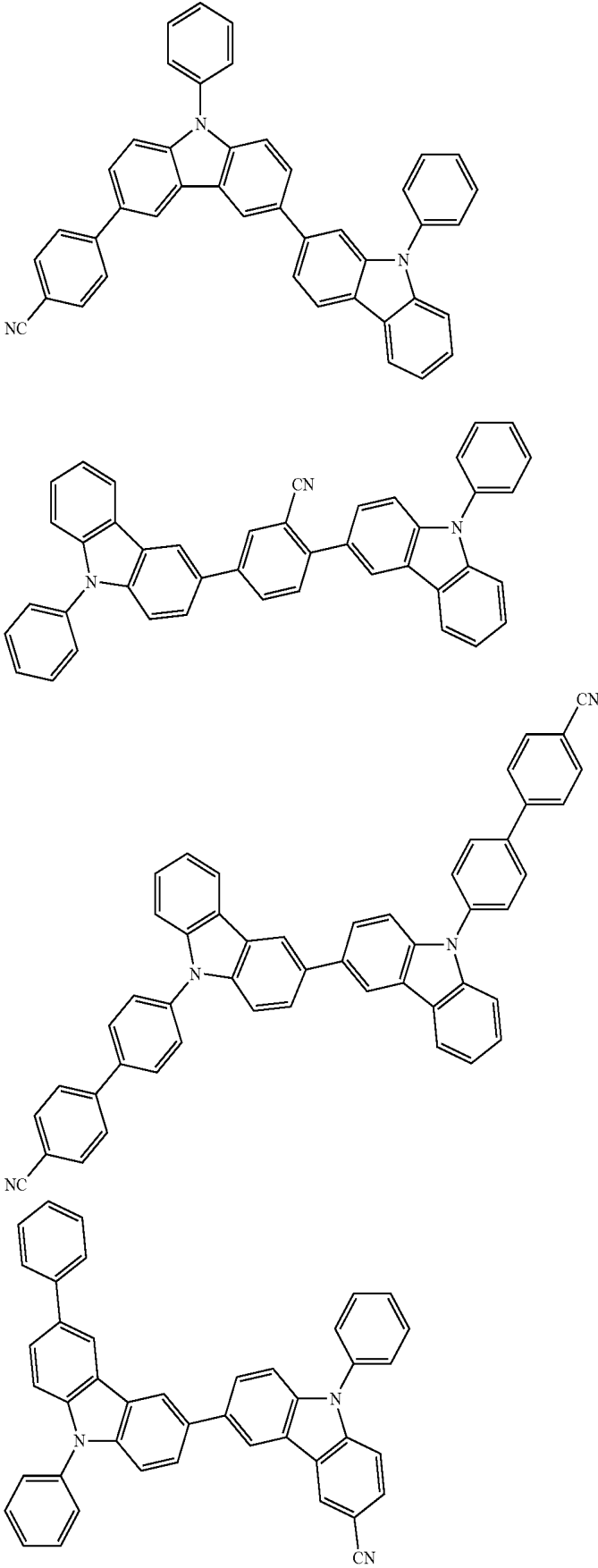
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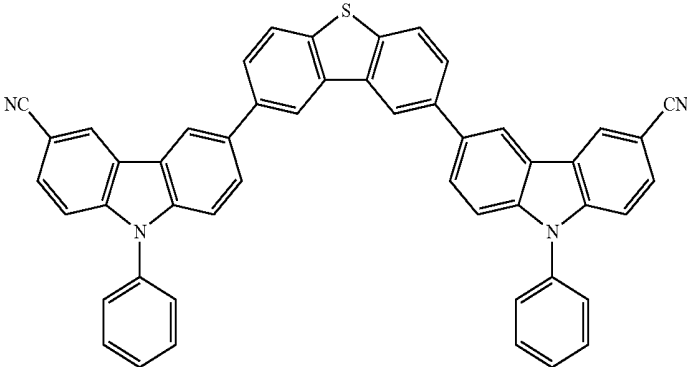
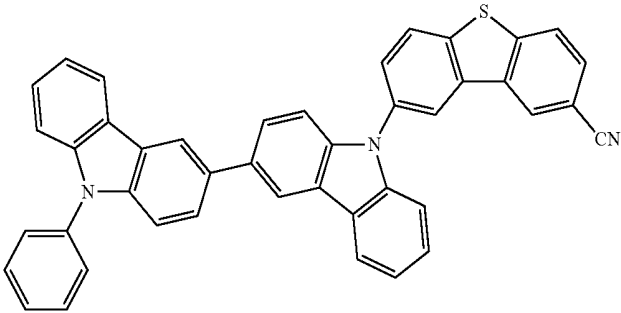
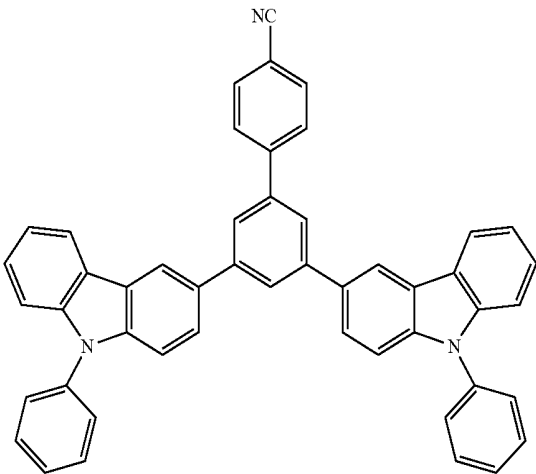
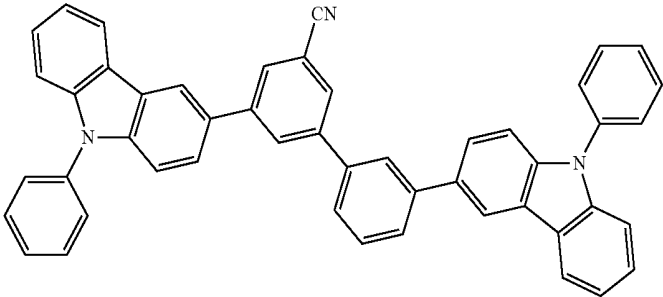
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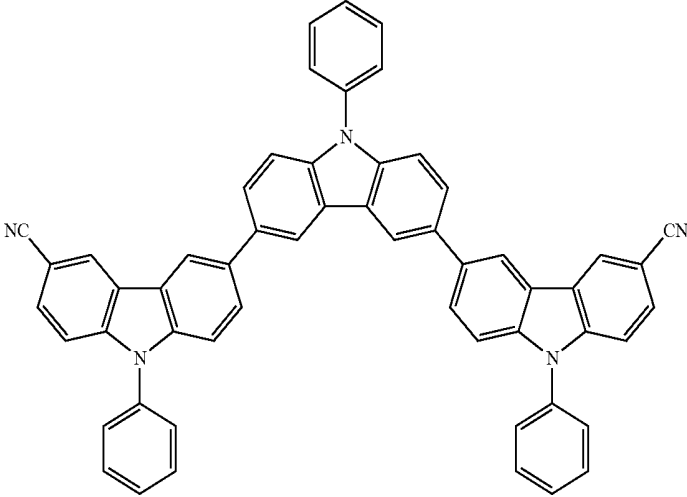
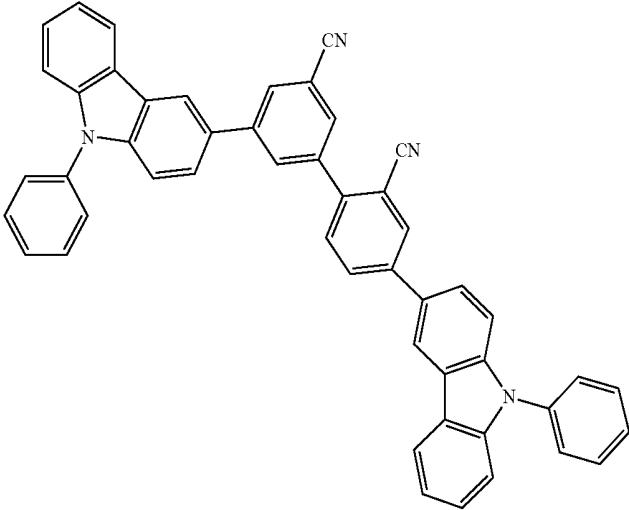
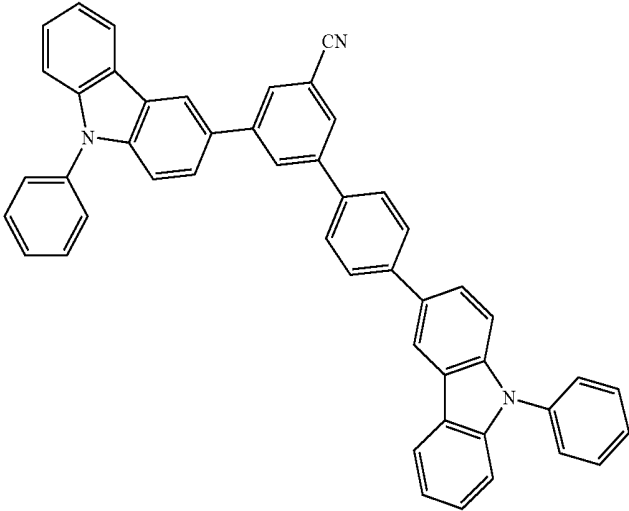
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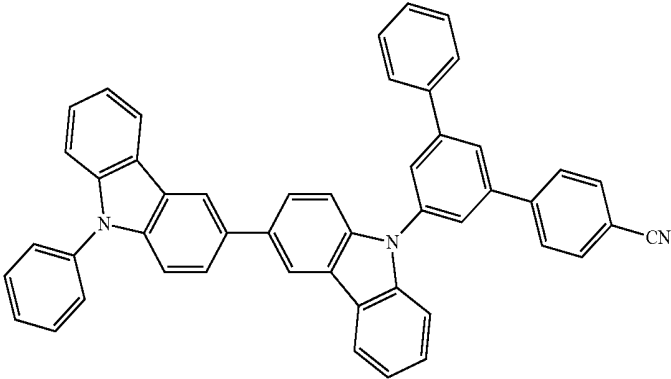
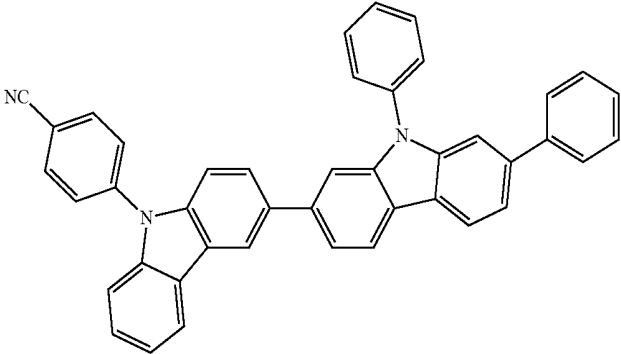
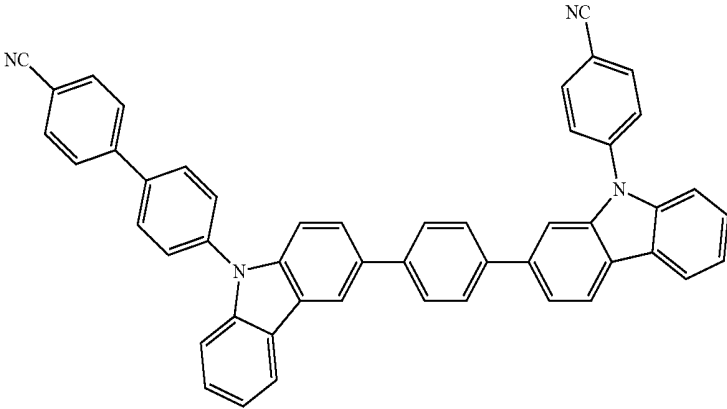
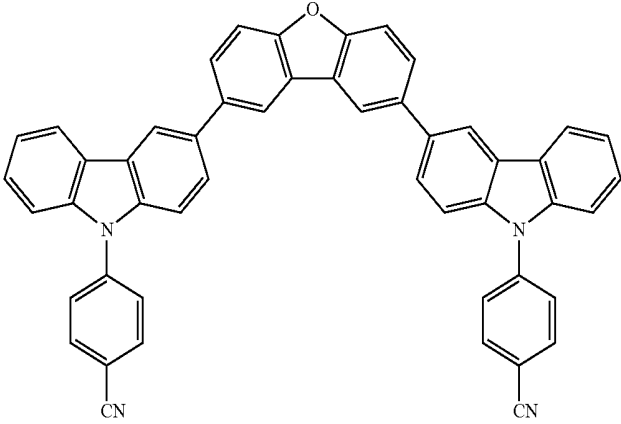
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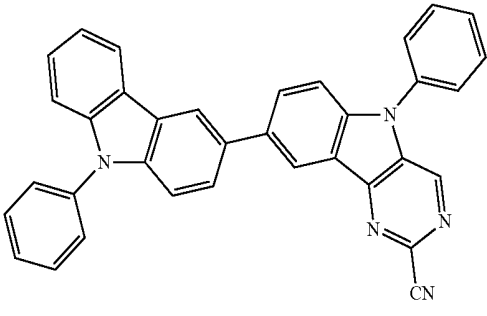
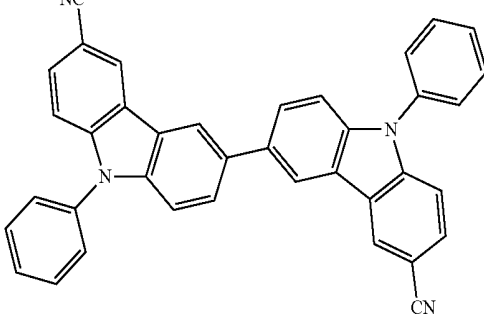
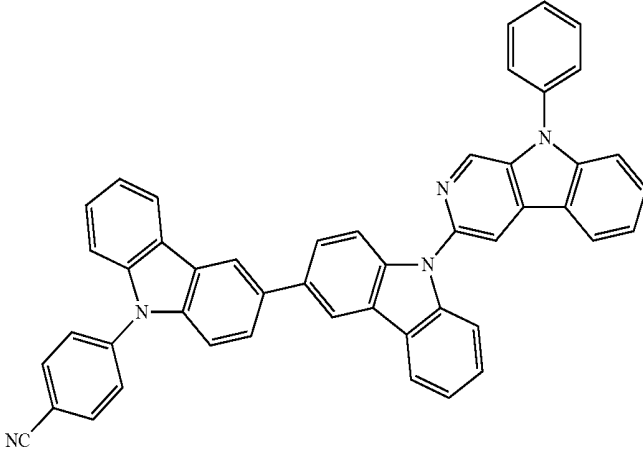
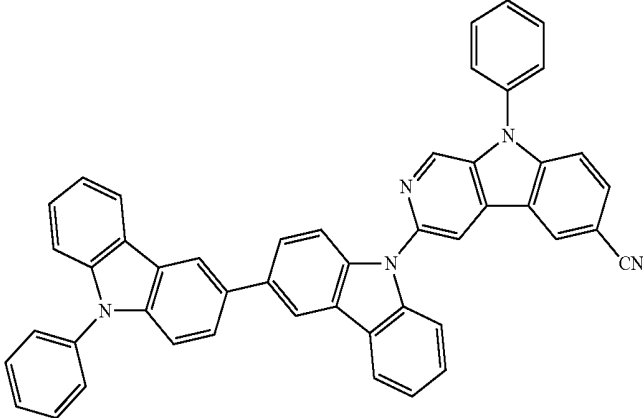
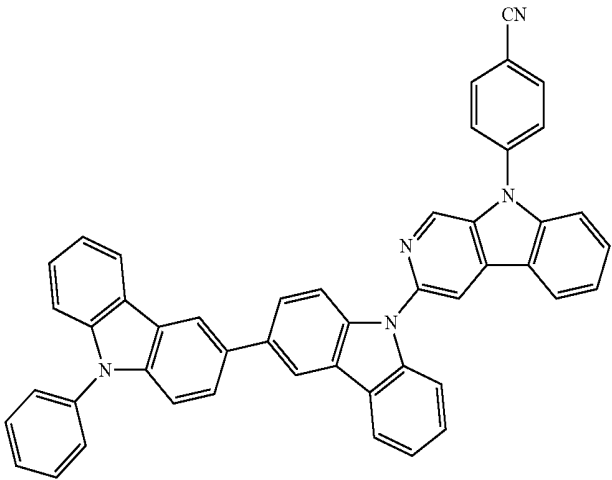
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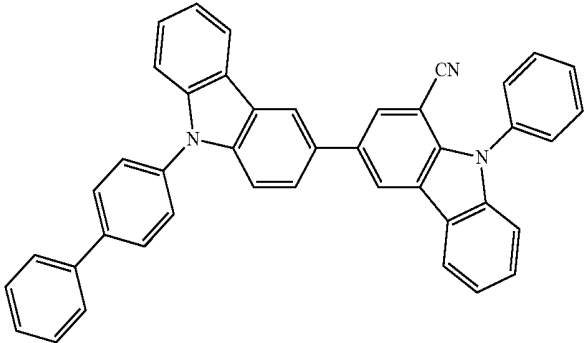
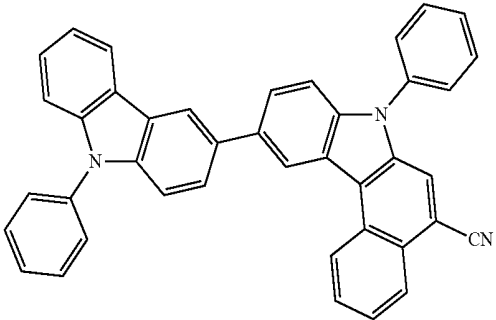
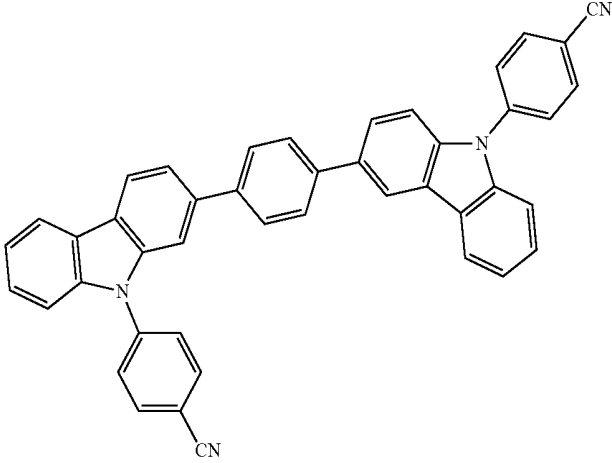
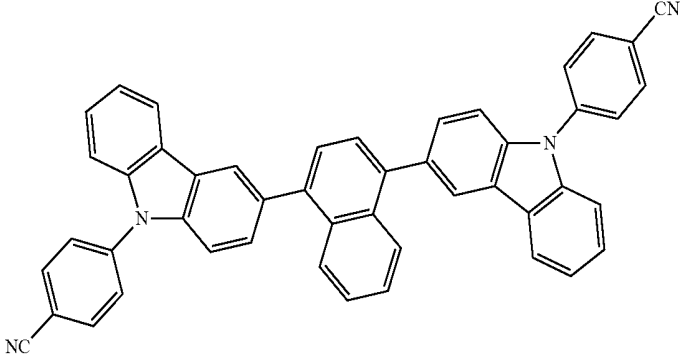
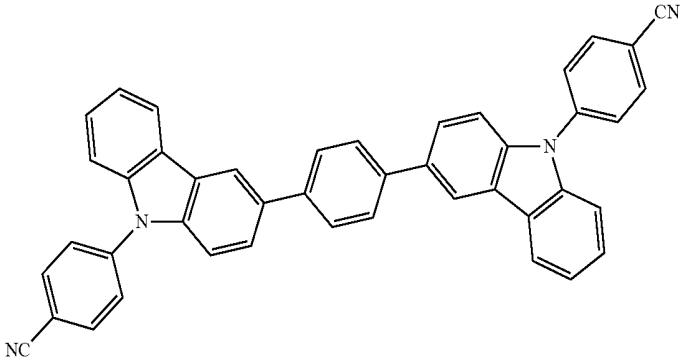
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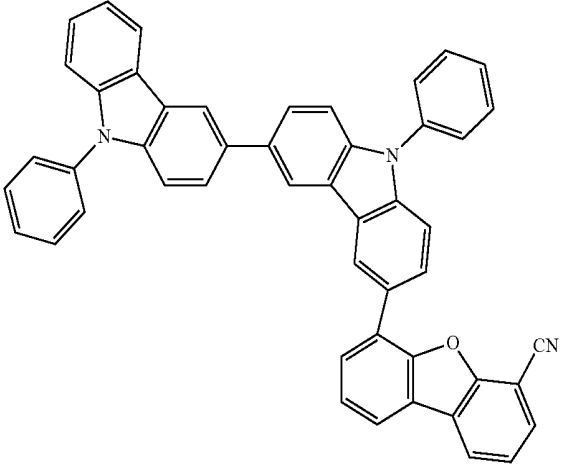
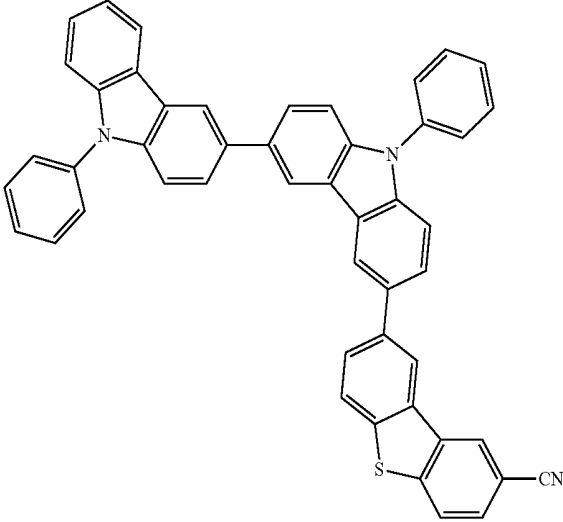
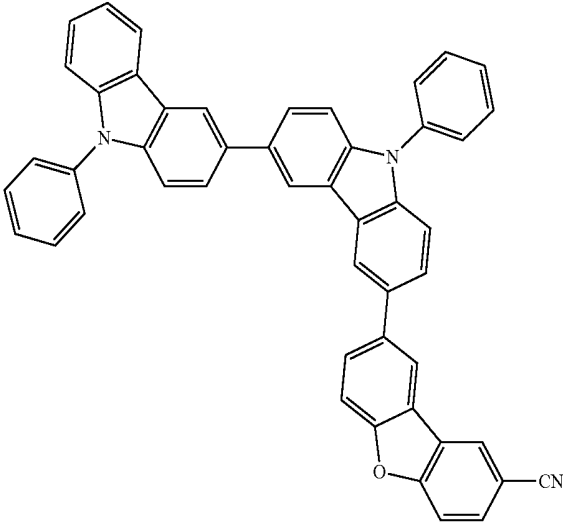
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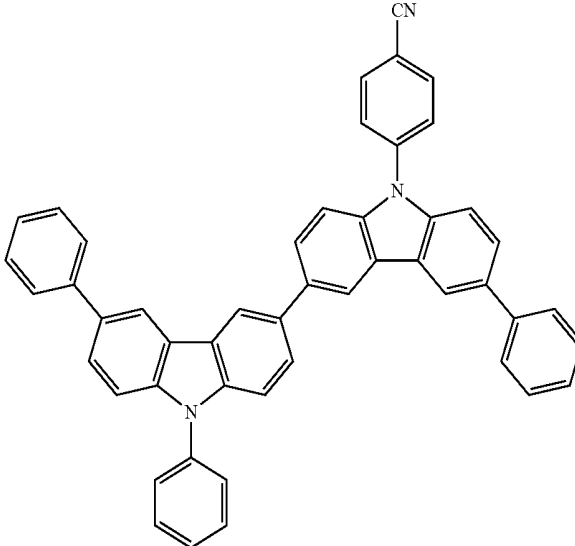
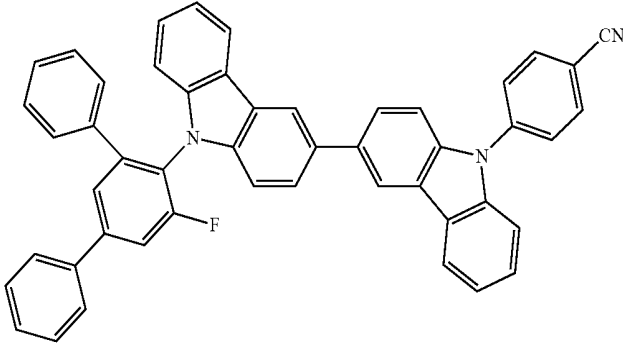
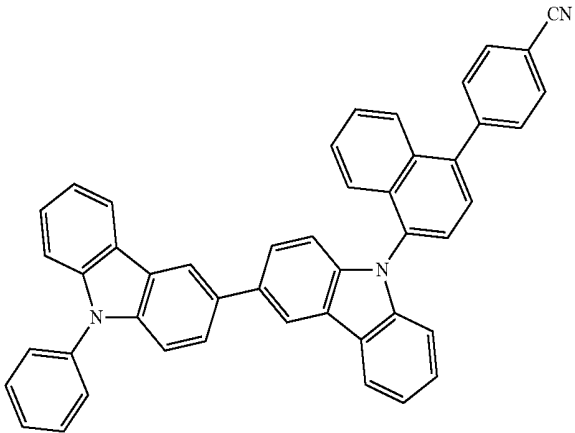
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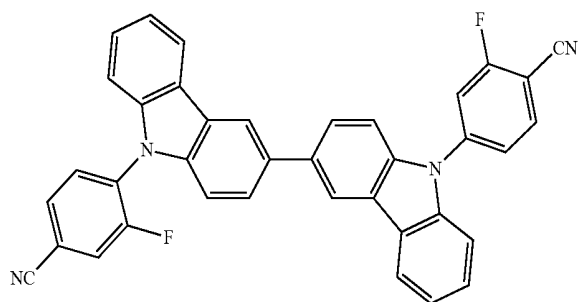
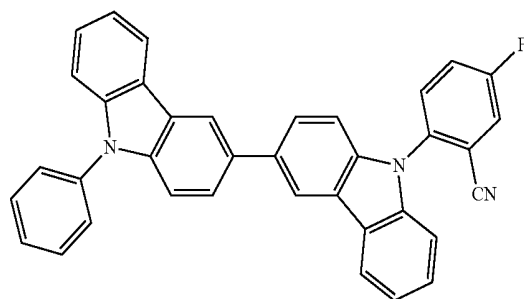
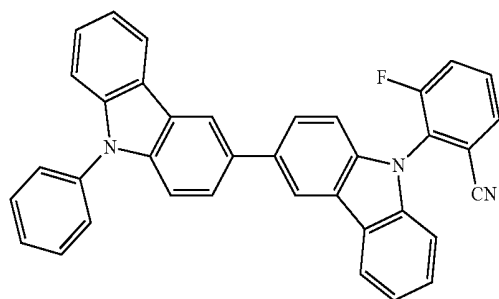
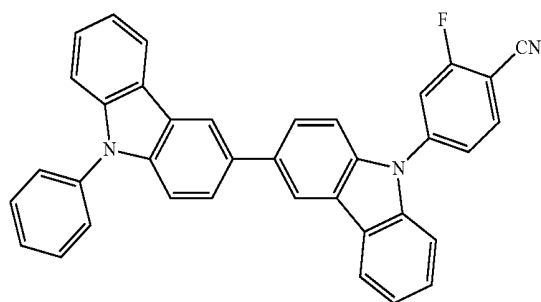
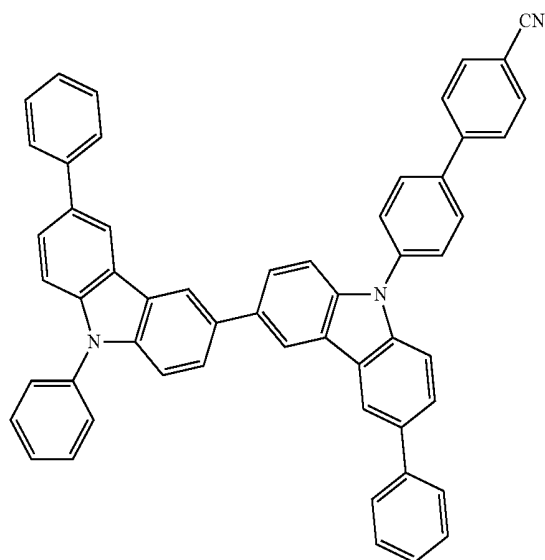
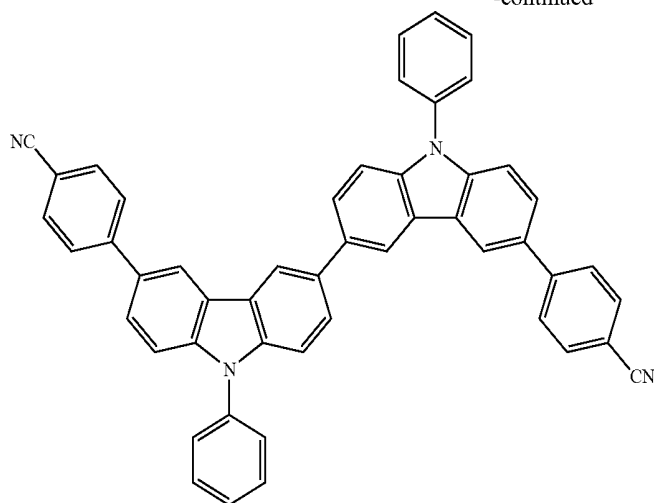
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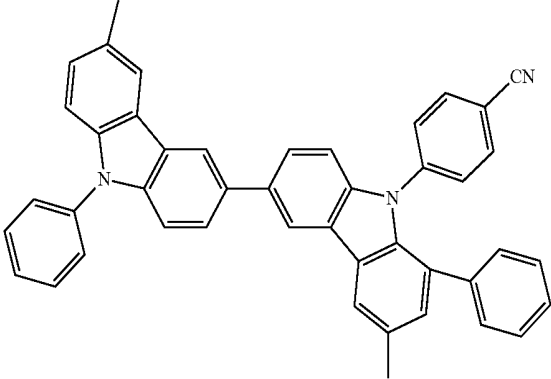
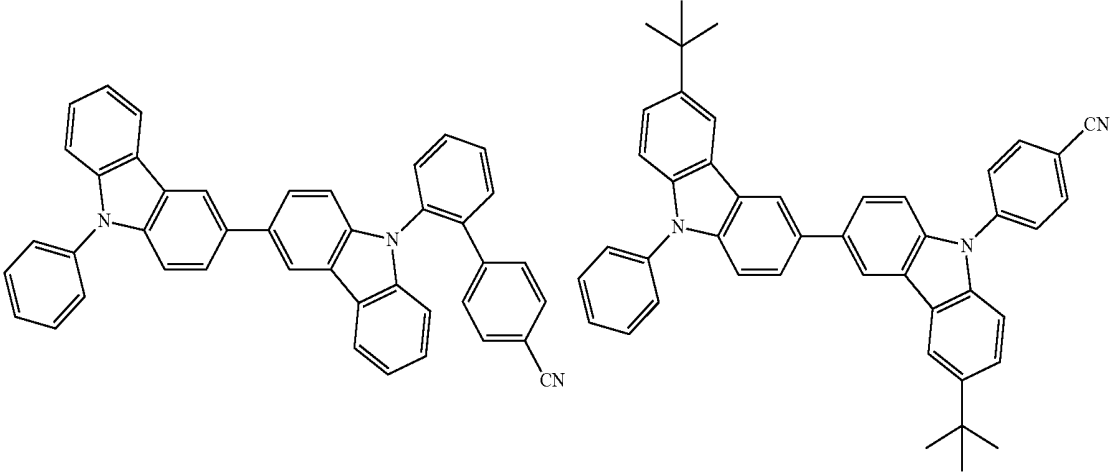
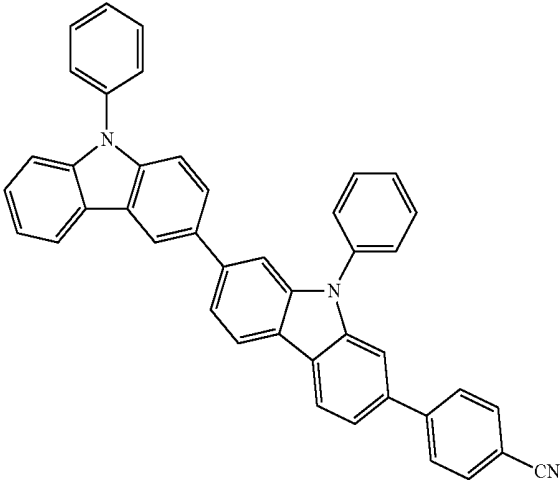
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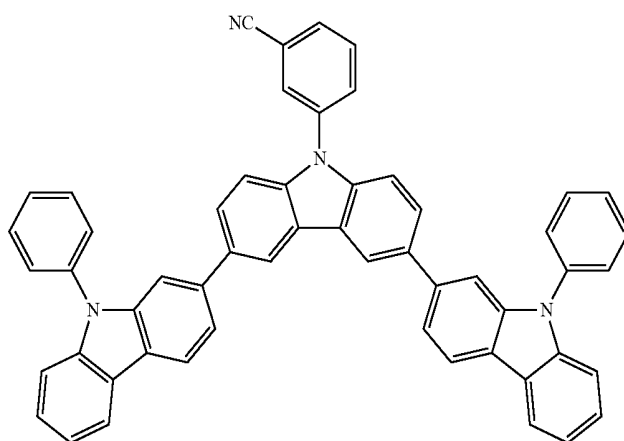
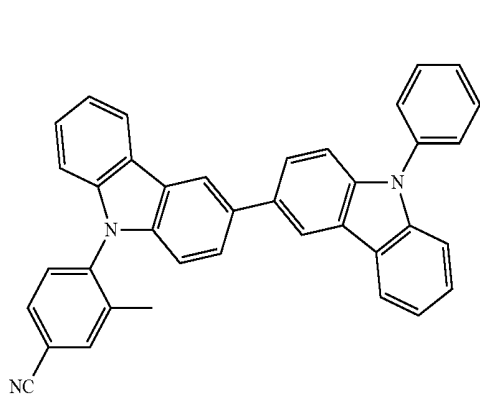
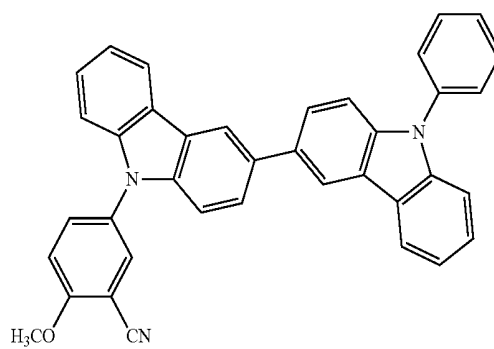
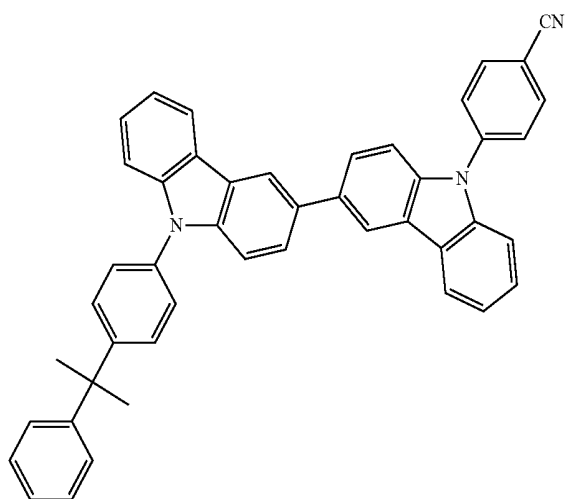
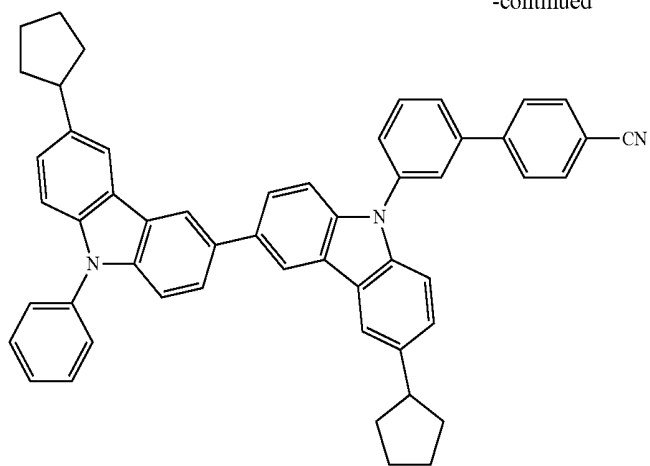
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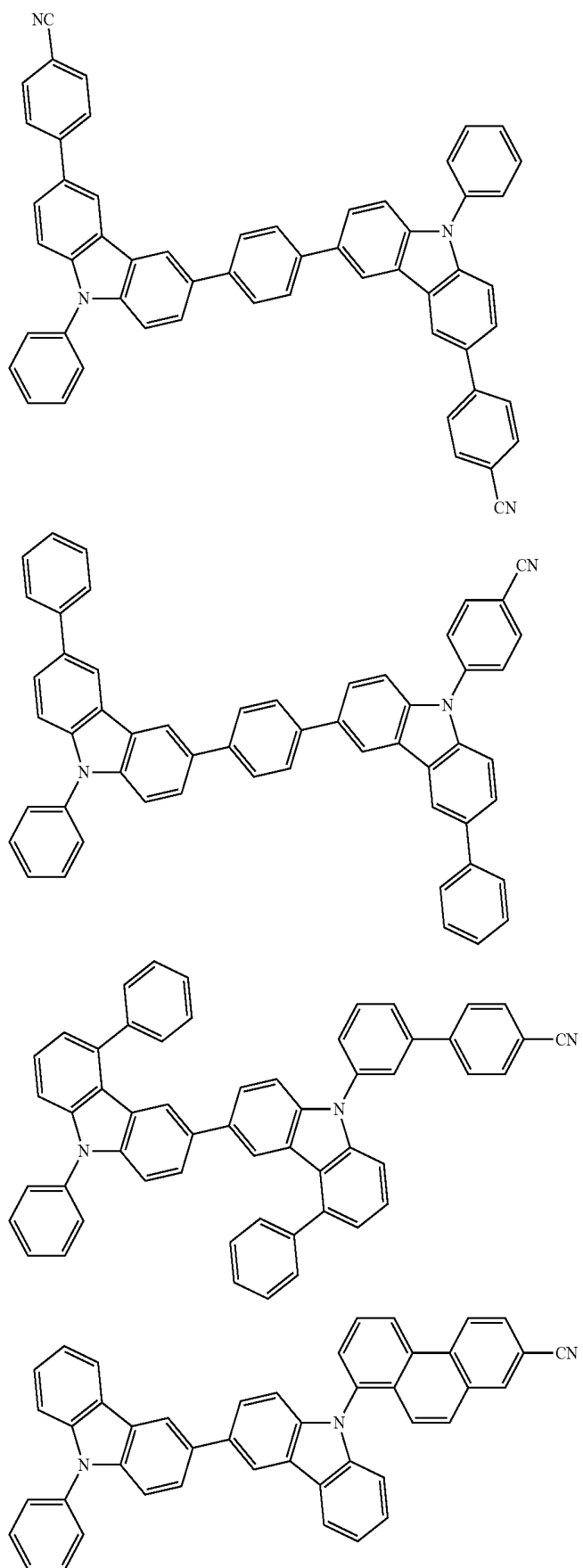
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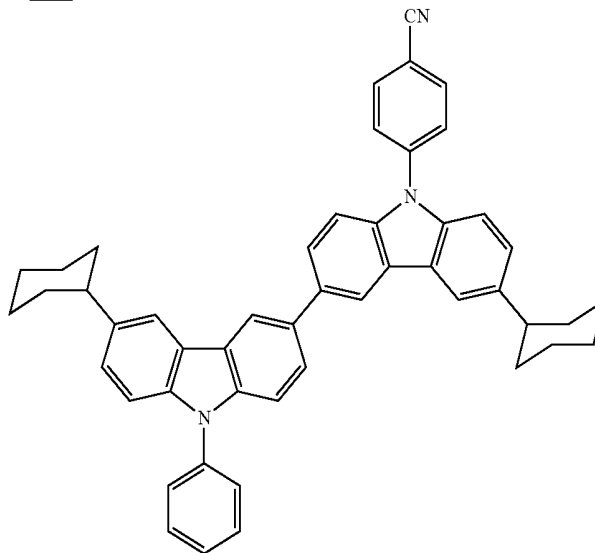
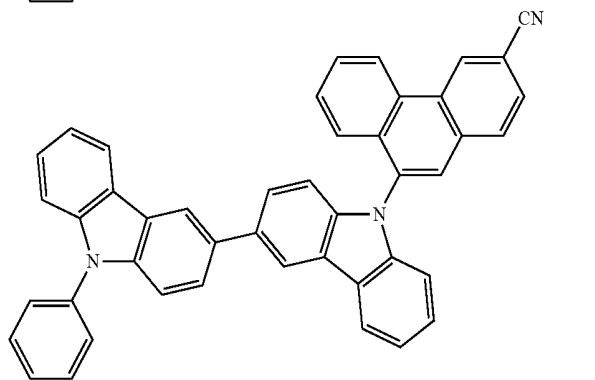
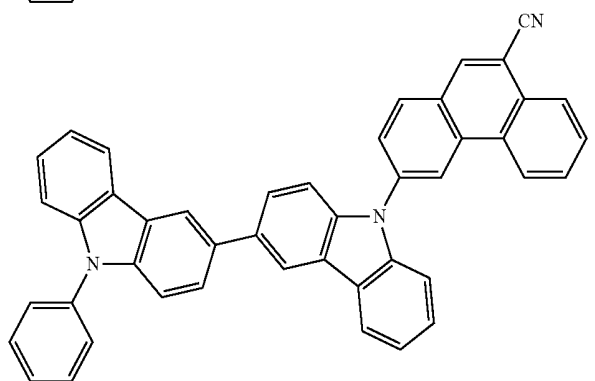
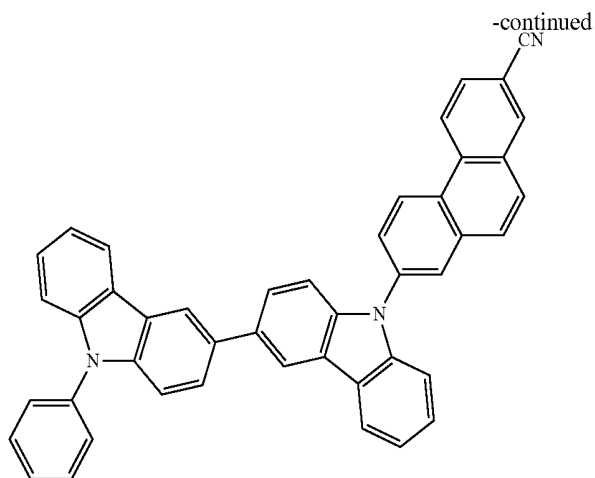
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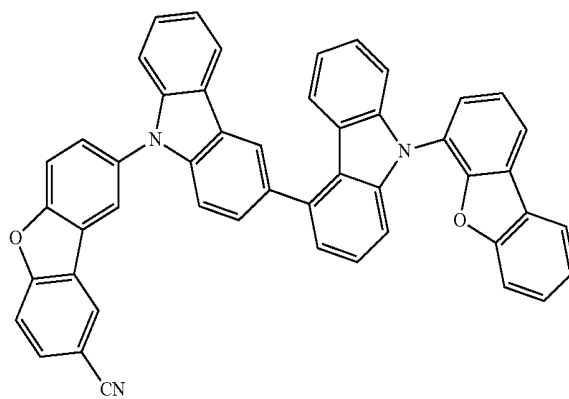
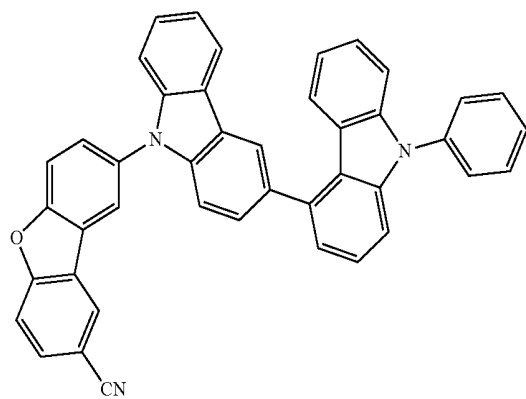
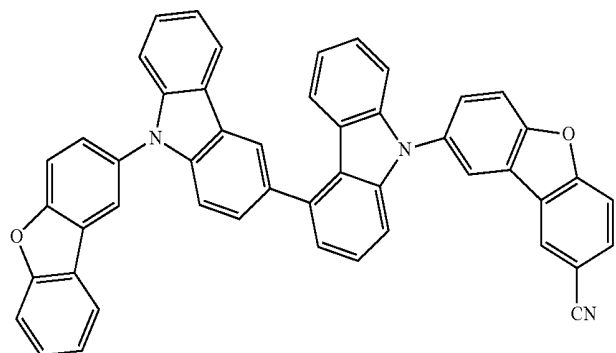
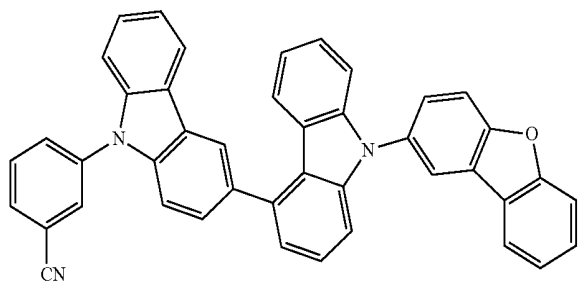
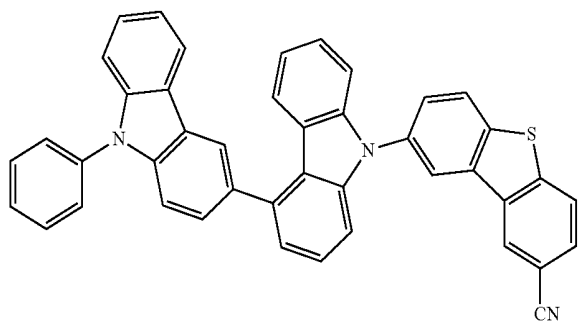
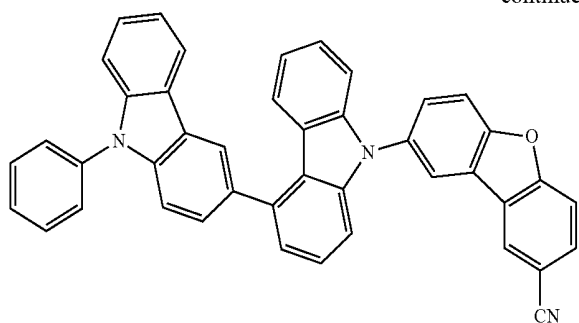
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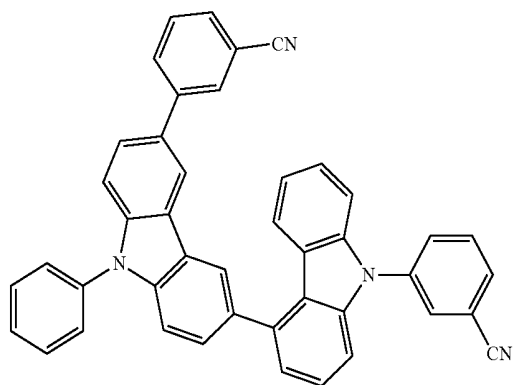
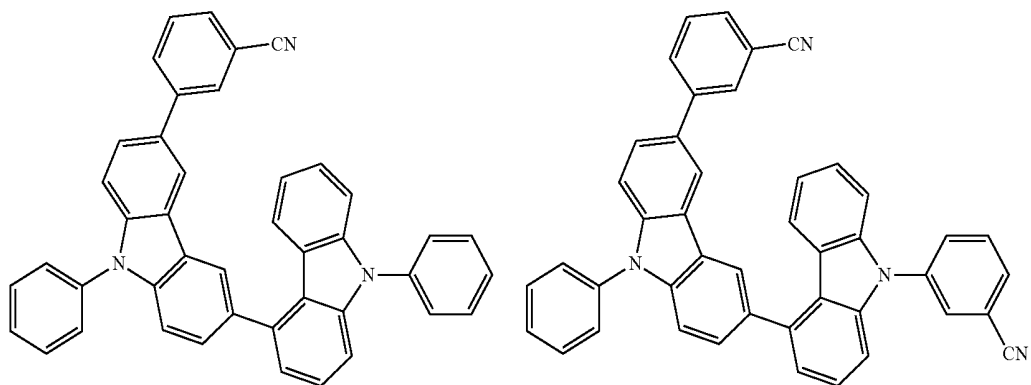
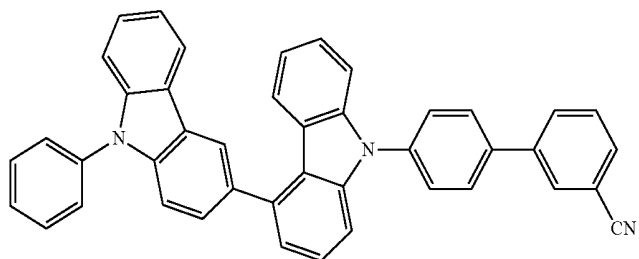
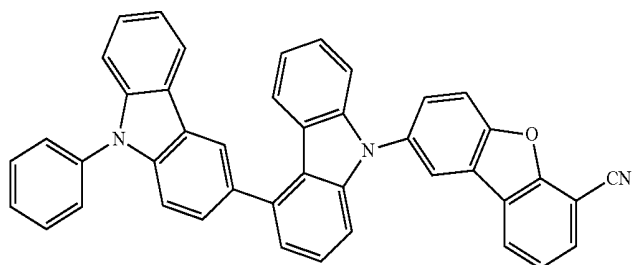
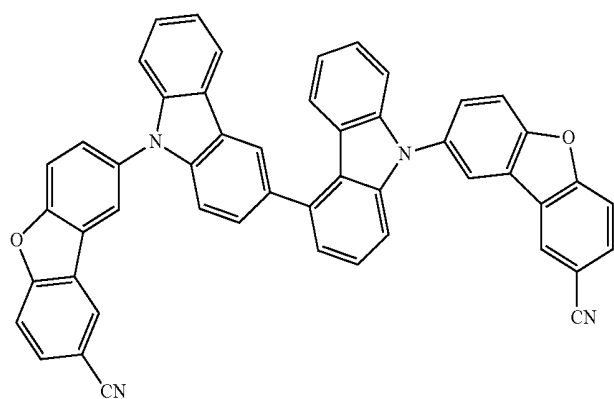
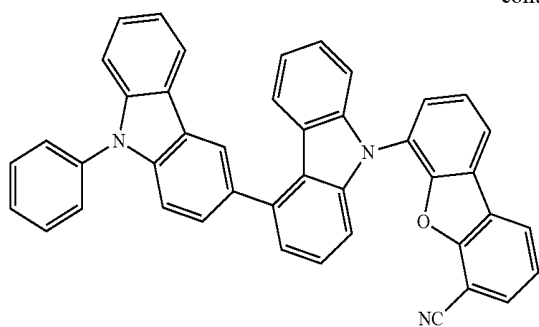
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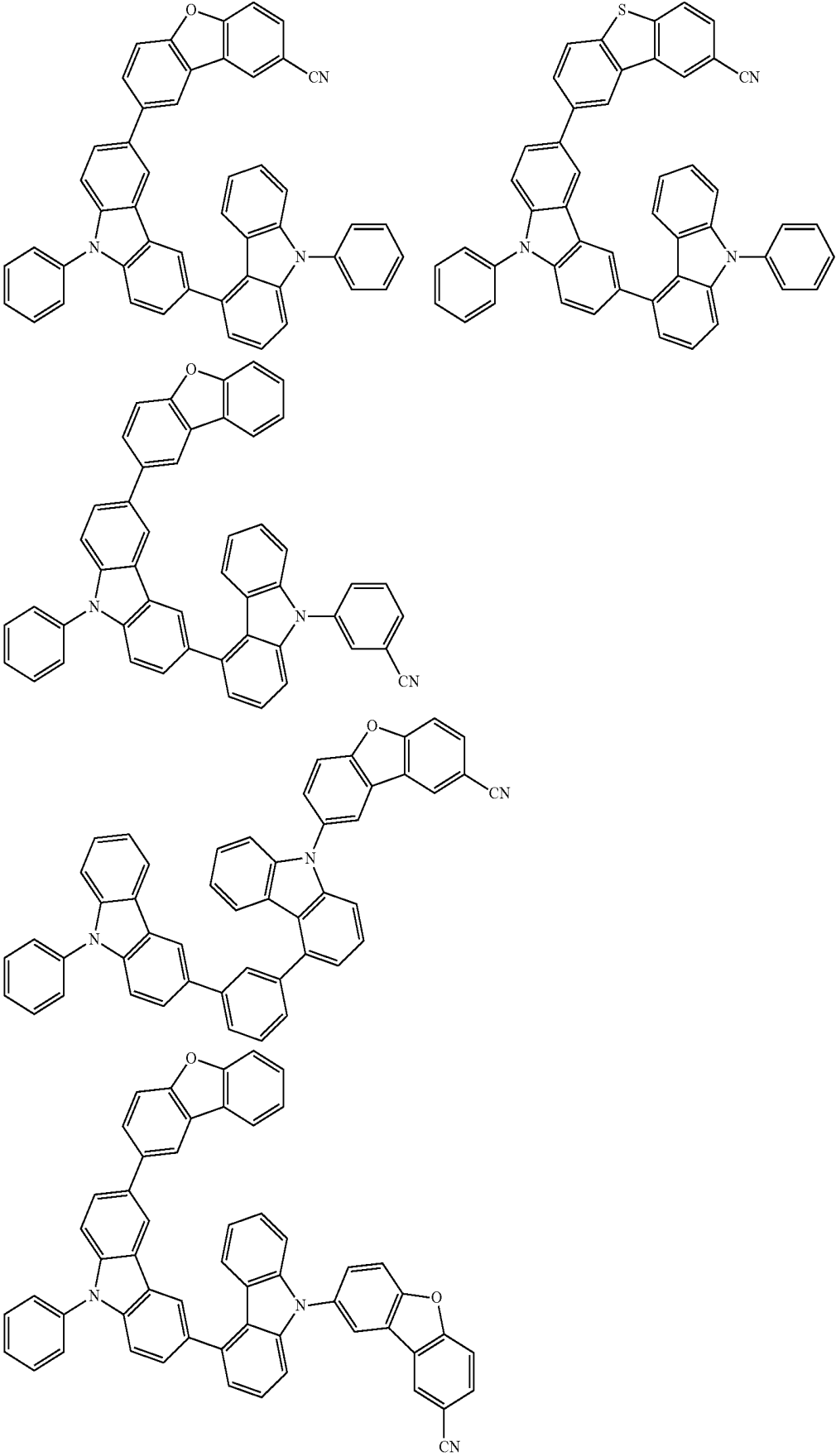
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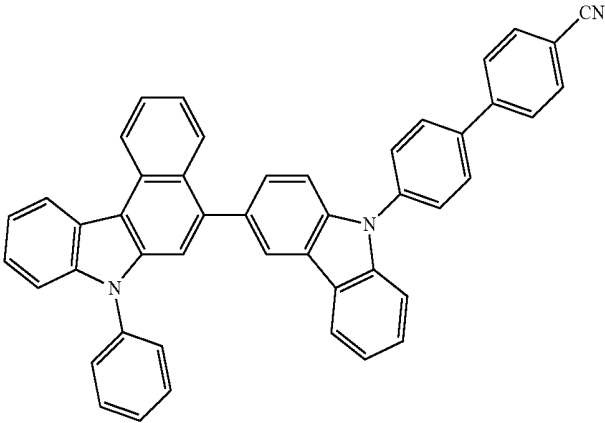
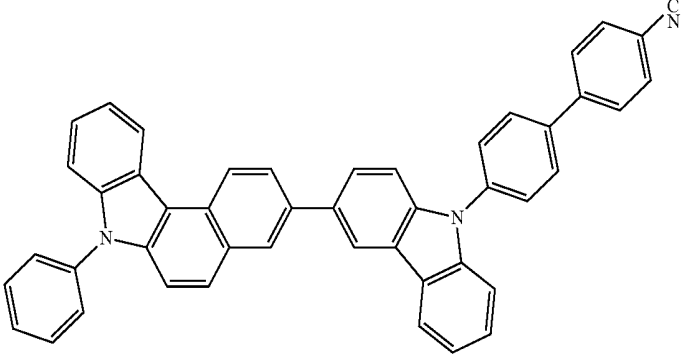
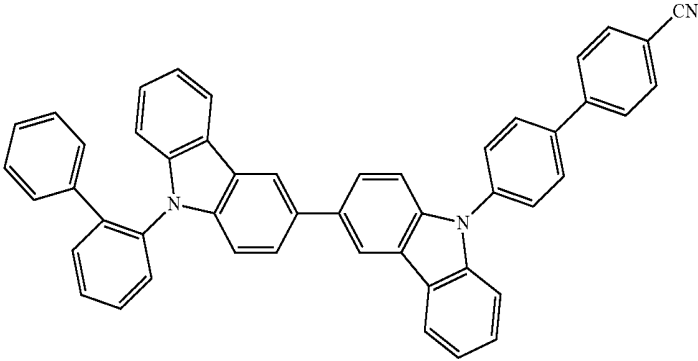
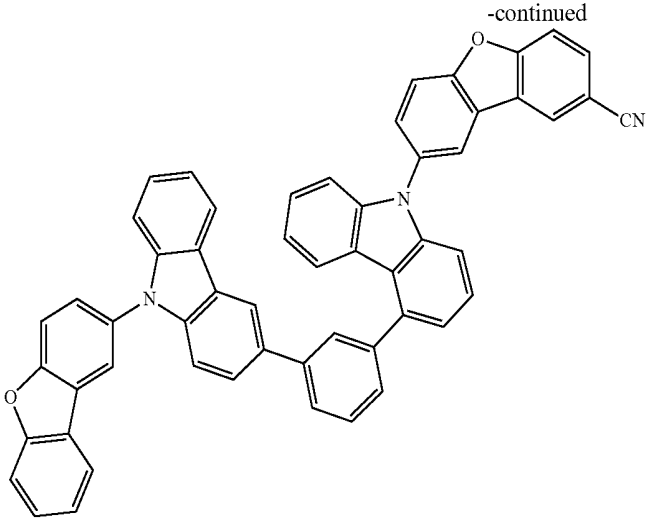


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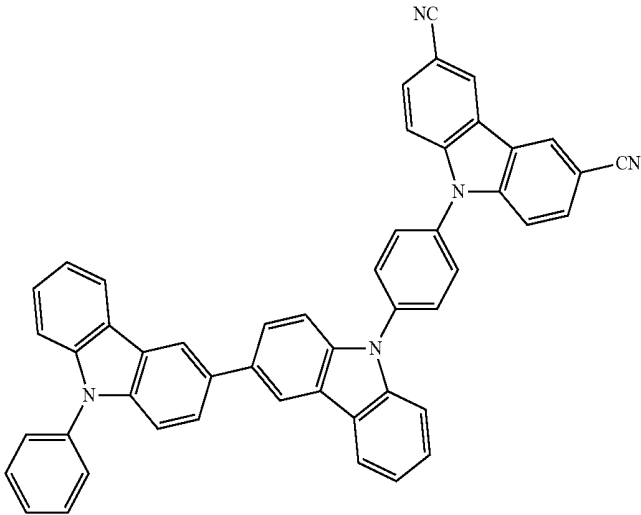
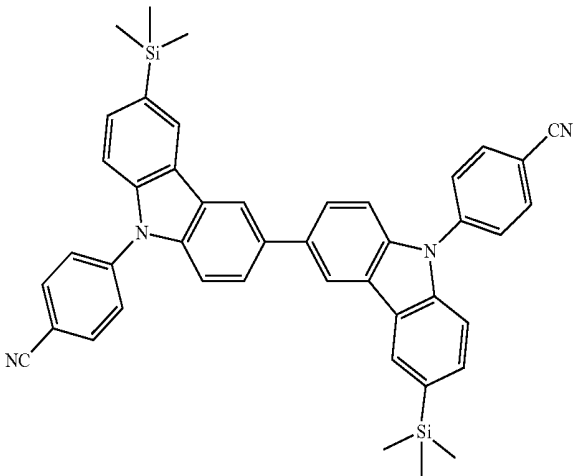
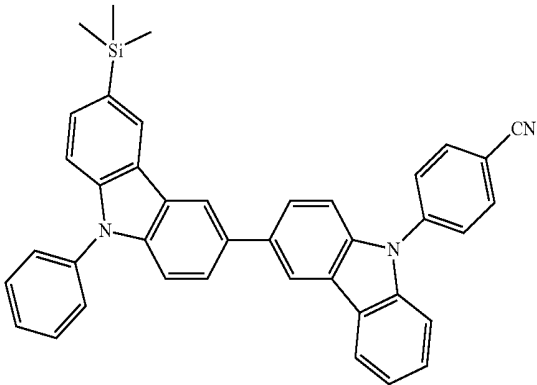
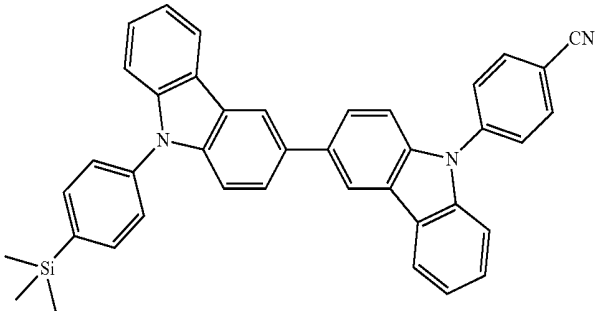


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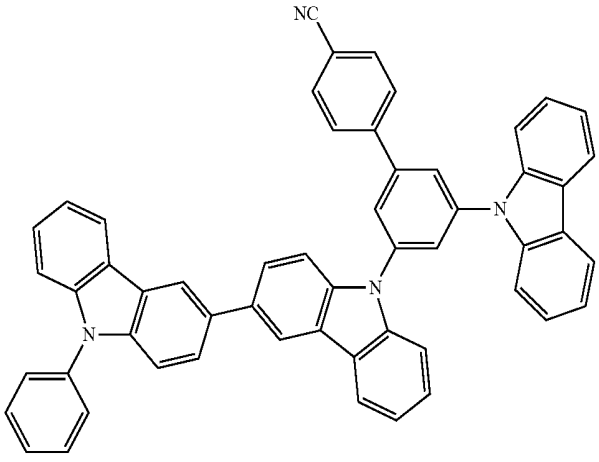
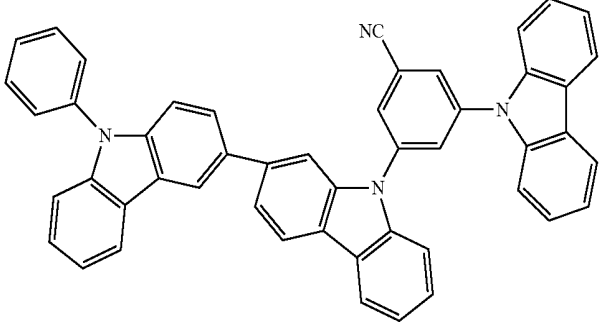
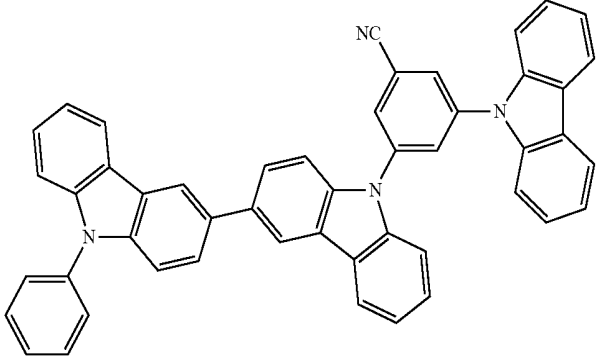
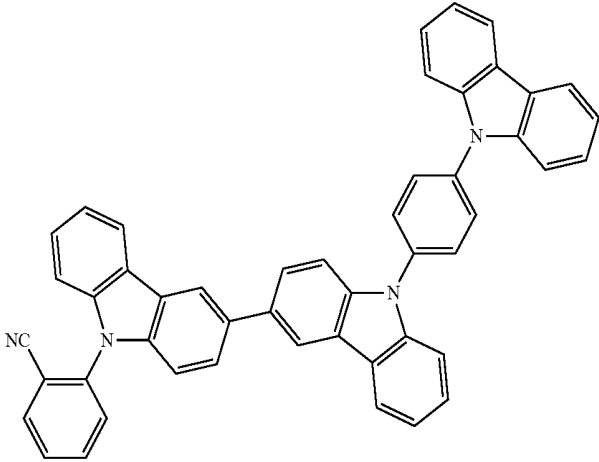


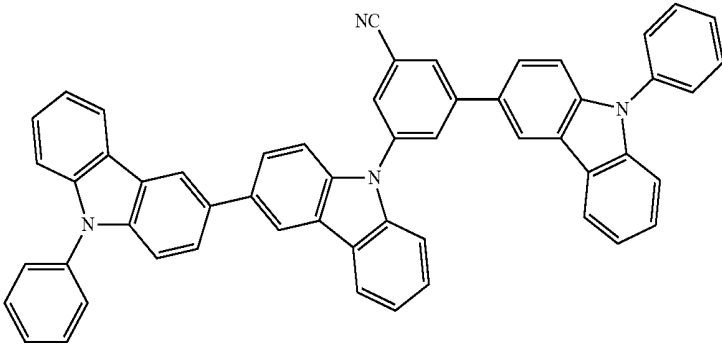
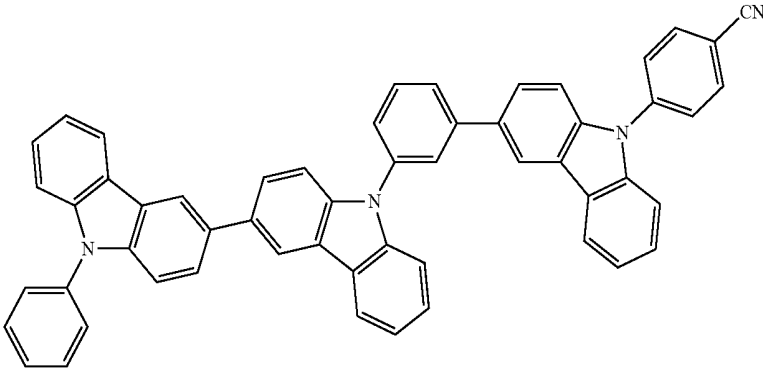
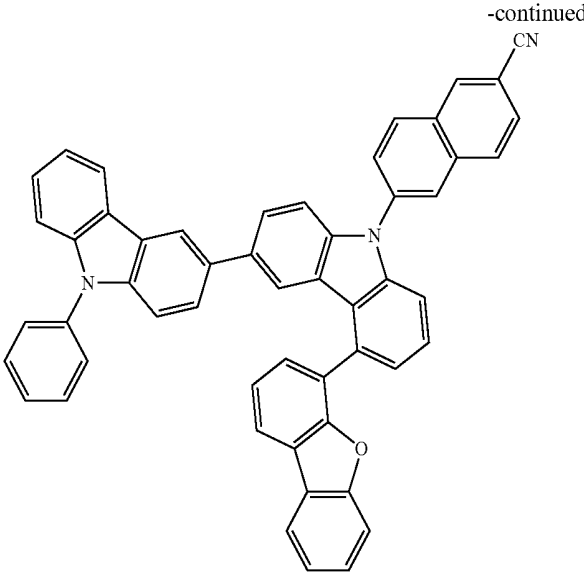


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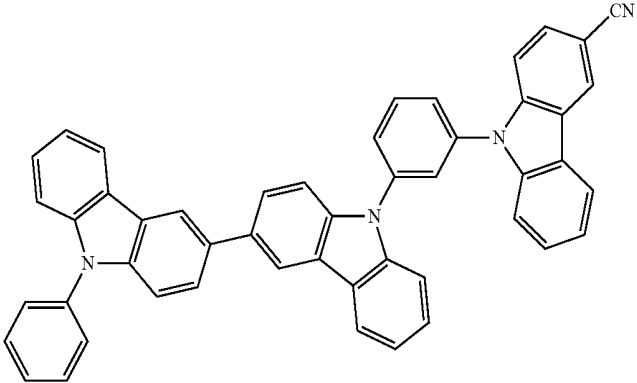
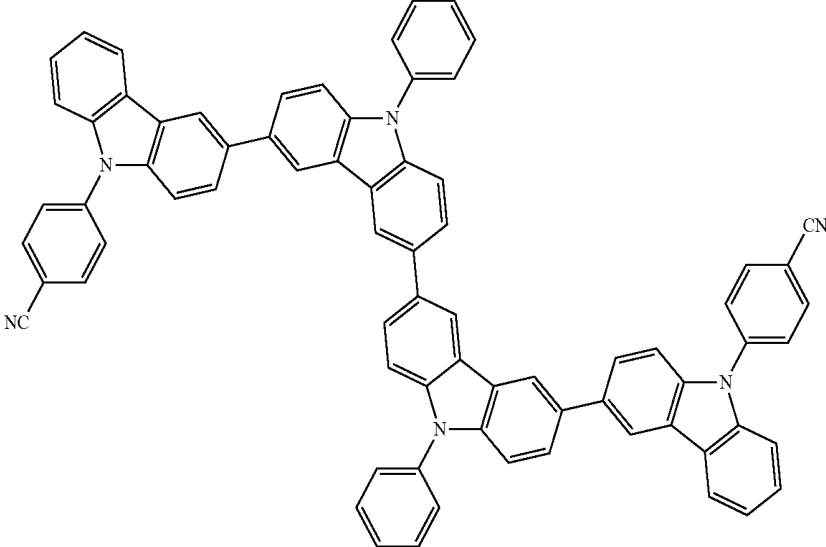
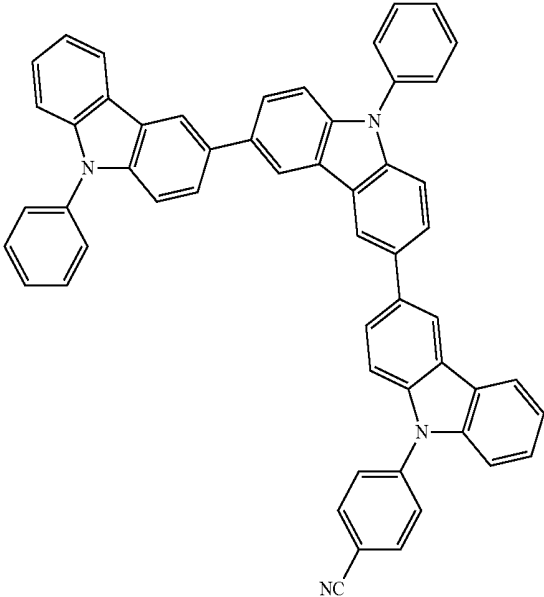


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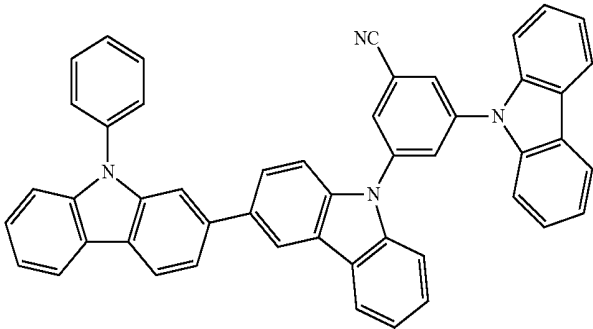
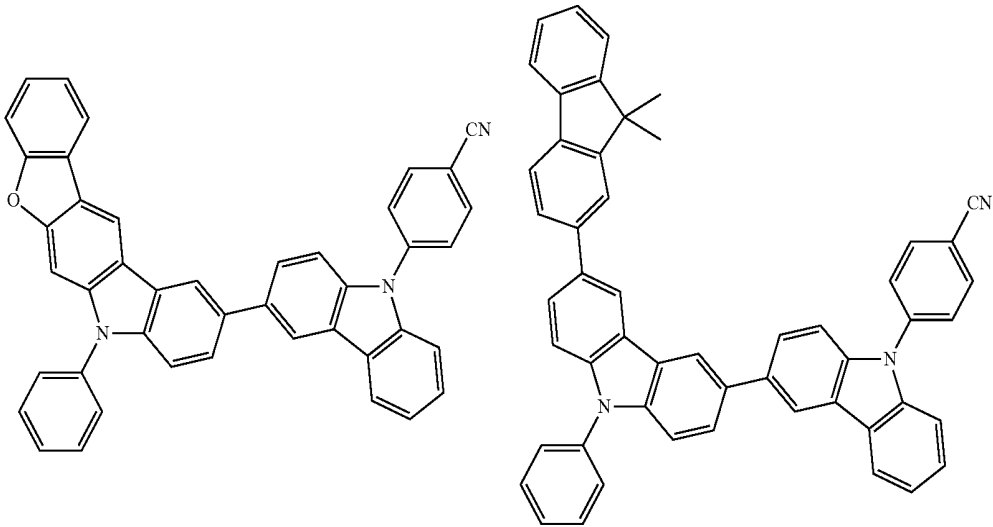
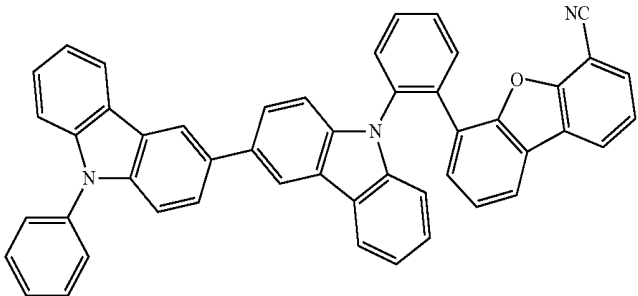
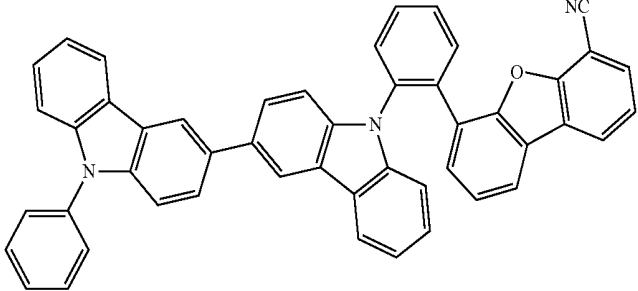




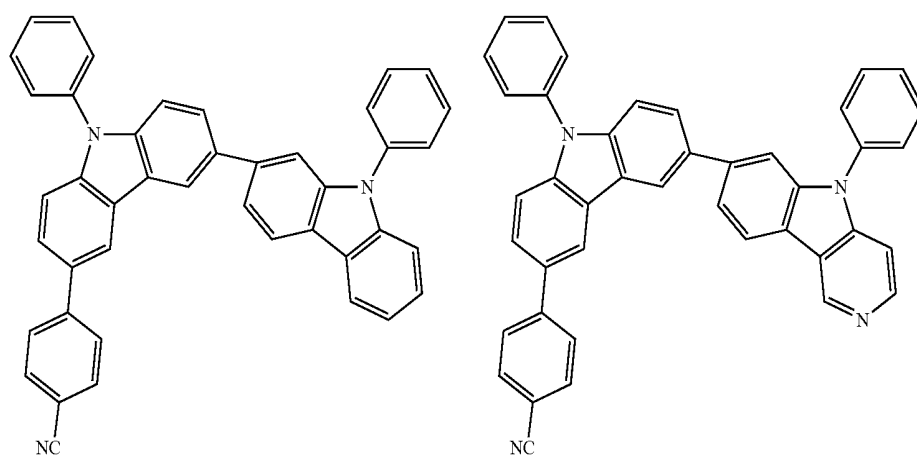
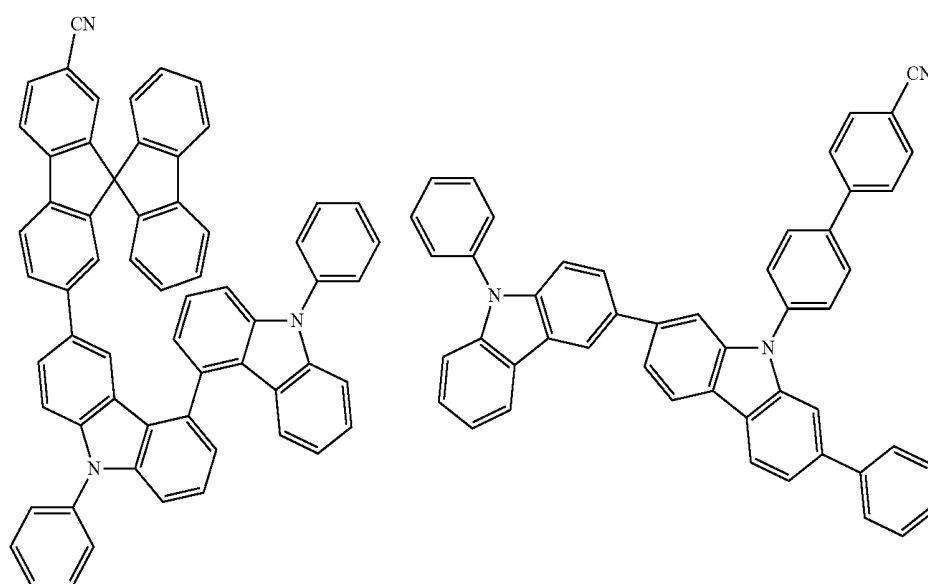
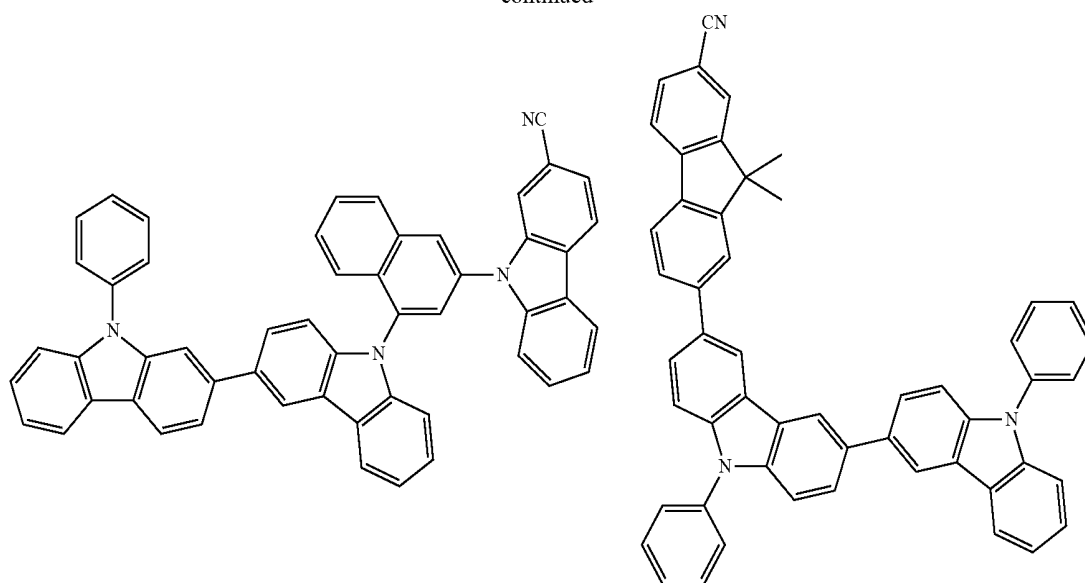
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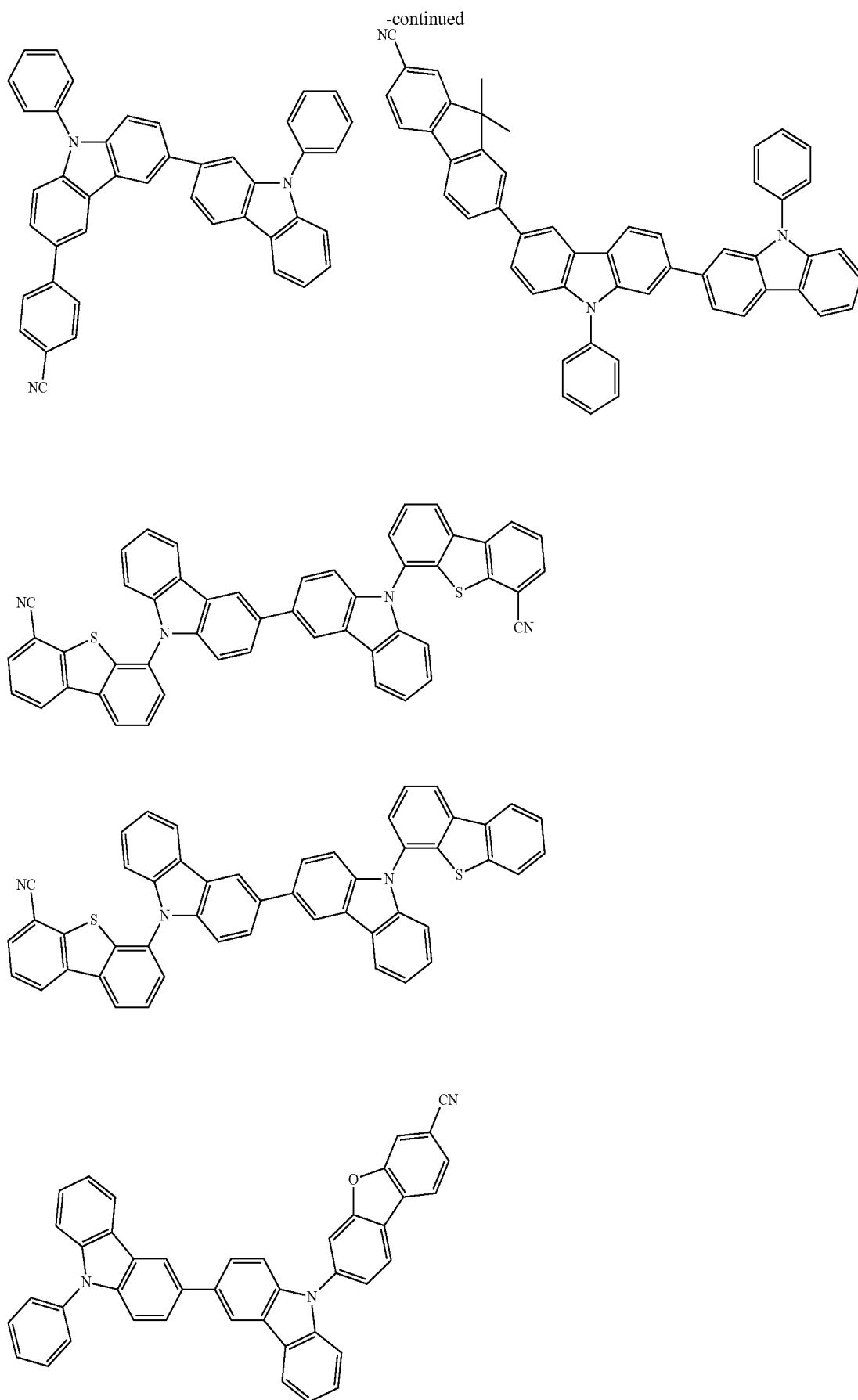


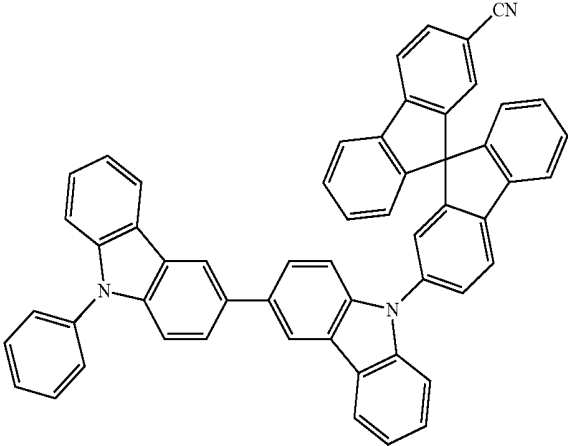
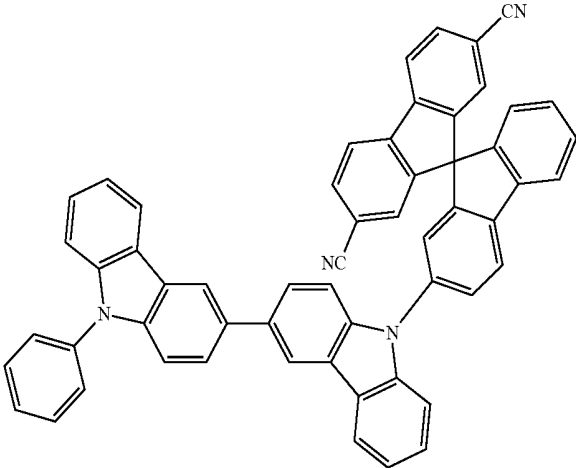
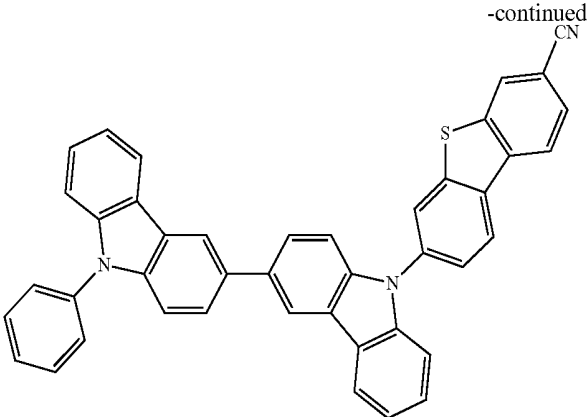
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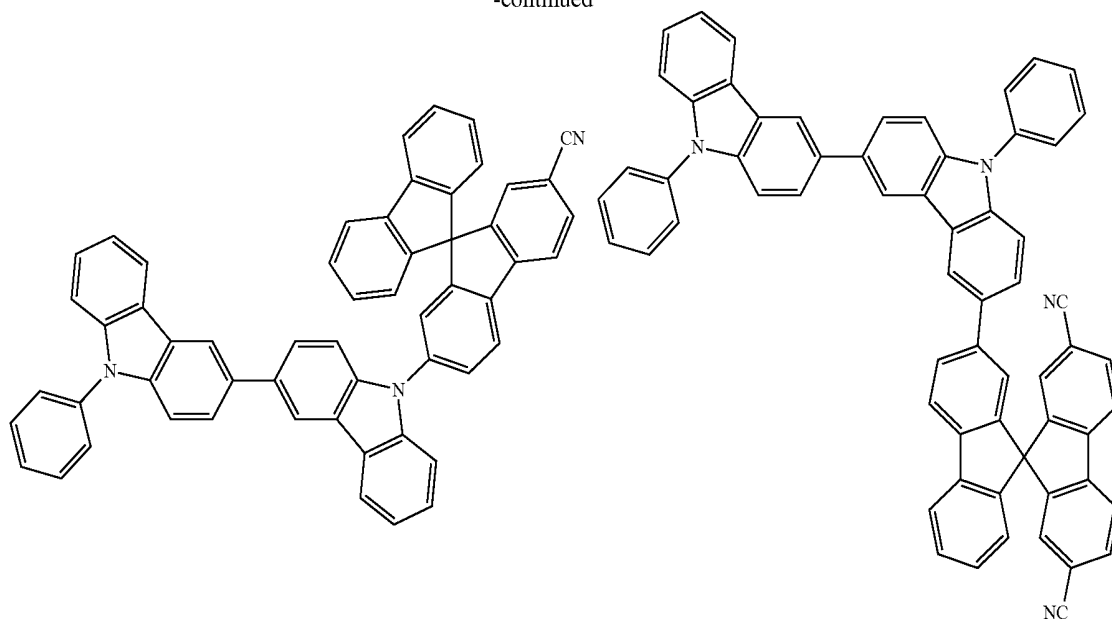
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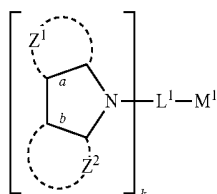




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**[0141]** Second Host Material

**[0142]** The second host material which is used in the light emitting layer of an embodiment of organic EL device is represented by formula (1). The lifetime of an organic EL device is increased by combinedly using the first host material represented by formula (A) and the second host material represented by formula (1) in the light emitting layer.



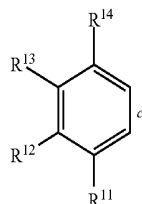
wherein

**[0143]**  $Z^1$  represents a ring structure fused to the side a and represented by formula (1-1) or (1-2), and  $Z^2$  represents a ring structure fused to the side b and represented by formula (1-1) or (1-2), provided that at least one of  $Z^1$  and  $Z^2$  is represented by formula (1-1);

**[0144]**  $M^1$  represent a substituted or unsubstituted nitrogen-containing aromatic heteroring having 5 to 30 ring atoms;

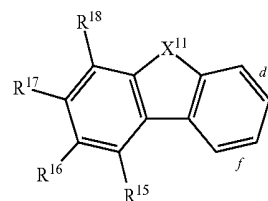
**[0145]**  $L^1$  represents a single bond, a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms, a cycloalkylene group having 5 to 30 ring atoms, or a group in which the preceding groups are directly linked to each other; and

**[0146]** k represents 1 or 2.



(1-1)

-continued



(1-2)

**[0147]** In formula (1-1), a side c is fused to the side a or b of formula (1).

**[0148]** In formula (1-2), any one of sides d, e and f is fused to the side a or b of formula (1).

**[0149]** In formulae (1-1) and (1-2),

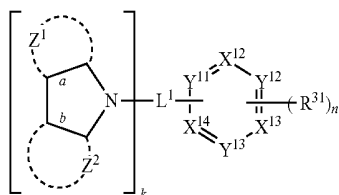
**[0150]**  $X^{11}$  represents a sulfur atom, an oxygen atom,  $N-R^{19}$ , or  $C(R^{20})(R^{21})$ ; and

**[0151]** each of  $R^{11}$  to  $R^{21}$  independently represents a hydrogen atom, a heavy hydrogen atom, a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms, provided that adjacent groups of  $R^{11}$  to  $R^{21}$  may be bonded to each other to form a ring.

**[0152]** The nitrogen-containing aromatic heteroring represented by  $M^1$  of formula (1) includes an azine rings

**[0153]** Examples of the nitrogen-containing aromatic heteroring include pyridine, pyrimidine, pyrazine, triazine, aziri-

dine, azaindolizine, indolizine, imidazole, indole, isoindole, indazole, purine, pteridine,  $\beta$ -carboline, naphthyridine, quinoxaline, terpyridine, bipyridine, acridine, phenanthroline, phenazine, and imidazopyridine, with pyridine, pyrimidine, and triazine being particularly preferred. The formula (1) is preferably represented by formula (2):



wherein

**[0154]**  $Z^1$  represents a ring structure fused to the side a and represented by formula (1-1) or (1-2), and  $Z^2$  represents a ring structure fused to the side b and represented by formula (1-1) or (1-2), provided that at least one of  $Z^1$  and  $Z^2$  is represented by formula (1-1);

**[0155]**  $L^1$  is as defined in formula (1);

**[0156]** each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

**[0157]** each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

**[0158]** each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

**[0159]** when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

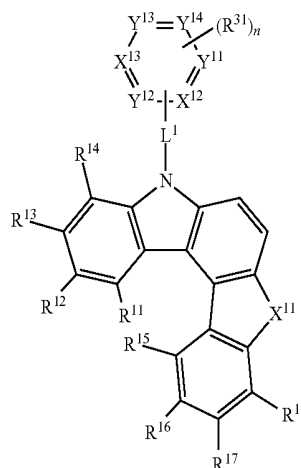
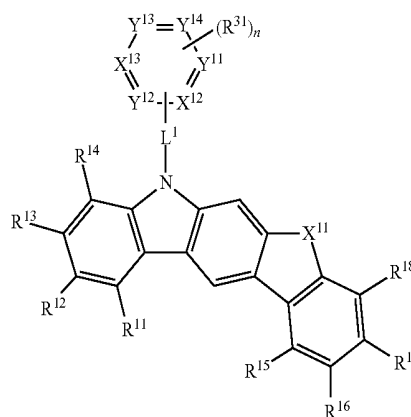
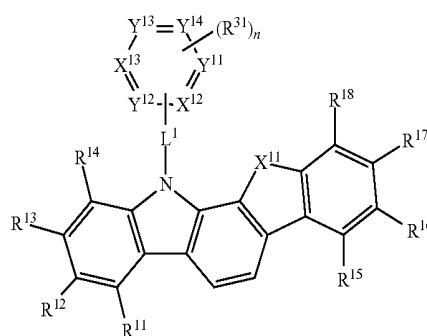
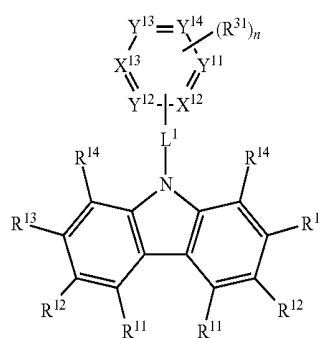
**[0160]**  $k$  represents 1 or 2, and  $n$  represents an integer of 0 to 4;

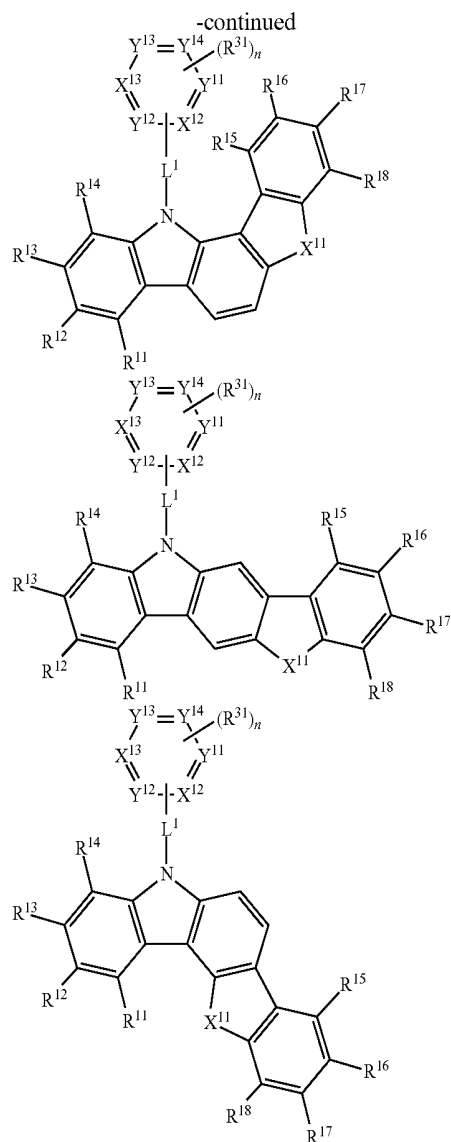
**[0161]** the side c of formula (1-1) is fused to the side a or b of formula (2); and

**[0162]** any one of sides d, e and f of formula (1-2) is fused to the side a or b of formula (2).

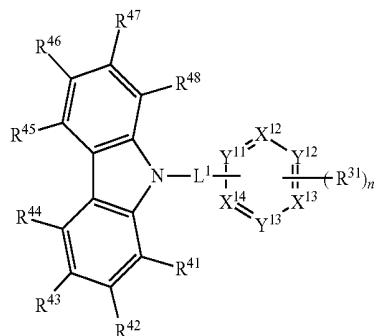
**[0163]** Examples of the compound wherein the ring represented by formula (1-1) or (1-2) is fused to the side a or b of formula (2) are shown below.

(2)





[0164] The compound represented by formula (1) or (2) is more preferably represented by formula (3) and particularly preferably represented by formula (4).



[0165] In formula (3),

[0166]  $L^1$  is as defined in formula (1);

[0167] each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

[0168] each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

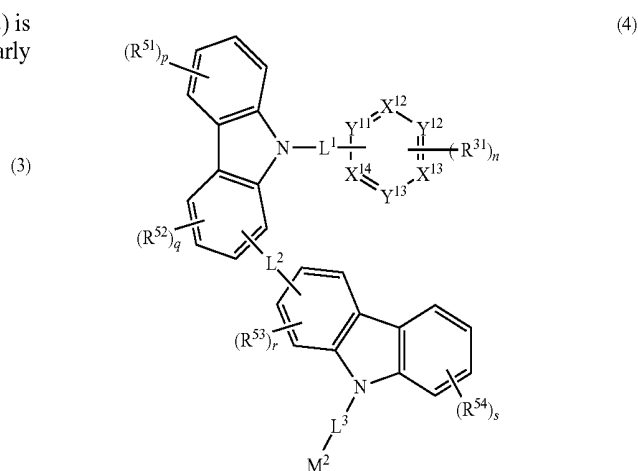
[0169] each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

[0170] when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

[0171]  $n$  represents an integer of 0 to 4;

[0172] each of  $R^{41}$  to  $R^{48}$  independently represents a hydrogen atom, a heavy hydrogen atom, a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms; and

[0173] adjacent groups of  $R^{41}$  to  $R^{48}$  may be bonded to each other to form a ring.



[0174] In formula (4),

[0175]  $L^1$  is as defined in formula (1);

[0176] each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

**[0177]** each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

**[0178]** each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

**[0179]** adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

**[0180]**  $n$  represents an integer of 0 to 4;

**[0181]** each of  $L^2$  and  $L^3$  independently represents a single bond, a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms, a cycloalkylene group having 5 to 30 ring atoms, or a group in which the preceding groups are directly linked to each other;

**[0182]** each of  $R^{51}$  to  $R^{54}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

**[0183]** when two or more  $R^{51}$  groups exist, the  $R^{51}$  groups may be the same or different and adjacent  $R^{51}$  groups may be bonded to each other to form a ring;

**[0184]** when two or more  $R^{52}$  groups exist, the  $R^{52}$  groups may be the same or different and adjacent  $R^{52}$  groups may be bonded to each other to form a ring;

**[0185]** when two or more  $R^{53}$  groups exist, the  $R^{53}$  groups may be the same or different and adjacent  $R^{53}$  groups may be bonded to each other to form a ring;

**[0186]** when two or more  $R^{54}$  groups exist, the  $R^{54}$  groups may be the same or different and adjacent  $R^{54}$  groups may be bonded to each other to form a ring;

**[0187]**  $M^2$  represents a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms; and

**[0188]** each of  $p$  and  $s$  independently represents an integer of 0 to 4, and each of  $q$  and  $r$  independently represents an integer of 0 to 3.

**[0189]** In formulae (1) to (4), (1-1), and (1-2), the groups represented by  $R^{11}$  to  $R^{21}$ ,  $R^{31}$ ,  $R^{41}$  to  $R^{48}$ , and  $R^{51}$  to  $R^{54}$  are as defined above with respect to formula (A).

**[0190]** Examples of the divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms and the divalent heterocyclic group having 5 to 30 ring atoms represented by  $L^1$  to  $L^3$  of formulae (1) to (4) includes divalent residues of the corresponding groups described above with respect to formula (A).

**[0191]** Examples of the compounds represented by any of formulae (1) to (4) are shown below. In the following structural formulae, the bond not terminated with a chemical symbol or structure (for example, CN and benzene ring) denotes a methyl group.

#### Organic EL Device

**[0192]** The organic EL device of the invention may include a hole transporting layer, a light emitting layer, a space layer, and a blocking layer. Each of these layers may contain a compound similar to the first host material and the second host material.

**[0193]** The light emitting material used in the light emitting layer may include a fluorescent emitting material and a phosphorescent emitting material, with the phosphorescent emitting material being preferred.

**[0194]** The organic EL device of the invention may be any of a single color emitting device of fluorescent or phosphorescent type, a white-emitting device of fluorescent-phosphorescent hybrid type, an emitting device of a simple type having a single emission unit, and an emitting device of a tandem type having two or more emission units, with the phosphorescent device being preferred. The "emission unit" referred to herein is the smallest unit for emitting light by the recombination of injected holes and injected electrons, which comprises one or more organic layers wherein at least one layer is a light emitting layer.

**[0195]** Representative device structures of the simple-type organic EL device are shown below.

#### (1) Anode/Emission Unit/Cathode

**[0196]** The emission unit may be a laminate comprising two or more layers selected from a phosphorescent light emitting layer and a fluorescent light emitting layer. A space layer may be disposed between the light emitting layers to prevent the diffusion of excitons generated in the phosphorescent light emitting layer into the fluorescent light emitting layer. Representative layered structures of the emission unit are shown below.

(a) hole transporting layer/light emitting layer (/electron transporting layer);

(b) hole transporting layer/first phosphorescent light emitting layer/second phosphorescent light emitting layer (/electron transporting layer);

(c) hole transporting layer/phosphorescent light emitting layer/space layer/fluorescent light emitting layer (/electron transporting layer);

(d) hole transporting layer/first phosphorescent light emitting layer/second phosphorescent light emitting layer/space layer/fluorescent light emitting layer (/electron transporting layer);

(e) hole transporting layer/first phosphorescent light emitting layer/space layer/second phosphorescent light emitting layer/space layer/fluorescent light emitting layer (/electron transporting layer);

(f) hole transporting layer/phosphorescent light emitting layer/space layer/first fluorescent light emitting layer/second fluorescent light emitting layer (/electron transporting layer);

(g) hole transporting layer/electron blocking layer/light emitting layer (/electron transporting layer);

(h) hole transporting layer/light emitting layer/hole blocking layer (/electron transporting layer); and

(i) hole transporting layer/fluorescent light emitting layer/triplet blocking layer (/electron transporting layer).

[0197] The emission color of the phosphorescent light emitting layer and that of the fluorescent light emitting layer may be different. For example, the layered structure of the laminated light emitting layer (d) may be hole transporting layer/first phosphorescent light emitting layer (red emission)/second phosphorescent light emitting layer (green emission)/space layer/fluorescent light emitting layer (blue emission)/electron transporting layer.

[0198] An electron blocking layer may be disposed between the light emitting layer and the hole transporting layer or between the light emitting layer and the space layer, if necessary. Also, a hole blocking layer may be disposed between the light emitting layer and the electron transporting layer, if necessary. With such an electron blocking layer or a hole blocking layer, electrons and holes are confined in the light emitting layer to increase the degree of charge recombination in the light emitting layer, thereby improving the emission efficiency.

[0199] Representative device structure of the tandem-type organic EL device is shown below.

(2) Anode/First Emission Unit/Intermediate Layer/Second Emission Unit/Cathode

[0200] The layered structure of the first emission unit and the second emission unit may be selected from those described above with respect to the emission unit.

[0201] Generally, the intermediate layer is also called an intermediate electrode, an intermediate conductive layer, a charge generation layer, an electron withdrawing layer, a connecting layer, or an intermediate insulating layer. The intermediate layer may be formed by known materials so as to supply electrons to the first emission unit and holes to the second emission unit.

[0202] A schematic structure of an example of the organic EL device of the invention is shown in FIG. 1 wherein the organic EL device 1 is constructed by a substrate 2, an anode 3, a cathode 4, and an emission unit 10 disposed between the anode 3 and the cathode 4. The emission unit 10 includes a light emitting layer 5 which comprises at least one layer containing the first host compound, the second host compound, and the light emitting material. A hole injecting/transporting layer 6, etc. may be disposed between the light emitting layer 5 and the anode 3, and an electron injecting/transporting layer 7, etc. may be disposed between the light emitting layer 5 and the cathode 4. An electron blocking layer may be disposed on the anode 3 side of the light emitting layer 5, and a hole blocking layer may be disposed on the cathode 4 side of the light emitting layer 5. With these blocking layers, electrons and holes are confined in the light emitting layer 5 to increase the degree of exciton generation in the light emitting layer 5.

[0203] In the present invention, the host is referred to as a fluorescent host when combinedly used with a fluorescent dopant and as a phosphorescent host when combinedly used with a phosphorescent dopant. Therefore, the fluorescent host and the phosphorescent host are not distinguished from each other merely by the difference in their molecular structures. Namely, the term "phosphorescent host" means a material for

constituting a phosphorescent emitting layer containing a phosphorescent dopant and does not mean that the material is not usable as a material for constituting a fluorescent emitting layer. The same also applies to the fluorescent host.

Substrate

[0204] The organic EL device of the invention is formed on a light-transmissive substrate. The light-transmissive substrate serves as a support for the organic EL device and preferably a flat substrate having a transmittance of 50% or more to 400 to 700 nm visible light. Examples of the substrate include a glass plate and a polymer plate. The glass plate may include a plate made of soda-lime glass, barium-strontium-containing glass, lead glass, aluminosilicate glass, borosilicate glass, barium borosilicate glass, or quartz. The polymer plate may include a plate made of polycarbonate, acryl, polyethylene terephthalate, polyether sulfide, or polysulfone.

Anode

[0205] The anode of the organic EL device injects holes to the hole transporting layer or the light emitting layer, and an anode having a work function of 4.5 eV or more is effective. Examples of material for anode include indium tin oxide alloy (ITO), tin oxide (NESA), indium zinc oxide alloy, gold, silver, platinum, and copper. The anode is formed by making the electrode material into a thin film by a method, such as a vapor deposition method or a sputtering method. When getting the light emitted from the light emitting layer through the anode, the transmittance of anode to visible light is preferably 10% or more. The sheet resistance of anode is preferably several hundreds  $\Omega/\square$  or less. The film thickness of anode depends upon the kind of material and generally 10 nm to 1  $\mu\text{m}$ , preferably 10 to 200 nm.

Cathode

[0206] The cathode injects electrons to the electron injecting layer, the electron transporting layer or the light emitting layer, and preferably formed from a material having a small work function. Examples of the material for cathode include, but not limited to, indium, aluminum, magnesium, magnesium-indium alloy, magnesium-aluminum alloy, aluminum-lithium alloy, aluminum-scandium-lithium alloy, and magnesium-silver alloy. Like the anode, the cathode is formed by making the material into a thin film by a method, such as the vapor deposition method and the sputtering method. The emitted light may be taken from the cathode, if appropriate.

Light Emitting Layer

[0207] The light emitting layer is an organic layer having a light emitting function and is formed from one or more layers, wherein one of the layers comprises the first host material, the second host material, and the light emitting material as described above.

[0208] When the light emitting layer is composed of two or more layers, the light emitting layer or layers other than that mentioned above contains or contain a host material and a dopant material when a doping system is employed. The major function of the host material is to promote the recombination of electrons and holes and confine excitons in the light emitting layer. The dopant material causes the excitons generated by recombination to emit light efficiently.

[0209] In case of a phosphorescent device, the major function of the host material is to confine the excitons generated on the dopant in the light emitting layer.

[0210] The light emitting layer may be made into a double dopant layer, in which two or more kinds of dopant materials having high quantum yield are combinedly used and each dopant material emits light with its own color. For example, to obtain a yellow emission, a light emitting layer formed by co-depositing a host, a red-emitting dopant and a green-emitting dopant is used.

[0211] In a laminate of two or more light emitting layers, electrons and holes are accumulated in the interface between the light emitting layers, and therefore, the recombination region is localized in the interface between the light emitting layers, to improve the quantum efficiency.

[0212] The light emitting layer may be different in the hole injection ability and the electron injection ability, and also in the hole transporting ability and the electron transporting ability each being expressed by mobility.

[0213] The light emitting layer is formed, for example, by a known method, such as a vapor deposition method, a spin coating method, and LB method. Alternatively, the light emitting layer may be formed by making a solution of a binder, such as resin, and the material for the light emitting layer in a solvent into a thin film by a method such as spin coating.

[0214] The light emitting layer is preferably a molecular deposit film. The molecular deposit film is a thin film formed by depositing a vaporized material or a film formed by solidifying a material in the state of solution or liquid. The molecular deposit film can be distinguished from a thin film formed by LB method (molecular build-up film) by the differences in the assembly structures and higher order structures and the functional difference due to the structural differences.

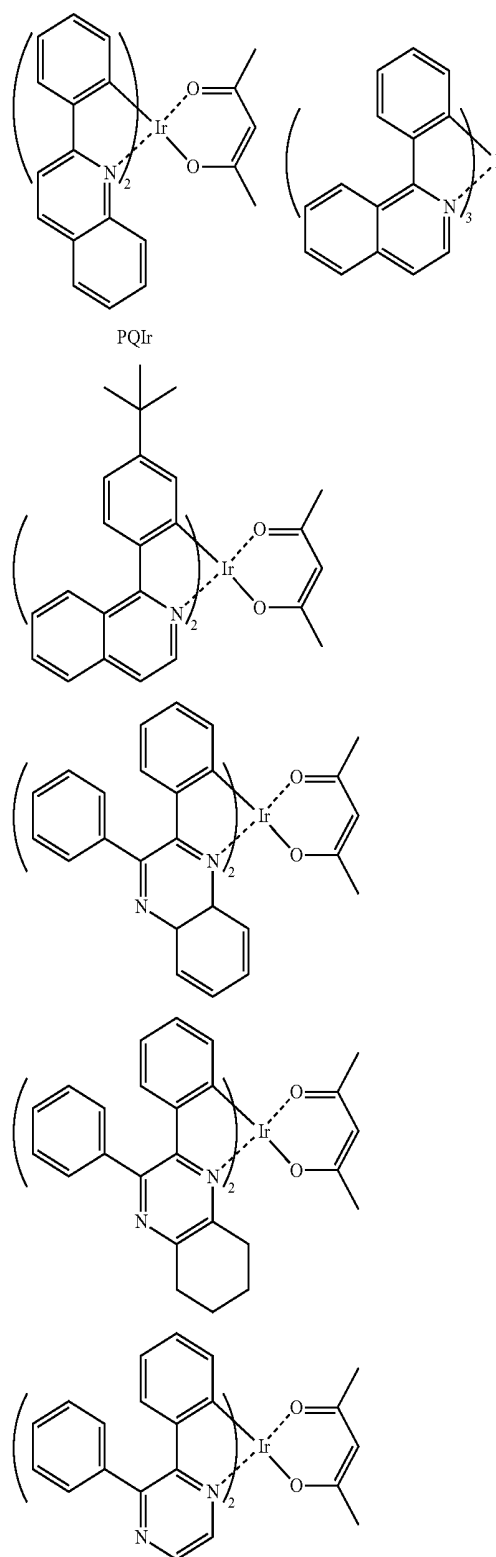
[0215] The content ratio of the first host material and the second host material in the light emitting layer is not particularly limited and may be selected accordingly, and the ratio of first host material:second host material is preferably 1:99 to 99:1, more preferably 10:90 to 90:10, each based on mass.

[0216] The phosphorescent dopant (phosphorescent emitting material) is a compound which emits light by releasing the energy of excited triplet state and preferably a organometallic complex comprising at least one metal selected from Ir, Pt, Os, Au, Cu, Re, and Ru and a ligand, although not particularly limited thereto as long as emitting light by releasing the energy of excited triplet state. A ligand having an ortho metal bond is preferred. In view of obtaining a high phosphorescent quantum yield and further improving the external quantum efficiency of electroluminescence device, a metal complex comprising a metal selected from Ir, Os, and Pt is preferred, with iridium complex, osmium complex, and platinum, particularly an ortho metallated complex thereof being more preferred, iridium complex and platinum complex being still more preferred, and an ortho metallated iridium complex being particularly preferred.

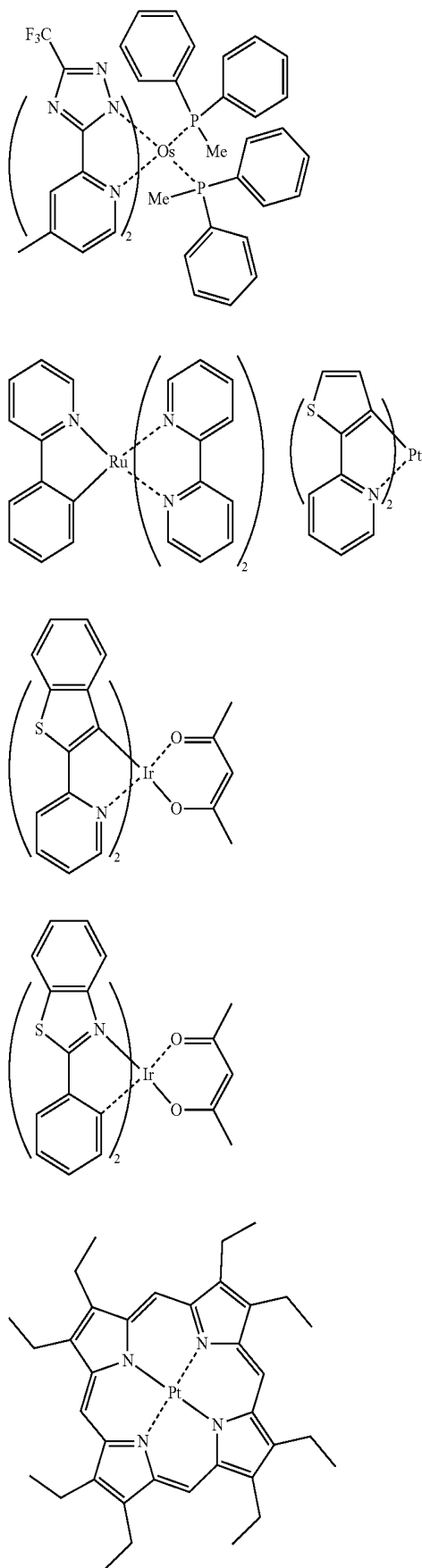
[0217] The content of the phosphorescent dopant in the light emitting layer is not particularly limited and selected according to the use of the device, and preferably 0.1 to 70% by mass, and more preferably 1 to 30% by mass. If being 0.1%

by mass or more, the amount of light emission is sufficient. If being 70% by mass or less, the concentration quenching can be avoided.

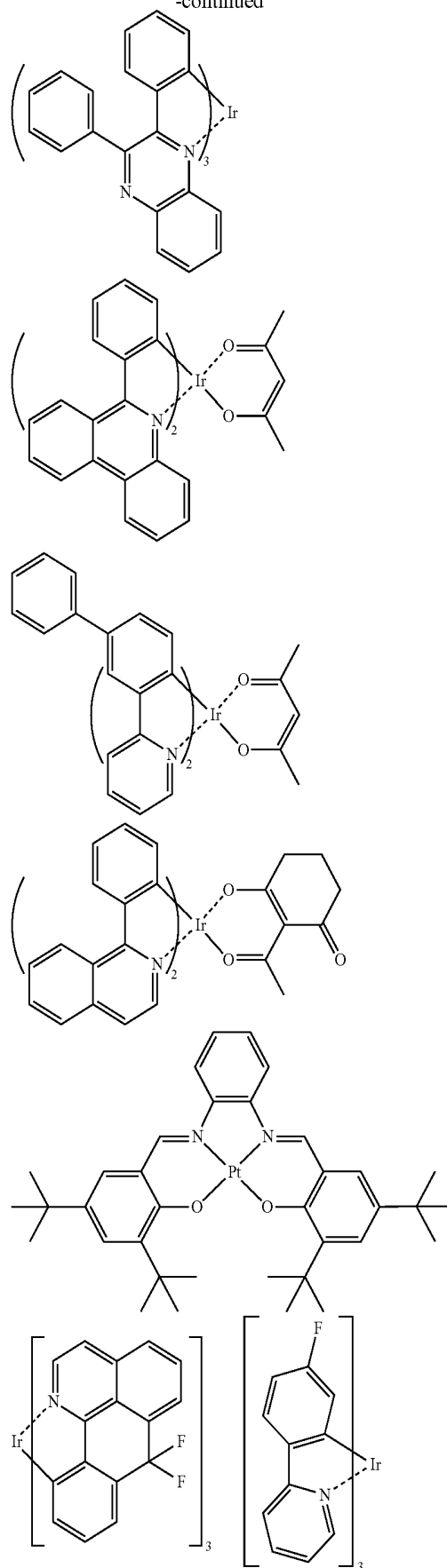
[0218] Preferred examples of the organometallic complex usable as the phosphorescent dopant are shown below.



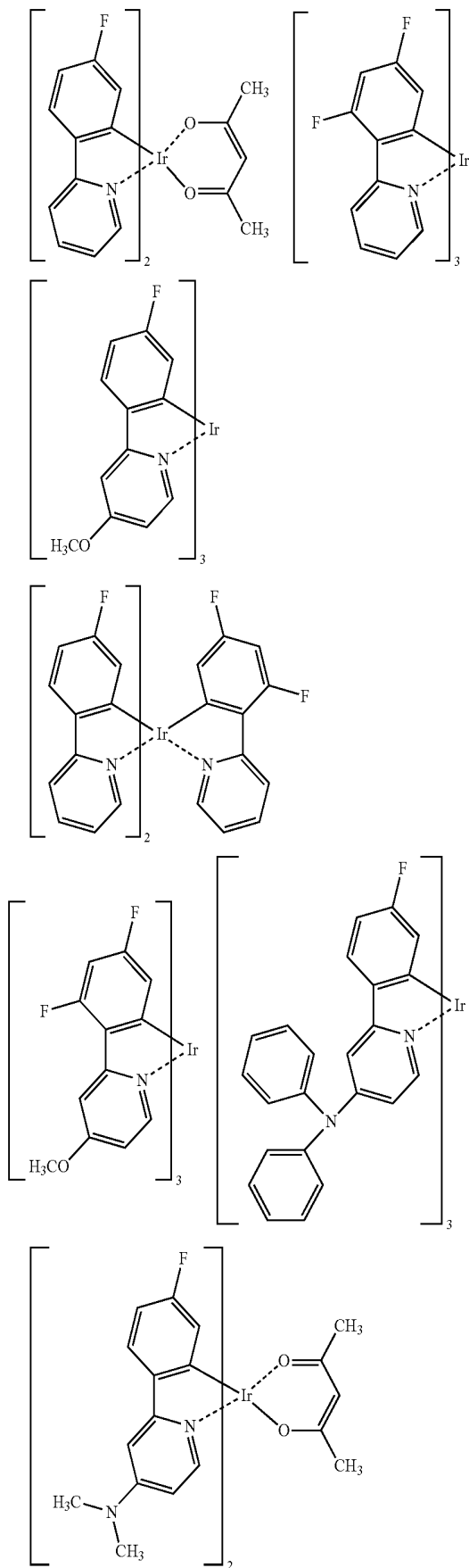
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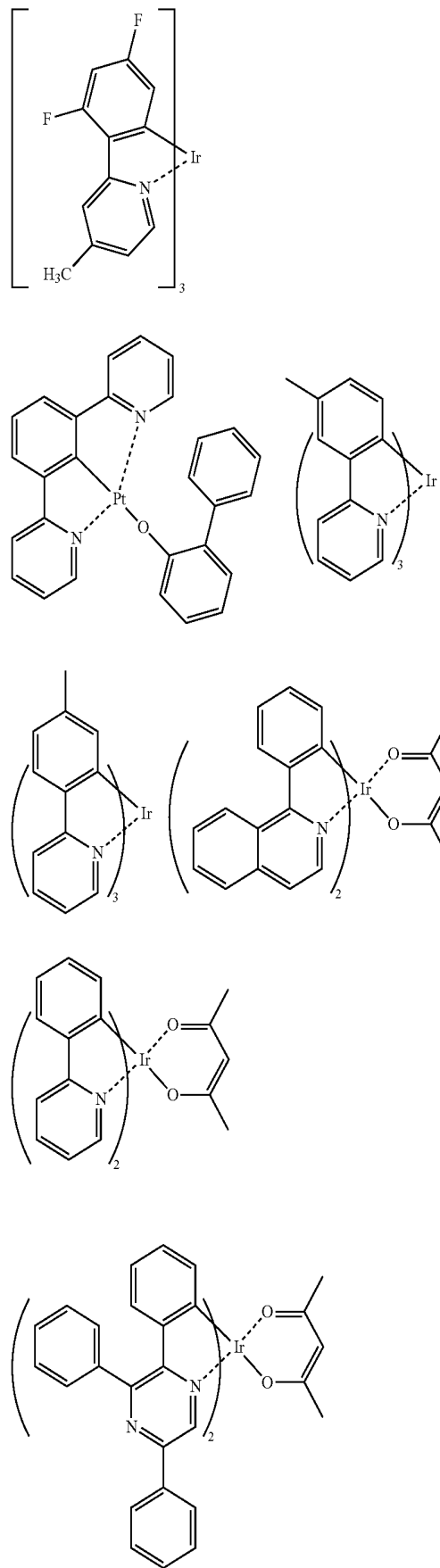
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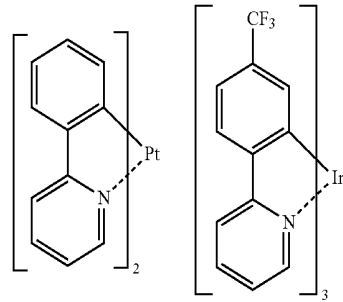
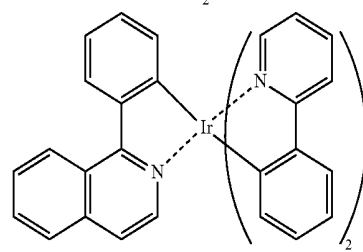
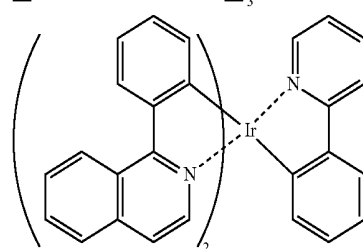
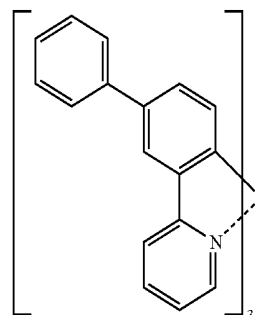
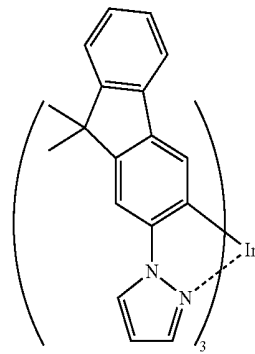
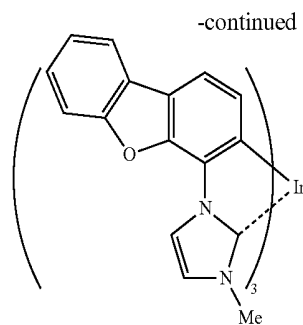
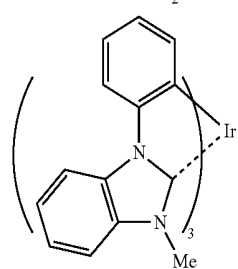
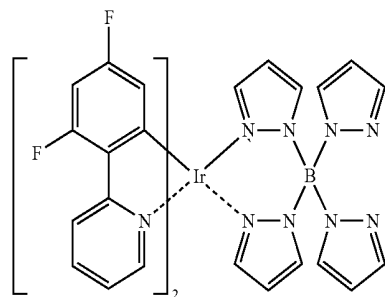
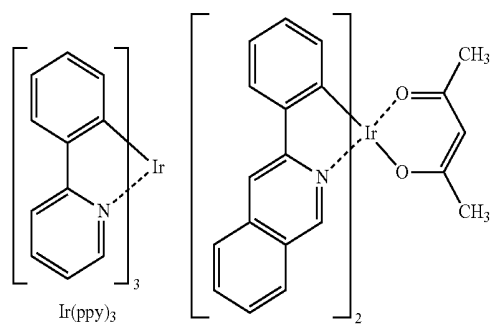
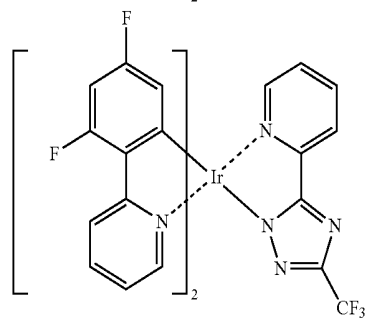
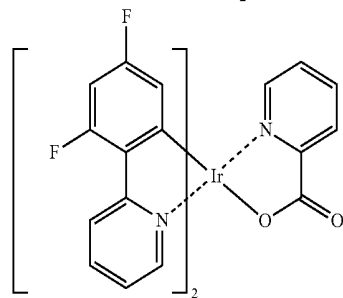
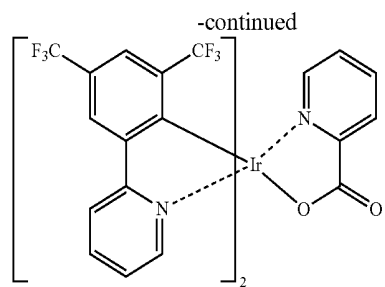


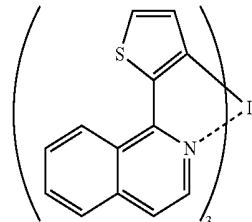
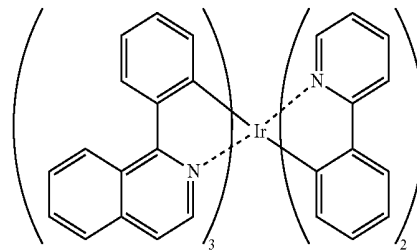
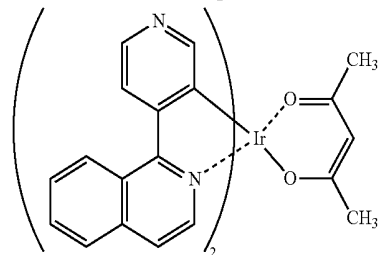
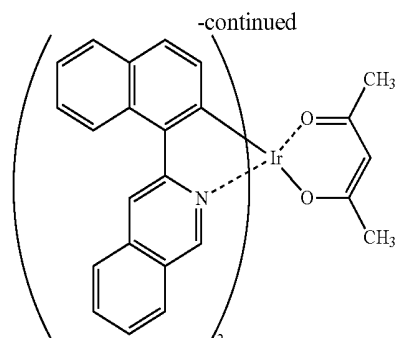
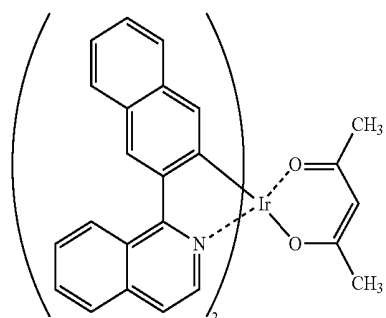
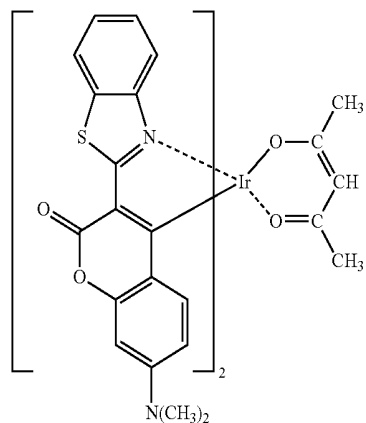
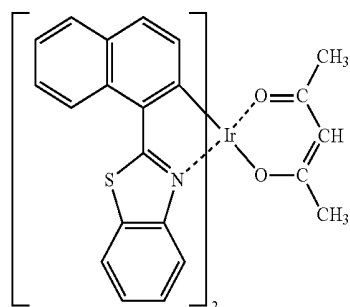
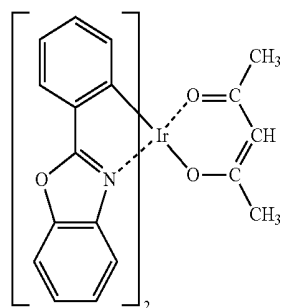
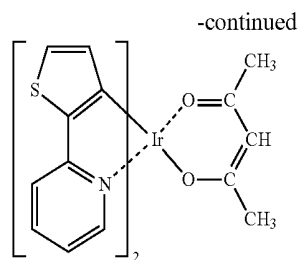
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**[0219]** The phosphorescent dopants may be used alone or in combination of two or more.

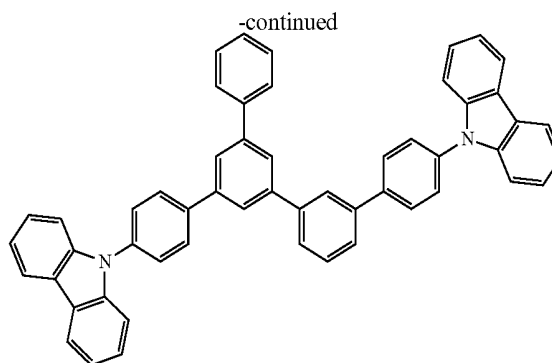
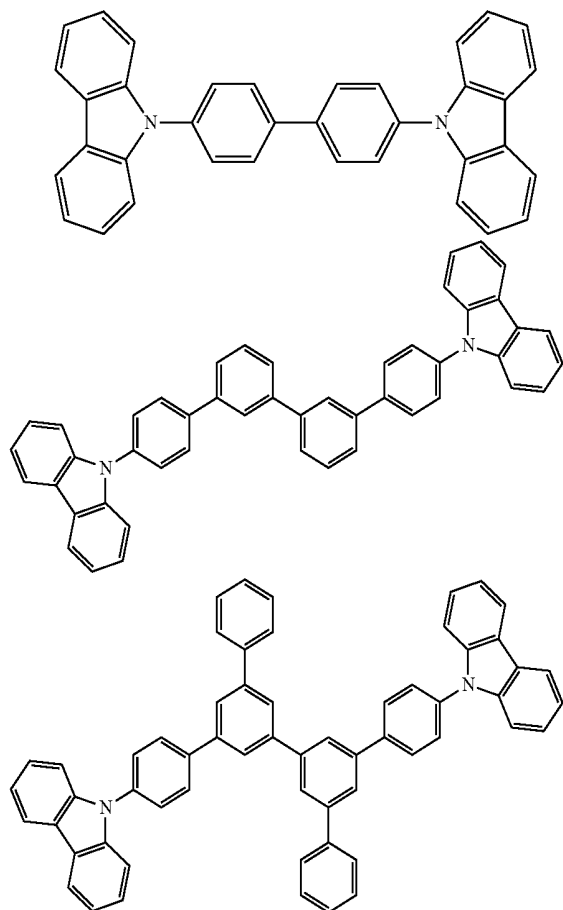
**[0220]** The emission wavelength of the phosphorescent dopant used in the light emitting layer is not particularly limited. In a preferred embodiment, at least one of the phosphorescent dopants used in the light emitting layer has the peak of emission wavelength of preferably 490 nm or longer and 700 nm or shorter and more preferably 490 nm or longer and 650 nm or shorter.

**[0221]** The phosphorescent host is a compound which confines the triplet energy of the phosphorescent dopant efficiently in the light emitting layer to cause the phosphorescent dopant to emit light efficiently. In addition to the first host material and the second host material, other compounds may be used as the phosphorescent host in the organic EL device of the invention according to the use of the device.

**[0222]** The first host material, the second host material and a compound other than those may be combinedly used in the same light emitting layer as the phosphorescent host material. If two or more light emitting layers are formed, the first host material and the second host material can be used in one light emitting layer as the phosphorescent host material and a compound other than the first host material and the second host material can be used in another light emitting layer as the

phosphorescent host material. The first host material and the second host material may be used in an organic layer other than the light emitting layer.

[0223] Examples of the compounds other than the first host material and the second host material, which are suitable as the phosphorescent host, include a carbazole derivative, a triazole derivative, an oxazole derivative, an oxadiazole derivative, an imidazole derivative, a polyaryllalkane derivative, a pyrazoline derivative, a pyrazolone derivative, a phenylenediamine derivative, an arylamine derivative, an amino-substituted chalcone derivative, a styrylanthracene derivative, a fluorenone derivative, a hydrazone derivative, a stilbene derivative, a silazane derivative, an aromatic tertiary amine compound, a styrylamine compound, an aromatic methylenedene compound, a porphyrin compound, an anthraquinodimethane derivative, an anthrone derivative, a diphenylquinone derivative, a thiopyran dioxide derivative, a carbodiimide derivative, a fluorenylidene methane derivative, a distyrylpyrazine derivative, a tetracarboxylic anhydride of fused ring such as naphthalene and perylene, a phthalocyanine derivative, a metal complex of 8-quinolinol derivative, metal phthalocyanine, metal complexes having a ligand such as benzoxazole and benzothiazole, an electroconductive oligomer, such as a polysilane compound, a poly(N-vinylcarbazole) derivative, an aniline copolymer, thiophene oligomer, and a polythiophene, and a polymer such as a polythiophene derivative, a polyphenylene derivative, a polyphenylenevinylene derivative, and a polyfluorene derivative. These phosphorescent hosts other than the first host material and the second host material may be used alone or in combination of two or more. Specific examples thereof are shown below.



[0224] The thickness of the light emitting layer is preferably 5 to 50 nm, more preferably 7 to 50 nm, and still more preferably 10 to 50 nm. If being 5 nm or more, the light emitting layer is easily formed. If being 50 nm or less, the increase in driving voltage is avoided.

#### Electron-Donating Dopant

[0225] It is preferred for the organic EL device of the invention to contain an electron-donating dopant in the interfacial region between the cathode and the light emitting unit. With such a construction, the organic EL device has an improved luminance and an elongated lifetime. The electron-donating dopant is a metal having a work function of 3.8 eV or less or a compound containing such metal. Examples thereof include at least one compound selected from alkali metal, alkali metal complex, alkali metal compound, alkaline earth metal, alkaline earth metal complex, alkaline earth metal compound, rare earth metal, rare earth metal complex, and rare earth metal compound.

[0226] Examples of the alkali metal include Na (work function: 2.36 eV), K (work function: 2.28 eV), Rb (work function: 2.16 eV), and Cs (work function: 1.95 eV), with those having a work function of 2.9 eV or less being particularly preferred. Of the above, preferred are K, Rb, and Cs, more preferred are Rb and Cs, and most preferred is Cs. Examples of the alkaline earth metal include Ca (work function: 2.9 eV), Sr (work function: 2.0 to 2.5 eV), and Ba (work function: 2.52 eV), with those having a work function of 2.9 eV or less being particularly preferred. Examples of the rare earth metal include Sc, Y, Ce, Tb, and Yb, with those having a work function of 2.9 eV or less being particularly preferred.

[0227] Examples of the alkali metal compound include alkali oxide, such as  $\text{Li}_2\text{O}$ ,  $\text{Cs}_2\text{O}$ ,  $\text{K}_2\text{O}$ , and alkali halide, such as LiF, NaF, CsF, and KF, with LiF,  $\text{Li}_2\text{O}$ , and NaF being preferred. Examples of the alkaline earth metal compound include BaO, SrO, CaO, and mixture thereof, such as  $\text{Ba}_x\text{Sr}_{1-x}\text{O}$  ( $0 < x < 1$ ) and  $\text{Ba}_x\text{Ca}_{1-x}\text{O}$  ( $0 < x < 1$ ), with BaO, SrO, and CaO being preferred. Examples of the rare earth metal compound include  $\text{YbF}_3$ ,  $\text{ScF}_3$ ,  $\text{ScO}_3$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{Ce}_2\text{O}_3$ ,  $\text{GdF}_3$ , and  $\text{TbF}_3$ , with  $\text{YbF}_3$ ,  $\text{ScF}_3$ , and  $\text{TbF}_3$  being preferred.

[0228] Examples of the alkali metal complex, alkaline earth metal complex, and rare earth metal are not particularly limited as long as containing at least one metal ion selected from alkali metal ions, alkaline earth metal ions, rare earth metal ions, respectively. The ligand is preferably, but not limited to, quinolinol, benzoquinolinol, acridinol, phenanthridinol, hydroxyphenyloxazole, hydroxyphenylthiazole, hydroxydiaryloxadiazole, hydroxydiarylthiadiazole, hydroxyphenylpyridine, hydroxyphenylbenzimidazole, hydroxybenzotriazole, hydroxyfulborane, bipyridyl, phenanthroline, phthalocyanine, porphyrin, cyclopentadiene,  $\beta$ -diketones, azomethines, and derivative thereof.

[0229] The electron-donating dopant is added to the interfacial region preferably into a form of layer or island. The electron-donating dopant is added preferably by co-depositing the electron-donating dopant with the organic compound (light emitting material, electron injecting material, etc.) for forming the interfacial region by a resistance heating deposition method, thereby dispersing the electron-donating dopant into the organic material. The disperse concentration expressed by the molar ratio of the organic material and the electron-donating dopant is 100:1 to 1:100 and preferably 5:1 to 1:5.

[0230] When the electron-donating dopant is formed into a form of layer, a light emitting material or an electron injecting material is made into a layer which serves as an organic layer in the interface, and then, the electron-donating dopant alone is deposited by a resistance heating deposition method into a layer having a thickness preferably 0.1 to 15 nm. When the electron-donating dopant is formed into a form of island, a light emitting material or an electron injecting material is made into a form of island which serves as an organic layer in the interface, and then, the electron-donating dopant alone is deposited by a resistance heating deposition method into a form of island having a thickness preferably 0.05 to 1 nm.

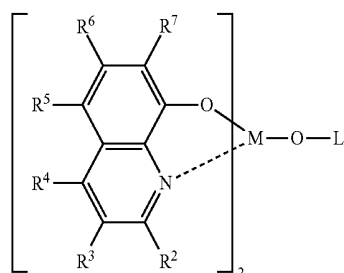
[0231] The molar ratio of the main component and the electron-donating dopant in the organic electroluminescence device of the invention is preferably 5:1 to 1:5 and more preferably 2:1 to 1:2.

#### Electron Transporting Layer

[0232] The electron transporting layer is an organic layer disposed between the light emitting layer and the cathode and transports electrons from the cathode to the light emitting layer. If two or more electron transporting layers are provided, the organic layer closer to the cathode may be called an electron injecting layer in some cases. The electron injecting layer injects electrons from the cathode to the organic layer unit efficiently.

[0233] An aromatic heterocyclic compound having one or more heteroatoms in its molecule is preferably used as the electron transporting material for the electron transporting layer, with a nitrogen-containing ring derivative being particularly preferred. The nitrogen-containing ring derivative is preferably an aromatic ring compound having a nitrogen-containing 6- or 5-membered ring or a condensed aromatic ring compound having a nitrogen-containing 6- or 5-membered ring.

[0234] The nitrogen-containing ring derivative is preferably, for example, a chelate metal complex having a nitrogen-containing ring represented by formula (AA).



[0235]  $R^2$  to  $R^7$  of formula (AA) each independently represent a hydrogen atom, a deuterium atom, a halogen atom, a hydroxyl group, an amino group, a hydrocarbon group having 1 to 40 carbon atoms, an alkoxy group having 1 to 40 carbon atoms, an aryloxy group having 6 to 50 carbon atoms, an alkoxycarbonyl group, or a heterocyclic group having 5 to 50 carbon atoms, each being optionally substituted.

[0236] The halogen atom may include fluorine, chlorine, bromine, and iodine.

[0237] The substituted amino group may include an alkylamino group, an arylamino group, and an aralkylamino group.

[0238] The alkylamino group and the aralkylamino group are represented by  $-NQ^1Q^2$ , wherein  $Q^1$  and  $Q^2$  each independently represent an alkyl group having 1 to 20 carbon atoms or an aralkyl group having 1 to 20 carbon atoms. One of  $Q^1$  and  $Q^2$  may be a hydrogen atom or a deuterium atom.

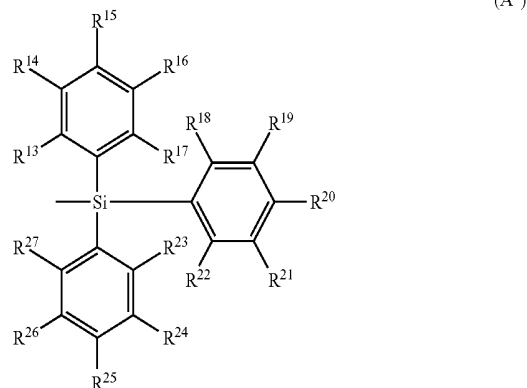
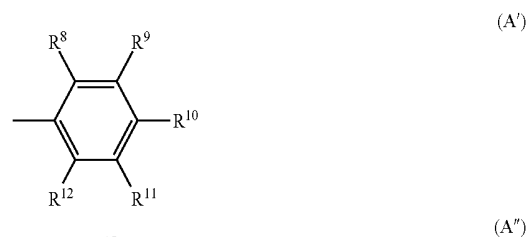
[0239] The arylamino group is represented by  $-NAr^1Ar^2$ , wherein  $Ar^1$  and  $Ar^2$  each independently represent a non-condensed aromatic hydrocarbon group or a condensed aromatic hydrocarbon group each having 6 to 50 carbon atoms. One of  $Ar^1$  and  $Ar^2$  may be a hydrogen atom or a deuterium atom.

[0240] The hydrocarbon group having 1 to 40 carbon atoms may include an alkyl group, an alkenyl group, a cycloalkyl group, an aryl group, and an aralkyl group.

[0241] The alkoxycarbonyl group is represented by  $-COOY'$ , wherein  $Y'$  is an alkyl group having 1 to 20 carbon atoms.

[0242]  $M$  of formula (AA) is aluminum (Al), gallium (Ga), or indium (In), with In being preferred.

[0243]  $L$  of formula (AA) is a group represented by formula (A') or (A''):



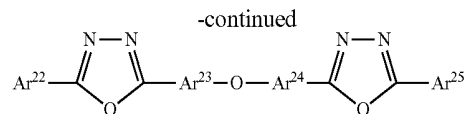
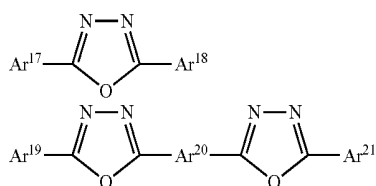
[0244]  $R^8$  to  $R^{12}$  in formula (A') each independently represent a hydrogen atom, a deuterium atom, or a substituted or

unsubstituted hydrocarbon group having 1 to 40 carbon atoms. The adjacent two groups may form a ring structure.  $R^{13}$  to  $R^{27}$  in formula (A'') each independently represent a hydrogen atom, a deuterium atom, or a substituted or unsubstituted hydrocarbon group having 1 to 40 carbon atoms. The adjacent two groups may form a ring structure.

**[0245]** Examples of the hydrocarbon group having 1 to 40 carbon atoms for  $R^8$  to  $R^{12}$  and  $R^{13}$  to  $R^{27}$  in formulae (A') and (A'') are the same as those described above with respect to  $R^2$  to  $R^7$  of formula (A). Examples of the divalent group formed by the adjacent two groups of  $R^8$  to  $R^{12}$  and  $R^{13}$  to  $R^{27}$  which completes the ring structure include tetramethylene group, pentamethylene group, hexamethylene group, diphenylmethane-2,2'-diyl group, diphenylethane-3,3'-diyl group, and diphenylpropane-4,4'-diyl group.

**[0246]** The electron transporting compound for the electron transporting layer is preferably a metal complex including 8-hydroxyquinoline or its derivative, an oxadiazole derivative, and a nitrogen-containing heterocyclic derivative.

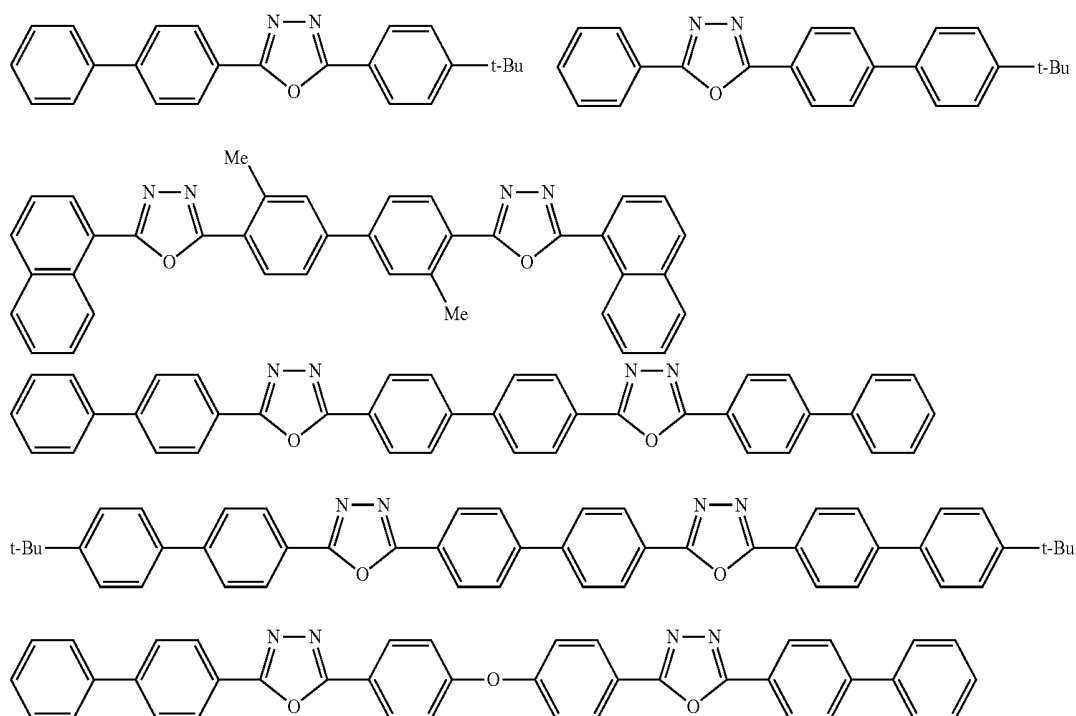
**[0247]** Examples of the metal complex including 8-hydroxyquinoline or its derivative include a metal chelate oxinoid including a chelated oxine (generally, 8-quinolinol or 8-hydroxyquinoline), for example, tris(8-quinolinol)aluminum. Examples of the oxadiazole derivative are shown below.



**[0248]** In the above formulae, each of  $Ar^{17}$ ,  $Ar^{18}$ ,  $Ar^{19}$ ,  $Ar^{21}$ ,  $Ar^{22}$ , and  $Ar^{25}$  is a substituted or unsubstituted aromatic hydrocarbon group or a substituted or unsubstituted condensed aromatic hydrocarbon group each having 6 to 50 carbon atoms, and  $Ar^{17}$  and  $Ar^{18}$ ,  $Ar^{19}$  and  $Ar^{21}$ , and  $Ar^{22}$  and  $Ar^{25}$  may be the same or different. Examples of the aromatic hydrocarbon group and the condensed aromatic hydrocarbon group include phenyl group, naphthyl group, biphenyl group, anthranyl group, perylenyl group, and pyrenyl group. The optional substituent may be an alkyl group having 1 to 10 carbon atoms, an alkoxy group having 1 to 10 carbon atoms or a cyano group.

**[0249]** Each of  $Ar^{20}$ ,  $Ar^{23}$ , and  $Ar^{24}$  is a substituted or unsubstituted bivalent aromatic hydrocarbon group or a substituted or unsubstituted bivalent condensed aromatic hydrocarbon group each having 6 to 50 carbon atoms, and  $Ar^{23}$  and  $Ar^{24}$  may be the same or different. Examples of the bivalent aromatic hydrocarbon group or the condensed aromatic hydrocarbon group include phenylene group, naphthylene group, biphenylene group, anthranylene group, perylenylene group, and pyrenylene group. The optional substituent may be an alkyl group having 1 to 10 carbon atoms, an alkoxy group having 1 to 10 carbon atoms or a cyano group.

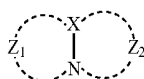
**[0250]** Electron transporting compounds which have a good thin film-forming property are preferably used. Examples of the electron transporting compound are shown below.



[0251] Examples of the nitrogen-containing heterocyclic derivative for use as the electron transporting compound include a nitrogen-containing heterocyclic derivative having the following formulae but exclusive of metal complex, for example, a compound having a 5- or 6-membered ring which has the skeleton represented by formula (B) or having the structure represented by formula (C).



(B)



(C)

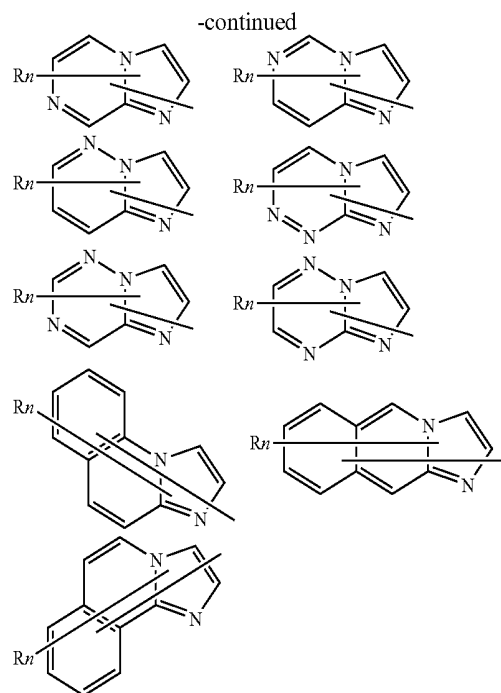
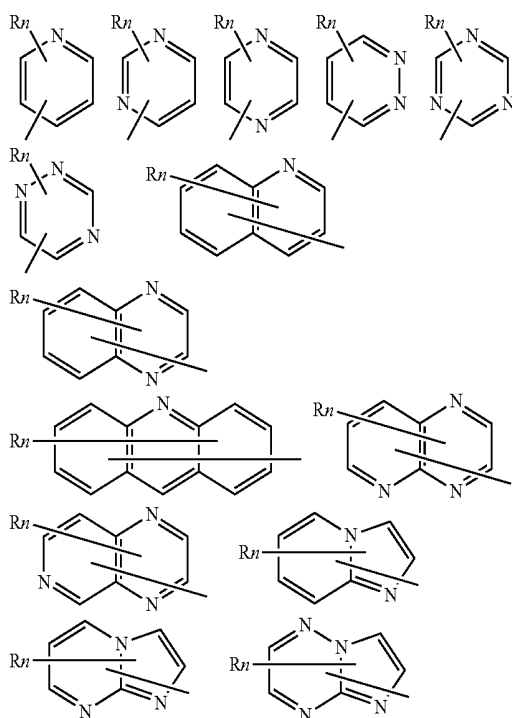
[0252] In formula (C), X is a carbon atom or a nitrogen atom. Z<sub>1</sub> and Z<sub>2</sub> each independently represent a group of atoms for completing the nitrogen-containing heteroring.

[0253] The nitrogen-containing heterocyclic derivative is more preferably an organic compound which has a nitrogen-containing aromatic polycyclic ring comprising a 5-membered ring or a 6-membered ring. If two or more nitrogen atoms are included, the nitrogen-containing aromatic polycyclic compound preferably has a skeleton of a combination of (B) and (C) or a combination of (B) and (D).



(D)

[0254] The nitrogen-containing group of the nitrogen-containing aromatic polycyclic compound is selected, for example, from the nitrogen-containing heterocyclic groups shown below.



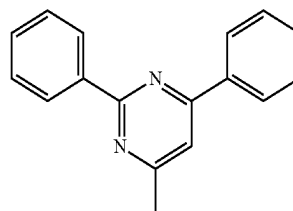
[0255] In the above formulae, R is an aromatic hydrocarbon group or a condensed aromatic hydrocarbon group each having 6 to 40 carbon atoms, an aromatic heterocyclic group or a condensed aromatic heterocyclic group each having 3 to 40 carbon atoms, an alkyl group having 1 to 20 carbon atoms, or an alkoxy group having 1 to 20 carbon atoms; and n is an integer of 0 to 5. If n is an integer of 2 or more, R groups may be the same or different.

[0256] More preferred is a nitrogen-containing heterocyclic derivative represented by the following formula:

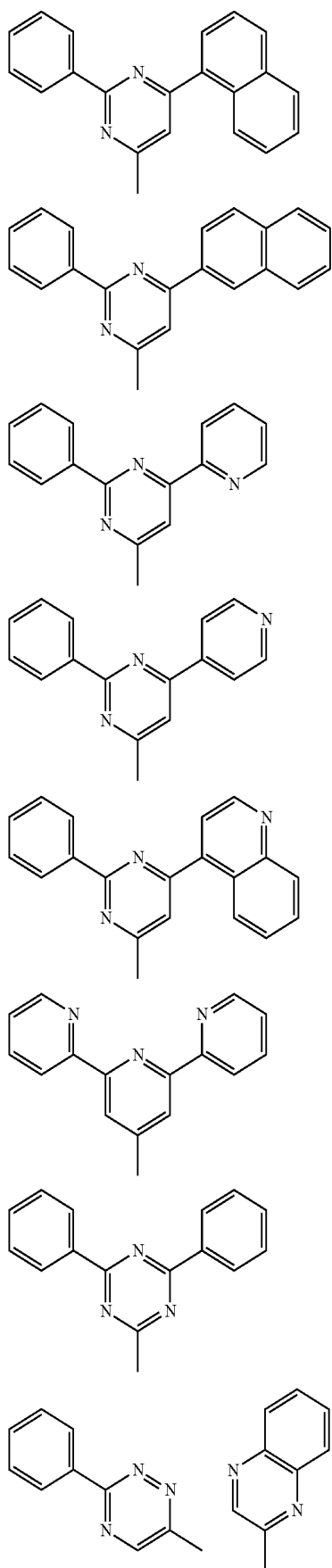


wherein HAr is a substitute or unsubstituted nitrogen-containing heterocyclic group having 3 to 40 carbon atoms; L<sup>1</sup> is a single bond, a substituted or unsubstituted aromatic hydrocarbon group or condensed aromatic hydrocarbon group each having 6 to 40 carbon atoms, or a substituted or unsubstituted aromatic heterocyclic group or condensed aromatic heterocyclic group each having 3 to 40 carbon atoms; Ar<sup>1</sup> is a substitute or unsubstituted divalent aromatic hydrocarbon group having 6 to 40 carbon atoms; and Ar<sup>2</sup> is a substitute or unsubstituted aromatic hydrocarbon group or condensed aromatic hydrocarbon group each having 6 to 40 carbon atoms or a substituted or unsubstituted aromatic heterocyclic group or condensed aromatic heterocyclic group each having 3 to 40 carbon atoms.

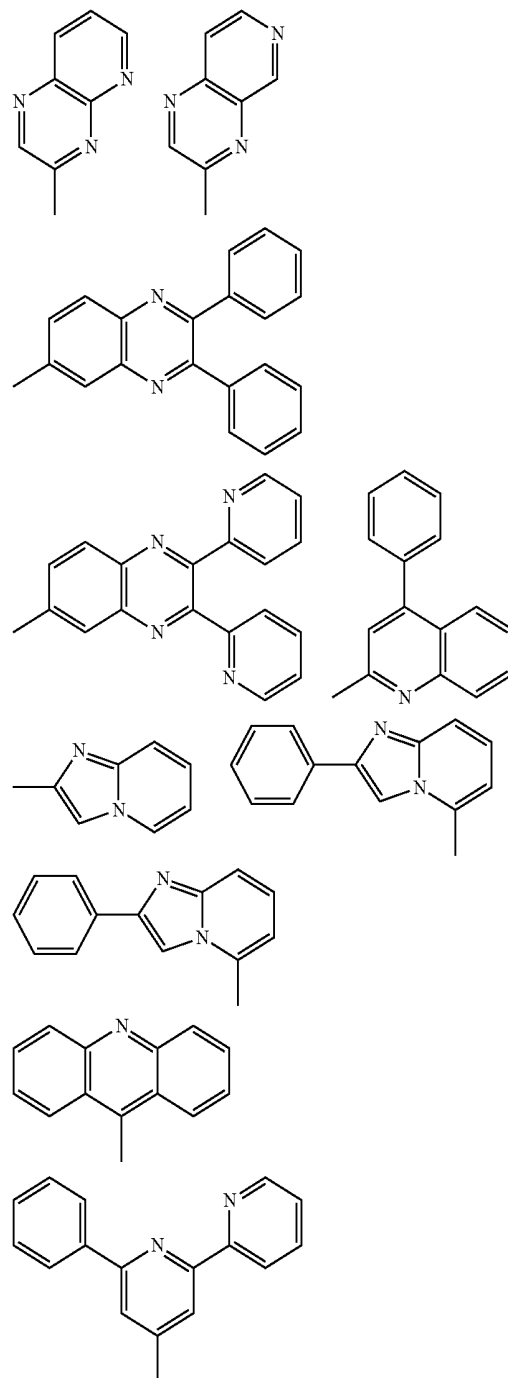
[0257] HAr of formula (D1) is selected, for example, from the following groups:



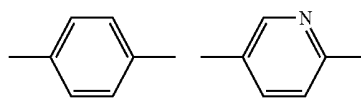
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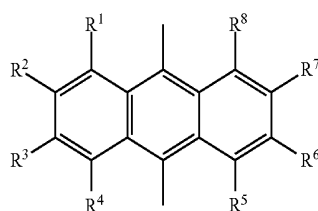
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[0258]  $L^1$  of formula (D1) is selected, for example, from the following groups:

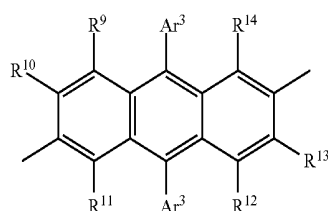
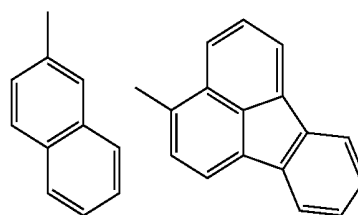


[0259]  $Ar^1$  of formula (D1) is selected, for example, from the following arylanthranlyl groups represented by formula (D2) or (D3):

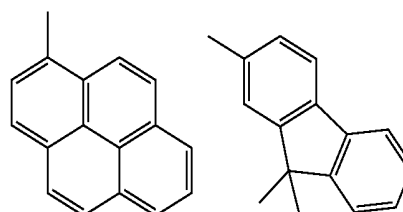


(D2)

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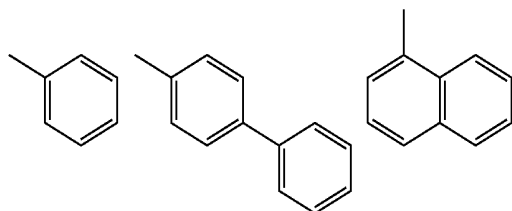


(D3)

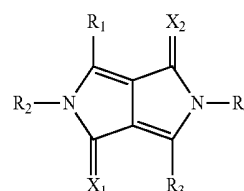


[0260] In the above formulae (D2) and (D3),  $R^1$  to  $R^{14}$  are each independently a hydrogen atom, a deuterium atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aromatic hydrocarbon group or condensed aromatic hydrocarbon group each having 6 to 40 carbon atoms, or a substituted or unsubstituted aromatic heterocyclic group or condensed aromatic heterocyclic group each having 3 to 40 carbon atoms; and  $Ar^3$  is a substituted or unsubstituted aromatic hydrocarbon group or condensed aromatic hydrocarbon group each having 6 to 40 carbon atoms or a substituted or unsubstituted aromatic heterocyclic group or condensed aromatic heterocyclic group each having 3 to 40 carbon atoms.  $R^1$  to  $R^8$  may be all selected from a hydrogen atom and a deuterium atom.

[0261]  $Ar^2$  of formula (D1) is selected, for example, from the following groups:



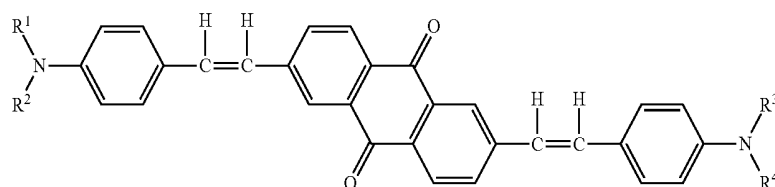
[0262] In addition, the following compound is preferably used as the nitrogen-containing aromatic polycyclic compound for use as the electron transporting compound.



(D4)

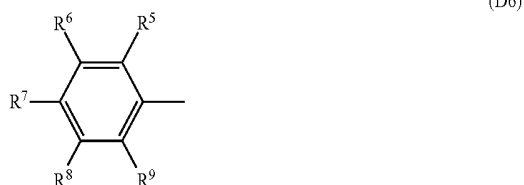
[0263] In the formula (D4),  $R_1$  to  $R_4$  each independently represent a hydrogen atom, a deuterium atom, a substituted or unsubstituted aliphatic group having 1 to 20 carbon atoms, a substituted or unsubstituted alicyclic group having 3 to 20 carbon atoms, a substituted or unsubstituted aromatic group having 6 to 50 carbon atoms, or a substituted or unsubstituted heterocyclic group having 3 to 50 carbon atoms; and  $X_1$  and  $X_2$  each independently represent an oxygen atom, a sulfur atom, or dicyanomethylene group.

[0264] Further, the following compound is also suitable as the electron transporting compound.



(D5)

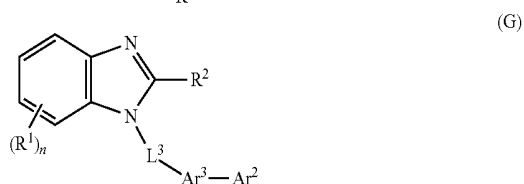
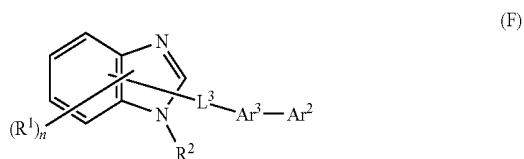
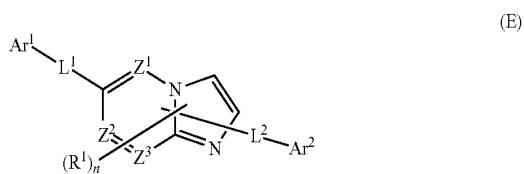
[0265] In the formula (D5),  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  may be the same or different and each represents an aromatic hydrocarbon group or a condensed aromatic hydrocarbon group each represented by the following formula (D6);



[0266] In the formula (D6),  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^8$ , and  $R^9$  may be the same or different and each represents a hydrogen atom, a deuterium atom, a saturated or unsaturated alkoxy group having 1 to 20 carbon atoms, a saturated or unsaturated alkyl group having 1 to 20 carbon atoms, an amino group, or an alkylamino group having 1 to 20 carbon atoms. At least one of  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^8$ , and  $R^9$  is a group other than hydrogen atom and deuterium atom.

[0267] Further, a polymer having the nitrogen-containing heterocyclic group or the nitrogen-containing heterocyclic derivative is also usable as the electron transporting compound.

[0268] It is particularly preferred for the electron transporting layer of the invention to contain at least one of the nitrogen-containing heterocyclic derivatives represented by the following formulae (E) to (G).



[0269] In the formulae (E) to (G),  $Z^1$ ,  $Z^2$ , and  $Z^3$  each independently represent a nitrogen atom or a carbon atom.

[0270]  $R^1$  and  $R^2$  each independently represent a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms, a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted haloalkyl group having 1 to 20 carbon atoms, or a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms.

[0271] The subscript  $n$  is an integer of 0 to 5. If  $n$  is an integer of 2 or more,  $R^1$  groups may be the same or different

from each other. The adjacent two  $R^1$  groups may bond to each other to form a substituted or unsubstituted hydrocarbon ring.

[0272]  $Ar^1$  represents a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms or a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms.

[0273]  $Ar^2$  represents a hydrogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted haloalkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms, or a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms.

[0274] However, one of  $Ar^1$  and  $Ar^2$  is a substituted or unsubstituted condensed aromatic hydrocarbon group having 10 to 50 ring carbon atoms or a substituted or unsubstituted condensed aromatic heterocyclic group having 9 to 50 ring atoms.

[0275]  $Ar^3$  represents a substituted or unsubstituted arylene group having 6 to 50 ring carbon atoms or a substituted or unsubstituted heteroarylene group having 5 to 50 ring atoms.

[0276]  $L^1$ ,  $L^2$ , and  $L^3$  each independently represent a single bond, a substituted or unsubstituted arylene group having 6 to 50 ring carbon atoms or a substituted or unsubstituted divalent condensed aromatic heterocyclic group having 9 to 50 ring atoms.

[0277] Examples of the aryl group having 6 to 50 ring carbon atoms include phenyl group, naphthyl group, anthryl group, phenanthryl group, naphthacenyl group, chrysenyl group, pyrenyl group, biphenyl group, terphenyl group, tolyl group, fluoranthenyl group, and fluorenyl group.

[0278] Examples of the heteroaryl group having 5 to 50 ring atoms include pyrrolyl group, furyl group, thienyl group, silolyl group, pyridyl group, quinolyl group, isoquinolyl group, benzofuryl group, imidazolyl group, pyrimidyl group, carbazolyl group, selenophenyl group, oxadiazolyl group, triazolyl group, pyrazinyl group, pyridazinyl group, triazinyl group, quinoxalinylyl group, acridinyl group, imidazo[1,2-a]pyridinyl group, and imidazo[1,2-a]pyrimidinyl.

[0279] Examples of the alkyl group having 1 to 20 carbon atoms include methyl group, ethyl group, propyl group, butyl group, pentyl group, and hexyl group.

[0280] Examples of the haloalkyl group having 1 to 20 carbon atoms include the groups obtained by replacing one or more hydrogen atoms of the alkyl group mentioned above with at least one halogen atom selected from fluorine, chlorine, iodine, and bromine.

[0281] Examples of the alkyl moiety of the alkoxy group having 1 to 20 carbon atoms include the alkyl group mentioned above.

[0282] Examples of the arylene groups include the groups obtained by removing one hydrogen atom from the aryl group mentioned above.

[0283] Examples of the divalent condensed aromatic heterocyclic group having 9 to 50 ring atoms include the groups obtained by removing one hydrogen atom from the condensed aromatic heterocyclic group mentioned above as the heteroaryl group.

[0284] The thickness of the electron transporting layer is preferably 1 to 100 nm, although not particularly limited thereto.

[0285] The electron injecting layer which may be formed adjacent to the electron transporting layer preferably includes an inorganic compound, such as an insulating material and a

semiconductor in addition to the nitrogen-containing ring derivative. The insulating material or semiconductor incorporated into the electron injecting layer effectively prevents the leak of electric current to enhance the electron injecting properties.

[0286] The insulating material is preferably at least one metal compound selected from the group consisting of alkali metal chalcogenides, alkaline earth metal chalcogenides, alkali metal halides and alkaline earth metal halides. The alkali metal chalcogenide, etc. incorporated into the electron injecting layer further enhances the electron injecting properties. Preferred examples of the alkali metal chalcogenides include  $\text{Li}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{S}$ ,  $\text{Na}_2\text{Se}$  and  $\text{Na}_2\text{O}$ , and preferred examples of the alkaline earth metal chalcogenides include  $\text{CaO}$ ,  $\text{BaO}$ ,  $\text{SrO}$ ,  $\text{BeO}$ ,  $\text{BaS}$  and  $\text{CaSe}$ . Preferred examples of the alkali metal halides include  $\text{LiF}$ ,  $\text{NaF}$ ,  $\text{KF}$ ,  $\text{LiCl}$ ,  $\text{KCl}$  and  $\text{NaCl}$ . Examples of the alkaline earth metal halides include fluorides such as  $\text{CaF}_2$ ,  $\text{BaF}_2$ ,  $\text{SrF}_2$ ,  $\text{MgF}_2$  and  $\text{BeF}_2$  and halides other than fluorides.

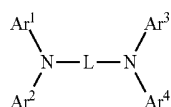
[0287] Examples of the semiconductor may include oxide, nitride or oxynitride each containing at least one element selected from the group consisting of Ba, Ca, Sr, Yb, Al, Ga, In, Li, Na, Cd, Mg, Si, Ta, Sb and Zn. The semiconductor may be used singly or in combination of two or more. The inorganic compound forming the electron injecting layer preferably forms a microcrystalline or amorphous insulating thin film. When the electron injecting layer is formed from such an insulating thin film, the thin film is made more uniform to decrease the pixel defects such as dark spots. Examples of such inorganic compound include alkali metal chalcogenides, alkaline earth metal chalcogenides, alkali metal halides and alkaline earth metal halide, each being described above.

[0288] The thickness of the layer including the insulating material or the semiconductor is preferably about 0.1 to 15 nm. The electron injecting layer may be included with the electron-donating dopant described above.

#### Hole Transporting Layer

[0289] The hole transporting layer is an organic layer formed between the light emitting layer and the anode and has a function of transporting holes from the anode to the light emitting layer. When the hole transporting layer is formed by two or more layers, the layer closer to the anode may be defined as the hole injecting layer in some cases. The hole injecting layer has a function of efficiently injecting holes from the anode to the organic layer unit.

[0290] An aromatic amine compound, for example, the aromatic amine derivative represented by formula (H), is also preferably used as the material for forming the hole transporting layer.

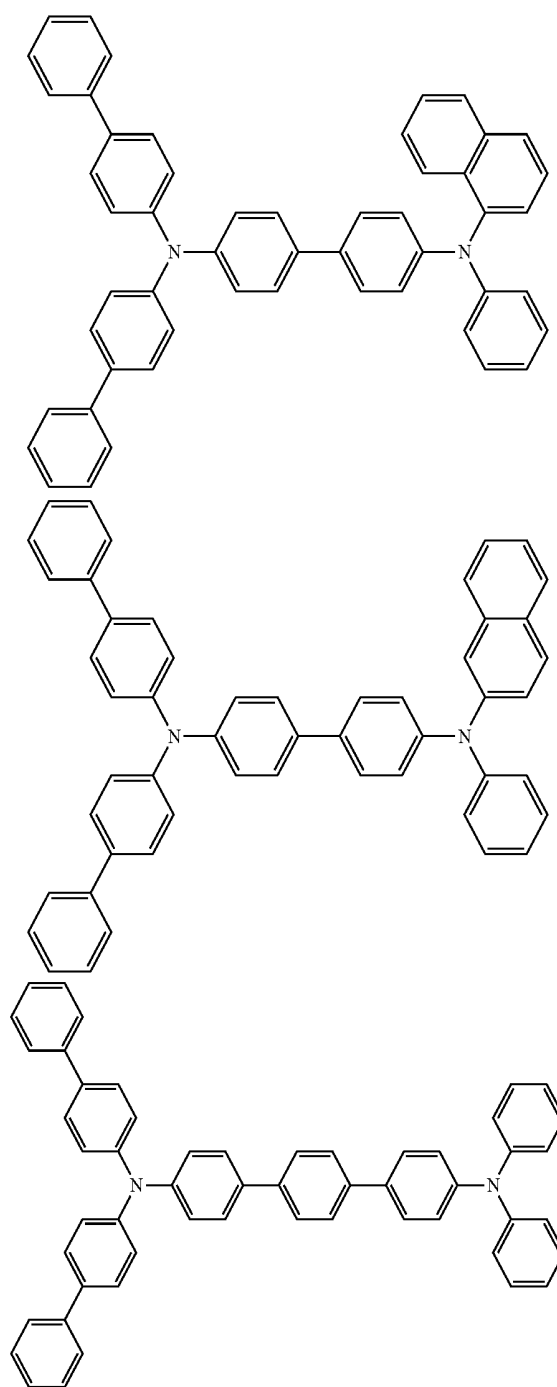


[0291] In the formula (H), each of  $\text{Ar}^1$  to  $\text{Ar}^4$  represents a substituted or unsubstituted aromatic hydrocarbon group or condensed aromatic hydrocarbon group having 6 to 50 ring carbon atoms, a substituted or unsubstituted aromatic heterocyclic group or condensed aromatic heterocyclic group hav-

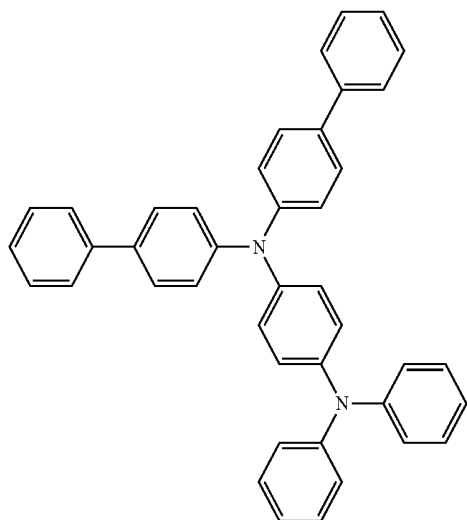
ing 5 to 50 ring atoms, or a group wherein the aromatic hydrocarbon group or condensed aromatic hydrocarbon group and the aromatic heterocyclic group or condensed aromatic heterocyclic group are bonded to each other.

[0292] L represents a substituted or unsubstituted aromatic hydrocarbon group or condensed aromatic hydrocarbon group each having 6 to 50 ring carbon atoms or a substituted or unsubstituted aromatic heterocyclic group or condensed aromatic heterocyclic group each having 5 to 50 ring atoms.

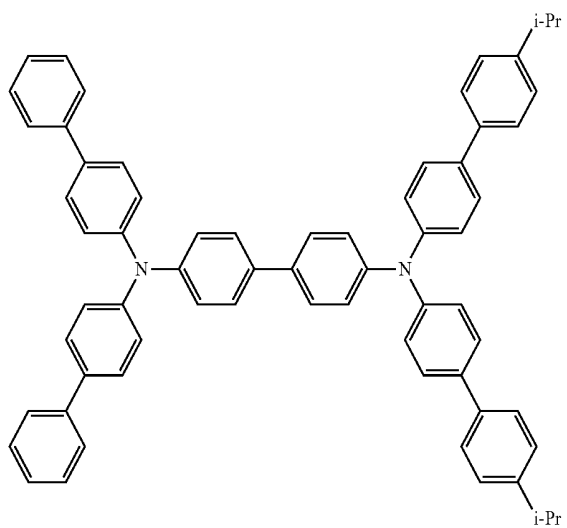
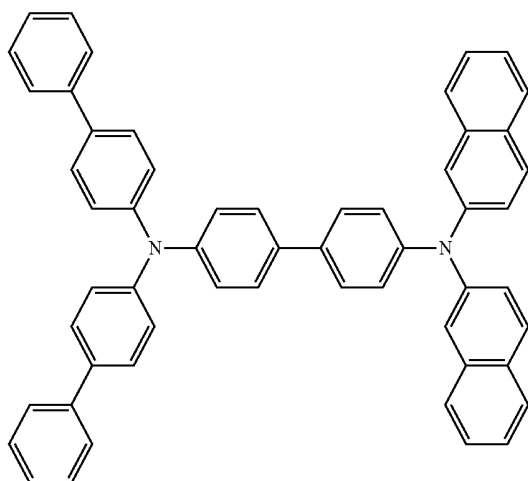
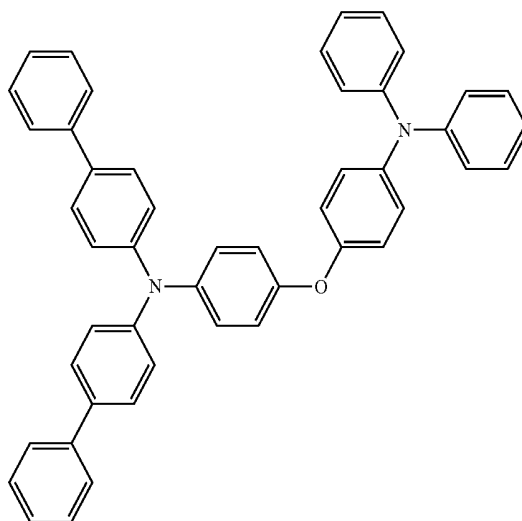
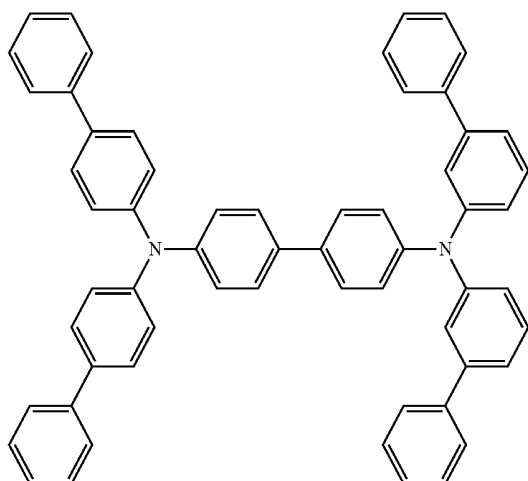
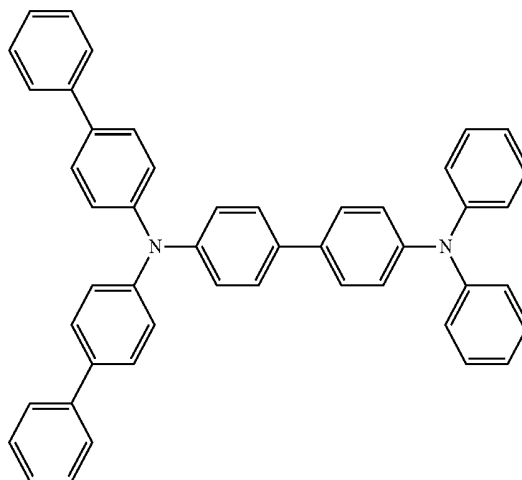
[0293] Specific examples of the compound represented by the formula (H) are shown below.



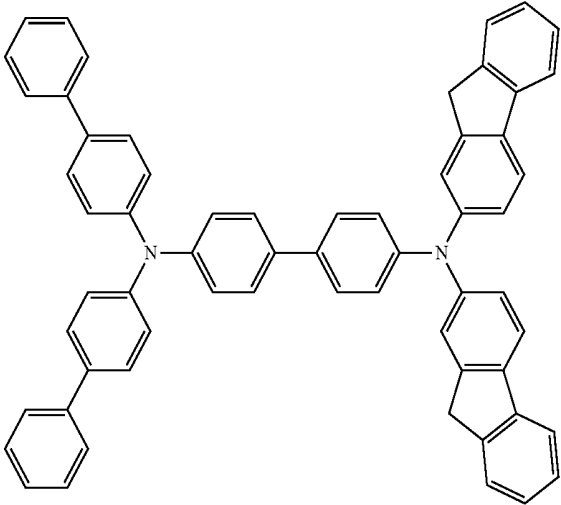
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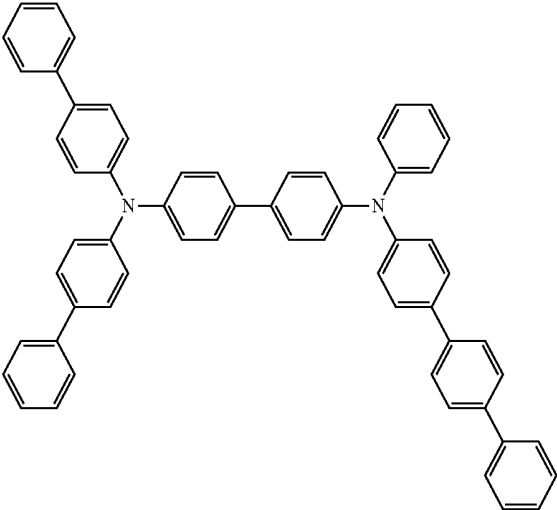
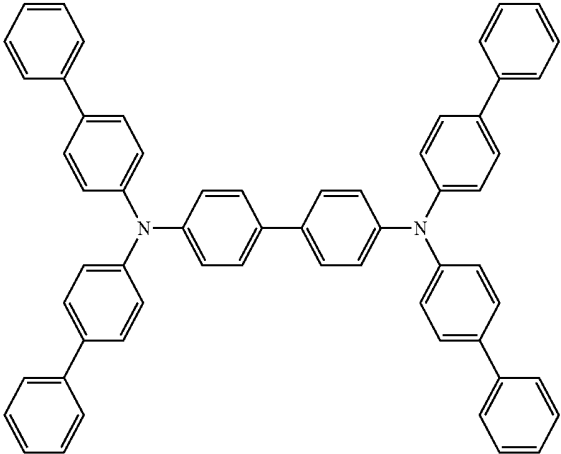
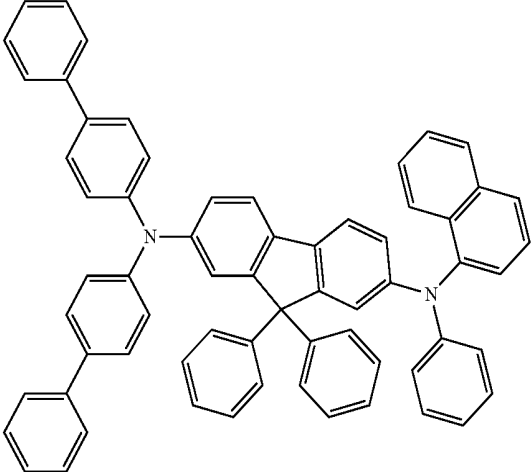
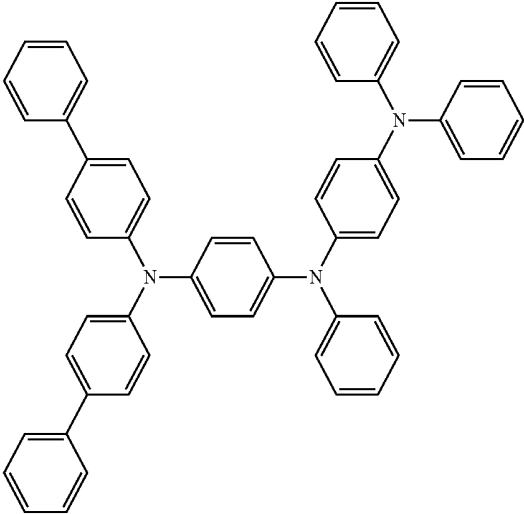
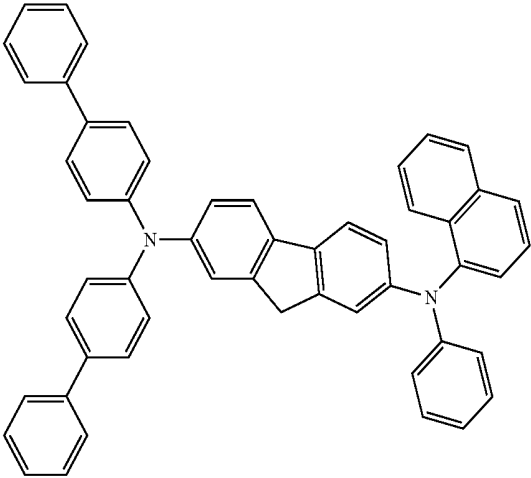
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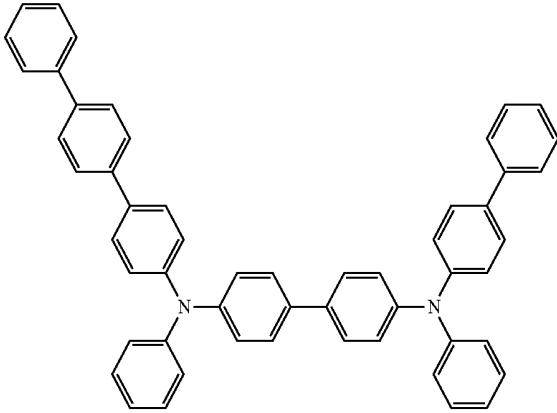
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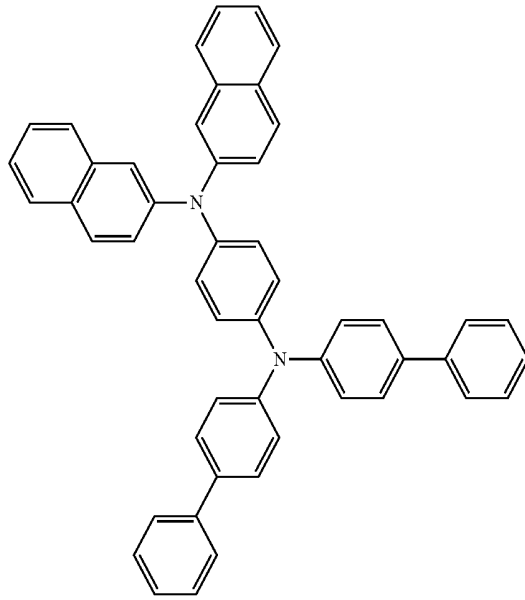
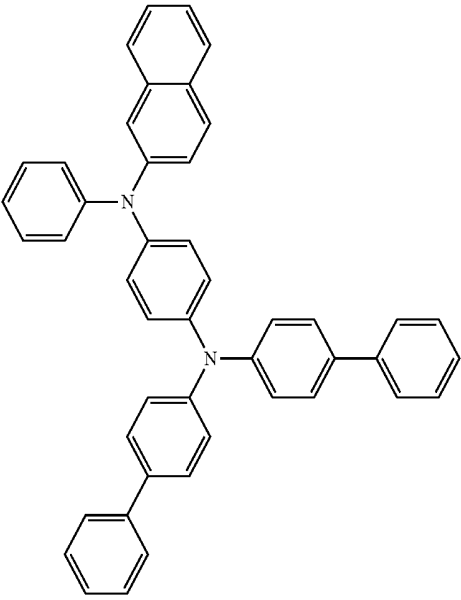
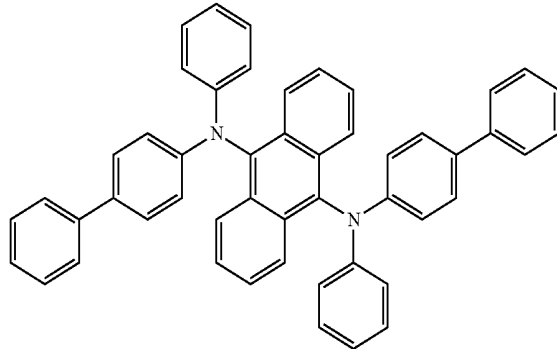
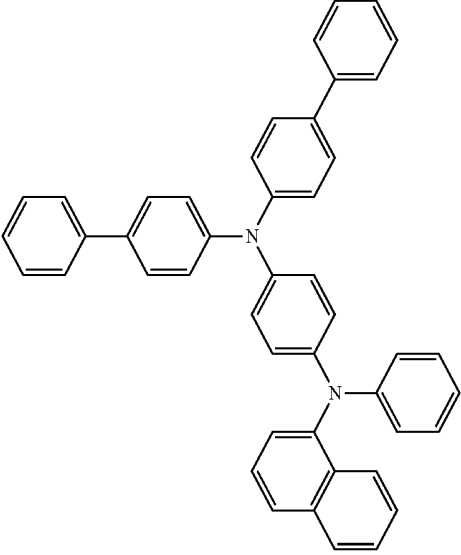
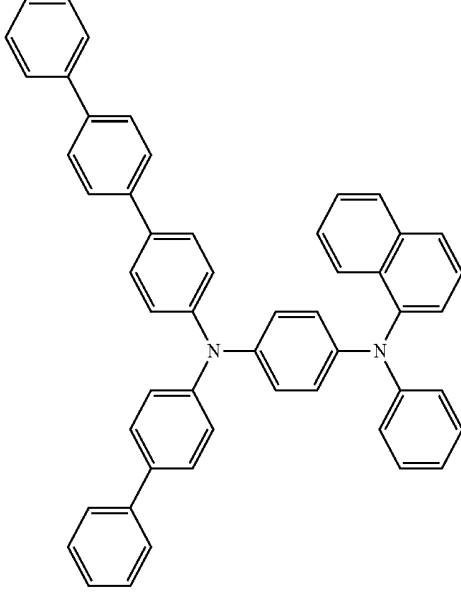
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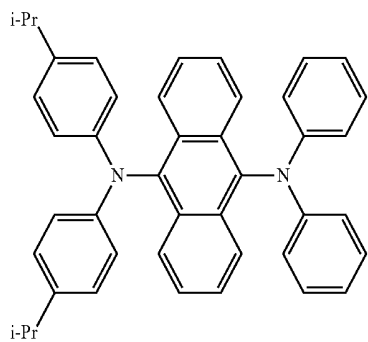
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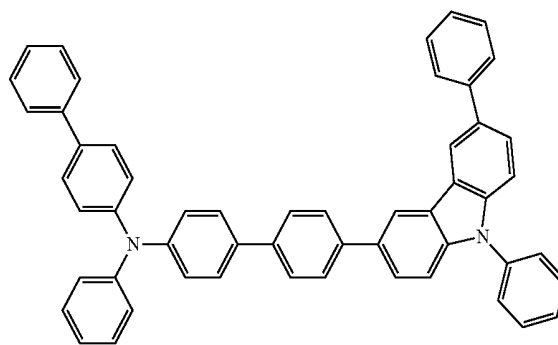
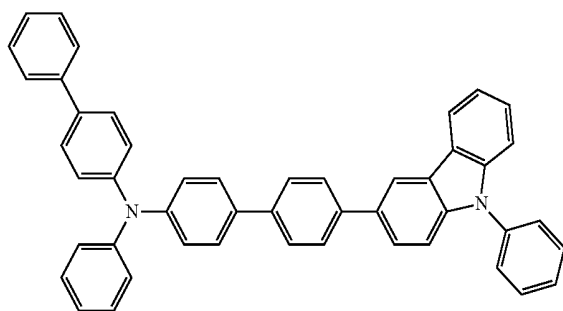
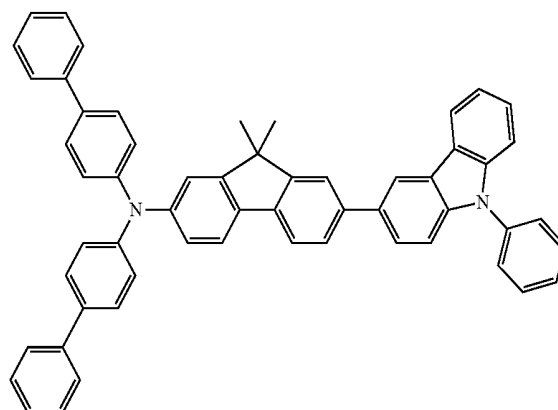
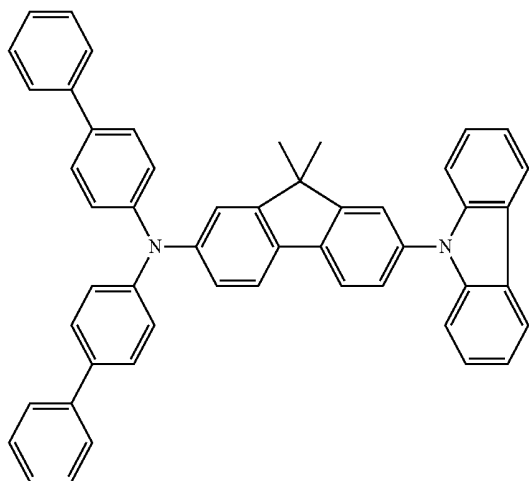
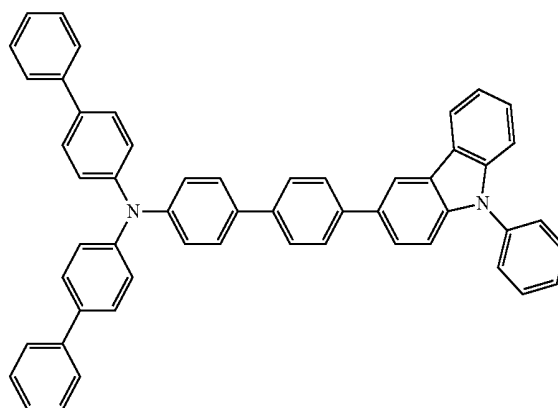
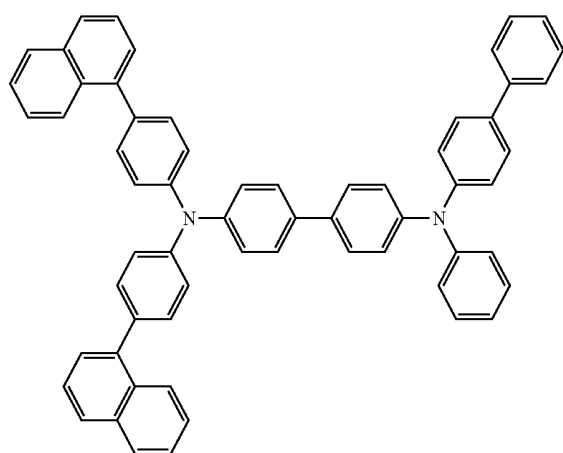
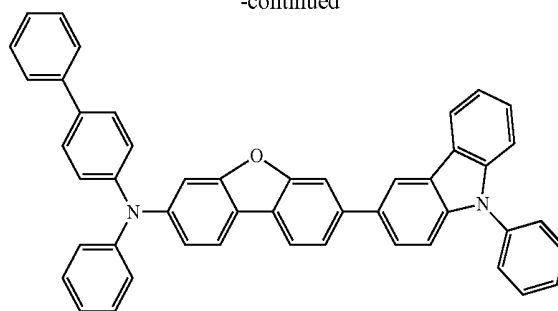
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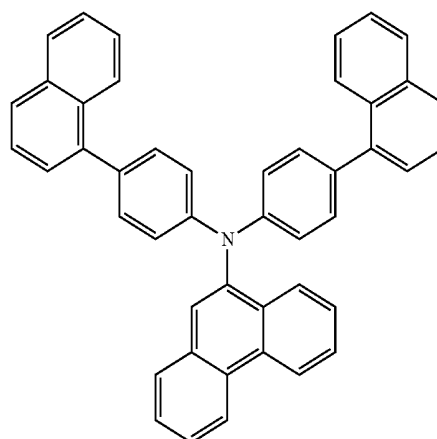
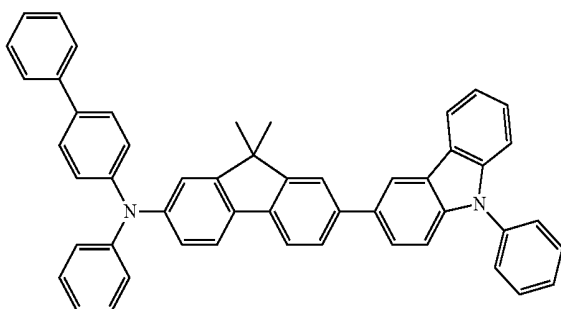
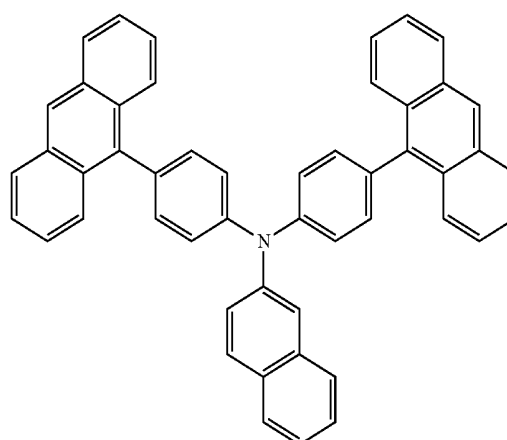
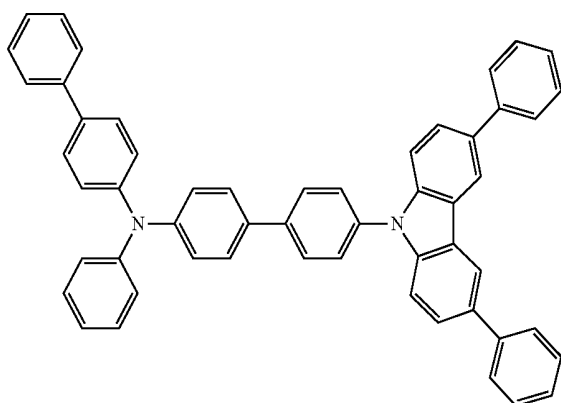
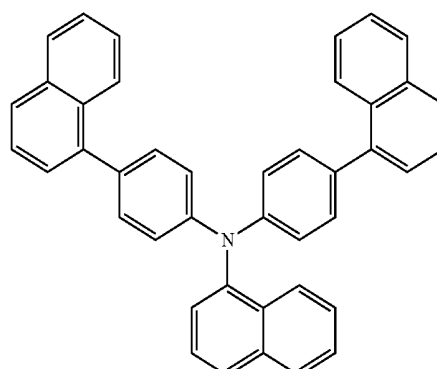
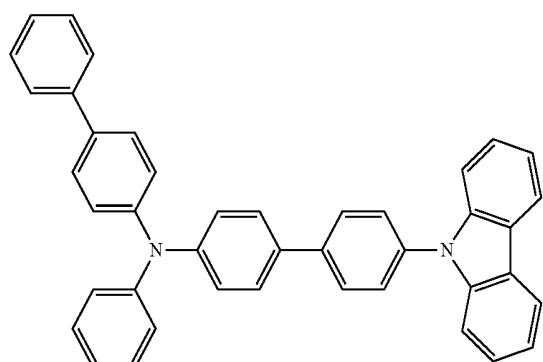
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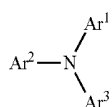
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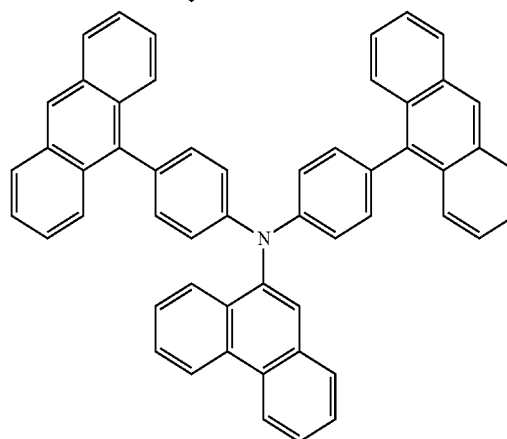
-continued



[0294] The aromatic amine represented by the formula (J) is also preferably used as the material for forming the hole transporting layer.

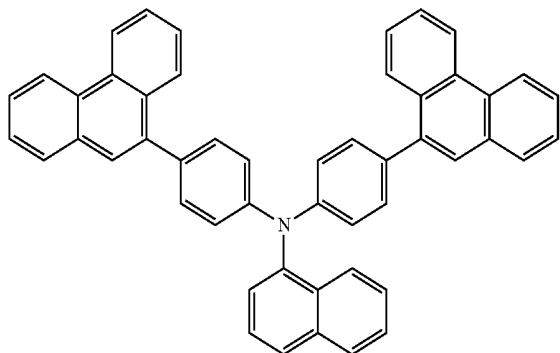


(J)

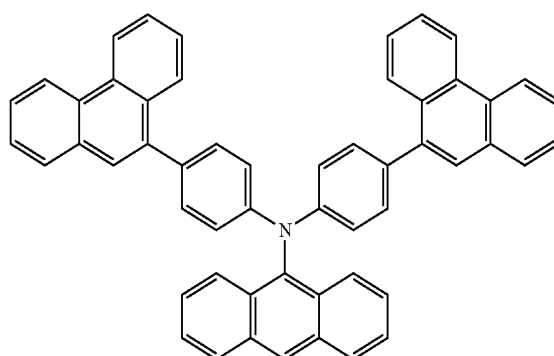
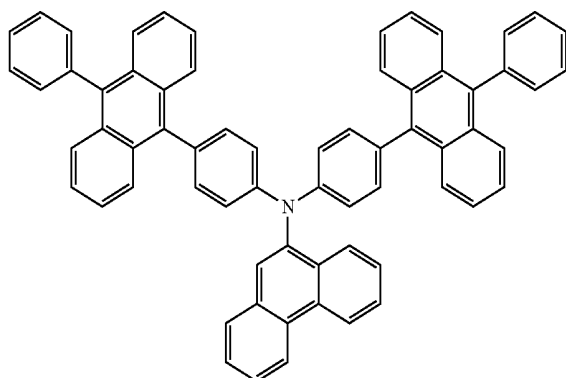
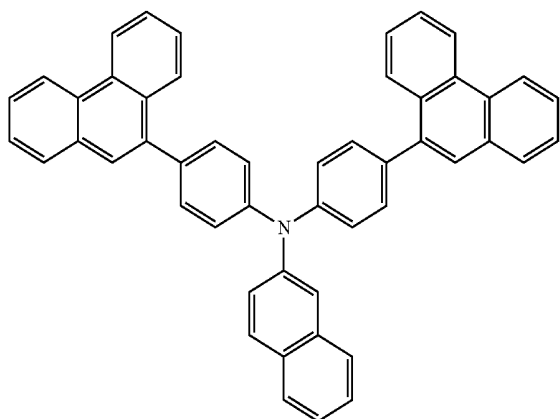
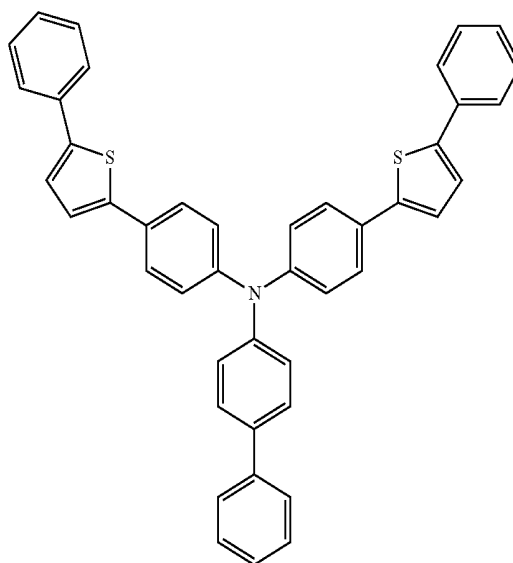
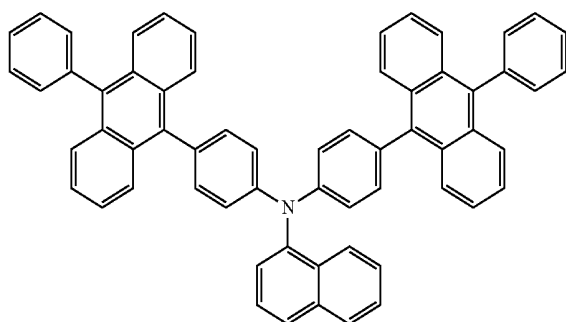
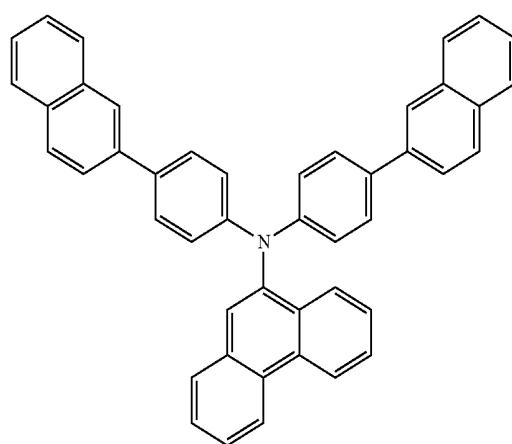


[0295] In the formula (J), each of Ar<sup>1</sup> to Ar<sup>3</sup> is defined in the same manner as in the definition of Ar<sup>1</sup> to Ar<sup>4</sup> of the formula (H). The specific examples of the compounds represented by the formula (J) are shown below, although not limited thereto.

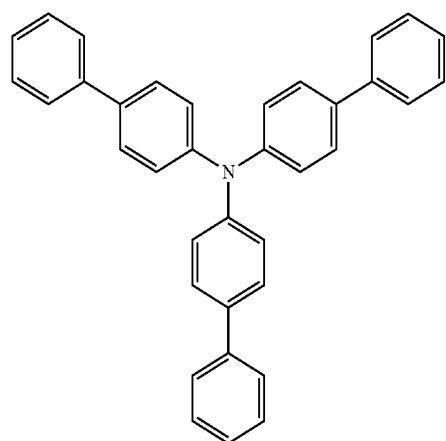
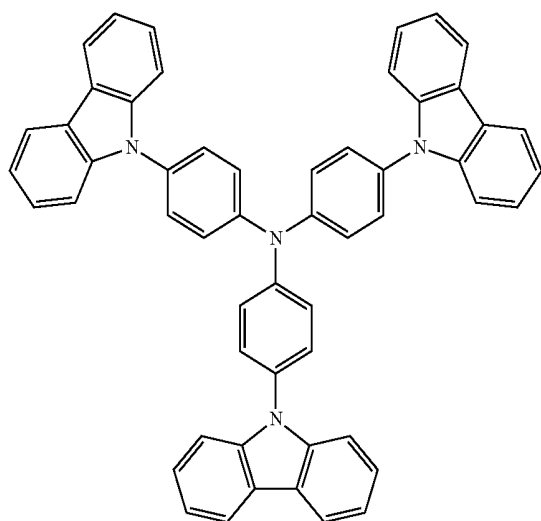
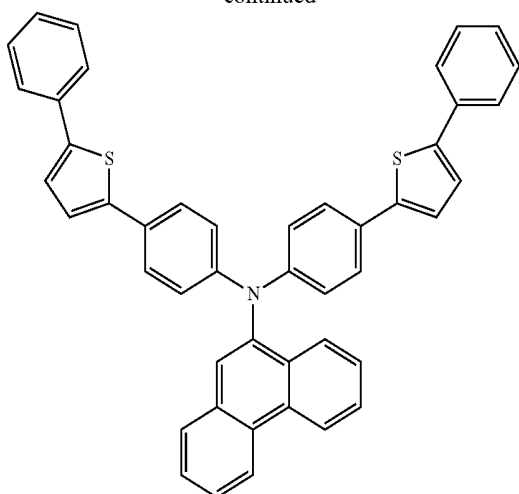
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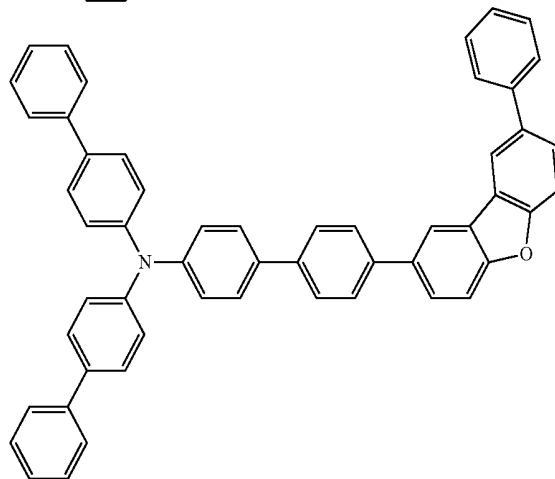
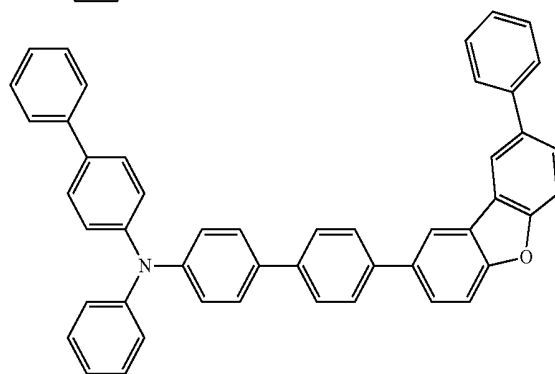
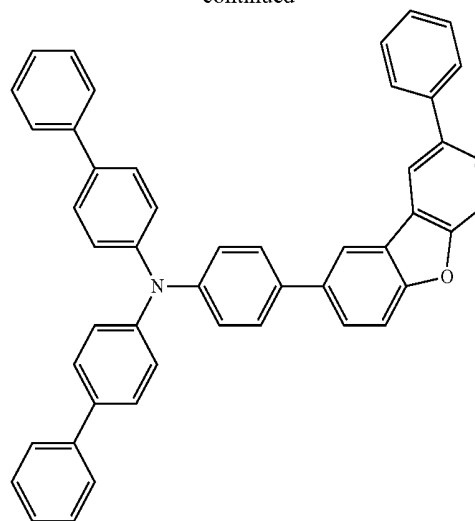
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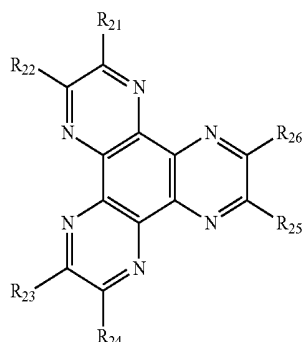


[0296] The hole transporting layer of the organic EL device of the invention may be made into two-layered structure of a first hole transporting layer (anode side) and a second hole transporting layer (cathode side).

[0297] The thickness of the hole transporting layer is preferably 10 to 200 nm, although not particularly limited thereto.

[0298] The organic EL device of the invention may have a layer comprising an acceptor material which is attached to the anode side of each of the hole transporting layer and the first hole transporting layer. With such a layer, it is expected that the driving voltage is lowered and the production cost is reduced.

[0299] The acceptor material is preferably a compound represented by the formula (K):



wherein  $R_{21}$  to  $R_{26}$  may be the same or different and each independently represent a cyano group,  $-\text{CONH}_2$ , a carboxyl group, or  $-\text{COOR}_{27}$  wherein  $R_{27}$  represents an alkyl group having 1 to 20 carbon atoms or a cycloalkyl group having 3 to 20 carbon atoms. One or more of a pair of  $R_{21}$  and  $R_{22}$ , a pair of  $R_{23}$  and  $R_{24}$ , and a pair of  $R_{25}$  and  $R_{26}$  may bond to each other to form a group represented by  $-\text{CO}-\text{O}-\text{CO}-$ .

[0300] Examples of  $R_{27}$  include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, t-butyl group, cyclopentyl group, and cyclohexyl group.

[0301] The thickness of the layer comprising the acceptor material is preferably 5 to 20 nm, although not particularly limited thereto.

#### N/P Doping

[0302] The carrier injecting properties of the hole transporting layer and the electron transporting layer can be controlled by, as described in JP 3695714B, the doping (n) with a donor material or the doping (p) with an acceptor material.

[0303] A typical example of the n-doping is an electron transporting material doped with a metal, such as Li and Cs, and a typical example of the p-doping is a hole transporting material doped with an acceptor material such as,  $\text{F}_4\text{TCNQ}$  (2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane).

#### Space Layer

[0304] For example, in an organic EL device wherein a fluorescent light emitting layer and a phosphorescent light emitting layer are laminated, a space layer is disposed between the fluorescent light emitting layer and the phosphorescent light emitting layer to prevent the diffusion of excitons generated in the phosphorescent light emitting layer to the fluorescent light emitting layer or to control the carrier balance. The space layer may be disposed between two or more phosphorescent light emitting layers.

[0305] Since the space layer is disposed between the light emitting layers, a material combining the electron transporting ability and the hole transporting ability is preferably used for forming the space layer. To prevent the diffusion of triplet energy in the adjacent phosphorescent light emitting layer, the triplet energy of the material for the space layer is preferably 2.6 eV or more. The materials described with respect to the hole transporting layer are usable as the material for the space layer.

#### Blocking Layer

[0306] The organic EL device of the invention preferably has a blocking layer, such as an electron blocking layer, a hole blocking layer, and a triplet blocking layer, which is disposed adjacent to the light emitting layer. The electron blocking layer is a layer which prevents the diffusion of electrons from the light emitting layer to the hole transporting layer. The hole blocking layer is a layer which prevents the diffusion of holes from the light emitting layer to the electron transporting layer. The material for organic EL device of the invention is also usable as the material for the hole blocking layer.

[0307] The triplet blocking layer prevents the diffusion of triplet excitons generated in the light emitting layer to adjacent layers and has a function of confining the triplet excitons in the light emitting layer, thereby preventing the deactivation of energy on molecules other than the emitting dopant of triplet excitons, for example, on molecules in the electron transporting layer.

[0308] If a phosphorescent device having a triplet blocking layer satisfies the following energy relationship:

$$E_d^T < E_{TB}^T$$

wherein  $E_d^T$  is the triplet energy of the phosphorescent dopant in the light emitting layer and  $E_{TB}^T$  is the triplet energy of the compound forming the triplet blocking layer,

the triplet excitons of phosphorescent dopant are confined (not diffuse to other molecules). Therefore, the energy deactivation process other than the emission on the phosphorescent dopant may be prevented to cause the emission with high efficiency. However, even in case of satisfying the relationship of  $E_d^T < E_{TB}^T$ , the triplet excitons may move into other molecules if the energy difference ( $\Delta E^T = E_{TB}^T - E_d^T$ ) is small, because the energy difference  $\Delta E^T$  may be overcome by the absorption of ambient heat energy when driving a device at around room temperature as generally employed in practical drive of device. As compared with the fluorescent emission, the phosphorescent emission is relatively likely to be affected by the diffusion of excitons due to the heat absorption because the lifetime of triplet excitons is longer. Therefore, as for the energy difference  $\Delta E^T$ , the larger as compared with the heat energy of room temperature, the better. The energy difference  $\Delta E^T$  is more preferably 0.1 eV or more and particularly preferably 0.2 eV or more.

[0309] The electron mobility of the material for the triplet blocking layer is preferably  $10^{-6} \text{ cm}^2/\text{Vs}$  or more at an electric field strength in a range of 0.04 to 0.5 MV/cm. There are several methods for measuring the electron mobility of organic material, for example, Time of Flight method. In the present invention, the electron mobility is determined by impedance spectroscopy.

[0310] The electron mobility of the electron injecting layer is preferably  $10^{-6} \text{ cm}^2/\text{Vs}$  or more at an electric field strength in a range of 0.04 to 0.5 MV/cm. Within the above range, the injection of electrons from the cathode to the electron transporting layer is promoted and the injection of electrons to the adjacent blocking layer and light emitting layer is also promoted, thereby enabling to drive a device at lower voltage.

#### EXAMPLES

[0311] The present invention will be described in more detail with reference to the examples. However, it should be noted that the scope of the invention is not limited to the following examples.

## Synthesis of Material for Organic EI Device

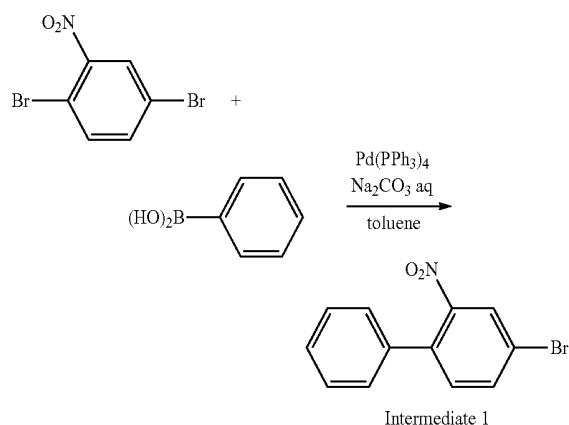
## Synthesis Example 1

## Synthesis of Compound H1

## Synthesis Example (1-1)

## Synthesis of Intermediate 1

[0312]



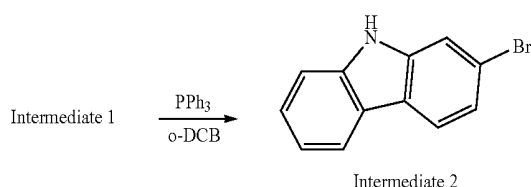
[0313] In argon stream, a mixture obtained by successively mixing 2-nitro-1,4-dibromobenzene (11.2 g, 40 mmol), phenylboronic acid (4.9 g, 40 mmol), tetrakis(triphenylphosphine)palladium (1.39 g, 1.2 mmol), toluene (120 mL), and a 2M aqueous solution of sodium carbonate (60 mL) was refluxed under heating for 8 h.

[0314] After cooling the reaction liquid to room temperature, the organic layer was separated and the organic solvent was removed from the organic layer by distillation under reduced pressure. The obtained residue was purified by a silica gel column chromatography to obtain the intermediate 1 (6.6 g, yield: 59%). The identification of the intermediate 1 was made by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (1-2)

## Synthesis of Intermediate 2

[0315]



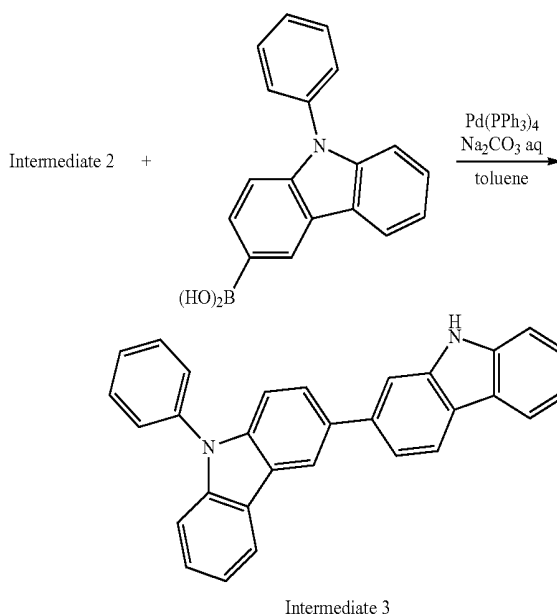
[0316] In argon stream, a mixture obtained by successively mixing the intermediate 1 (6.6 g, 23.7 mmol), triphenylphosphine (15.6 g, 59.3 mmol), and o-dichlorobenzene (24 mL) was heated at 180° C. for 8 h.

[0317] After cooling the reaction liquid to room temperature, the reaction product was purified by a silica gel column chromatography to obtain the intermediate 2 (4 g, yield: 68%). The identification of the intermediate 2 was made by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (1-3)

## Synthesis of Intermediate 3

[0318]

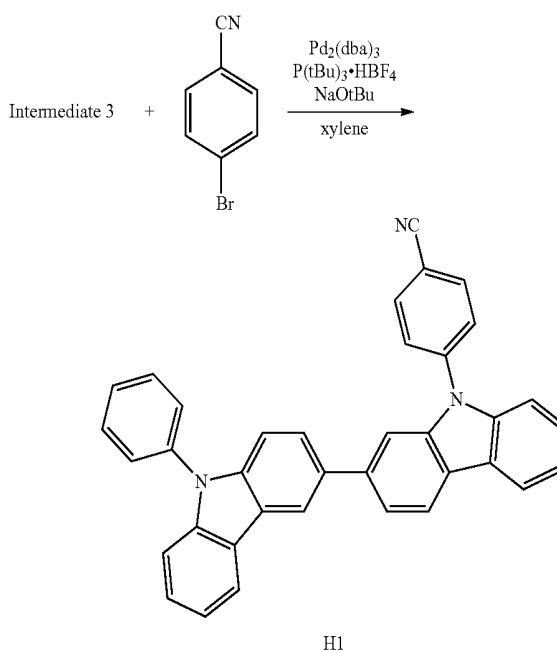


[0319] The procedure of Synthesis of Intermediate 1 was repeated except for using the intermediate 2 in place of 2-nitro-1,4-dibromobenzene and using 9-phenylcarbazole-3-ylboronic acid in place of phenylboronic acid. The obtained compound was identified as the intermediate 3 by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (1-4)

## Synthesis of Compound H1

[0320]



[0321] In argon stream, a mixture obtained by successively mixing the intermediate 3 (1.6 g, 3.9 mmol), 4-bromobenzonitrile (0.71 g, 3.9 mmol), tris(dibenzylideneacetone)dipalladium (0.071 g, 0.078 mmol), tri-*t*-butylphosphonium tetrafluoroborate (0.091 g, 0.31 mmol), sodium *t*-butoxide (0.53 g, 5.5 mmol), and dry toluene (20 mL) was refluxed under heating for 8 h.

[0322] After cooling the reaction liquid to room temperature, the organic layer was separated and the organic solvent was removed from the organic layer by distillation under reduced pressure. The obtained residue was purified by a silica gel column chromatography to obtain 0.79 g of white solid (H1).

[0323] The obtained compound was measured for FD-MS (field desorption mass spectrometry), maximum ultraviolet absorption wavelength (UV(PhMe) $\lambda_{\max}$ ) in toluene, and maximum fluorescence wavelength (FL(PhMe,  $\lambda_{\text{ex}}=300$  nm),  $\lambda_{\max}$ ) in toluene. The results are shown below.

[0324] FDMS: calcd. for  $C_{37}H_{23}N_3=509$ . found  $m/z=509$  (M<sup>+</sup>)

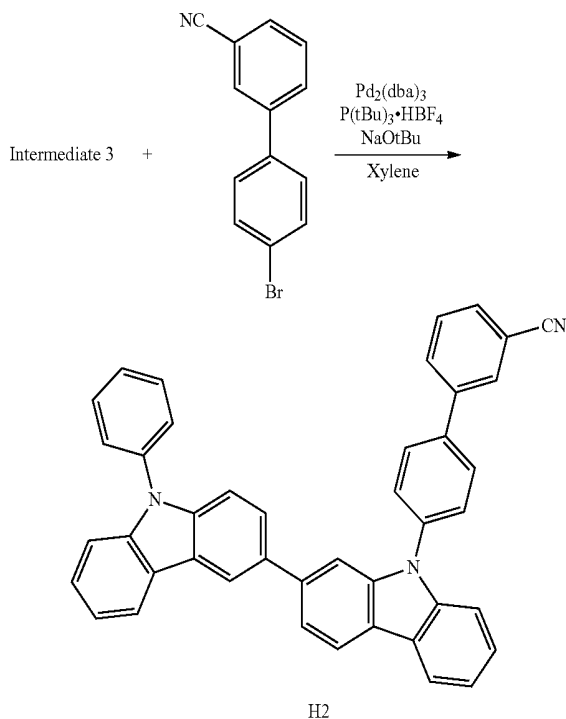
[0325] (UV(PhMe)  $\lambda_{\max}$ : 324 nm

[0326] FL(PhMe,  $\lambda_{\text{ex}}=300$  nm)  $\lambda_{\max}$ : 376 nm

#### Synthesis Example 2

##### Synthesis of Compound H2

[0327]



[0328] The procedure of Synthesis of Compound H1 was repeated except for using 4'-bromobiphenyl-3-carbonitrile in place of 4-bromobenzonitrile.

[0329] The obtained compound was measured for FD-MS (field desorption mass spectrometry), maximum ultraviolet absorption wavelength ((UV(PhMe) $\lambda_{\max}$ ) in toluene, and maximum fluorescence wavelength (FL(PhMe,  $\lambda_{\text{ex}}=300$  nm)  $\lambda_{\max}$ ) in toluene. The results are shown below.

[0330] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M<sup>+</sup>)

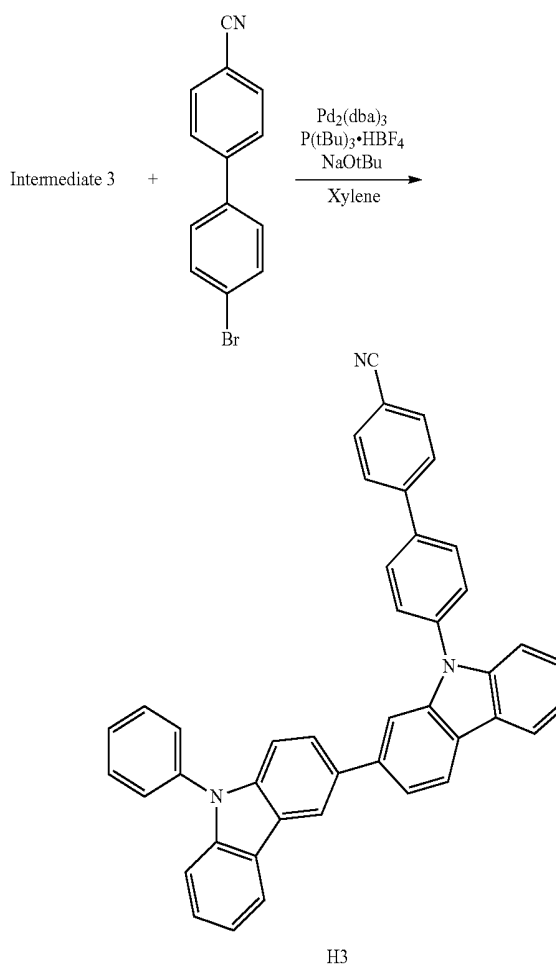
[0331] (UV(PhMe)  $\lambda_{\max}$ : 322 nm

[0332] FL(PhMe,  $\lambda_{\text{ex}}=300$  nm)  $\lambda_{\max}$ : 375 nm

#### Synthesis Example 3

##### Synthesis of Compound H3

[0333]



[0334] The procedure of Synthesis of Compound H1 was repeated except for using 4'-bromobiphenyl-4-carbonitrile in place of 4-bromobenzonitrile.

[0335] The obtained compound was measured for FD-MS (field desorption mass spectrometry), maximum ultraviolet absorption wavelength ((UV(PhMe) $\lambda_{\max}$ ) in toluene, and maximum fluorescence wavelength (FL(PhMe,  $\lambda_{\text{ex}}=300$  nm)  $\lambda_{\max}$ ) in toluene. The results are shown below.

[0336] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M<sup>+</sup>)

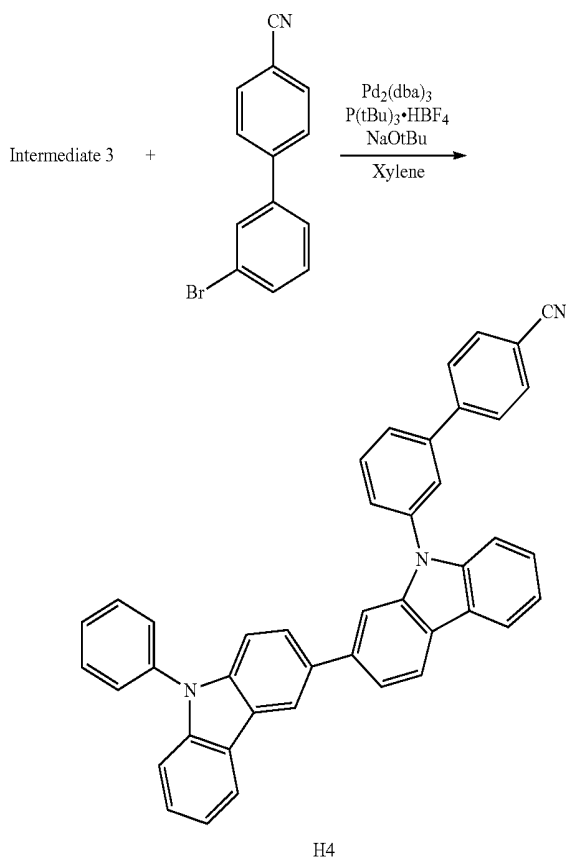
[0337] (UV(PhMe) $\lambda_{\max}$ : 324 nm

[0338] FL(PhMe,  $\lambda_{\text{ex}}=300$  nm)  $\lambda_{\max}$ : 393 nm

## Synthesis Example 4

## Synthesis of Compound H4

[0339]



[0340] The procedure of Synthesis of Compound H1 was repeated except for using 3'-bromobiphenyl-4-carbonitrile in place of 4-bromobenzonitrile.

[0341] The obtained compound was measured for FD-MS (field desorption mass spectrometry), maximum ultraviolet absorption wavelength ((UV(PhMe) $\lambda_{max}$ ) in toluene, and maximum fluorescence wavelength (FL(PhMe,  $\lambda_{ex}$ =300 nm)  $\lambda_{max}$ ) in toluene. The results are shown below.

[0342] FDMS: calcd. for  $C_{43}H_{27}N_3$ =585. found  $m/z$ =585 (M<sup>+</sup>)

[0343] (UV(PhMe) $\lambda_{max}$ : 322 nm

[0344] FL(PhMe,  $\lambda_{ex}$ =300 nm) $\lambda_{max}$ : 376 nm

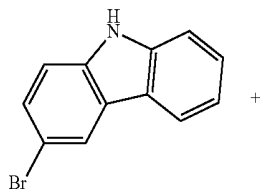
## Synthesis Example 5

## Synthesis of Compound H5

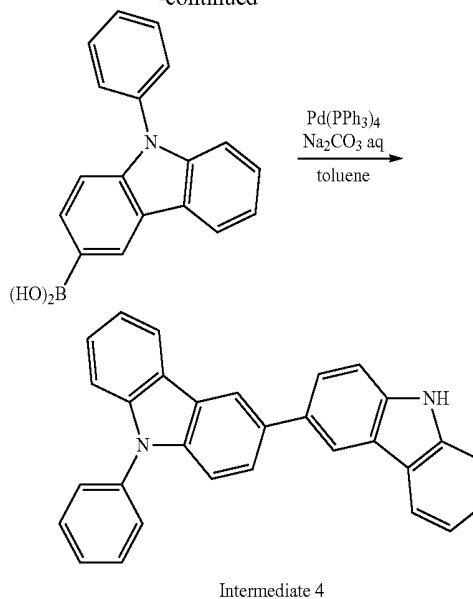
## Synthesis Example (5-1)

## Synthesis of Intermediate 4

[0345]



-continued



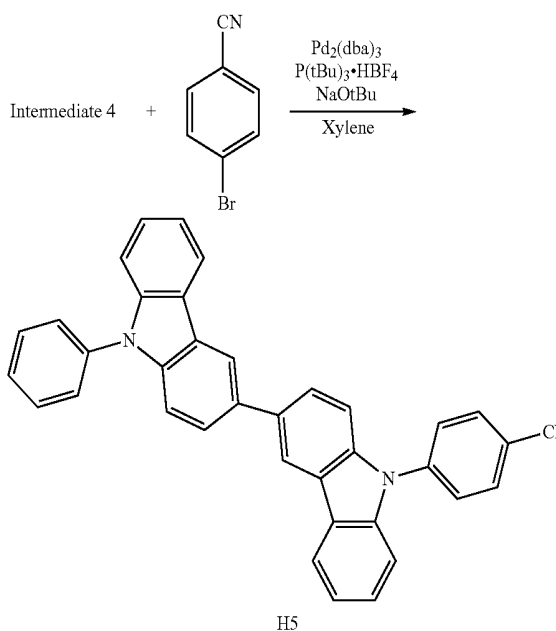
[0346] The procedure of Synthesis of Intermediate 1 was repeated except for using 3-bromocarbazole in place of 2-nitro-1,4-dibromobenzene and using 9-phenylcarbazole-3-ylboronic acid in place of phenylboronic acid.

[0347] The obtained compound was identified as the intermediate 4 by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (5-2)

## Synthesis of Compound H5

[0348]



[0349] The procedure of Synthesis of Compound H1 was repeated except for using the intermediate 4 in place of the intermediate 3.

[0350] The obtained compound was measured for FD-MS (field desorption mass spectrometry), maximum ultraviolet absorption wavelength ((UV(PhMe) $\lambda_{max}$ ) in toluene, and maximum fluorescence wavelength (FL(PhMe,  $\lambda_{ex}$ =300 nm)  $\lambda_{max}$ ) in toluene. The results are shown below.

[0351] FDMS: calcd. for  $C_{37}H_{23}N_3=509$ . found  $m/z=509$  (M+)

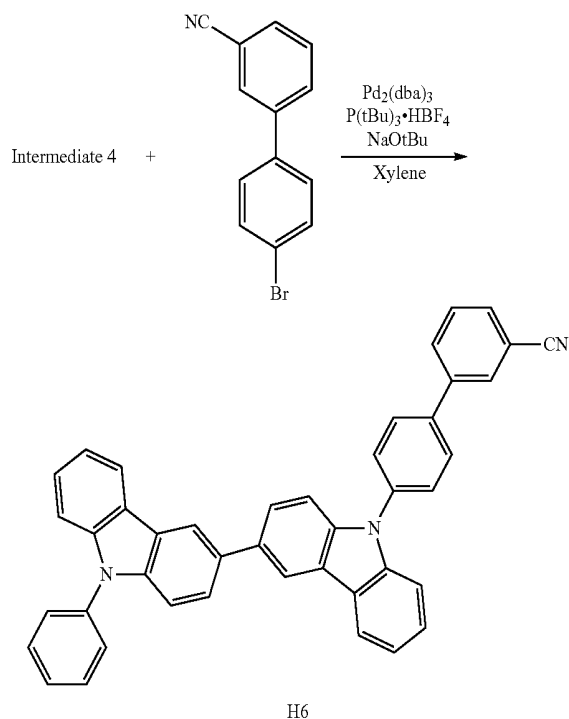
[0352] (UV(PhMe)) $\lambda_{max}$ : 339 nm

[0353] FL(PhMe,  $\lambda_{ex}=300$  nm) $\lambda_{max}$ : 404 nm

### Synthesis Example 6

#### Synthesis of Compound H6

[0354]



[0355] The procedure of Synthesis of Compound H1 was repeated except for using 4'-bromobiphenyl-3-carbonitrile in place of 4-bromobenzonitrile and using the intermediate 4 in place of the intermediate 3.

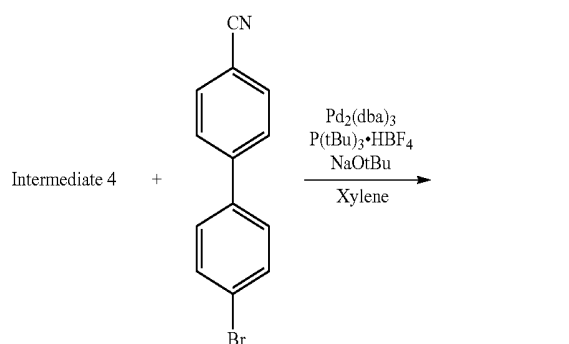
[0356] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0357] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M+)

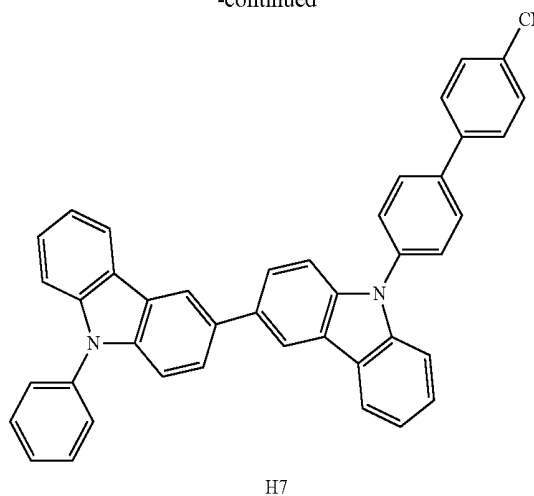
### Synthesis Example 7

#### Synthesis of Compound H7

[0358]



-continued



[0359] The procedure of Synthesis of Compound H1 was repeated except for using 4'-bromobiphenyl-4-carbonitrile in place of 4-bromobenzonitrile and using the intermediate 4 in place of the intermediate 3.

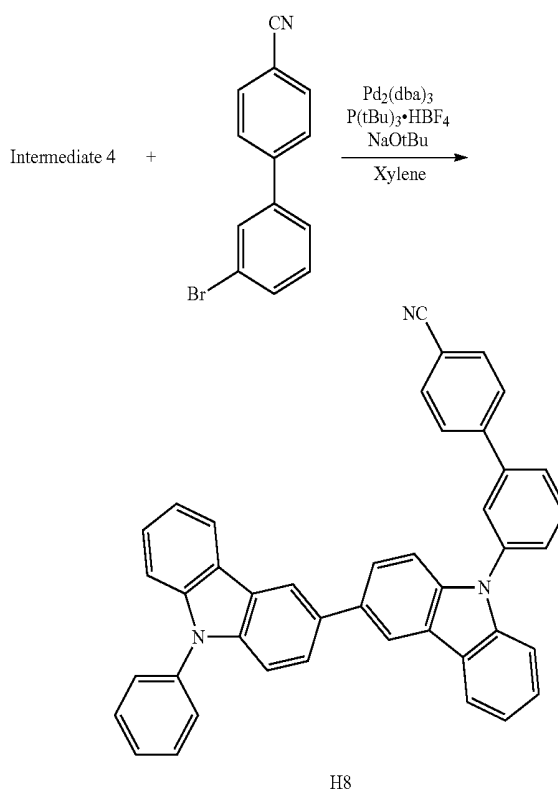
[0360] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0361] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M+)

### Synthesis Example 8

#### Synthesis of Compound H8

[0362]



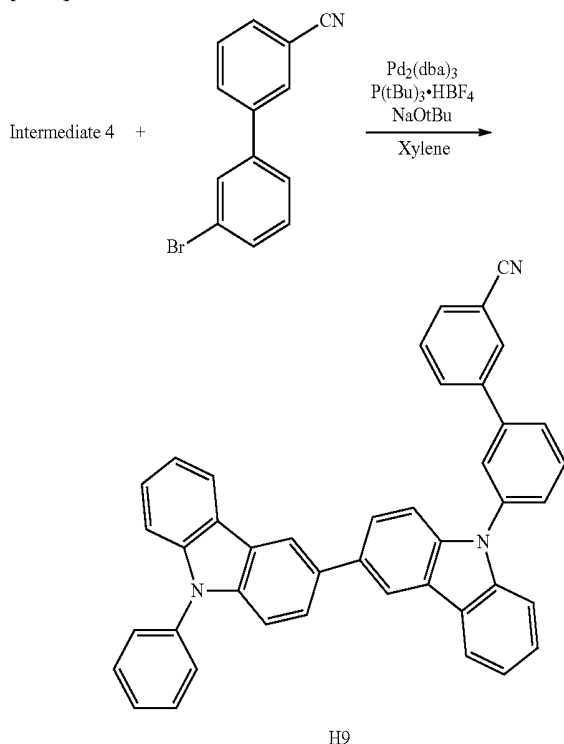
[0363] The procedure of Synthesis of Compound H1 was repeated except for using 3'-bromobiphenyl-4-carbonitrile in place of 4-bromobenzonitrile and using the intermediate 4 in place of the intermediate 3.

[0364] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0365] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M+)

Synthesis Example 9  
Synthesis of Compound H9

[0366]



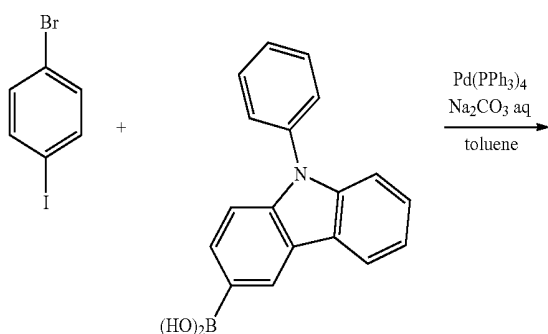
[0367] The procedure of Synthesis of Compound H1 was repeated except for using 3'-bromobiphenyl-3-carbonitrile in place of 4-bromobenzonitrile and using the intermediate 4 in place of the intermediate 3.

[0368] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

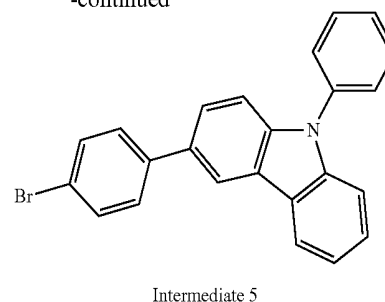
[0369] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M+)

Synthesis Example 10  
Synthesis of Compound H10  
Synthesis Example (10-1)  
Synthesis of Intermediate 5

[0370]



-continued



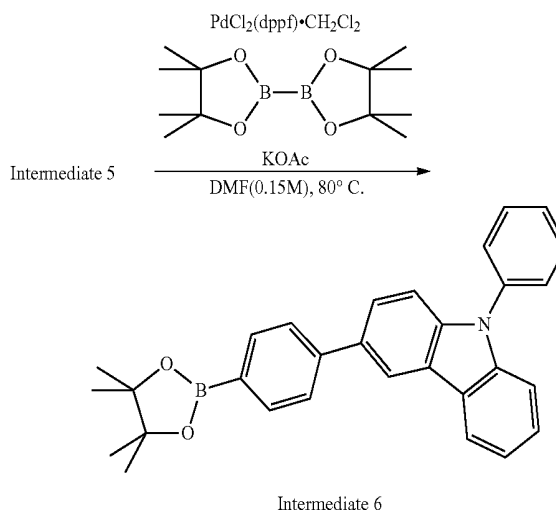
[0371] The procedure of Synthesis of Intermediate 1 was repeated except for using 1-bromo-4-iodobenzene in place of 2-nitro-1,4-dibromobenzene and using 9-phenylcarbazole-3-ylboronic acid in place of phenylboronic acid.

[0372] The obtained compound was identified as the intermediate 5 by FD-MS (field desorption mass spectrometry) analysis.

Synthesis Example (10-2)

Synthesis of Intermediate 6

[0373]



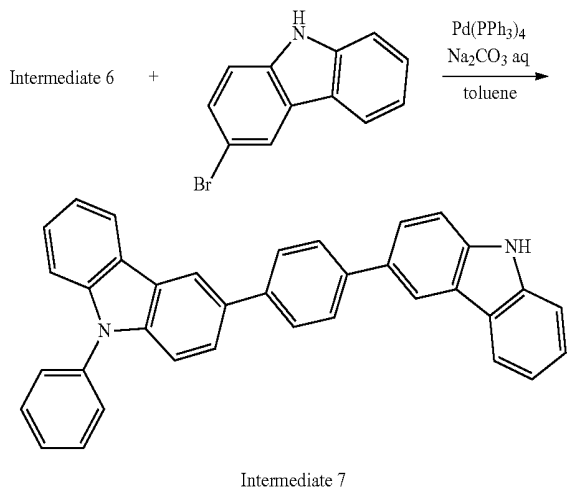
[0374] In argon stream, a mixture obtained by successively mixing the intermediate 5 (10 g, 25 mmol), bis(pinacolato) diboron (8.3 g, 33 mmol), dichloromethane adduct of [1,1'-bis(diphenylphosphino)ferrocene]palladium(II) dichloride (0.62 g, 0.75 mmol), potassium acetate (7.4 g, 75 mmol), and N,N-dimethylformamide (170 mL) was refluxed under heating for 8 h.

[0375] After cooling the reaction liquid to room temperature, the organic layer was separated and the organic solvent was removed from the organic layer by distillation under reduced pressure. The obtained residue was purified by a silica gel column chromatography to obtain the intermediate 6 (10 g, yield: 91%). The identification of the intermediate 6 was made by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (10-3)

## Synthesis of Intermediate 7

[0376]

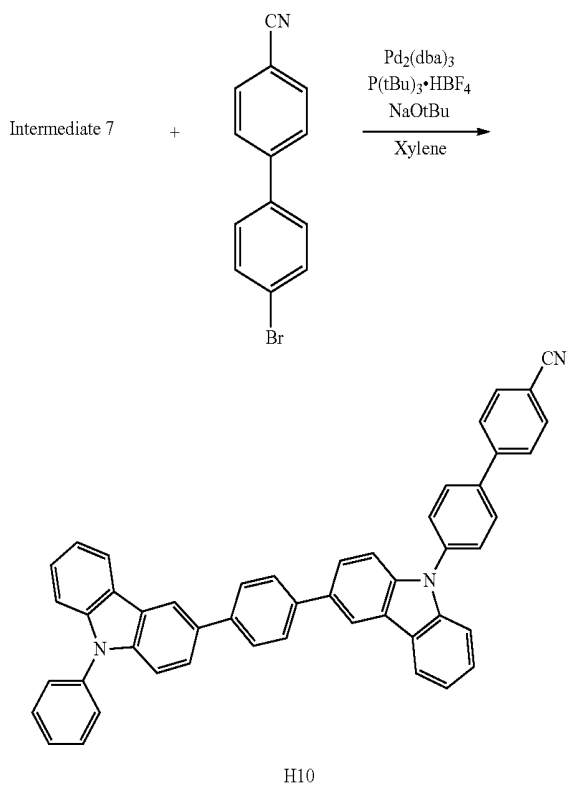


[0377] The procedure of Synthesis of Intermediate 1 was repeated except for using 3-bromocarbazole in place of 2-nitro-1,4-dibromobenzene and using the intermediate 6 in place of phenylboronic acid. The obtained compound was identified as the intermediate 7 by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (10-4)

## Synthesis of H10

[0378]



[0379] The procedure of Synthesis of Compound H1 was repeated except for using 4'-bromobiphenyl-4-carbonitrile in place of 4-bromobenzonitrile and using the intermediate 7 in place of the intermediate 3.

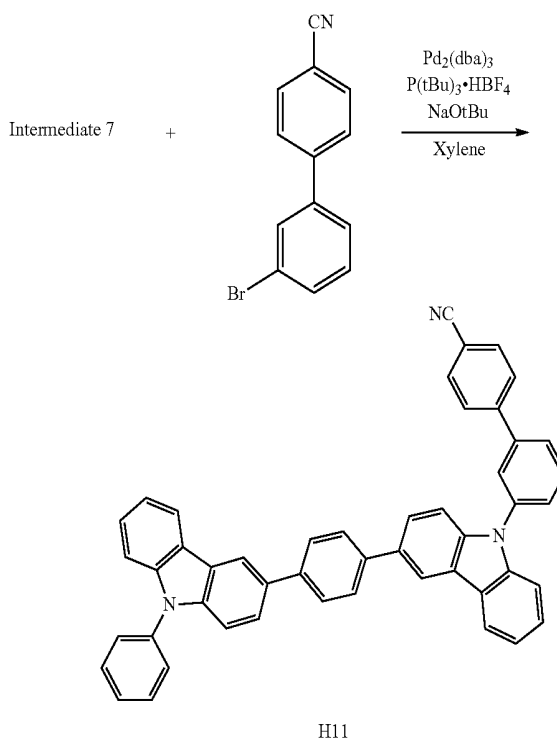
[0380] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0381] FDMS: calcd. for  $\text{C}_{49}\text{H}_{31}\text{N}_3=661$ . found  $m/z=661$  (M+)

## Synthesis Example 11

## Synthesis of Compound H11

[0382]



[0383] The procedure of Synthesis of Compound H1 was repeated except for using 3'-bromobiphenyl-4-carbonitrile in place of 4-bromobenzonitrile and using the intermediate 7 in place of the intermediate 3.

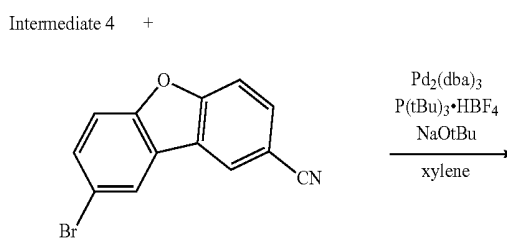
[0384] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0385] FDMS: calcd. for  $\text{C}_{49}\text{H}_{31}\text{N}_3=661$ . found  $m/z=661$  (M+)

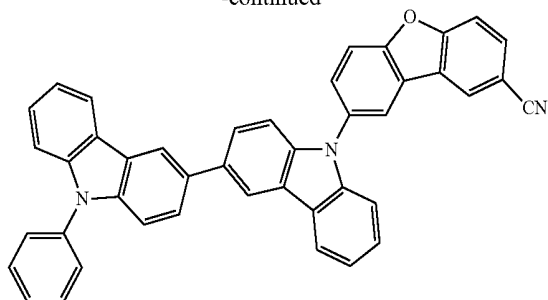
## Synthesis Example 12

## Synthesis of Compound H12

[0386]



-continued



H12

[0387] The procedure of Synthesis of Compound H1 was repeated except for using 2-bromo-8-cyanodibenzofuran in place of 4-bromobenzonitrile and using the intermediate 4 in place of the intermediate 3.

[0388] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0389] FDMS: calcd. for  $C_{43}H_{25}N_3O=599$ . found  $m/z=599$  ( $M^+$ )

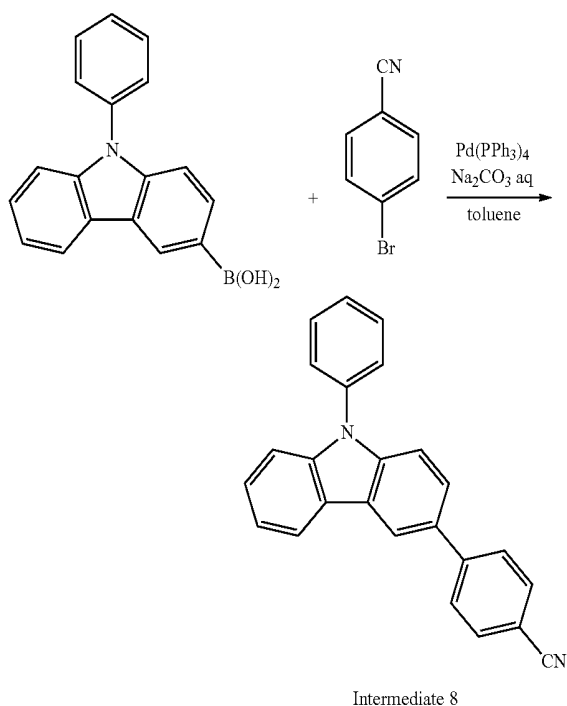
## Synthesis Example 13

## Synthesis of Compound H13

## Synthesis Example (13-1)

## Synthesis of Intermediate 8

[0390]



Intermediate 8

[0391] The procedure of Synthesis of Intermediate 1 was repeated except for using 4-bromobenzonitrile in place of

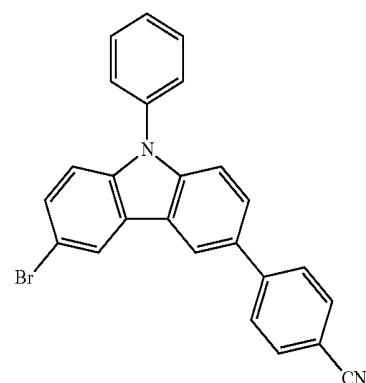
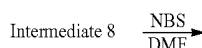
2-nitro-1,4-dibromobenzene and using 9-phenylcarbazole-3-ylboronic acid in place of phenylboronic acid.

[0392] The obtained compound was identified as the intermediate 8 by FD-MS (field desorption mass spectrometry) analysis.

## Synthesis Example (13-2)

## Synthesis of Intermediate 9

[0393]



Intermediate 9

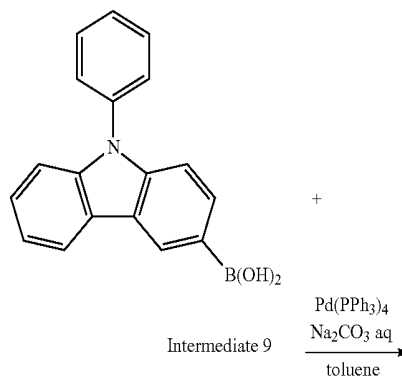
[0394] In argon stream, a mixture obtained by successively mixing N,N-dimethylformamide (80 mL), the intermediate 8 (5.6 g, 16.3 mmol), and N-bromosuccinimide (3.5 g, 19.5 mmol) was stirred at 0° C. for 8 h.

[0395] After returning the temperature to room temperature, the reaction liquid was added with distilled water and then filtered. The obtained solid was purified by silica gel column chromatography to obtain the intermediate 9 (6.2 g, yield: 90%). The identification of the intermediate 9 was made by FD-MS (field desorption mass spectrometry) analysis.

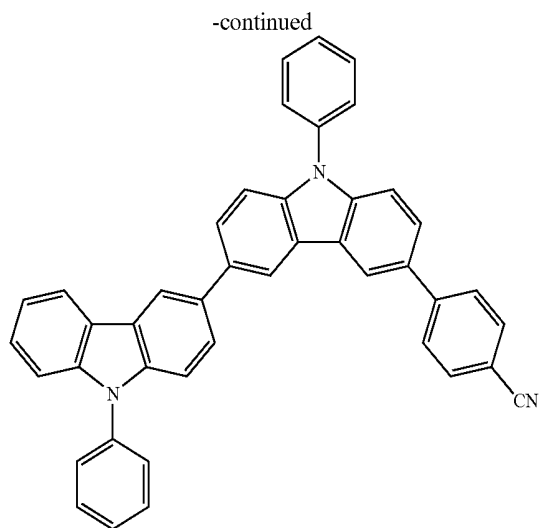
## Synthesis Example (13-3)

## Synthesis of Compound H13

[0396]



Intermediate 9



H13

[0397] The procedure of Synthesis of Intermediate 1 was repeated except for using the intermediate 9 in place of 2-nitro-1,4-dibromobenzene and using 9-phenylcarbazole-3-ylboronic acid in place of phenylboronic acid.

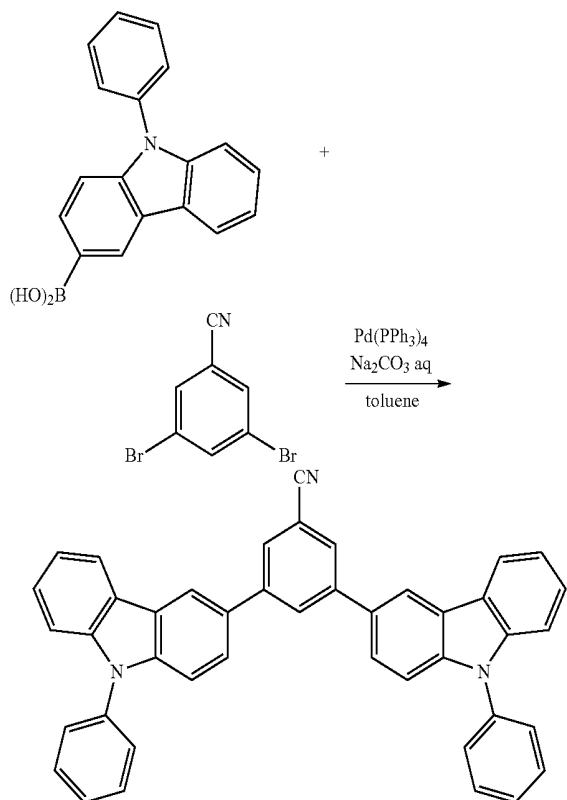
[0398] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0399] FDMS: calcd. for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M+)

#### Synthesis Example 14

##### Synthesis of Compound H14

[0400]



H14

[0401] The procedure of Synthesis of Intermediate 1 was repeated except for using 3,5-dibromobenzonitrile (1 equiv) in place of 2-nitro-1,4-dibromobenzene and using 9-phenylcarbazole-3-ylboronic acid (2 equiv) in place of phenylboronic acid.

[0402] The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

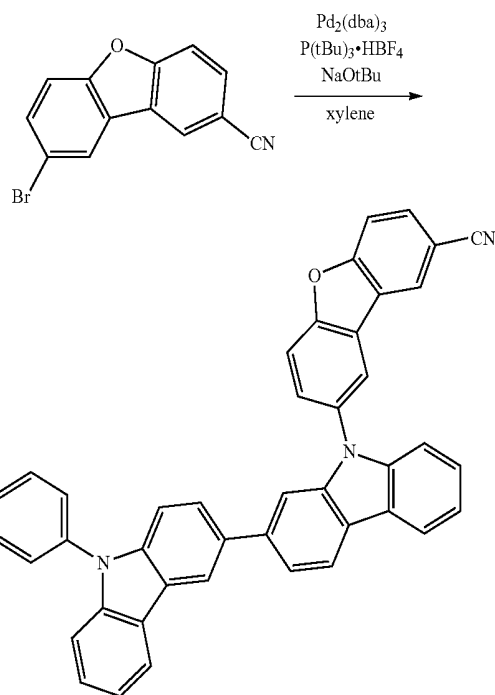
[0403] FDMS, calcd for  $C_{43}H_{27}N_3=585$ . found  $m/z=585$  (M+)

#### Synthesis Example 15

##### Synthesis of Compound H15

[0404]

Intermediate 3 +



H15

[0405] The procedure of Synthesis of Compound H1 was repeated except for using 2-bromo-8-cyanodibenzofuran in place of 4-bromobenzonitrile. The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

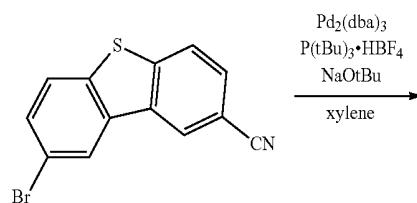
[0406] FDMS: calcd. for  $C_{43}H_{25}N_3O=599$ . found  $m/z=599$  (M+)

#### Synthesis Example 16

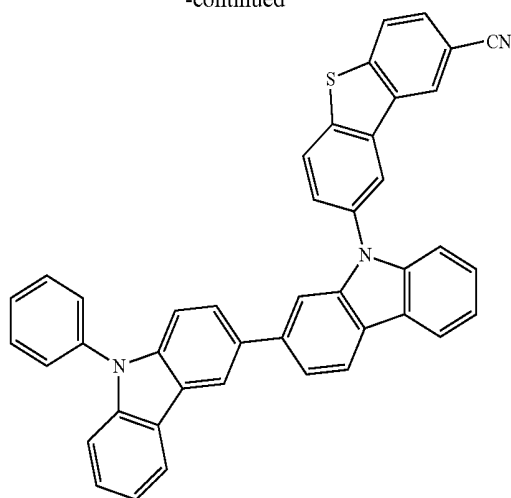
##### Synthesis of Compound H16

[0407]

Intermediate 3 +



-continued



H16

[0408] The procedure of Synthesis of Compound H1 was repeated except for using 2-bromo-8-cyanodibenzothiophene in place of 4-bromobenzonitrile. The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

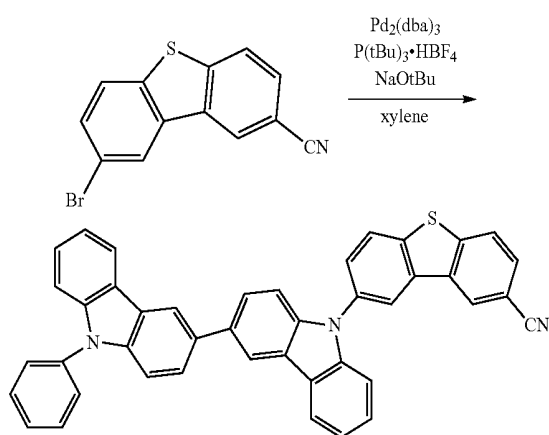
[0409] FDMS: calcd. for  $C_{43}H_{25}N_3S=615$ . found  $m/z=615$  ( $M^+$ )

## Synthesis Example 17

## Synthesis of Compound H17

[0410]

Intermediate 4 +



H17

[0411] The procedure of Synthesis of Compound H1 was repeated except for using 2-bromo-8-cyanodibenzothiophene in place of 4-bromobenzonitrile and using the intermediate 4 in place of the intermediate 3. The obtained compound was measured for FD-MS (field desorption mass spectrometry). The result is shown below.

[0412] FDMS: calcd. for  $C_{43}H_{25}N_3S=615$ . found  $m/z=615$  ( $M^+$ )

## Production of Organic EL Device and Evaluation of Emission Performance

## Example 1

## Production of Organic EL Device

[0413] A glass substrate of 25 mm×75 mm x 1.1 mm thickness having an ITO transparent electrode (product of Geomatec Company) was cleaned by ultrasonic cleaning in isopropyl alcohol for 5 min and then UV ozone cleaning for 30 min.

[0414] The cleaned glass substrate was mounted to a substrate holder of a vacuum vapor deposition apparatus. The electron accepting compound C-1 (acceptor) shown below was vapor-deposited so as to cover the transparent electrode to form a compound C-1 film with a thickness of 5 nm. On the compound C-1 film, a first hole transporting material (aromatic amine derivative (compound X1) shown below) was vapor-deposited to form a first hole transporting layer with a thickness of 65 nm. Successively after forming the first hole transporting layer, a second hole transporting material (aromatic amine derivative (compound X2) shown below) was vapor-deposited to form a second hole transporting layer with a thickness of 10 nm.

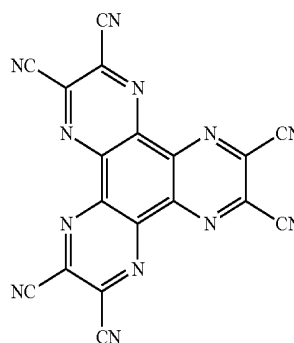
[0415] On the second hole transporting layer, the host material 1, the host material 2, each being listed in Table 1 and  $Ir(bzq)_3$  (phosphorescent emitting material) shown below were co-deposited to form a phosphorescent light emitting layer with a thickness of 25 nm. The concentration in the light emitting layer was 10.0% by mass for  $Ir(bzq)_3$ , 45.0% by mass for the host compound 1, and 45.0% by mass for the host compound 2. The co-deposited film works as a light emitting layer.

[0416] Successively after forming the light emitting layer, the compound ET shown below was vapor-deposited into a film with a thickness of 35 nm. The compound ET film works as an electron transporting layer.

[0417] Then, LiF was vapor-deposited into a film with a thickness of 1 nm at a film-forming speed of 0.1 Å/min to form an electron injecting electrode (cathode). On the LiF film, metallic Al was vapor-deposited to form a metallic cathode with a thickness of 80 nm, thereby obtaining an organic EL device.

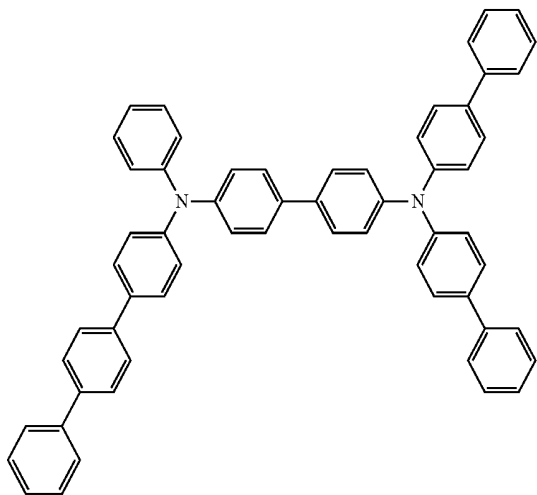
[0418] The compounds used in the examples and comparative examples are shown below.

Compound C-1



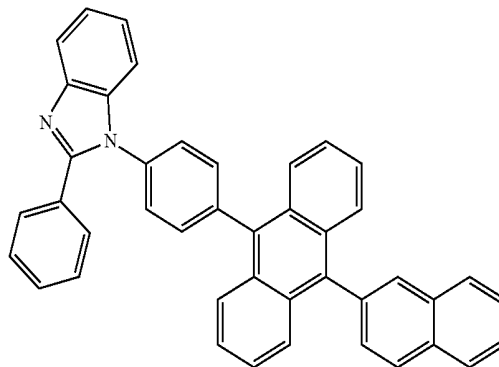
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Compound X1

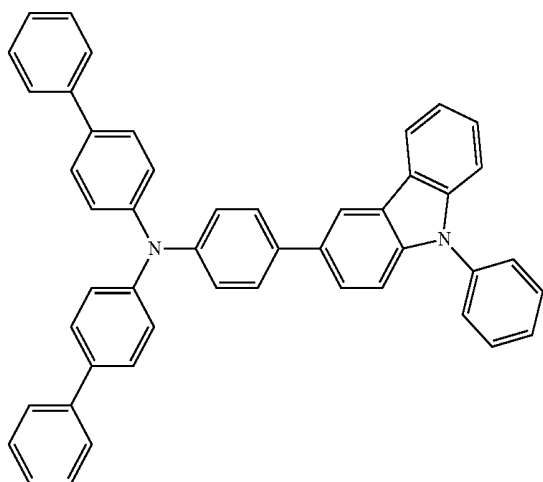


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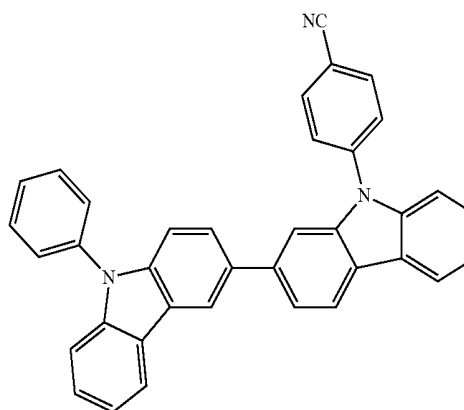
Compound ET



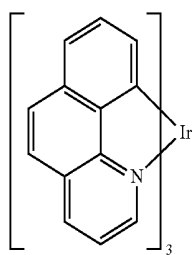
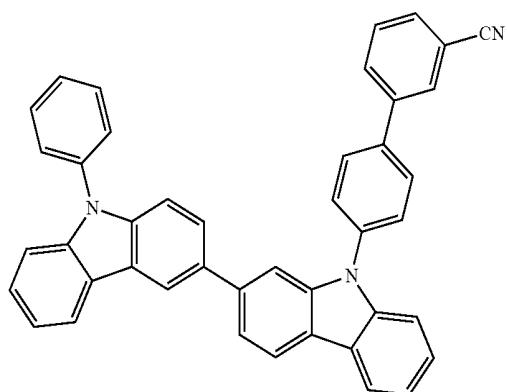
Compound X2



Compound H1



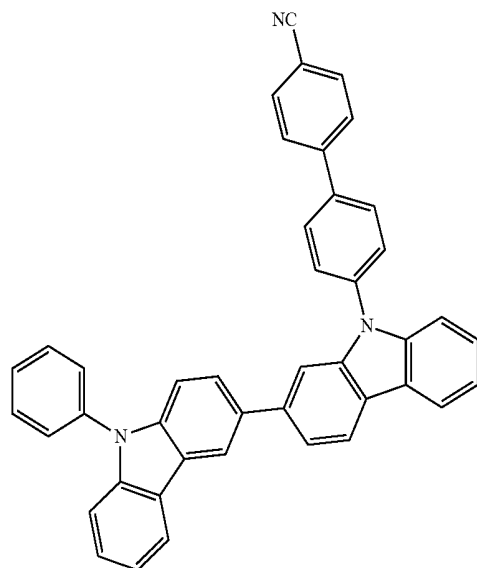
Compound H2



Ir(bzq)<sub>3</sub>

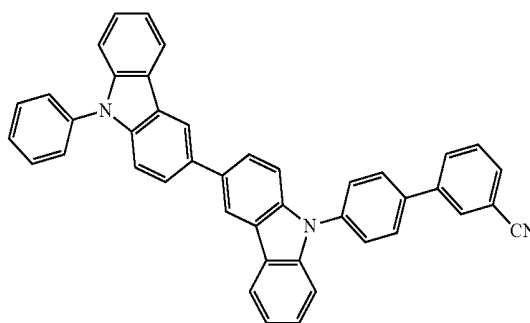
-continued

Compound H3

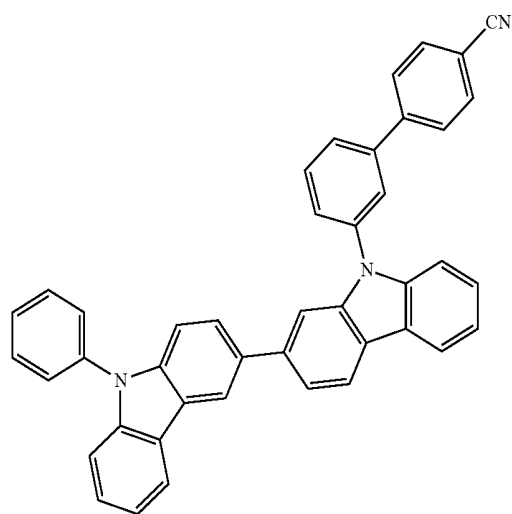


-continued

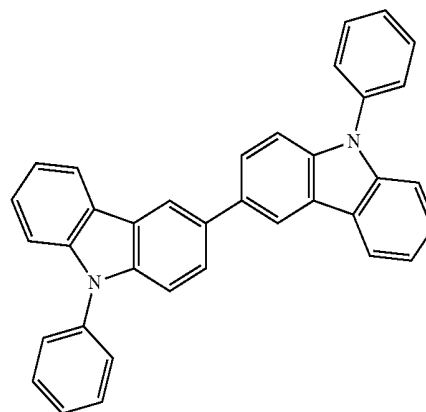
Compound H6



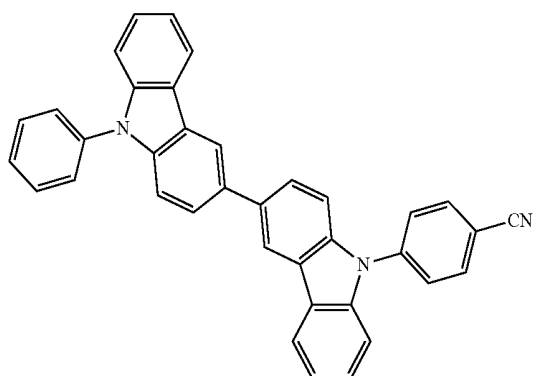
Compound H4



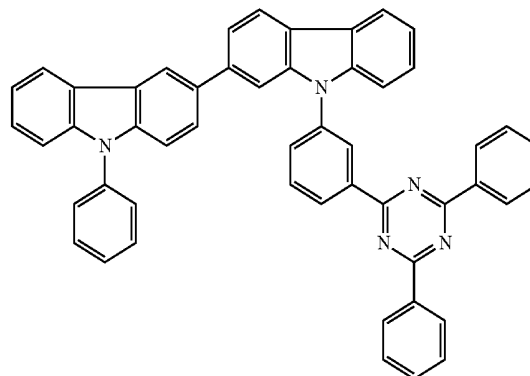
Compound F1



Compound H5

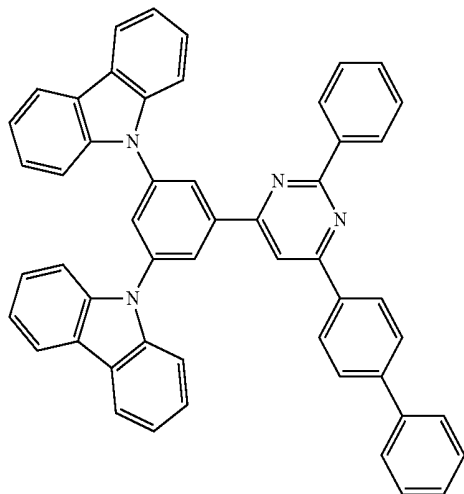


Compound F2

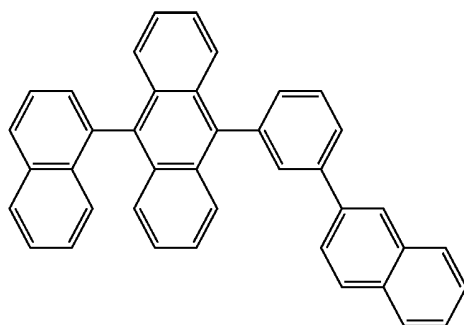


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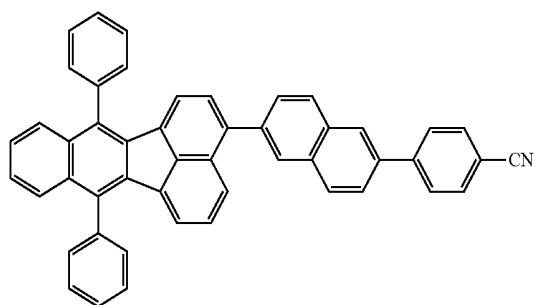
Compound F3



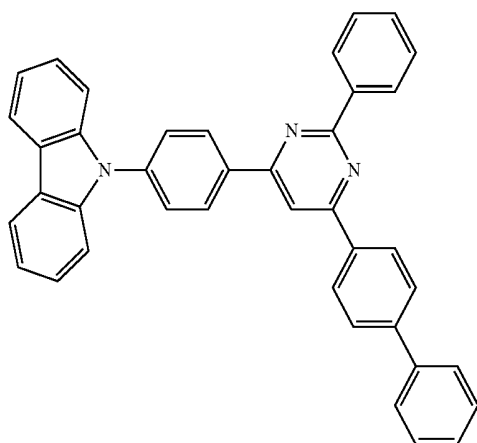
Compound BH1



Compound BD1

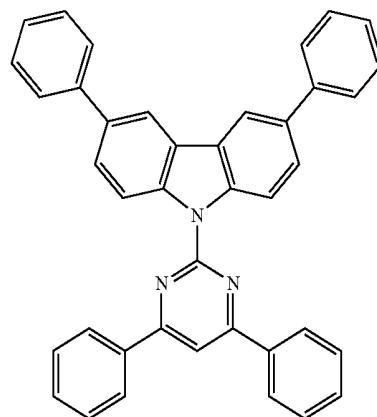


Compound F4

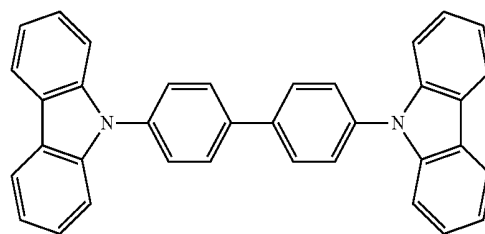


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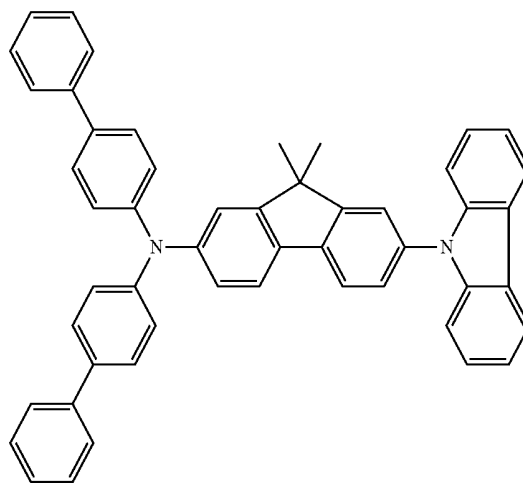
Compound F5



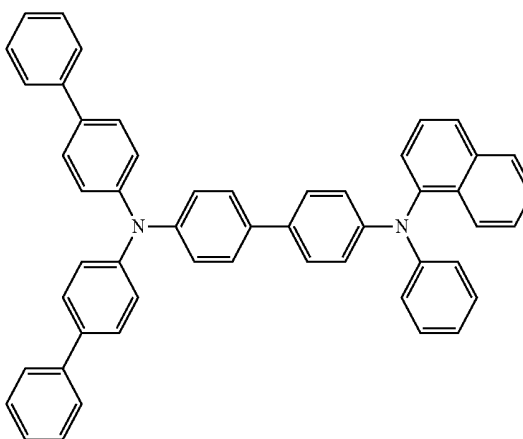
Compound F6



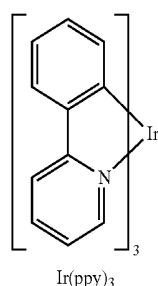
Compound X3



Compound X4



-continued



## Evaluation of Emission Performance of Organic EL Device

**[0419]** Each of the obtained organic EL devices was measured for the emission efficiency at room temperature by driving the device at constant DC current (current density: 1 mA/cm<sup>2</sup>) and measured for 80% lifetime at an initial luminance of 10,000 cd/m<sup>2</sup> (time taken until the luminance was reduced to 80% of the initial luminance when driving the device at constant current). The results are shown in Table 1.

## Examples 2 to 5 and Comparative Example 1

**[0420]** In the same manner as in Example 1 except for forming the light emitting layer by using each host material 1 and host material 2 shown in Table 2, each organic EL device was produced.

**[0421]** The emission efficiency and 80% lifetime of each organic EL device are shown in Table 1.

TABLE 1

	Light emitting layer		Emission	80%
	Host material 1	Host material 2	efficiency (cd/A)	Lifetime (h)
Example 1	compound H1	compound F2	68	1040
Example 2	compound H1	compound F3	68	800
Example 3	compound H3	compound F2	66	800
Example 4	compound H4	compound F2	70	1120
Example 5	compound H5	compound F2	60	1040
Comparative Example 1	compound F1	compound F3	50	480

**[0422]** As seen from Table 1, the organic EL devices of Examples 1 to 5, wherein the combination of the first host material represented by formula (A) (compounds H1 and H3 to H5) and the second host material represented by formula (1) (compounds F2 and F3) was used as the host material (co-host) of the light emitting layer, showed good emission efficiency. In addition, the organic EL devices of Examples 1 to 5 showed longer lifetime as compared with the organic EL device of Comparative Example 1 which employed the co-host of the compound F1 and the compound F3 each having a similar central skeleton but having no cyano substituent at its terminal end.

## Example 6

## Production of Organic EL Device

**[0423]** A glass substrate of 25 mm×75 mm x 1.1 mm thickness having an ITO transparent electrode (anode, 70 nm

manufactured by Geomatec Company was cleaned by ultrasonic cleaning in isopropyl alcohol for 5 min and then UV ozone cleaning for 30 min.

**[0424]** The cleaned glass substrate was mounted to a substrate holder of a vacuum vapor deposition apparatus. The compound C-1 was vapor-deposited by resistance heating so as to cover the transparent electrode to form a hole injecting layer with a thickness of 10 nm adjacent to the anode.

**[0425]** On the hole injecting layer, the compound X4 was vapor-deposited by resistance heating to form a first hole transporting layer with a thickness of 65 nm.

**[0426]** On the first hole transporting layer, the compound X3 was vapor-deposited by resistance heating to form a second hole transporting layer with a thickness of 10 nm.

**[0427]** On the second hole transporting layer, the compound H5 (first host material), the compound F2 (second host material), and Ir(bzq)<sub>3</sub> (phosphorescent dopant) were co-deposited by resistance heating to form a yellow-light emitting layer with a thickness of 25 nm. The concentration in the light emitting layer was 45% by mass for the first host material, 45% by mass for the second host material, and 10% by mass for the phosphorescent dopant.

**[0428]** On the light emitting layer, the compound ET was vapor-deposited by resistance heating to form an electron transporting layer with a thickness of 35 nm.

**[0429]** Then, LiF was vapor-deposited on the electron transporting layer to form an electron injecting layer with a thickness of 1 nm. Then, metallic Al was vapor-deposited on the electron injecting layer to form a cathode with a thickness of 80 nm.

## Evaluation of Emission Performance of Organic EL Device

**[0430]** Each of the obtained organic EL devices was measured for the voltage and external quantum efficiency at room temperature by driving the device at constant DC current (current density: 10 mA/cm<sup>2</sup>) and further measured for 90% lifetime (time taken until the luminance was reduced to 90% of the initial luminance when driving the device at constant current) at a current density of 50 mA/cm<sup>2</sup>. The results are shown in Table 2.

## Examples 7 to 17 and Comparative Examples 3 and 6 to 7

**[0431]** Each organic EL device was produced in the same manner as in Example 6 except for forming the light emitting layer by using the host material 1 and the host material 2 listed in Table 2.

**[0432]** The voltage, emission efficiency and 90% lifetime of the obtained organic EL devices are shown in Table 2.

## COMPARATIVE EXAMPLES 2, 4 and 5

**[0433]** Each organic EL device was produced in the same manner as in Example 6 except for forming the light emitting layer by using the host material 2 (90% by mass) listed in Table 2.

**[0434]** The voltage, emission efficiency and 90% lifetime of the obtained organic EL devices are shown in Table 2.

TABLE 2

	Light emitting layer		Volt- age (V)	External quantum efficiency (%)	90% Life- time (h)
	Host material 1	Host material 2			
Example 6	compound H5	compound F2	3.05	20.2	160
Example 7	compound H1	compound F2	3.27	18.0	120
Example 8	compound H2	compound F2	3.43	19.4	130
Example 9	compound H3	compound F2	3.38	19.2	160
Example 10	compound H4	compound F2	3.42	20.7	120
Example 11	compound H7	compound F2	3.24	20.8	160
Example 12	compound H10	compound F2	3.28	22.1	150
Example 13	compound H12	compound F2	3.44	20.9	110
Example 14	compound H14	compound F2	3.09	14.6	160
Example 15	compound H13	compound F2	3.20	19.9	160
Comparative Example 2	—	compound F2	3.40	20.5	70
Comparative Example 3	compound F1	compound F2	3.34	22.2	60
Example 16	compound H5	compound F4	3.02	20.7	90
Comparative Example 4	—	compound F4	3.30	19.8	40
Example 17	compound H5	compound F5	3.33	22.0	95
Comparative Example 5	—	compound F5	4.10	21.7	11
Comparative Example 6	compound F1	compound F5	3.42	22.3	20
Comparative Example 7	compound F1	compound F6	4.85	13.0	0

[0435] As seen from Table 2, the organic EL devices of Examples 6 to 15, each employing the compound represented by formula (A) as the first host material and the compound represented by formula (1) as the second host material, show increased lifetimes as compared with the organic EL devices of Comparative Examples 2 and 3.

[0436] The organic EL devices of Examples 16 and 17, in which the compound represented by formula (A) was used as the first host material and the compound represented by formula (1) and having one carbazole ring and one azine ring in its molecule was used as the second host material show increased lifetimes as compared with the organic EL devices of Comparative Examples 4 to 7.

#### Example 18

##### Production of Organic EL Device

[0437] A glass substrate of 25 mm×75 mm x 1.1 mm thickness having an ITO transparent electrode (anode, 130 nm) manufactured by Geomatec Company was cleaned by ultrasonic cleaning in isopropyl alcohol for 5 min and then UV ozone cleaning for 30 min.

[0438] The cleaned glass substrate was mounted to a substrate holder of a vacuum vapor deposition apparatus. The compound C-1 was vapor-deposited by resistance heating so as to cover the transparent electrode to form a hole injecting layer with a thickness of 5 nm adjacent to the anode.

[0439] On the hole injecting layer, the compound X1 was vapor-deposited by resistance heating to form a first hole transporting layer with a thickness of 160 nm.

[0440] On the first hole transporting layer, the compound X3 was vapor-deposited by resistance heating to form a second hole transporting layer with a thickness of 10 nm.

[0441] On the second hole transporting layer, the compound H5 (first host material), the compound F2 (second host material), and Ir(ppy)<sub>3</sub> (phosphorescent dopant) were co-deposited by resistance heating to form a green-light emitting

layer with a thickness of 25 nm. The concentration in the light emitting layer was 45% by mass for the first host material, 45% by mass for the second host material, and 10% by mass for the phosphorescent dopant.

[0442] On the light emitting layer, the compound ET was vapor-deposited by resistance heating to form an electron transporting layer with a thickness of 35 nm.

[0443] Then, LiF was vapor-deposited on the electron transporting layer to form an electron injecting layer with a thickness of 1 nm. Then, metallic Al was vapor-deposited on the electron injecting layer to form a cathode with a thickness of 80 nm.

##### Evaluation of Emission Performance of Organic EL Device

[0444] Each of the obtained organic EL devices was measured for the voltage and external quantum efficiency at room temperature by driving the device at constant DC current (current density: 10 mA/cm<sup>2</sup>) and further measured for 95% lifetime at an initial luminance of 4,000 cd/m<sup>2</sup> (time taken until the luminance was reduced to 95% of the initial luminance when driving the device at constant current). The results are shown in Table 3.

##### Examples 19 to 20 and Comparative Example 8

[0445] Each organic EL device was produced in the same manner as in Example 18 except for forming the light emitting layer by using the host material 1 and the host material 2 listed in Table 3.

[0446] The voltage, external quantum efficiency and 95% lifetime of the obtained organic EL devices are shown in Table 3.

TABLE 3

	Light emitting layer		Volt- age (V)	External quantum efficiency (%)	95% Life- time (h)
	Host material 1	Host material 2			
Example 18	compound H5	compound F2	3.88	14.9	210
Example 19	compound H3	compound F2	3.92	15.1	210
Example 20	compound H7	compound F2	3.90	15.3	220
Comparative Example 8	compound F6	compound F2	4.51	13.8	90

[0447] The organic EL devices of Examples 18 to 20, each employing the compound represented by formula (A) as the first host material and the compound represented by formula (1) as the second host material, show increased lifetimes as compared with the organic EL device of Comparative Example 8.

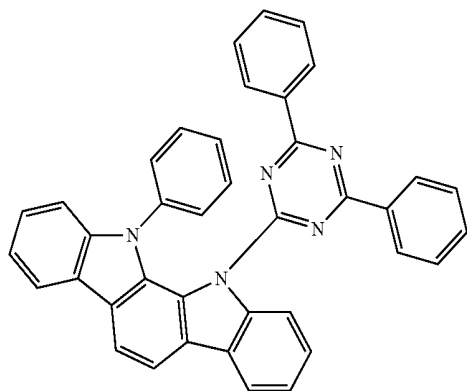
##### Examples 21 to 28 and Comparative Examples 9 to

11

[0448] Each organic EL device was produced in the same manner as in Example 1 except for forming the light emitting layer by using the host material 1 and the host material 2 listed in Table 4.

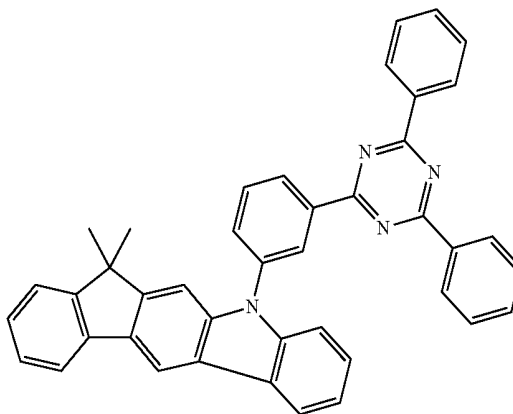
[0449] The emission efficiency and 90% lifetime of the obtained organic EL devices are shown in Table 4.

Compound F7

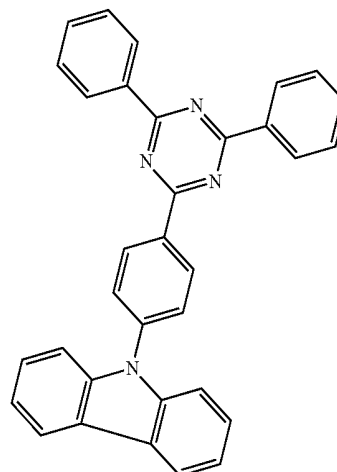


-continued

Compound F10



Compound F11



Compound F8

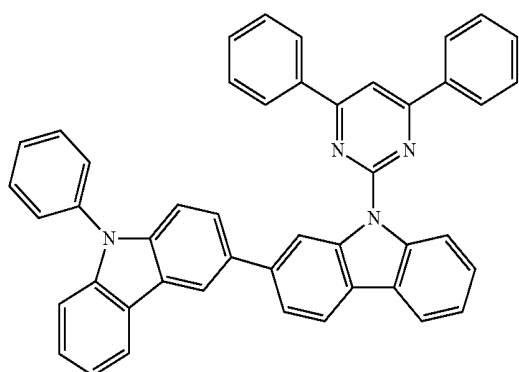
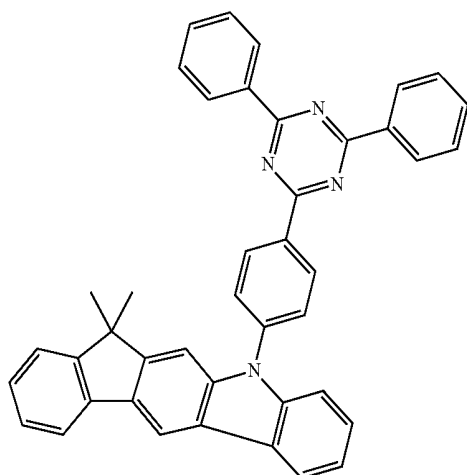


TABLE 4

	Light emitting layer		Volt- age (V)	External quantum efficiency (%)	90% Life- time (h)
	Host material 1	Host material 2			
Example 21	compound H7	compound F7	3.11	19.9	170
Example 22	compound H7	compound F8	3.30	17.5	120
Example 23	compound H7	compound F9	3.14	21.0	140
Example 24	compound H7	compound F10	3.20	20.5	150
Example 25	compound H7	compound F11	3.20	19.8	130
Example 26	compound H15	compound F2	3.60	23.0	90
Example 27	compound H16	compound F2	3.61	23.5	90
Example 28	compound H17	compound F2	3.55	23.0	100
Comparative Example 9	—	compound F9	3.00	19.8	30
Comparative Example 10	—	compound F10	3.00	20.0	55
Comparative Example 11	—	compound F11	3.10	16.9	35

Compound F9



Examples 29 to 35 and Comparative Examples 12 to 14

[0450] Each organic EL device was produced in the same manner as in Example 18 except for forming the light emitting layer by using the host material 1 and the host material 2 listed in Table 5.

[0451] The voltage, external quantum efficiency and 95% lifetime of the obtained organic EL devices are shown in Table 5.

TABLE 5

	Light emitting layer		Volt- age (V)	External quantum efficiency (%)	95% Life- time (h)
	Host material 1	Host material 2			
Example 29	compound H7	compound F8	3.95	15.0	200
Example 30	compound H7	compound F9	3.80	14.0	140
Example 31	compound H7	compound F10	3.81	14.2	150
Example 32	compound H15	compound F2	4.30	14.0	130
Example 33	compound H16	compound F2	4.30	14.1	130
Example 34	compound H17	compound F2	4.25	14.0	140
Example 35	compound H17	compound F11	3.80	14.1	140
Comparative Example 12	—	compound F9	3.74	12.0	30
Comparative Example 13	—	compound F10	3.74	11.5	60
Comparative Example 14	—	compound F11	3.75	13.6	30

## INDUSTRIAL APPLICABILITY

[0452] As described above in detail, the organic EL device of the invention exhibits an improved long lifetime.

## REFERENCE NUMERALS

[0453] 1: Organic electroluminescence device

[0454] 2: Substrate

[0455] 3: Anode

[0456] 4: Cathode

[0457] 5: Phosphorescent light emitting layer

[0458] 6: Hole injecting/transporting layer

[0459] 7: Electron injecting/transporting layer

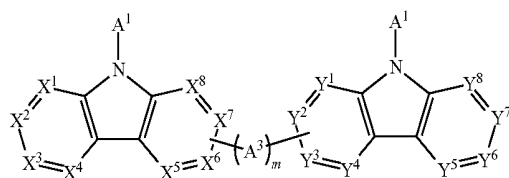
[0460] 10: Organic thin film layer

1. An organic electroluminescence device which comprises a light emitting layer which is disposed between a cathode and an anode and comprises a first host material, a second host material and a light emitting material,

wherein

the first host material is represented by formula (A):

(A)



wherein

each of  $A^1$  and  $A^2$  independently represents a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms;

$A^3$  represents a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms

$m$  represents an integer of 0 to 3;

each of  $X^1$  to  $X^8$  and  $Y^1$  to  $Y^8$  independently represents N or  $CR^a$ ;

each of  $R^a$  independently represents a hydrogen atom, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted silyl group, a halogen atom, or a cyano group, provided that when two or more  $R^a$  groups exist, the  $R^a$  groups may be the same or different and one of  $X^5$  to  $X^8$  and one of  $Y^1$  to  $Y^4$  are bonded to each other via  $A^3$ ; and

the formula (A) satisfies at least one of the following requirements (i) to (v):

(i) at least one of  $A^1$  and  $A^2$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms;

(ii) at least one of  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  represents  $CR^a$ , and at least one of  $R^a$  in  $X^1$  to  $X^4$  and  $Y^5$  to  $Y^8$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms;

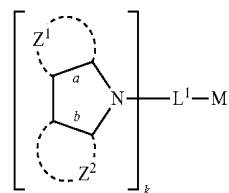
(iii)  $m$  represents an integer of 1 to 3 and at least one of  $A^3$  represents a cyano-substituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted divalent heterocyclic group having 5 to 30 ring atoms;

(iv) at least one of  $X^5$  to  $X^8$  and  $Y^1$  to  $Y^4$  represents  $CR^a$ , and at least one of  $R^a$  in  $X^5$  to  $X^8$  and  $Y^1$  to  $Y^8$  represents a cyano-substituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a cyano-substituted heterocyclic group having 5 to 30 ring atoms; and

(v) at least one of  $X^1$  to  $X^8$  and  $Y^1$  to  $Y^8$  represents  $C-CN$ ; and

the second host material is represented by formula (1):

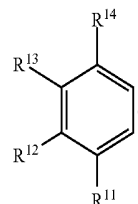
(1)



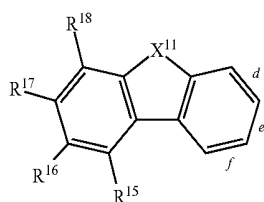
wherein

$Z^1$  represents a ring structure fused to a side a and represented by formula (1-1) or (1-2), and  $Z^2$  represents a ring structure fused to a side b and represented by formula (1-1) or (1-2), provided that at least one of  $Z^1$  and  $Z^2$  is represented by formula (1-1):

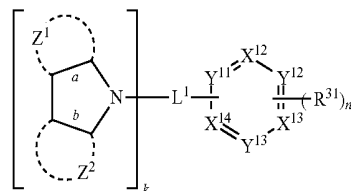
(1-1)



-continued



(1-2)



(2)

in formula (1-1),

a side c is fused to the side a or b of formula (1);

in formula (1-2),

any one of sides d, e and f is fused to the side a or b of formula (1);

in formulae (1-1) and (1-2),

$X^{11}$  represents a sulfur atom, an oxygen atom,  $N-R^{19}$ , or  $C(R^{20})(R^{21})$ ;

each of  $R^{11}$  to  $R^{21}$  independently represents a hydrogen atom, a heavy hydrogen atom, a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms, provided that adjacent groups of  $R^{11}$  to  $R^{21}$  may be bonded to each other to form a ring;

$M^1$  represent a substituted or unsubstituted nitrogen-containing aromatic heteroring having 5 to 30 ring atoms;

$L^1$  represents a single bond, a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms, a cycloalkylene group having 5 to 30 ring atoms, or a group in which the preceding groups are directly linked to each other; and

k represents 1 or 2.

2. The organic electroluminescence device according to claim 1, wherein the first host material satisfies at least one of the requirements (i) and (ii).

3. The organic electroluminescence device according to claim 1, wherein  $A^3$  of formula (A) represents a substituted or unsubstituted divalent monocyclic hydrocarbon group having 6 or less ring carbon atoms or a substituted or unsubstituted divalent monocyclic heterocyclic group having 6 or less ring atoms.

4. The organic electroluminescence device according to claim 1, wherein the second host material is represented by formula (2):

wherein

$Z^1$  represents a ring structure fused to the side a and represented by formula (1-1) or (1-2), and  $Z^2$  represents a ring structure fused to the side b and represented by formula (1-1) or (1-2), provided that at least one of  $Z^1$  and  $Z^2$  is represented by formula (1-1);

$L^1$  is as defined in formula (1);

each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

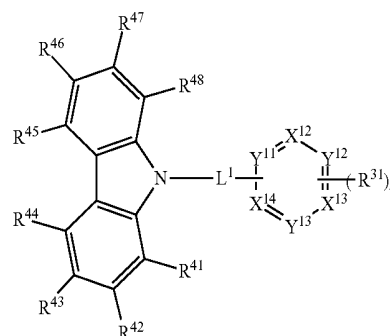
each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

k represents 1 or 2, and n represents an integer of 0 to 4; the side c of formula (1-1) is fused to the side a or b of formula (2); and

any one of sides d, e and f of formula (1-2) is fused to the side a or b of formula (2).

5. The organic electroluminescence device according to claim 1, wherein the second host material is represented by formula (3):



(3)

wherein

$L^1$  is as defined in formula (1);

each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , pro-

vided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

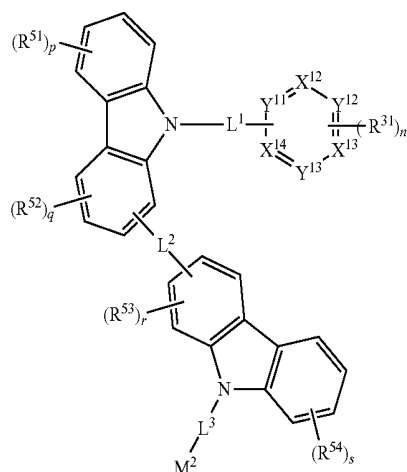
n represents an integer of 0 to 4;

each of  $R^{41}$  to  $R^{48}$  independently represents a hydrogen atom, a heavy hydrogen atom, a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms; and

adjacent groups of  $R^{41}$  to  $R^{48}$  may be bonded to each other to form a ring.

6. The organic electroluminescence device according to claim 1, wherein the first host material satisfies only the requirement (i).

7. The organic electroluminescence device according to claim 1, wherein the second host material is represented by formula (4):



wherein

$L^1$  is as defined in formula (1);

each of  $X^{12}$  to  $X^{14}$  independently represents a nitrogen atom, CH, or a carbon atom bonded to  $R^{31}$  or  $L^1$ , provided that at least one of  $X^{12}$  to  $X^{14}$  represents a nitrogen atom;

each of  $Y^{11}$  to  $Y^{13}$  independently represents CH or a carbon atom bonded to  $R^{31}$  or  $L^1$ ;

each of  $R^{31}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

when two or more  $R^{31}$  groups exist, the  $R^{31}$  groups may be the same or different and adjacent  $R^{31}$  groups may be bonded to each other to form a ring;

n represents an integer of 0 to 4;

each of  $L^2$  and  $L^3$  independently represents a single bond, a substituted or unsubstituted divalent aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted divalent heterocyclic group having 5 to 30 ring atoms, a cycloalkylene group having 5 to 30 ring atoms, or a group in which the preceding groups are directly linked to each other;

each of  $R^{51}$  to  $R^{54}$  independently represents a halogen atom, a cyano group, a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms, a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms, a substituted or unsubstituted alkyl group having 1 to 30 carbon atoms, a substituted or unsubstituted alkenyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkynyl group having 2 to 30 carbon atoms, a substituted or unsubstituted alkylsilyl group having 3 to 30 carbon atoms, a substituted or unsubstituted arylsilyl group having 6 to 30 ring carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, a substituted or unsubstituted aralkyl group having 6 to 30 ring carbon atoms, or a substituted or unsubstituted aryloxy group having 6 to 30 ring carbon atoms;

when two or more  $R^{51}$  groups exist, the  $R^{51}$  groups may be the same or different and adjacent  $R^{51}$  groups may be bonded to each other to form a ring;

when two or more  $R^{52}$  groups exist, the  $R^{52}$  groups may be the same or different and adjacent  $R^{52}$  groups may be bonded to each other to form a ring;

when two or more  $R^{53}$  groups exist, the  $R^{53}$  groups may be the same or different and adjacent  $R^{53}$  groups may be bonded to each other to form a ring;

when two or more  $R^{54}$  groups exist, the  $R^{54}$  groups may be the same or different and adjacent  $R^{54}$  groups may be bonded to each other to form a ring;

M<sup>2</sup> represents a substituted or unsubstituted aromatic hydrocarbon group having 6 to 30 ring carbon atoms or a substituted or unsubstituted heterocyclic group having 5 to 30 ring atoms; and

each of p and s independently represents an integer of 0 to 4, and each of q and r independently represents an integer of 0 to 3.

8. The organic electroluminescence device according to claim 1, wherein at least one of A<sup>1</sup> and A<sup>2</sup> represents a cyano-substituted phenyl group, a cyano-substituted naphthyl group, a cyano-substituted phenanthryl group, a cyano-substituted dibenzofuranyl group, a cyano-substituted dibenzothiophenyl group, a cyano-substituted biphenyl group, a cyano-substituted terphenyl group, a cyano-substituted 9,9-diphenylfluorenyl group, a cyano-substituted 9,9'-spirobi[9H-fluorene]-2-yl group, a cyano-substituted 9,9'-dimethylfluorenyl group, or a cyano-substituted triphenylenyl group.

9. The organic electroluminescence device according to claim 1, wherein the light emitting material comprises a phosphorescent emitting material selected from ortho metallated complexes of a metal selected from iridium (Ir), osmium (Os), and platinum (Pt).

10. The organic electroluminescence device according to claim 1, wherein a peak of emission wavelength of the phosphorescent emitting material is 490 nm or longer and 700 nm or shorter.

\* \* \* \* \*

专利名称(译)	用于有机电致发光器件和有机电致发光器件的材料		
公开(公告)号	<a href="#">US20140151647A1</a>	公开(公告)日	2014-06-05
申请号	US13/705686	申请日	2012-12-05
[标]申请(专利权)人(译)	MIZUKI YUMIKO ITO充则 井上哲也 日比野久美子 西村KAZUKI		
申请(专利权)人(译)	水木YUMIKO ITO, 充则 井上哲也 日比野, 久美子 西村, KAZUKI		
当前申请(专利权)人(译)	出光兴产股份有限公司.		
[标]发明人	MIZUKI YUMIKO ITO MITSUNORI INOUE TETSUYA HIBINO KUMIKO NISHIMURA KAZUKI		
发明人	MIZUKI, YUMIKO ITO, MITSUNORI INOUE, TETSUYA HIBINO, KUMIKO NISHIMURA, KAZUKI		
IPC分类号	H01L51/50		
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优先权	2012083145 2012-03-30 JP 61/582694 2012-01-03 US 61/669406 2012-07-09 US 2011266238 2011-12-05 JP		
外部链接	<a href="#">Espacenet</a> <a href="#">USPTO</a>		

#### 摘要(译)

一种有机电致发光器件，其使用具有氰基的特定双咪唑衍生物作为第一主体和具有咪唑结构和含氮芳族杂环两者的化合物作为第二主体。有机电致发光器件具有延长的寿命。

