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Yamada et al.

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(54) **ORGANIC COMPOUND AND ORGANIC
LIGHT-EMITTING DEVICE**

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(30) **Foreign Application Priority Data**

Feb. 8, 2021 (JP) 2021-018115

(51) **Int. Cl.**

C07D 498/10 (2006.01)

H10K 50/11 (2023.01)

(Continued)

(52) **U.S. Cl.**

CPC **C07D 498/10** (2013.01); **H10K 85/657**

(2023.02); **H10K 50/11** (2023.02);

(Continued)

(58) **Field of Classification Search**

CPC C07D 498/10; H10K 85/657

See application file for complete search history.

(56) **References Cited**

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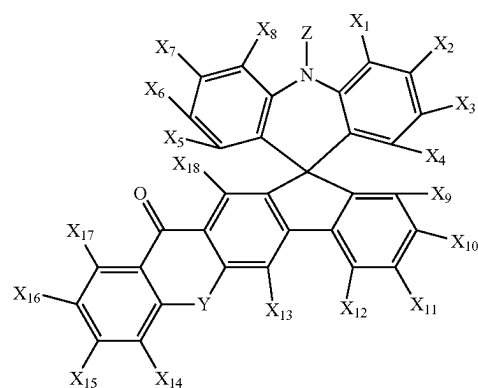
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Assistant Examiner — Rachel Simbana

(74) *Attorney, Agent, or Firm* — Canon U.S.A., Inc. IP
Division

(57) **ABSTRACT**

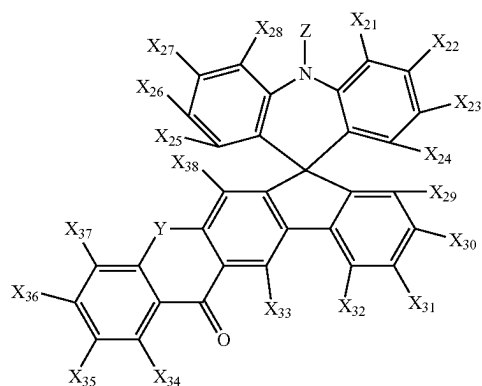
An organic compound, represented by formula [1] or [2],
suitably used for a thermally activated delayed fluorescent
device:



(Continued)

No.	COMPOUND	HOMO DISTRIBUTION	LUMO DISTRIBUTION	S ₁ -T ₁ DIFFERENCE (eV)	S ₁ (nm)
B-1				0.01	467
B-2				0.01	479
B-3				0.07	424
b-1				0.75	364
b-2				0.55	344
b-3				0.38	439

-continued



where X_1 to X_{18} and X_{21} to X_{38} are each independently selected from the group consisting of a hydrogen atom, and substituents, Y is oxygen, sulfur, selenium, tellurium, a CR_1R_2 group, or a carbonyl group, where R_1 and R_2 are each independently selected from the group consisting of a hydrogen atom, and substituents, and Z

is an alkyl group, an aryl group, or a heterocyclic group.

16 Claims, 8 Drawing Sheets

- (51) **Int. Cl.**
H10K 85/60 (2023.01)
H10K 101/10 (2023.01)
H10K 101/20 (2023.01)
H10K 101/30 (2023.01)
H10K 101/40 (2023.01)
- (52) **U.S. Cl.**
 CPC *H10K 2101/10* (2023.02); *H10K 2101/30* (2023.02); *H10K 2101/40* (2023.02)
- (56) **References Cited**

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Woo, S.J. et al., "Strategies for the Molecular Design of Donor-Acceptor-type Fluorescent Emitters for Efficient Deep Blue Organic Light Emitting Diodes", *Chemistry of Materials*, Feb. 13, 2018, pp. 857-863, vol. 30, No. 3.

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FIG. 1

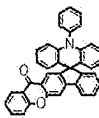
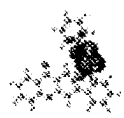

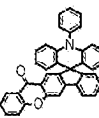
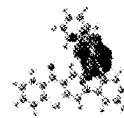

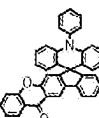
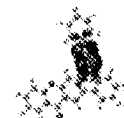

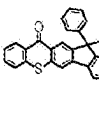


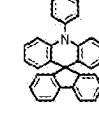

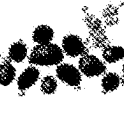
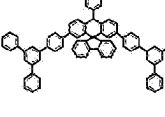


No.	COMPOUND	HOMO DISTRIBUTION	LUMO DISTRIBUTION	S_1-T_1 DIFFERENCE (eV)	S_1 (nm)
B-1				0.01	467
B-2				0.01	479
B-3				0.07	424
b-1				0.75	364
b-2				0.55	344
b-3				0.38	439

FIG. 2A

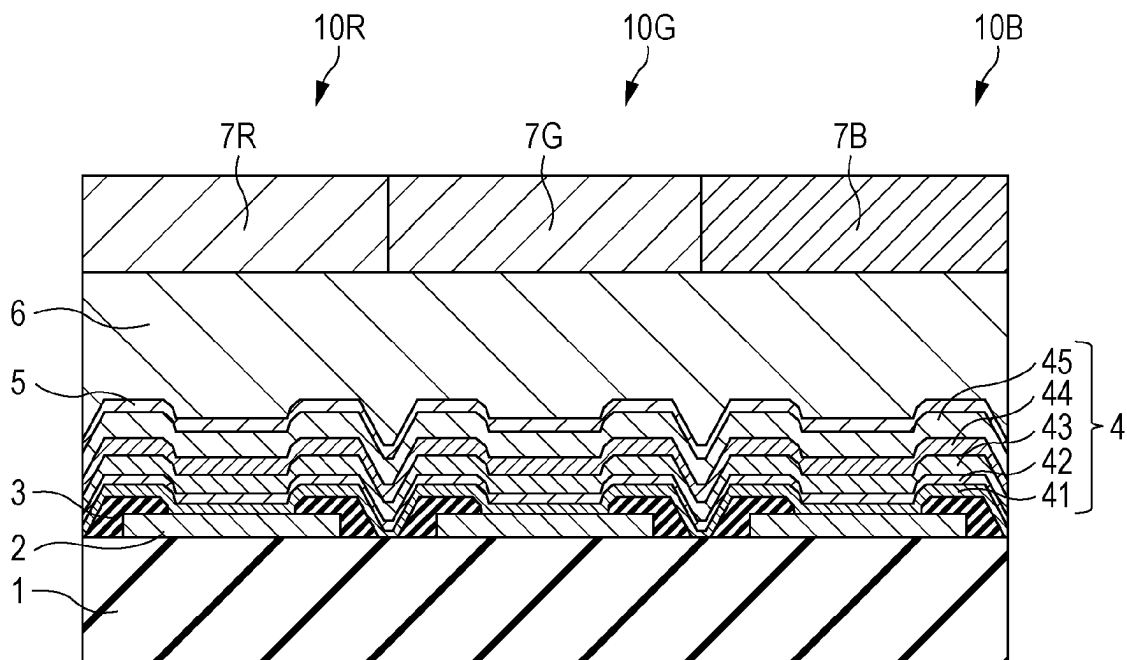


FIG. 2B

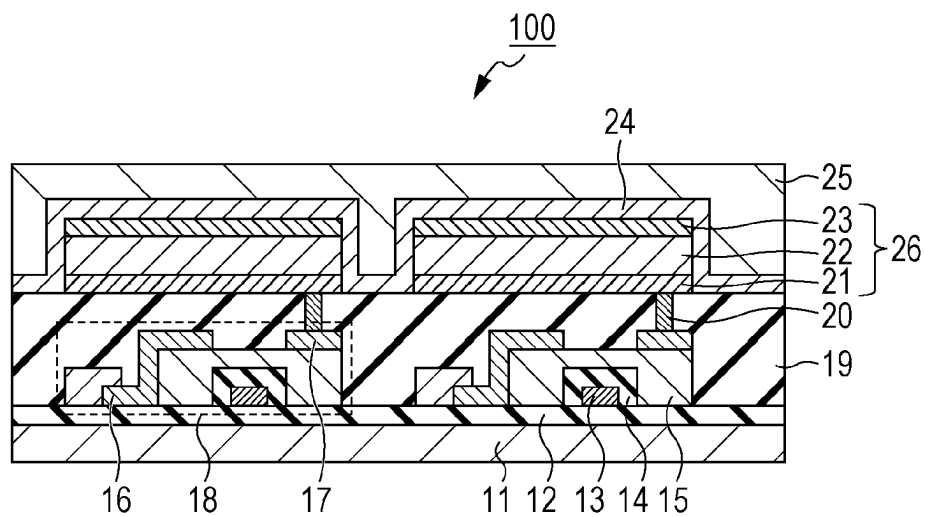


FIG. 3A

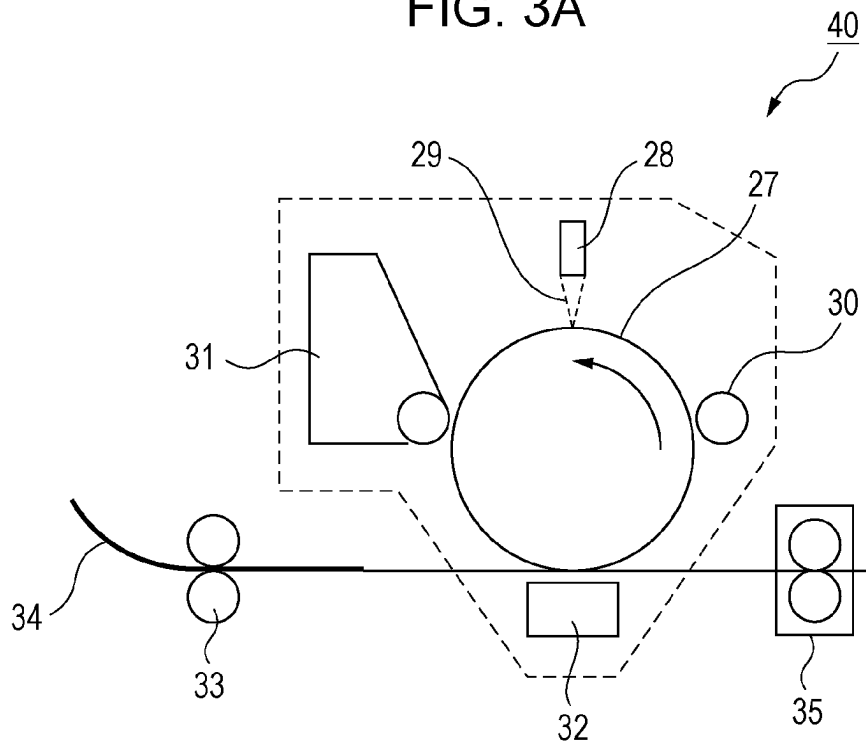


FIG. 3B

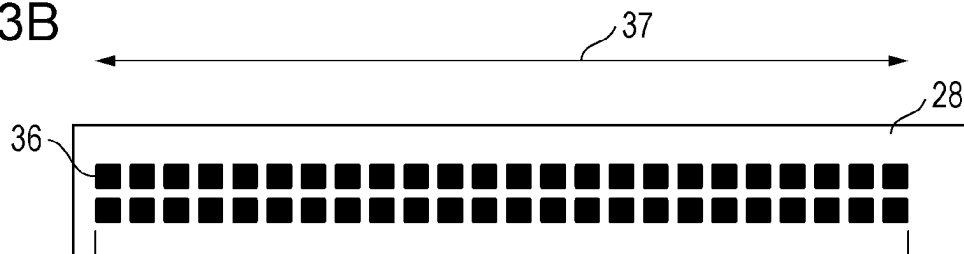


FIG. 3C

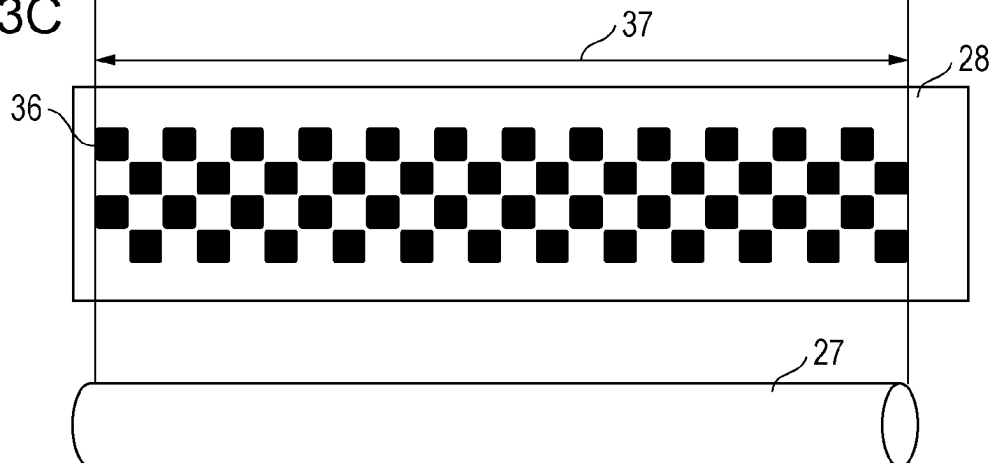


FIG. 4

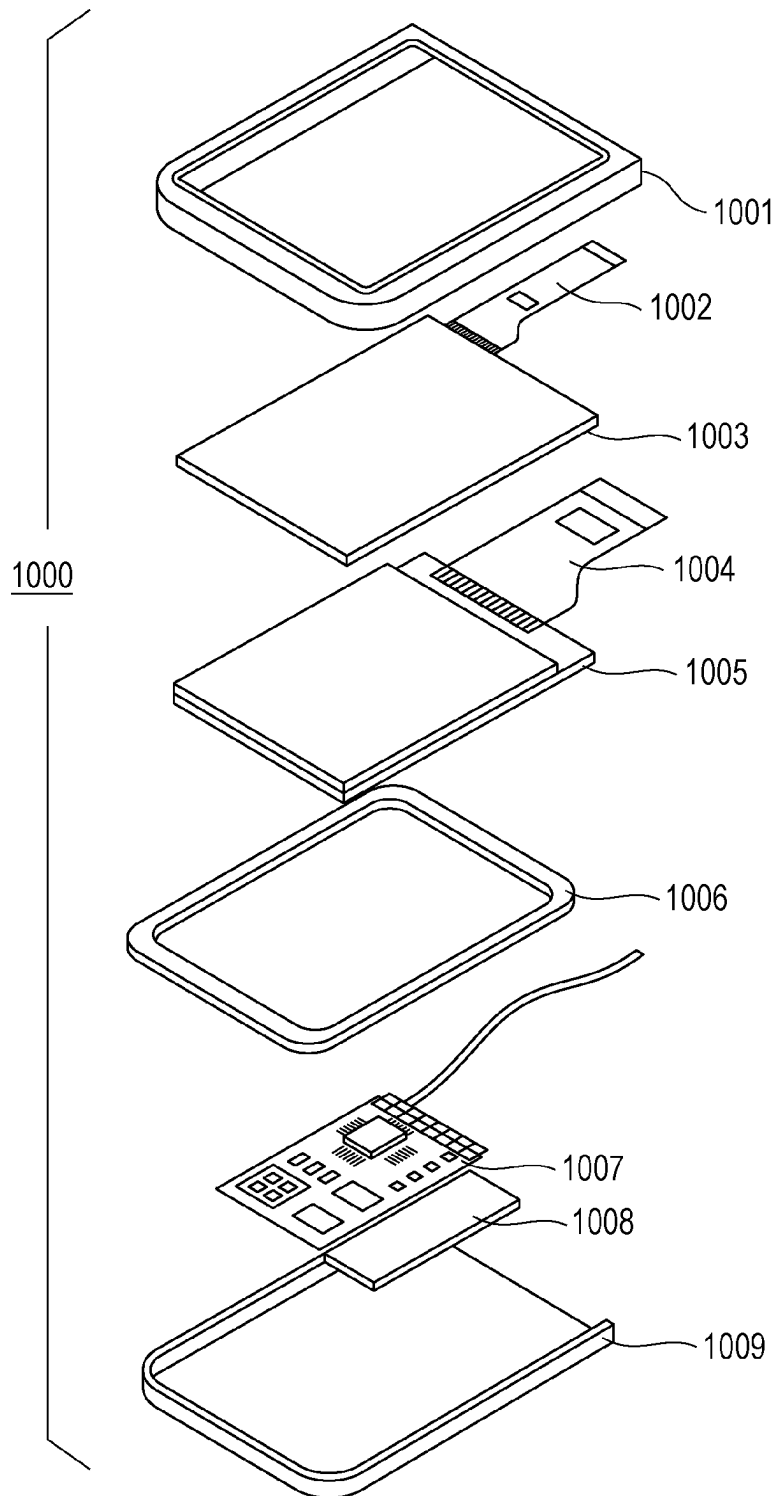


FIG. 5A

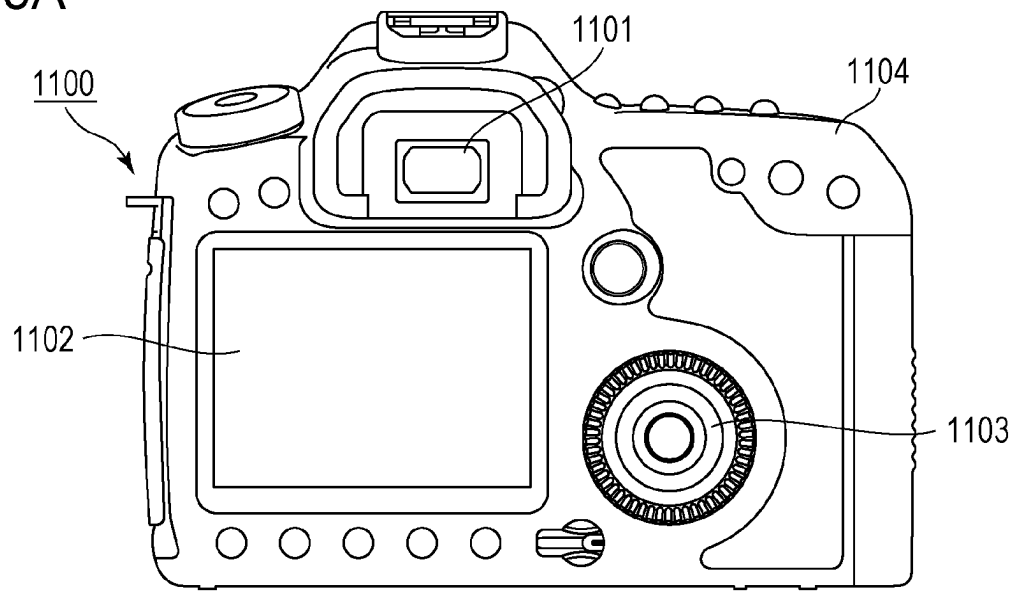


FIG. 5B

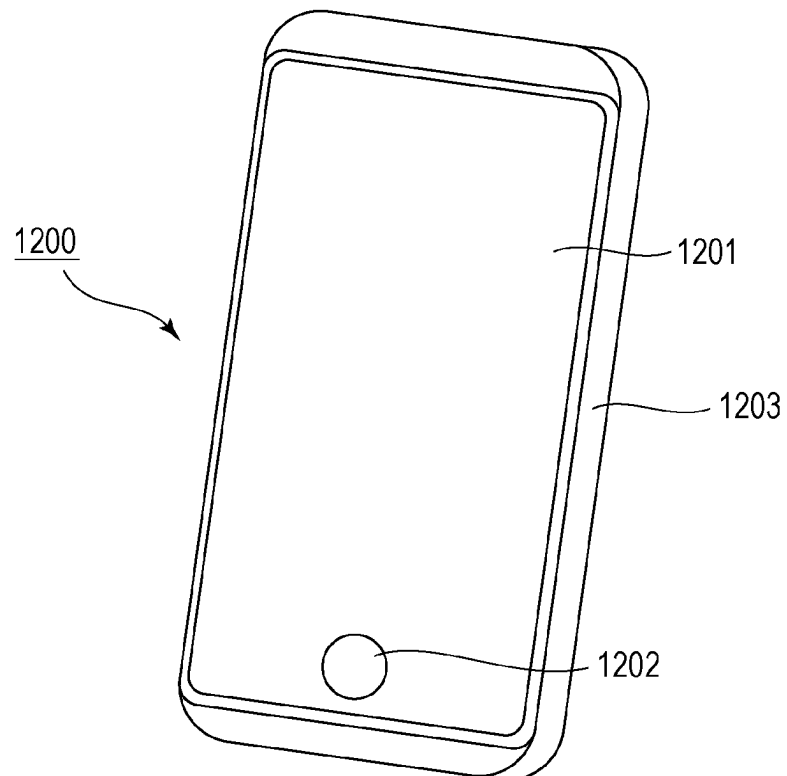


FIG. 6A

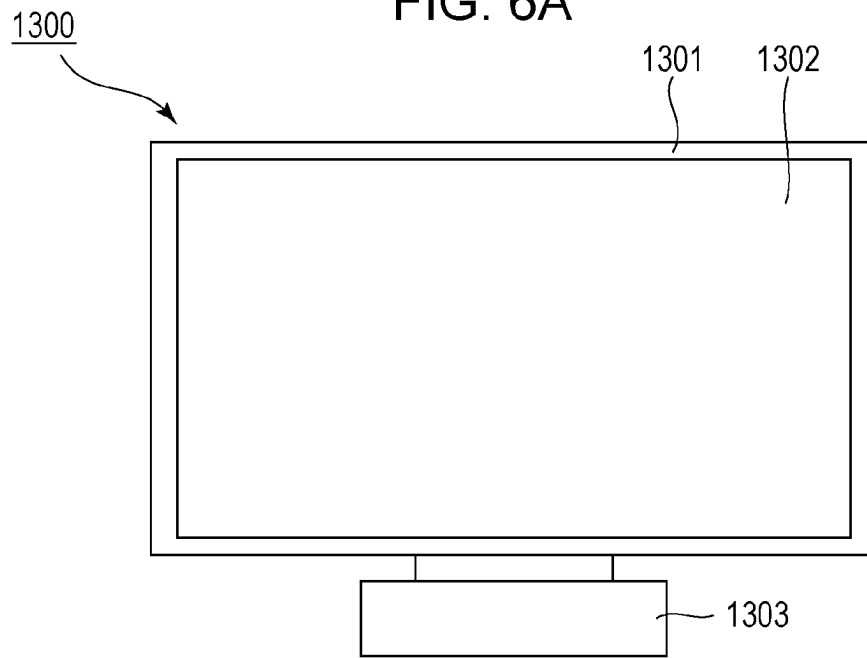


FIG. 6B

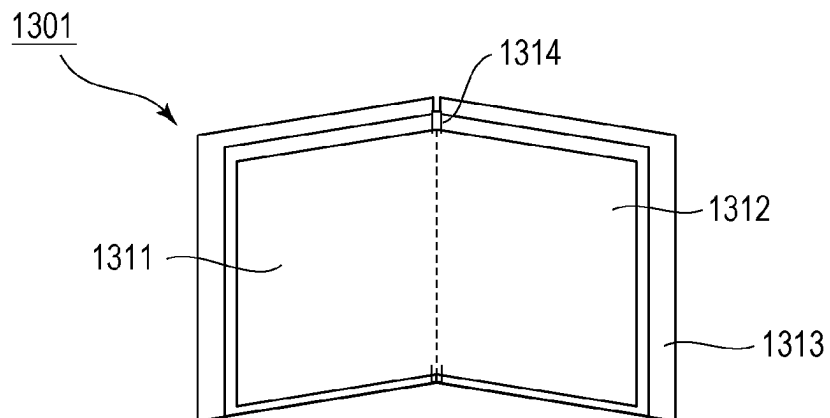


FIG. 7A

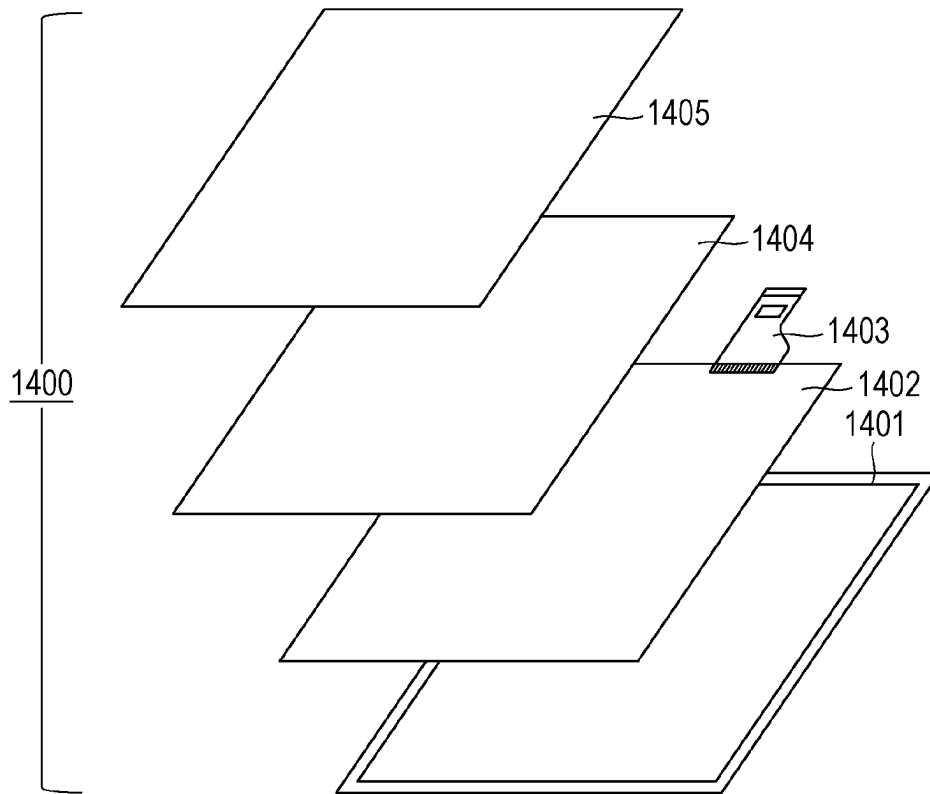


FIG. 7B

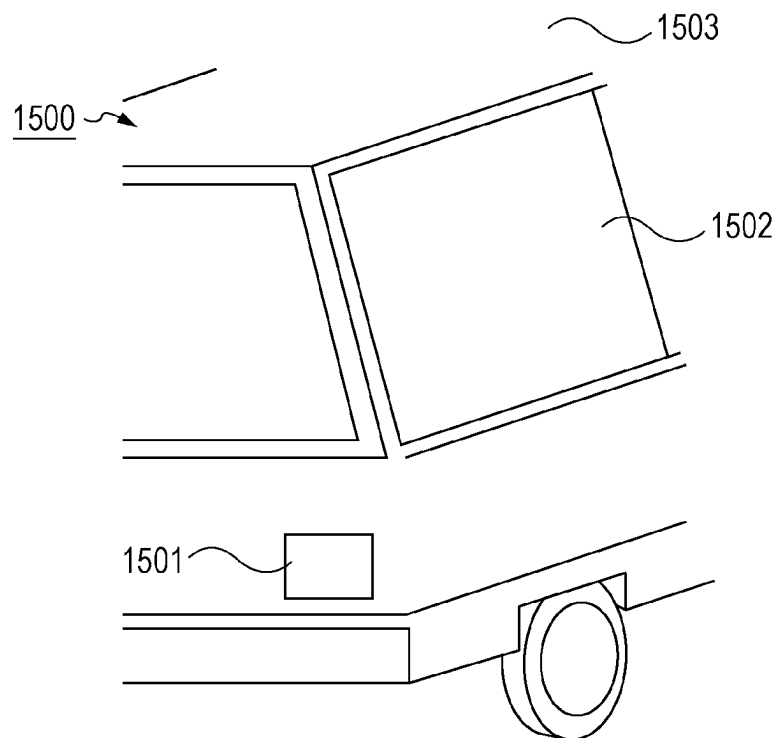


FIG. 8A

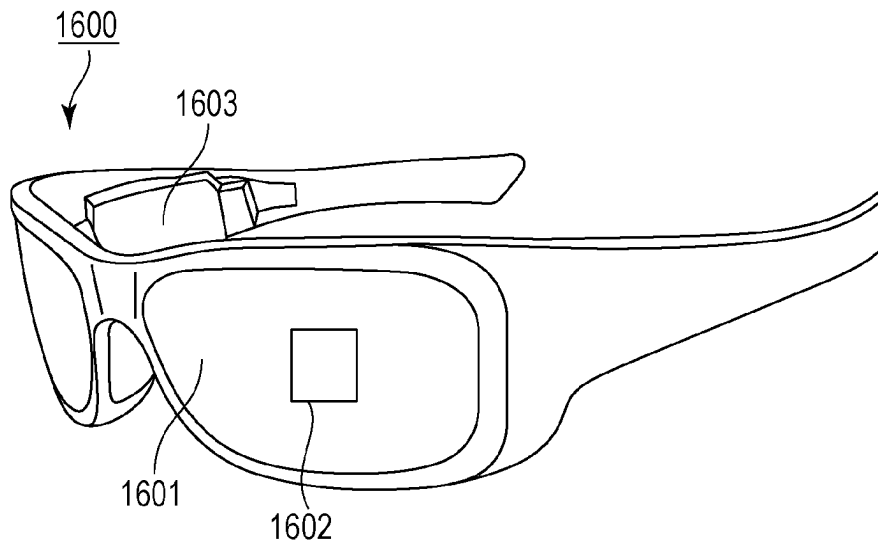
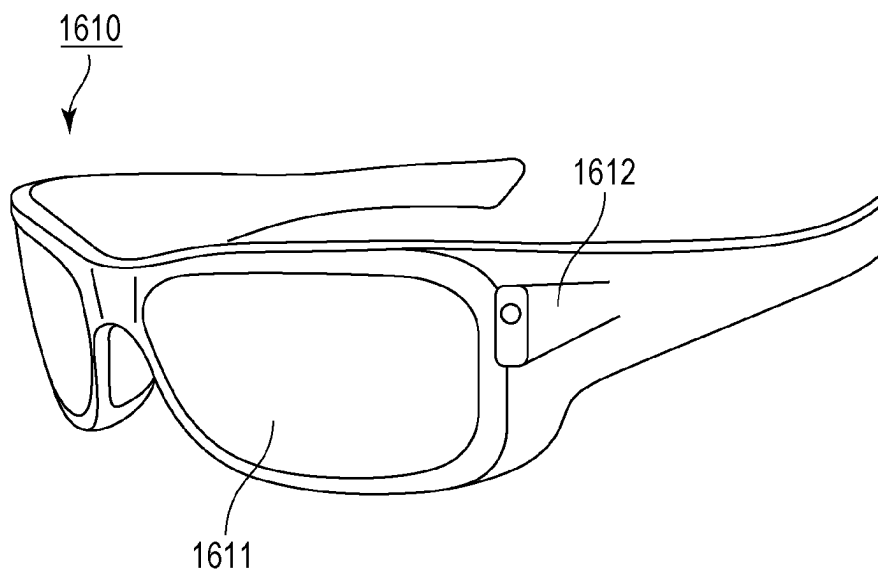


FIG. 8B



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**ORGANIC COMPOUND AND ORGANIC
LIGHT-EMITTING DEVICE****BACKGROUND OF THE INVENTION****Field of the Invention**

The present disclosure relates to an organic compound and an organic light-emitting device containing the organic compound.

Description of the Related Art

Organic light-emitting devices (hereinafter, also referred to as “organic electroluminescent devices” or “organic EL devices”) are electronic devices each including a pair of electrodes and an organic compound layer disposed between

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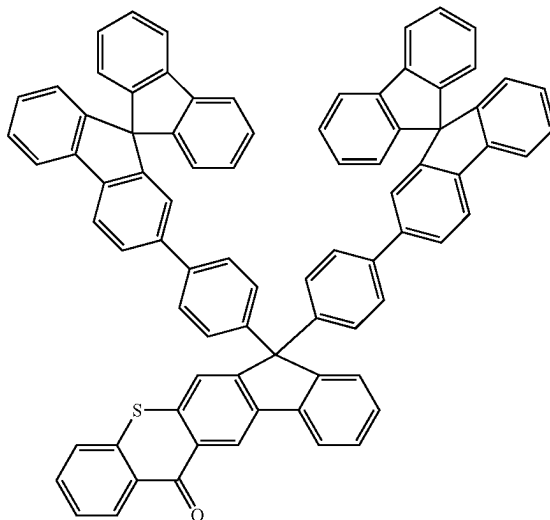
these electrodes. The injection of electrons and holes from these pairs of electrodes generates excitons in the light-emitting organic compound in the organic compound layer, and when the excitons return to the ground state, the organic light-emitting device emits light.

Recently, organic light-emitting devices have made remarkable progress and have achieved low-driving voltage, various emission wavelengths, and fast response time. The use thereof has enabled the development of thinner and lighter light-emitting apparatuses.

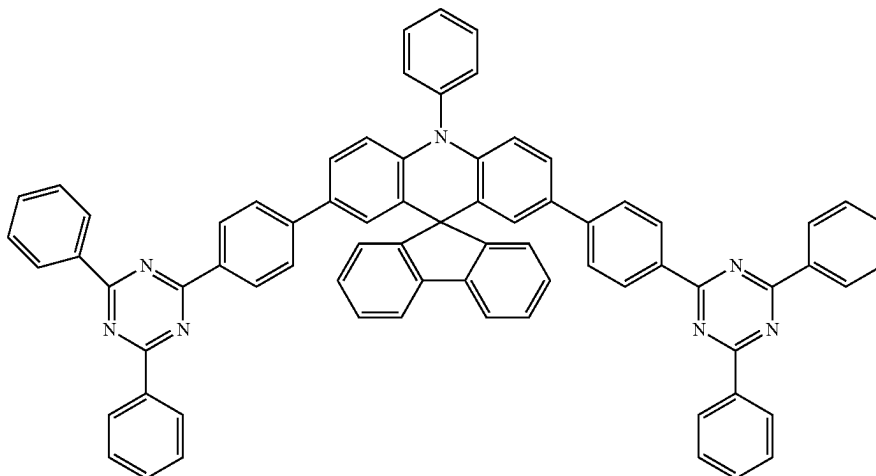
Examples of high-efficiency light-emitting devices include devices containing high-efficiency materials, such as phosphorescent materials and delayed fluorescent materials.

International Publication No. 2017/092476 discloses compound A-1 illustrated below. Compound A-2 illustrated below is described in Chemistry of Materials (2018), 30(3), 857-863.

A-1



A-2



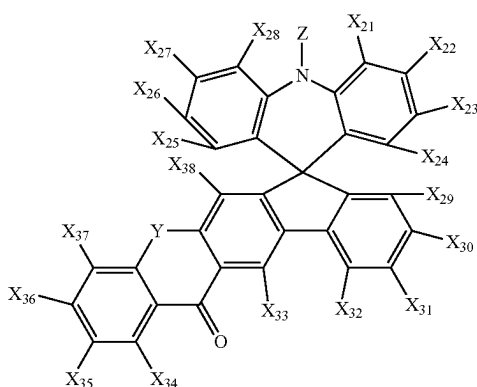
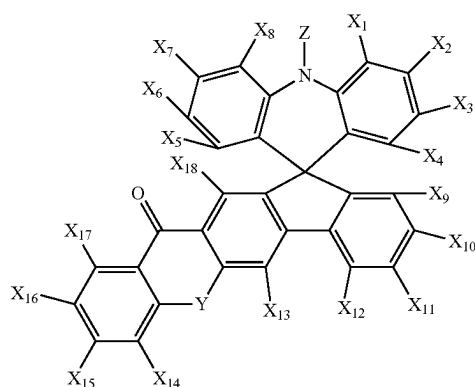
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When compounds A-1 and A-2 described in International Publication Nos. 2017/092476 and Chemistry of Materials (2018), 30(3), 857-863 are used for light-emitting layers of organic light-emitting devices, there are disadvantages with luminous efficiency.

SUMMARY OF THE INVENTION

The present disclosure has been accomplished in light of the foregoing disadvantages and provides an organic compound and an organic light-emitting device that have superior luminous efficiency. The present disclosure also provides an organic light-emitting device having superior luminous efficiency and driving durability characteristics.

An organic compound according to an embodiment of the present disclosure is represented by formula [1] or [2]:



where in formulae [1] and [2], X_1 to X_{18} and X_{21} to X_{38} are each independently selected from the group consisting of a hydrogen atom, a halogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted amino group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, a substituted or unsubstituted aryloxy group, a substituted or unsubstituted heteroaryloxy group, a silyl group, and a cyano group, Y is oxygen, sulfur, selenium, tellurium, a CR_1R_2 group, or a carbonyl group, where R_1 and R_2 are each independently selected from the

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group consisting of a hydrogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted amino group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, a substituted or unsubstituted aryloxy group, a substituted or unsubstituted heteroaryloxy group, a silyl group, and a cyano group, and Z is a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic group.

Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a table presenting molecular models of HOMO distributions and LUMO distributions of exemplified compounds and comparative compounds and their respective S_1-T_1 differences.

FIG. 2A is a schematic cross-sectional view of an example of pixels of a display apparatus according to an embodiment of the present disclosure, and FIG. 2B is a schematic cross-sectional view of an example of a display apparatus including organic light-emitting devices according to an embodiment of the present disclosure.

FIG. 3A is a schematic view of an example of an image-forming apparatus according to an embodiment of the present disclosure, FIG. 3B is a schematic view of an example of an exposure light source of an image-forming apparatus according to an embodiment of the present disclosure, and FIG. 3C is a schematic view of a modification of an exposure light source of an image-forming apparatus according to an embodiment of the present disclosure.

FIG. 4 is a schematic view of an example of a display apparatus according to an embodiment of the present disclosure.

FIG. 5A is a schematic view of an example of an image pickup apparatus according to an embodiment of the present disclosure, and FIG. 5B is a schematic view of an example of an electronic apparatus according to an embodiment of the present disclosure.

FIG. 6A is a schematic view of an example of a display apparatus according to an embodiment of the present disclosure, and FIG. 6B is a schematic view of an example of a foldable display apparatus.

FIG. 7A is a schematic view of an example of a lighting apparatus according to an embodiment of the present disclosure, and FIG. 7B is a schematic view of an example of an automobile including an automotive lighting unit according to an embodiment of the present disclosure.

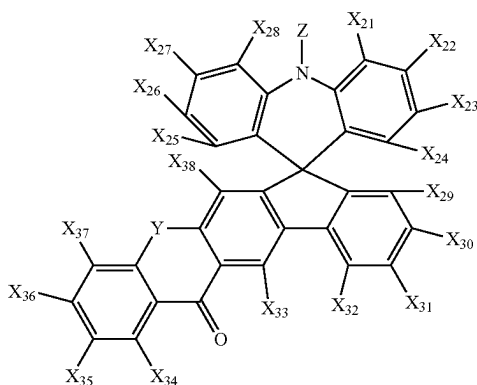
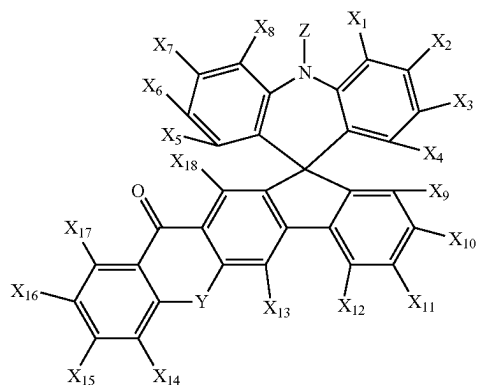
FIG. 8A is a schematic view of an example of a wearable device according to an embodiment of the present disclosure, and FIG. 8B is a schematic view of another example of a wearable device according to an embodiment of the present disclosure.

DESCRIPTION OF THE EMBODIMENTS

Organic Compound

An organic compound according to an embodiment will be described. The organic compound according to this embodiment is represented by formula [1] or [2].

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X_1 to X_{18} and X_{21} to X_{38}

X_1 to X_{18} and X_{21} to X_{38} are each independently selected from the group consisting of a hydrogen atom, a halogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted amino group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, a substituted or unsubstituted aryloxy group, a substituted or unsubstituted heteroaryloxy group, a silyl group, and a cyano group.

Non-limiting examples of the halogen atom include fluorine, chlorine, bromine, and iodine.

Non-limiting examples of the alkyl group include a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a tert-butyl group, a sec-butyl group, an octyl group, a cyclohexyl group, a 1-adamantyl group, and a 2-adamantyl group. As the alkyl group, an alkyl group having 1 to 10 carbon atoms can be used.

Non-limiting examples of the alkoxy group include a methoxy group, an ethoxy group, a propoxy group, a 2-ethyloxy group, and a benzyloxy group. As the alkoxy group, an alkoxy group having 1 to 10 carbon atoms can be used.

Non-limiting examples of the amino group include an N-methylamino group, an N-ethylamino group, an N,N-dimethylamino group, an N,N-diethylamino group, an N-methyl-N-ethylamino group, an N-benzylamino group, an N-methyl-N-benzylamino group, an N,N-dibenzylamino

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group, an anilino group, an N,N-diphenylamino group, an N,N-dinaphthylamino group, an N,N-difluorenylamino group, an N-phenyl-N-tolylamino group, an N,N-ditolylamino group, an N-methyl-N-phenylamino group, an N,N-dianisylamino group, an N-mesityl-N-phenylamino group, an N,N-dimesitylamino group, an N-phenyl-N-(4-tert-butylphenyl)amino group, an N-phenyl-N-(4-trifluoromethylphenyl)amino group, an N-piperidyl group, a carbazolyl group, and an acridyl group.

Non-limiting examples of the aryl group include a phenyl group, a naphthyl group, an indenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthryl group, a triphenylenyl group, a pyrenyl group, an anthracenyl group, a perylenyl group, a chrysenyl group, and a fluoranthenyl group. As the aryl group, an aromatic hydrocarbon group having 6 to 60 carbon atoms can be used.

Non-limiting examples of the heterocyclic group include a pyridyl group, a pyrimidinyl group, a pyrazinyl group, a triazinyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an oxazolyl group, an oxadiazolyl group, a thiazolyl group, a thiadiazolyl group, a carbazolyl group, an acridinyl group, and a phenanthrolinyl group. As the heterocyclic group, a heterocyclic group having 3 to 60 carbon atoms can be used.

Non-limiting examples of the aryloxy group include a phenoxy group and a naphthoxy group.

Non-limiting examples of the heteroaryloxy group include a furanyloxy group and a thienyloxy group.

Non-limiting examples of the silyl group include a trimethylsilyl group and a triphenylsilyl group.

Non-limiting examples of substituents that may be further contained in the alkyl group, the alkoxy group, the amino group, the aryl group, the heterocyclic group, the aryloxy group, and the heteroaryloxy group include alkyl groups, such as a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a tert-butyl group; aralkyl groups, such as a benzyl group; aryl groups, such as a phenyl group and a biphenyl group; heterocyclic groups, such as a pyridyl group and a pyrrolyl group; amino groups, such as a dimethylamino group, a diethylamino group, a dibenzylamino group, a diphenylamino group, and a ditolylamino group; alkoxy groups, such as a methoxy group, an ethoxy group, and a propoxy group; aryloxy groups, such as a phenoxy group; halogen atoms, such as fluorine, chlorine, bromine, and iodine atoms; and a cyano group.

Y

Y is oxygen, sulfur, selenium, tellurium, a CR_1R_2 group, or a carbonyl group.

R_1 and R_2 are each independently selected from the group consisting of a hydrogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted amino group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, a substituted or unsubstituted aryloxy group, a substituted or unsubstituted heteroaryloxy group, a silyl group, and a cyano group.

Specific examples of the alkyl group, the alkoxy group, the amino group, the aryl group, the heterocyclic group, the aryloxy group, the heteroaryloxy group, and the silyl group that are represented by R_1 and R_2 include, but are not limited to, the same as those described for X_1 to X_{18} and X_{21} to X_{38} . As the alkyl group, an alkyl group having 1 to 10 carbon atoms can be used. As the alkoxy group, an alkoxy group having 1 to 10 carbon atoms can be used. As the aryl group, an aryl group having 6 to 60 carbon atoms can be used. As the heterocyclic group, a heterocyclic group having 3 to 60 carbon atoms can be used. Specific examples of substituents

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that may further be contained in the alkyl group, the alkoxy group, the amino group, the aryl group, the heterocyclic group, the aryloxy group, and the heteroaryloxy group include, but are not limited to, the same as those described for X_1 to X_{18} and X_{21} to X_{38} .

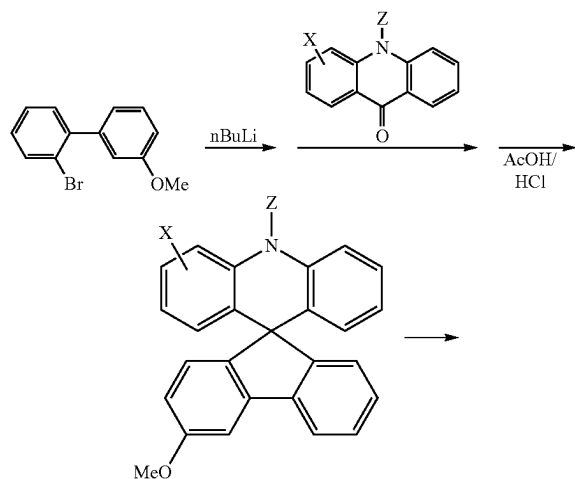
Z

Z is a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic group, and can be a substituted or unsubstituted aryl group.

Non-limiting examples of the alkyl group, the aryl group, and the heterocyclic group represented by Z include the same as those described for X_1 to X_{18} and X_{21} to X_{38} . As the alkyl group, an alkyl group having 1 to 10 carbon atoms can be used. As the aryl group, an aryl group having 6 to 60 carbon atoms can be used. As the heterocyclic group, a heterocyclic group having 3 to 60 carbon atoms can be used. Specific examples of substituents that may be further contained in the alkyl group, the aryl group, and the heterocyclic group include, but are not limited to, the same as those described for X_1 to X_{18} and X_{21} to X_{38} .

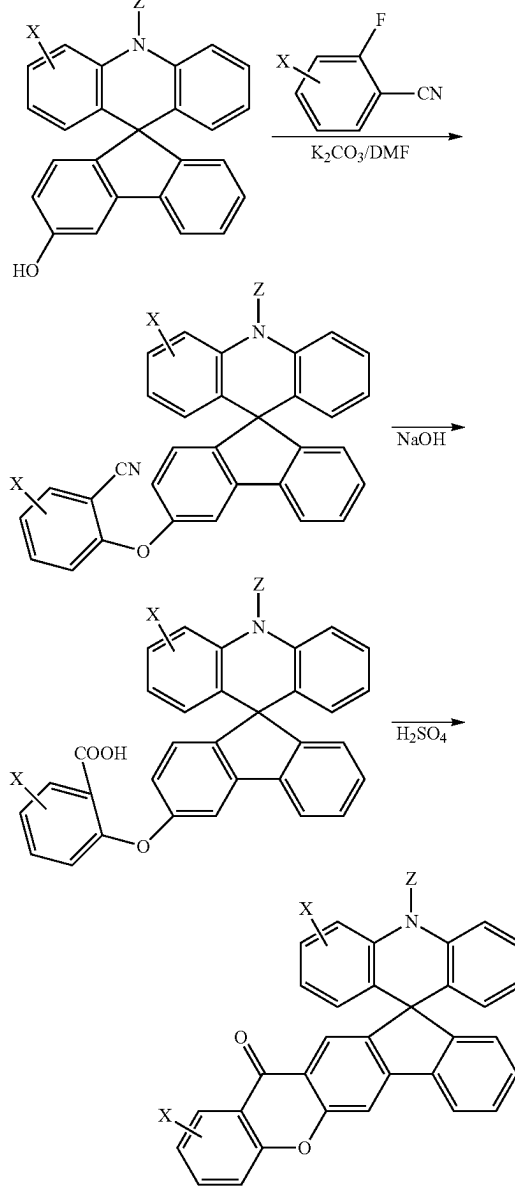
A method for synthesizing an organic compound according to this embodiment of the present disclosure will be described below. The organic compound according to the embodiment of the present disclosure is synthesized, for example, by a reaction scheme described below.

Scheme 1



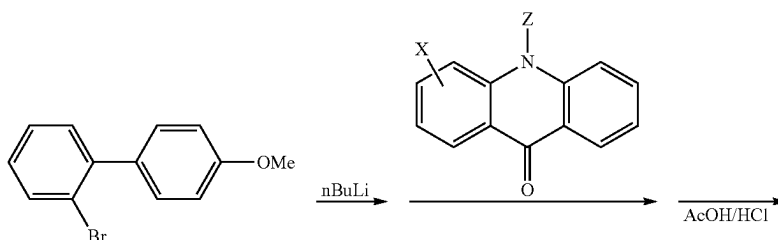
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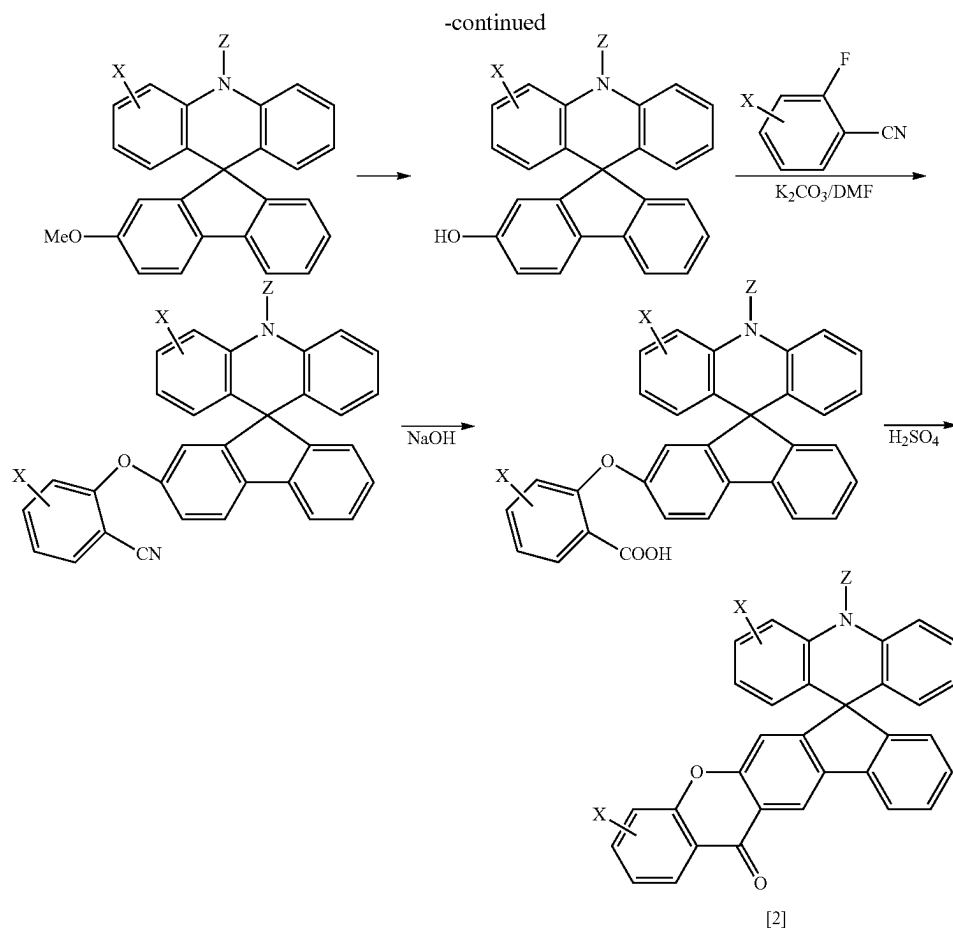
[1]

Scheme 2

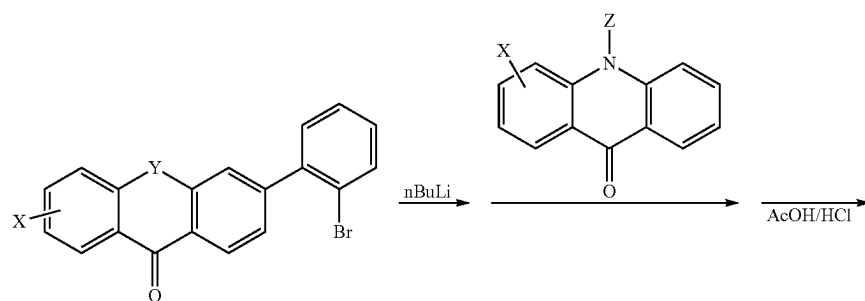
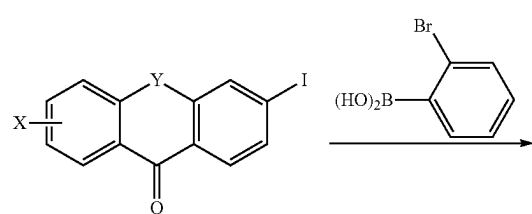


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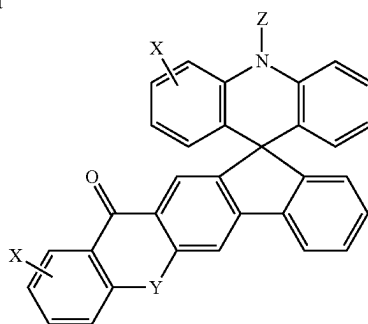
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Scheme 3



-continued



[1]

Here, each of the compounds represented by formulae [1] and [2] can be synthesized by changing the substituent X as appropriate and changing Y from oxygen, sulfur, selenium, tellurium, the CR_1R_2 group, or the carbonyl group. The synthesis method is not limited thereto.

The organic compound according to the embodiment has features described below. The use of the organic compound according to the embodiment for an organic light-emitting device allows the organic light-emitting device to have high luminous efficiency and superior driving durability characteristics. A basic skeleton in this embodiment is a skeleton in which in the compound represented by formula [1] or [2], X_1 to X_{18} and X_{21} to X_{38} are each a hydrogen atom, Z is an unsubstituted phenyl group, and in addition, when Y is a CR_1R_2 group, R_1 and R_2 are each a hydrogen atom.

(1) The compound has a small S-T gap because it contains an electron-withdrawing carbonyl group on the side of the fluorene ring, which is one of the rings of the spiro structure, and an electron-donating acridine ring, which is the other ring.

(2) The use of an electron-donating group as Y results in the molecule having a wider band gap more suitable for a light-emitting layer.

(3) The presence of the spiro structure is less likely to lead to molecular association.

(4) The presence of the spiro structure is less likely to lead to cleavage of a bond in the quaternary carbon moiety.

These features will be described below.

(1) The compound has a small S-T gap because it contains an electron-withdrawing carbonyl group on the side of the fluorene ring, which is one of the rings of the spiro structure, and an electron-donating acridine ring, which is the other ring.

In the compound according to the embodiment, a moiety occupying the electron orbital distribution of the lowest unoccupied molecular orbital (LUMO) and a moiety occupying the electron orbital distribution of the highest occupied molecular orbital (HOMO) are separated by the spiro moiety of the spiro structure as B-1 to B-3 illustrated in FIG. 1. It can be seen that a portion occupying both the HOMO and LUMO is small.

This leads to a small overlap integral and a small difference between the excited singlet state (S_1) and the excited triplet state (T_1).

The above feature is the effect due to the fact that the compound contains the electron-withdrawing carbonyl group on the side of the fluorene ring, which is one of the rings of the spiro structure, and the electron-donating acridine ring, which is the other ring. In contrast, each of b-1 and b-2 has only one of the electron-withdrawing carbonyl group

and the electron-donating acridine ring; thus, it can be seen that the moiety occupying the electron orbital distribution of the LUMO and the moiety occupying the electron orbital distribution of the HOMO are not separated. Meanwhile, b-3 does not contain an electron-withdrawing carbonyl group or an electron-donating acridine ring via the spiro structure.

It can thus be seen that the moiety occupying the electron orbital distribution of the LUMO and the moiety occupying the electron orbital distribution of the HOMO overlap each other on the phenylene groups connecting the triazine rings and the acridine rings and are not separated. This leads to a large overlap integral and a large difference between the excited singlet state (S_1) and the excited triplet state (T_1). B-1, B-2, and B-3 are exemplified compound C-1, exemplified compound D-1, and exemplified compound C-13, respectively, described below. In addition, b-3 is compound A-2 (comparative compound J-2 described below) described in Chemistry of Materials (2018), 30(3), 857-863.

The above calculation results were visualized using molecular orbital calculations. As the molecular orbital calculation method, the density functional theory (DFT), which is widely used at present, was used with the B3LYP functional and 6-31G* as the basis function.

The molecular orbital calculation method was performed using Gaussian 09 (Gaussian 09, Revision C.01, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Men- nucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, T. Keith, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, O. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, and D. J. Fox, Gaussian, Inc., Wallingford CT, 2010), which is widely used at present.

As described above, each of B-1 to B-3, which are compounds according to the embodiment, is characterized by having a small difference between S_1 and T_1 . Thus, when the compound according to the embodiment is used in the light-emitting layer of an organic light-emitting device, the device has high luminous efficiency. The reason for this is as

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follows: For excitons consisting of singlet and triplet excitons in a ratio of 1:3, the triplet excitons, which undergo thermal deactivation normally, can be used for delayed fluorescence from the excited singlet state due to the small difference between S_1 and T_1 . To convert the triplet excitons into the excited singlet state, a smaller difference between S_1 and T_1 is advantageous because of a smaller energy barrier. The compound of this embodiment is advantageous in that condition, thus providing a device with high luminous efficiency.

The comparative compounds, b-1 and b-2, have only one of the electron-withdrawing carbonyl group and the electron-donating acridine ring. b-3 does not contain an electron-withdrawing carbonyl group or an electron-donating acridine ring via the spiro structure. Thus, the difference between S_1 and T_1 is large and the energy barrier is large, which is disadvantageous with respect to delayed fluorescence.

(2) The use of an electron-donating group as Y results in the molecule having a wider band gap more suitable for a light-emitting layer.

When Y is oxygen, sulfur, selenium, tellurium, or a CR_1R_2 group, Y has the electron-donating property. Thus, as described in FIG. 1, the value of S_1 is in the range of 424 nm to 467 nm, which is suitable for blue and green emission in the visible region. When Y is a carbonyl group, Y has electron-withdrawing property. Thus, the value of S_1 is 550 nm or more, which is suitable for a red light-emitting layer.

(3) The presence of the spiro structure is less likely to lead to molecular association.

The compound according to the embodiment has a spiro structure and thus is less likely to undergo molecular association. The two rings are almost orthogonal to each other with respect to the spiro structure, thus resulting in a low degree of flatness of the molecule. Thus, the molecules are less likely to stack together and are less likely to undergo molecular association. In contrast, in the case of spiro

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structure-free compound b-1 as illustrated in FIG. 1, the two phenyl groups attached to the fluorene ring can rotate freely, resulting in a high degree of flatness. Thus, molecular association occurs easily.

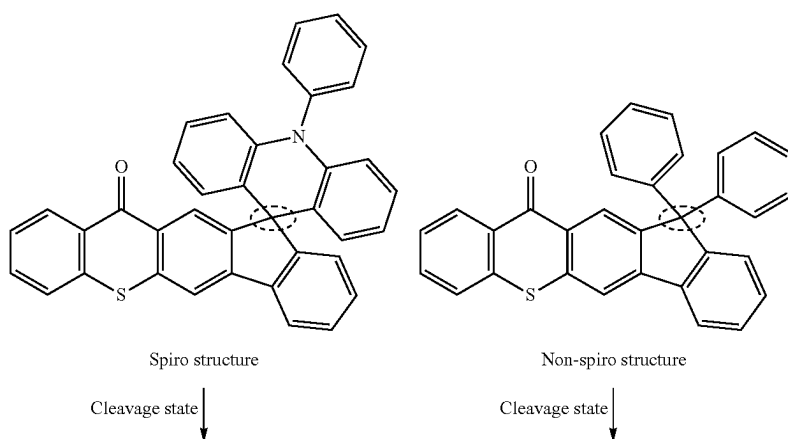
The above feature provides the following effects: when the compound according to the embodiment is used in the organic layer of an organic light-emitting device, a stable amorphous film that is less likely to crystallize is provided, and the organic light-emitting device has high durability without the occurrence of crystallization even in the case of long-term operation.

In addition, when the compound according to the embodiment is used in the light-emitting layer of an organic light-emitting device, molecular association is less likely to occur, and thus concentration quenching is less likely to occur. Accordingly, the organic light-emitting device has high luminous efficiency.

The above effect also improves sublimability. The improvement of sublimability enables the purification of the material by sublimation and the production of an organic light-emitting device by vapor deposition. This can reduce the amount of impurities contained in the organic light-emitting device and can inhibit deteriorations in luminous efficiency and driving durability due to impurities.

(4) The presence of the spiro structure is less likely to lead to cleavage of a bond in the quaternary carbon moiety.

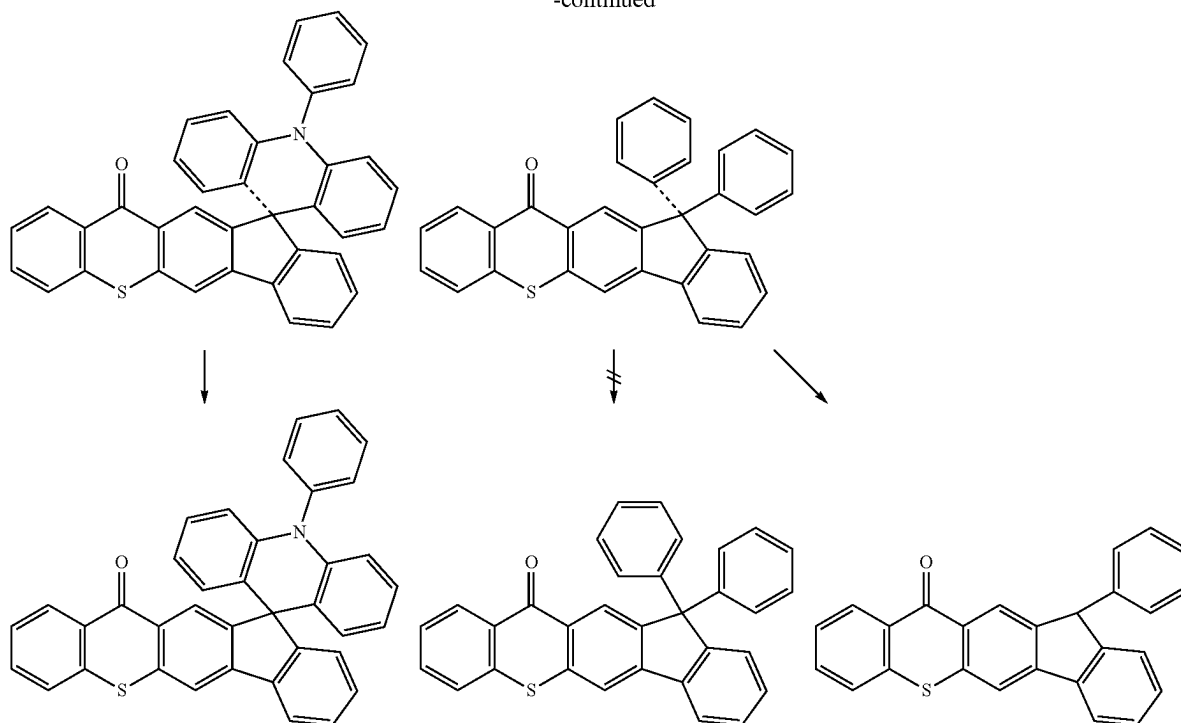
In the compound according to the embodiment, the quaternary carbon surrounded by a dotted line in the chemical formula below has a spiro structure. Even if the molecule is cleaved, the cleaved phenyl group is bonded to the structure of the main body and thus easily returns to its original structure. In the case of a non-spiro structure, such as compound A-1 described in International Publication No. 2017/092476, when the molecule is cleaved, the structure does not easily return to its original structure because the cleaved phenyl group is not bonded to the structure of the main body. The compound is easily cleavage and structural changes, thus deteriorating the device durability.



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In addition, the compounds according to the embodiment have the following features in terms of emission wavelength. In the compounds according to the embodiment, a compound represented by formula [1] emits light at a longer wavelength than that of a compound represented by formula [2]. As described in FIG. 1, compound B-1 represented by formula [1] has an S_1 level of 467 nm and emits green light, and compound B-3 represented by formula [2] has an S_1 level of 424 nm and emits blue light.

Furthermore, the compound according to the embodiment can be used in the light-emitting layer of an organic light-emitting device. In this case, the compound has the following features.

(5) The compound according to the embodiment is mixed with a host material in the light-emitting layer to facilitate exciton recombination of the compound according to the embodiment, thereby providing the light-emitting device with high efficiency.

(6) The mixture of the compound according to the embodiment and the host material in the light-emitting layer and the presence of a light-emitting material provide the light-emitting device with high efficiency and high color purity.

(7) The use of a hydrocarbon compound as the light-emitting material provides the light-emitting device with high efficiency and good durability characteristics.

These features described above will be described below.

(5) The compound according to the embodiment is mixed with a host material in the light-emitting layer to facilitate exciton recombination of the compound according to the embodiment, thereby providing the light-emitting device with high efficiency.

The compound according to the embodiment contains an electron-withdrawing carbonyl group and an electron-donating acridine ring. When the compound according to the embodiment is mixed with the host material in the light-

emitting layer of the organic light-emitting device, the LUMO of the compound according to the embodiment is at a lower level (farther from the vacuum level) than that of the host material, and the HOMO of the compound according to the embodiment is at a higher level (closer to the vacuum level) than that of the host material. Accordingly, in the light-emitting layer, electrons and holes fed from the transport layer are trapped by the compound according to the embodiment, and exciton recombination occurs. As described in feature (1) above, the compound according to the embodiment has a small difference between S_1 and T_1 , can efficiently produce delayed fluorescence in the light-emitting layer, and can use a larger number of triplet excitons for light emission. This effect is especially significant when the host material is a hydrocarbon compound. The reason for this is that the larger energy difference between the HOMO and LUMO of the host and those of the compound according to the embodiment leads to easier trapping of electrons and holes. The hydrocarbon compound is a compound that consists of only carbon and hydrogen.

As described in feature (3) above, the compound according to the embodiment is less likely to undergo molecular association and thus is less likely to undergo concentration quenching in the host material. This effect leads to the prevention of quenching due to exciton interaction when the compound according to the embodiment is in the excited state, and is effective in efficiently producing delayed fluorescence in the light-emitting layer.

(6) The mixture of the compound according to the embodiment and the host material in the light-emitting layer and the presence of a light-emitting material provide the light-emitting device with high efficiency and high color purity.

The use of the light-emitting layer that contains the compound according to the embodiment and that is doped with a light-emitting material having a high emission quan-

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tum yield or a light-emitting material whose emission spectrum has a spectrum suitable for exhibiting high color purity provides a light-emitting device having even higher efficiency and high color purity. In this case, the compound according to the embodiment needs to be contained in a concentration sufficient to preferentially trap electrons and holes in the light-emitting layer in order to facilitate exciton recombination. The concentration of the organic compound according to the embodiment is preferably 0.1% or more by mass and 45% or less by mass, more preferably 1% or more by mass and 30% or less by mass based on the entire light-emitting layer.

As a light-emitting material, a smaller doping concentration is less susceptible to the influence of concentration quenching and a change in emission spectrum due to the interaction between molecules. Thus, the light-emitting layer can be doped with the light-emitting material other than the compound according to the embodiment. The concentration of the light-emitting material is preferably 0.01% or more by mass and 20% or less by mass, more preferably 1% or more by mass and 15% or less by mass based on the entire light-emitting layer. This provides the light-emitting device with high efficiency and high color purity.

(7) The use of a hydrocarbon compound as the light-emitting material provides the light-emitting device with high efficiency and good durability characteristics.

The compound according to the embodiment contains a strong electron-withdrawing carbonyl group. Because of this, as a light-emitting material serving as a dopant described in feature (6) above, a light-emitting material that does not contain an amino group, which is an electron-donating group, can be used, and a hydrocarbon compound can be used. The reason for this is that an amino group-containing light-emitting material may interact with the carbonyl group of the compound according to the embodiment in the light-emitting layer to cause a decrease in luminous efficiency due to exciplex formation and a change in the emission spectrum of the light-emitting material, thereby deteriorating the color purity of the light-emitting device.

An amino group-containing light-emitting material is easily oxidized due to its low ionization potential and thus has poor device durability. For this reason, a hydrocarbon compound can be used as a light-emitting material, and a five-membered ring-containing fused polycyclic compound can be used. This is because the structure is less susceptible to oxidation due to its higher ionization potential. A hydrocarbon compound is a compound consisting of only carbon and hydrogen.

As described above, the organic light-emitting device having high luminous efficiency can be provided by mixing the compound according to the embodiment with the host material in the light-emitting layer. Here, the light-emitting material may be the compound according to the embodiment. In addition, a light-emitting material may be mixed, and the compound according to the embodiment may function as an assist material.

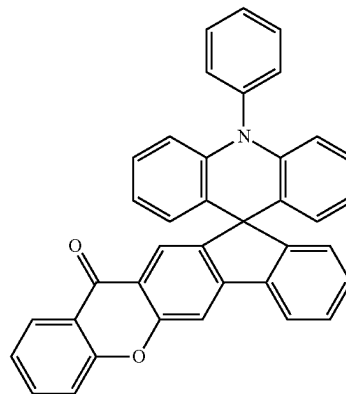
The use of a light-emitting material with good color purity makes it possible to provide an organic light-emitting device with high efficiency and high color purity. When the host material is a hydrocarbon compound, the compound accord-

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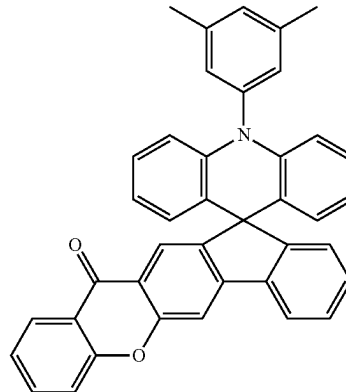
ing to the embodiment can easily trap electrons and holes to contribute to higher efficiency.

Specific examples of the organic compound according to the embodiment are illustrated below. However, the present disclosure is not limited thereto.

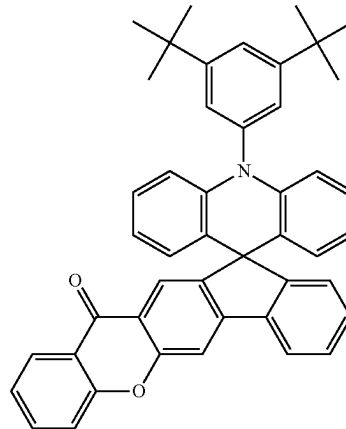
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C-2

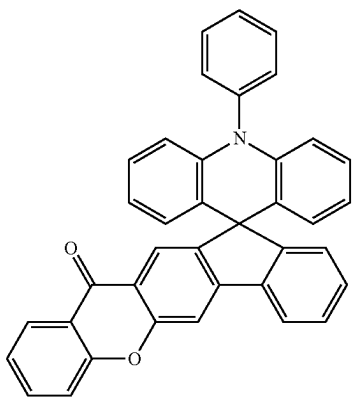
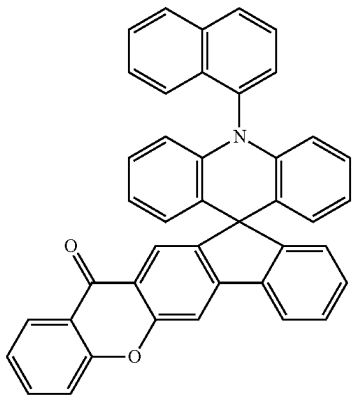
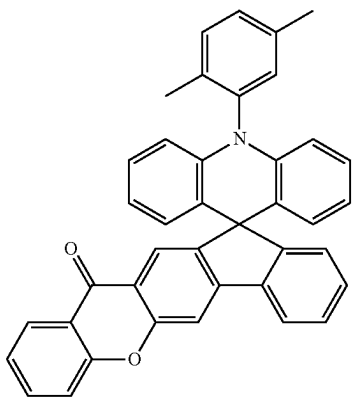
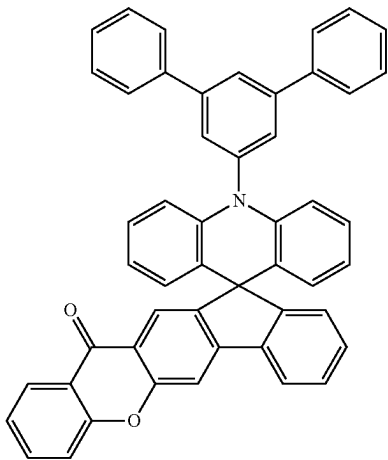


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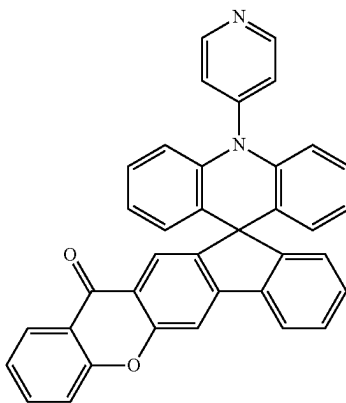
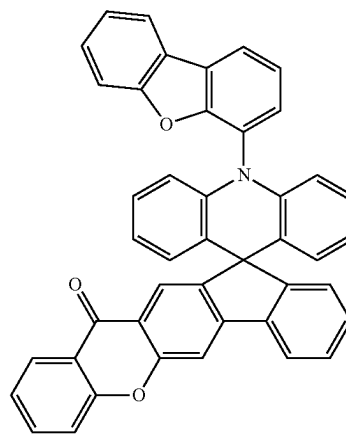
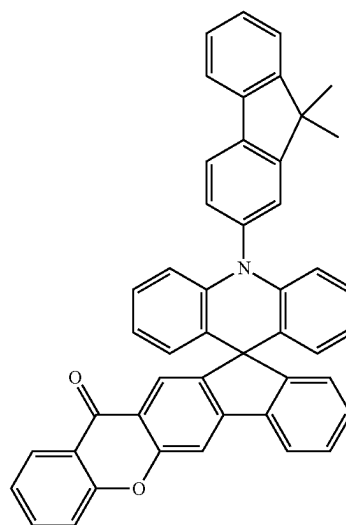


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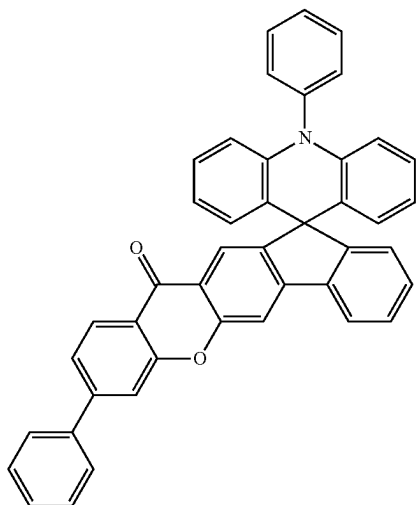
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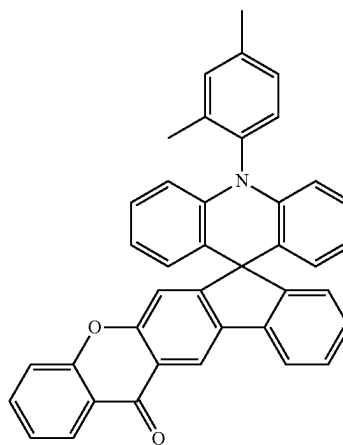
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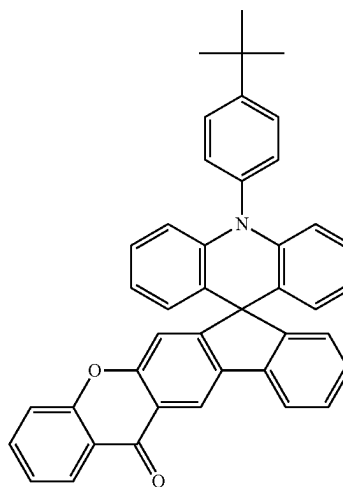
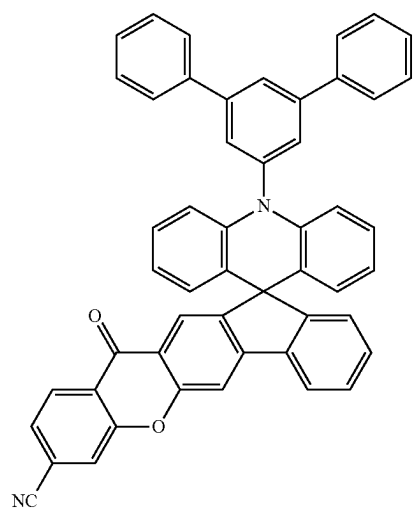
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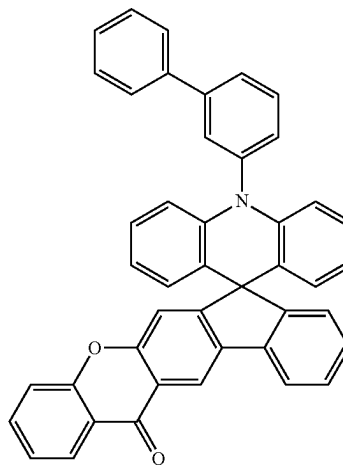
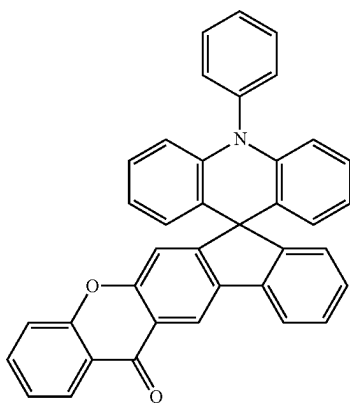
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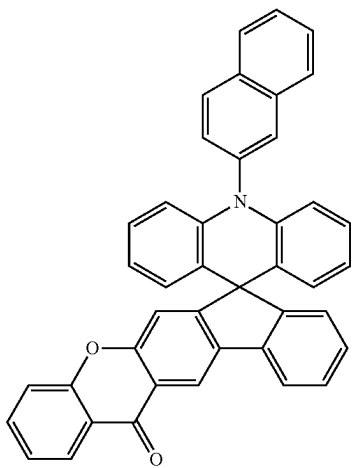
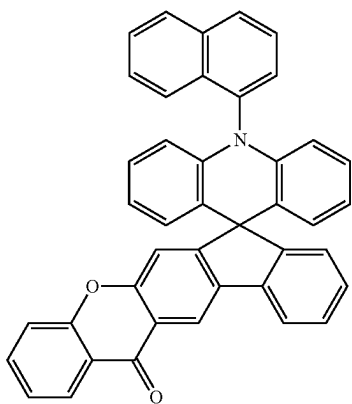
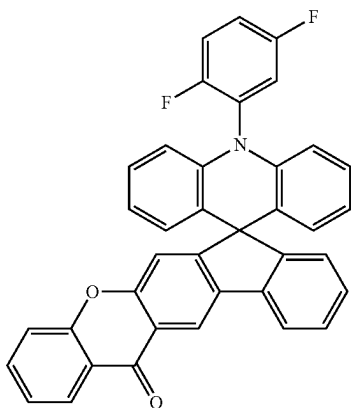
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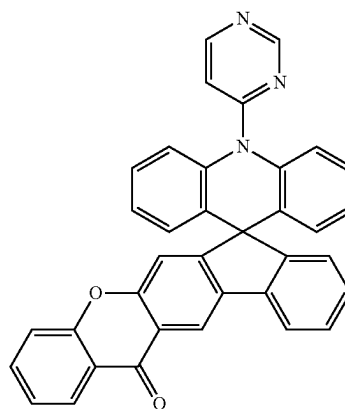
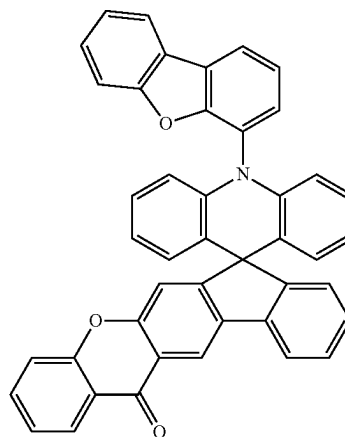
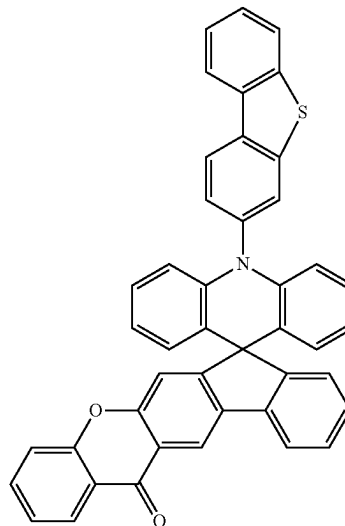
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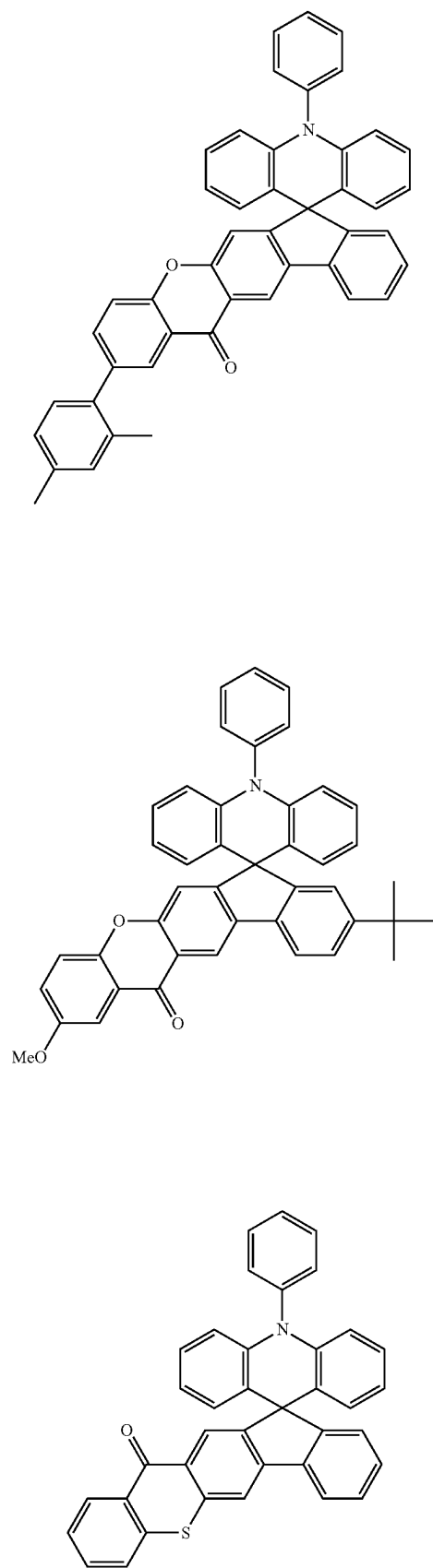
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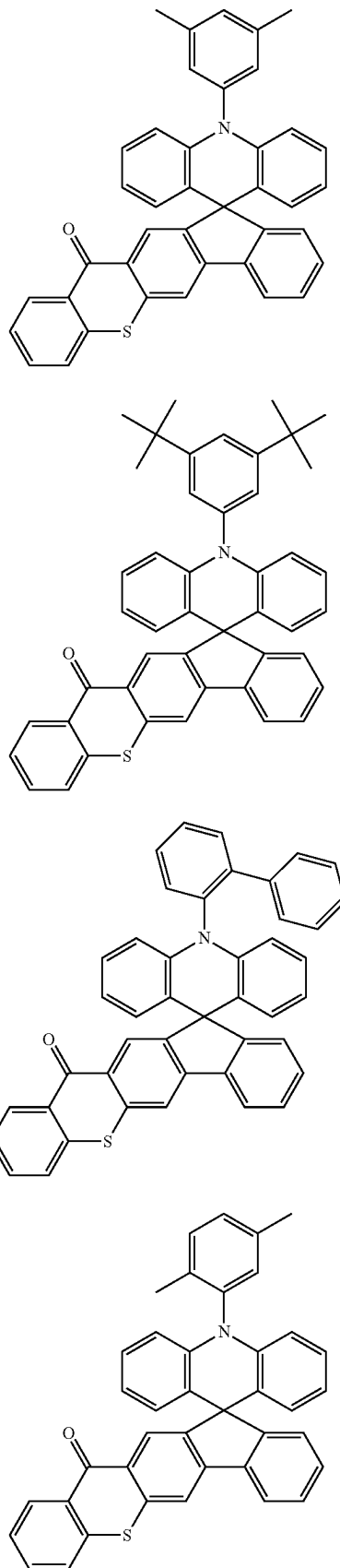
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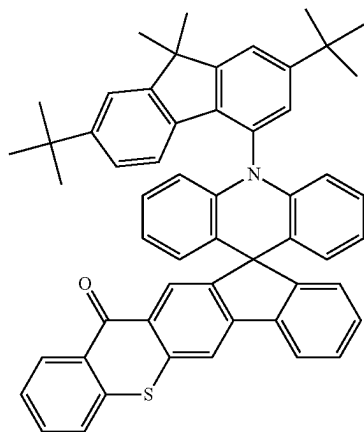
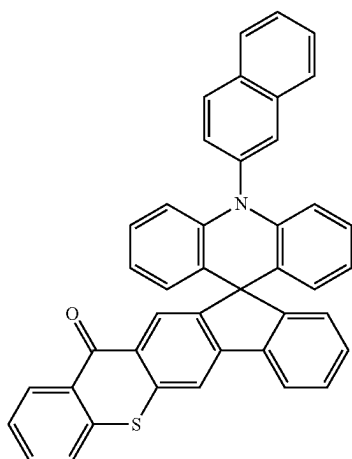
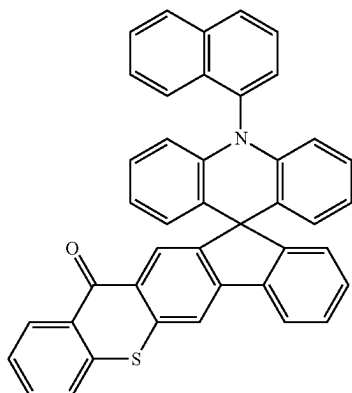
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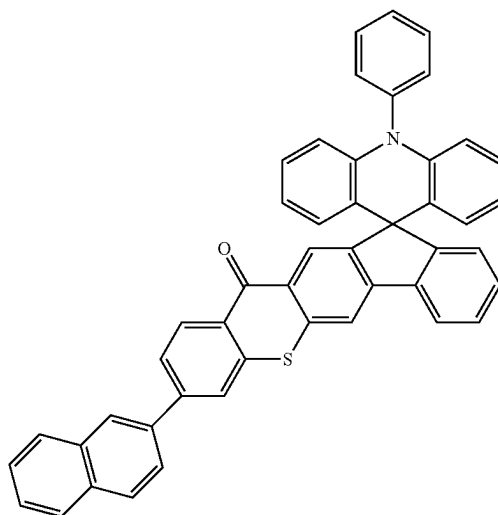
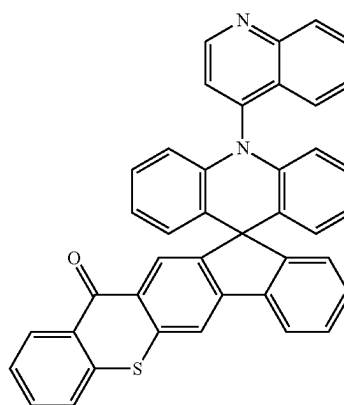
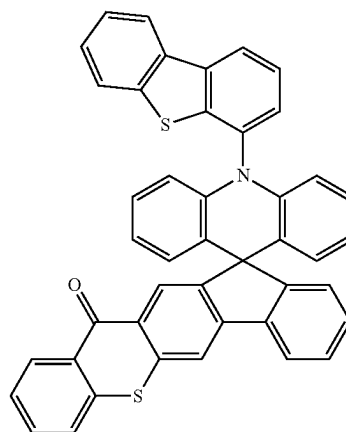
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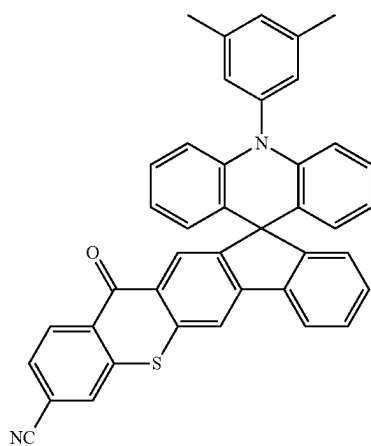
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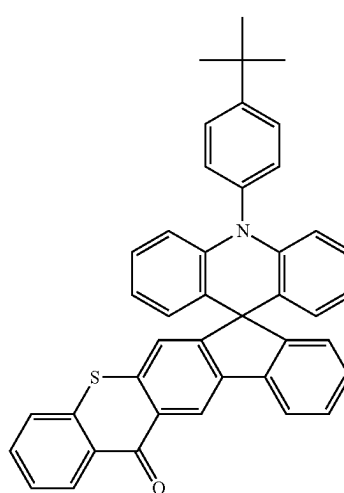
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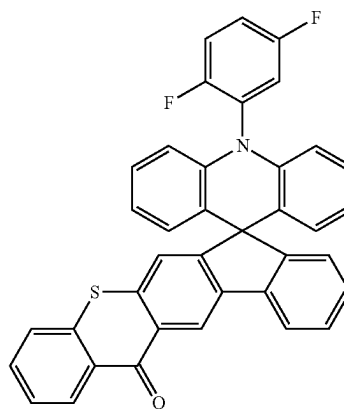
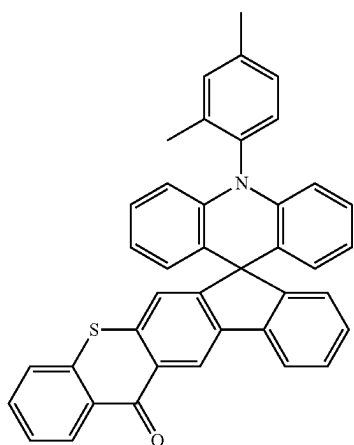
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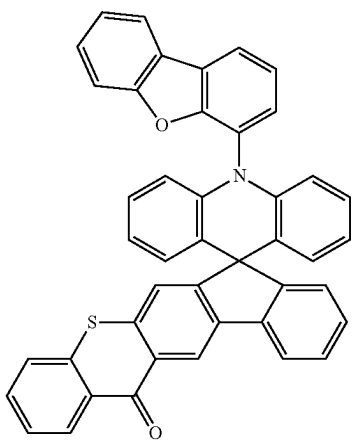
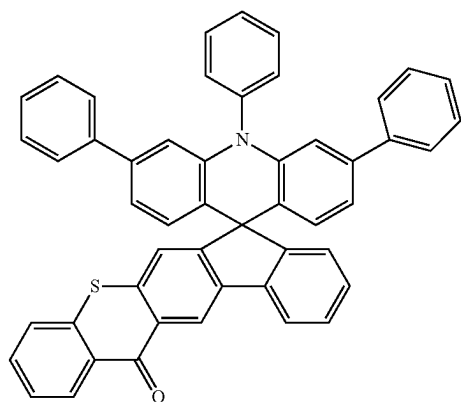
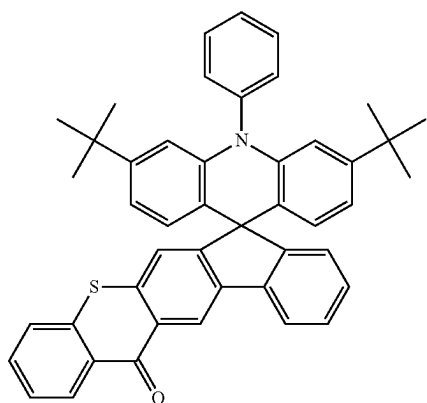
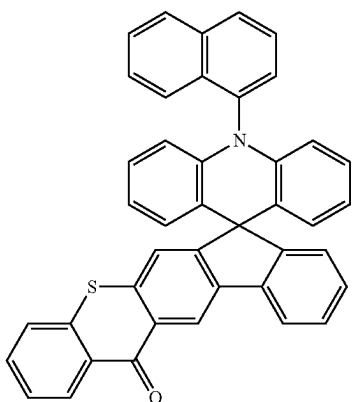
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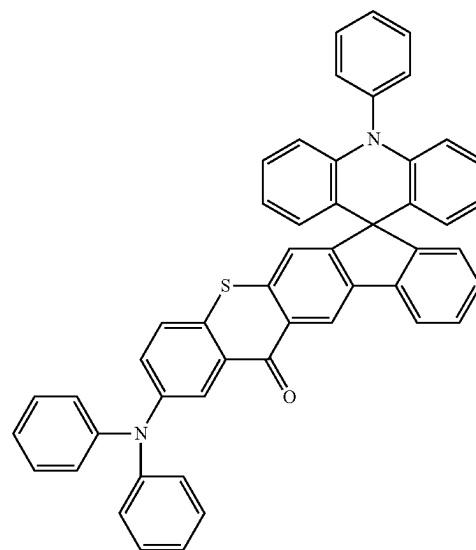
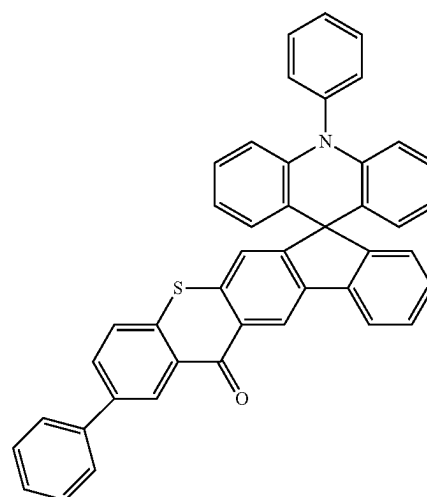
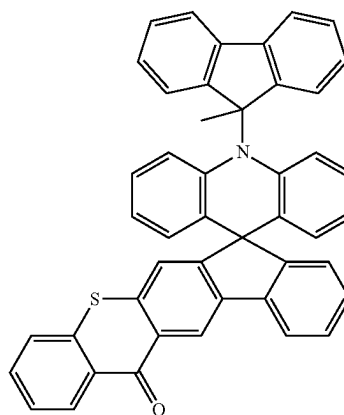


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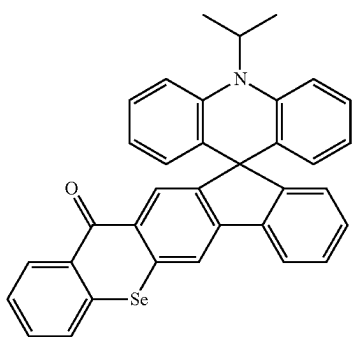
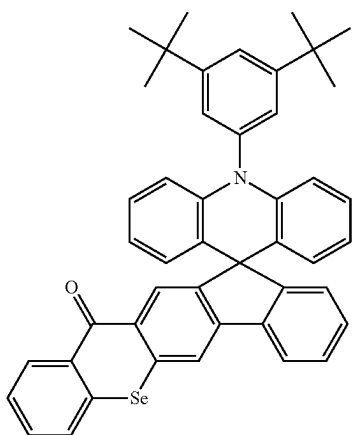
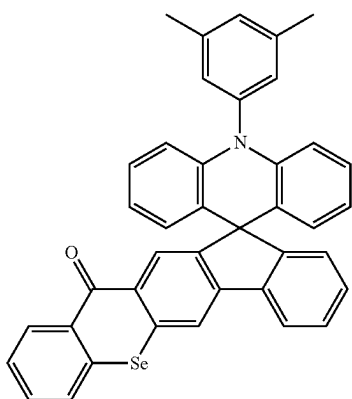
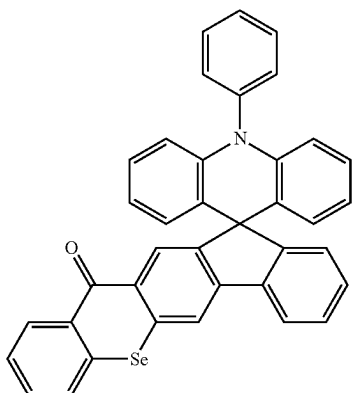
D-22

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E-1

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E-2

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E-3

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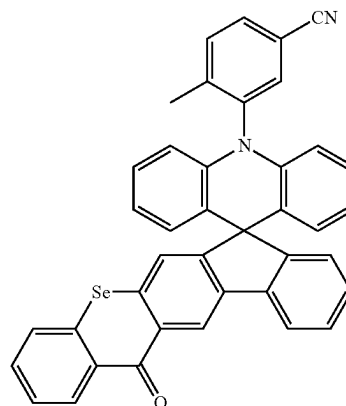
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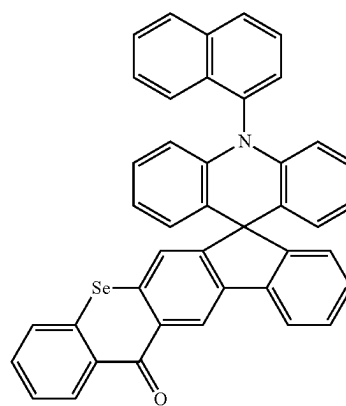
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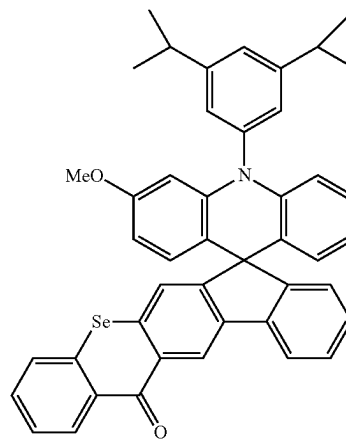
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E-6

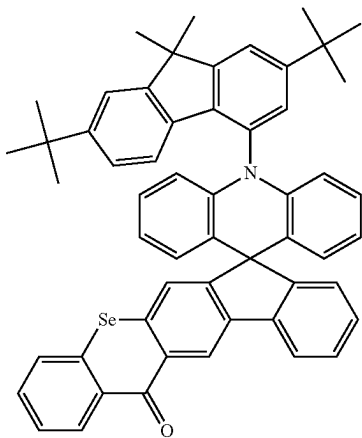


E-7



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E-8

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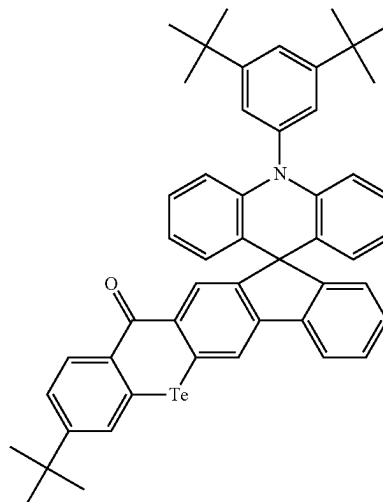
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E-11

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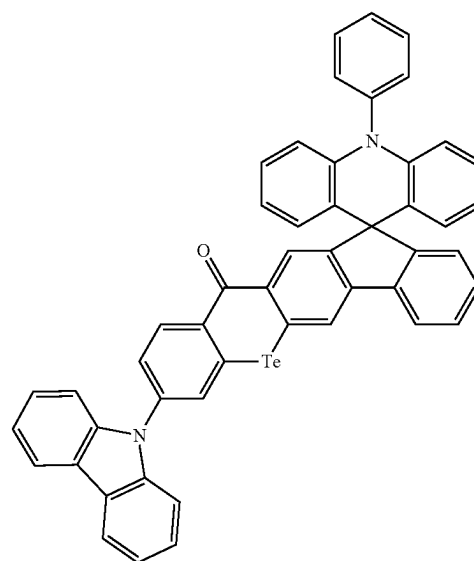
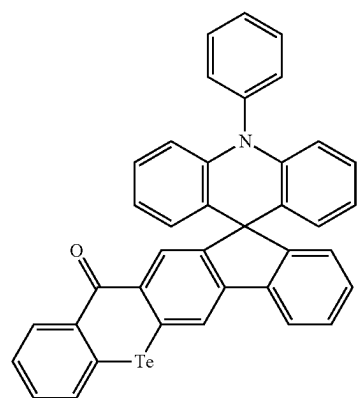
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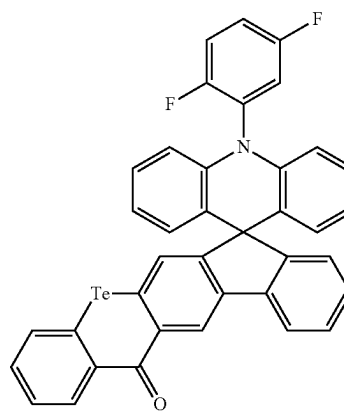
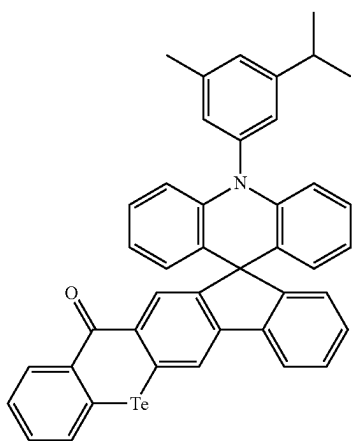
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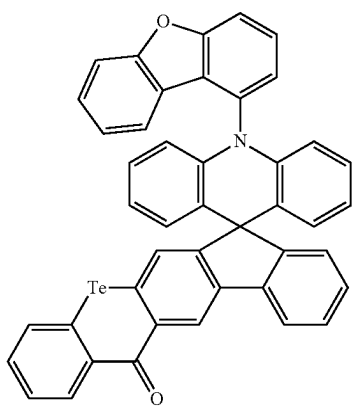
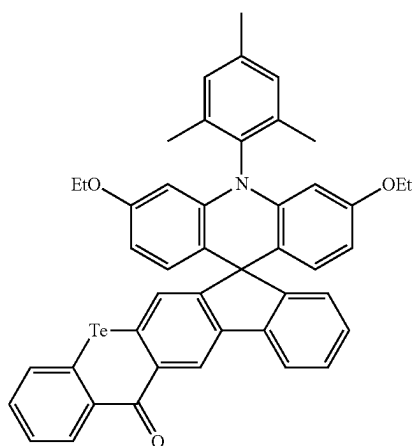
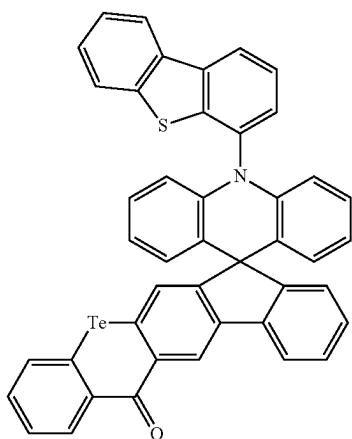
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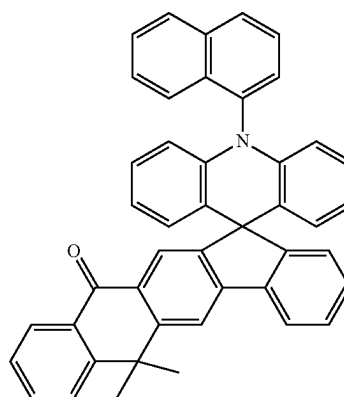
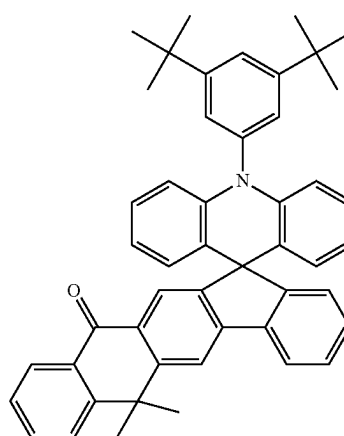
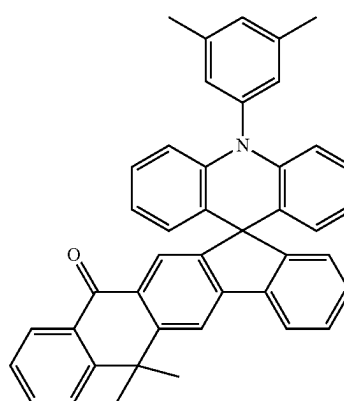
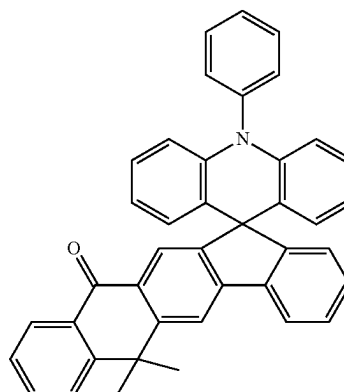
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**38**

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E-14

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E-15

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E-16

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F-1

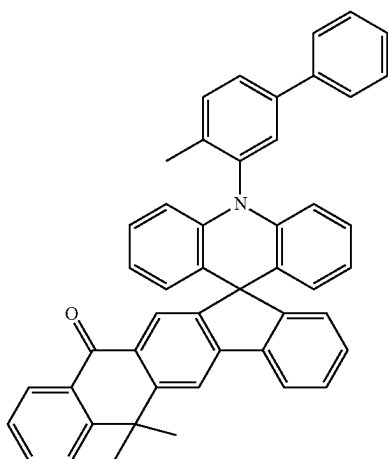
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F-3

F-4

39

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F-5

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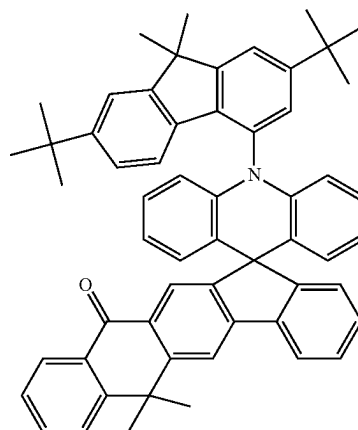
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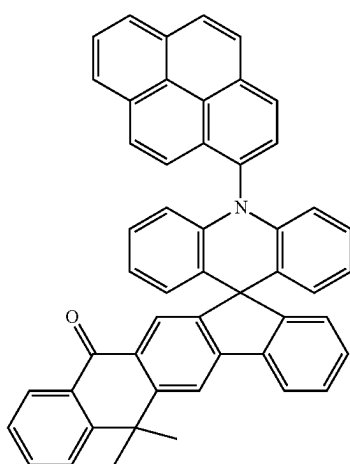
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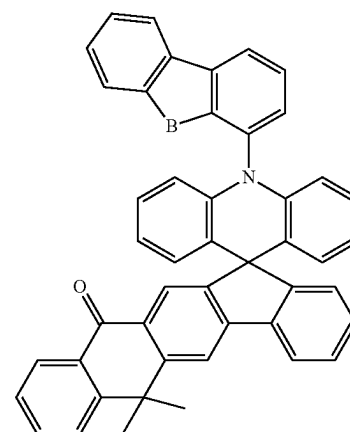
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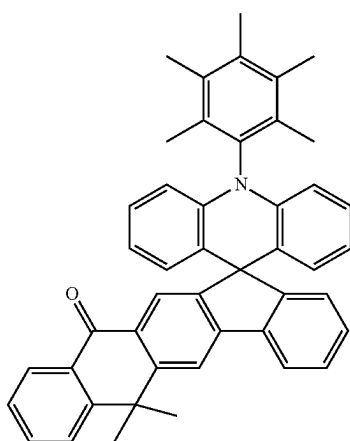
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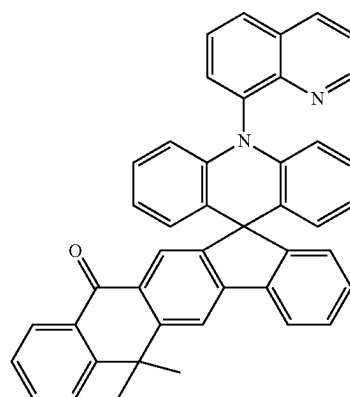
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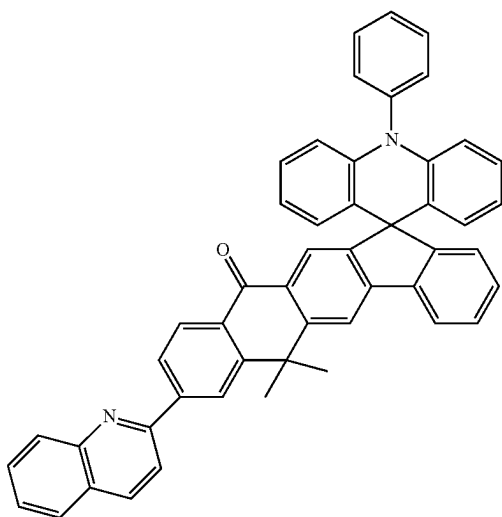


F-10



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F-11

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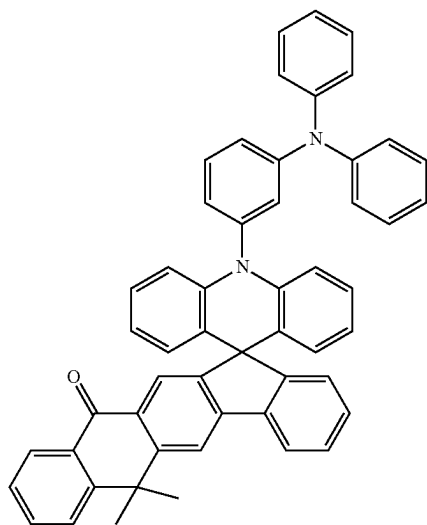
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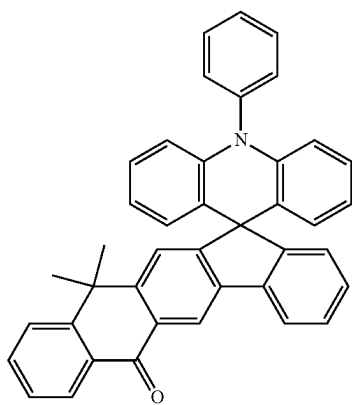


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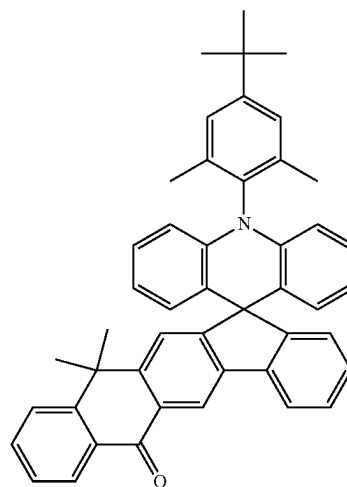
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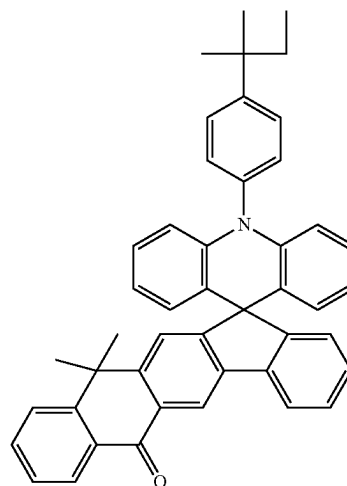
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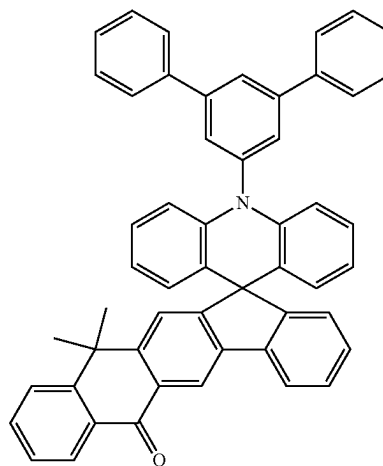


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F-15

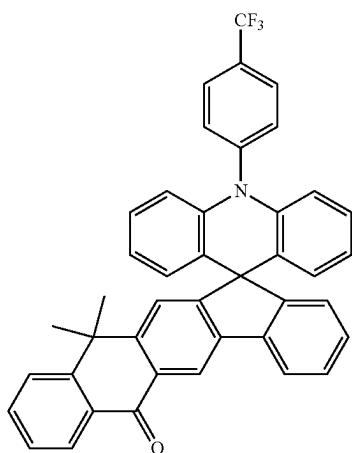


F-16



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F-17

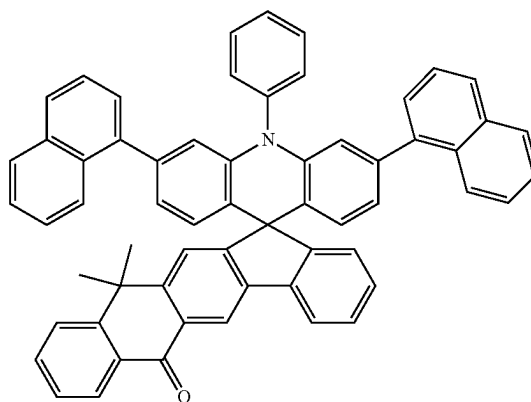
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F-18

F-21

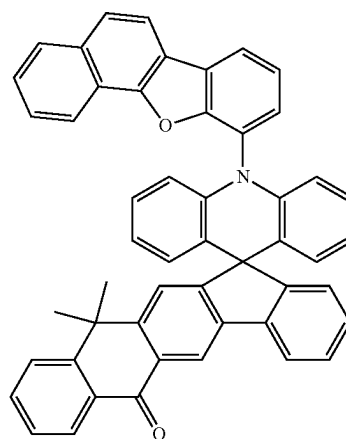
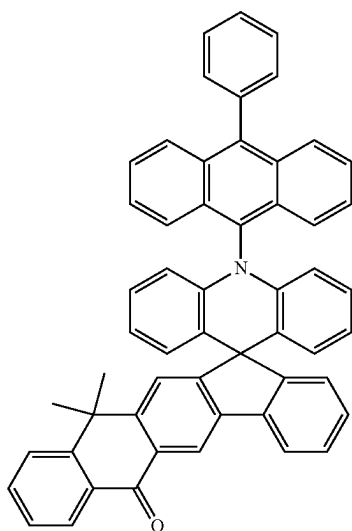
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F-19

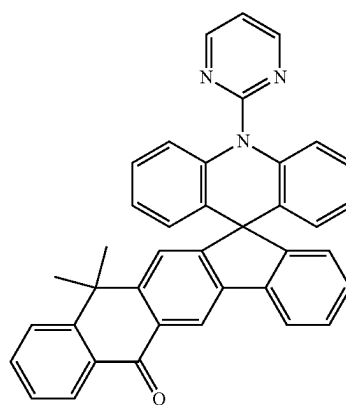
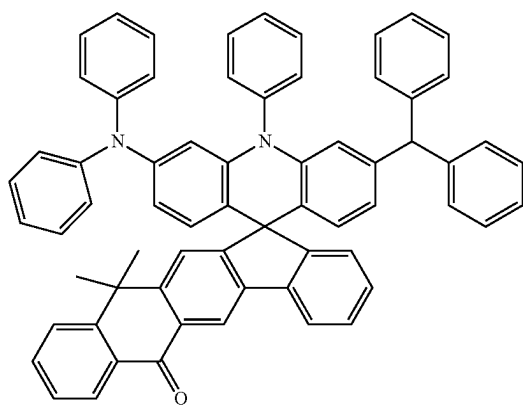
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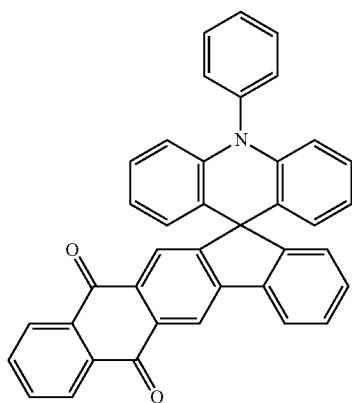
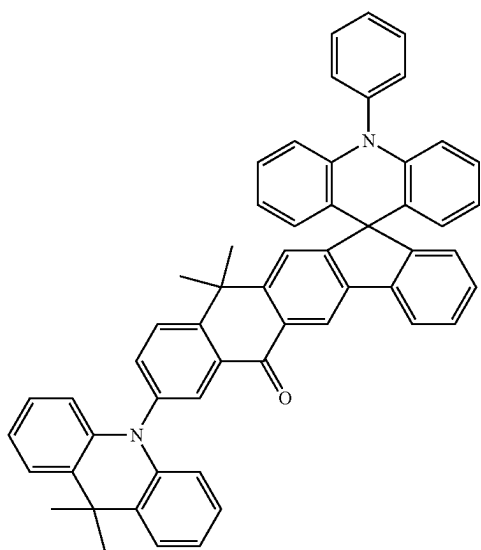
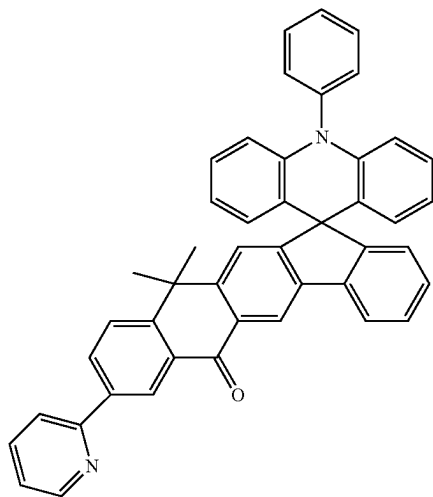
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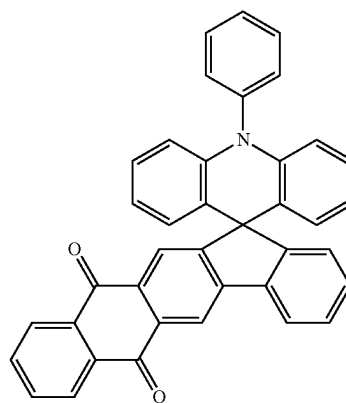
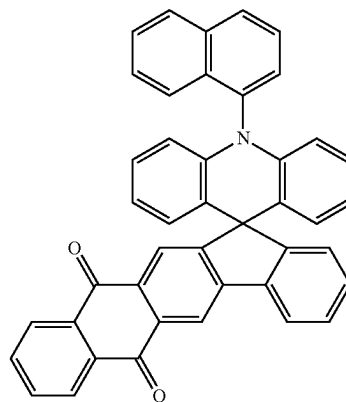
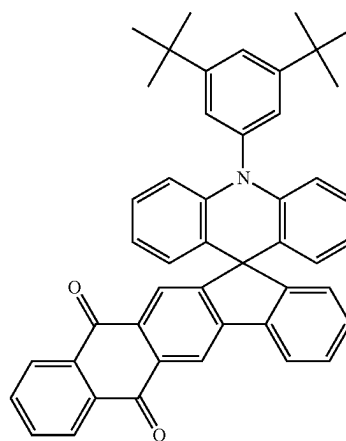
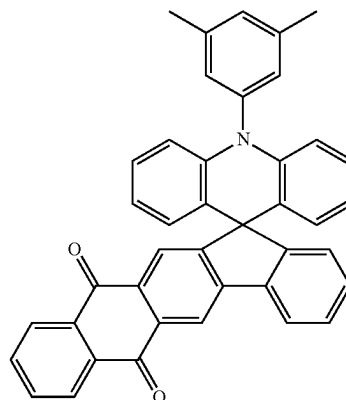


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**46**

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F-23

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F-24 25

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G-1 50

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G-2

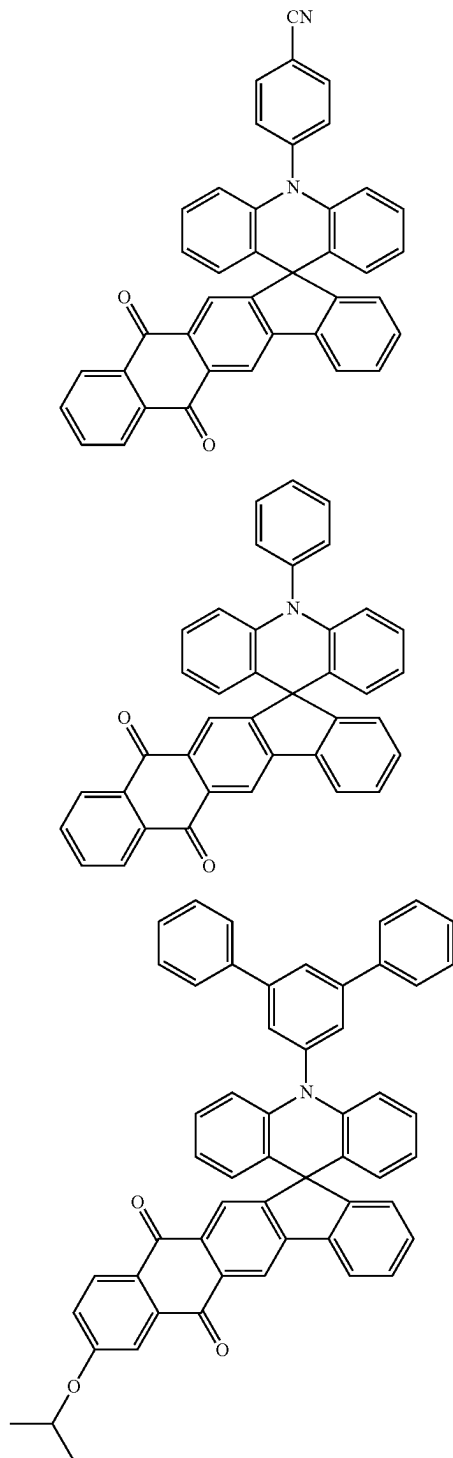
G-3

G-4

G-5

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-continued



Compounds belonging to group C are each a compound in which Y is oxygen in the compound represented by formula [1] or [2]. The fact that Y is oxygen inhibits the occurrence of a chemical reaction, such as oxidation, and thus provides a chemically stable compound.

Compounds belonging to group D are each a compound in which Y is sulfur in the compound represented by formula [1] or [2]. When Y is sulfur, because the elemental radius of sulfur is larger than that of oxygen, the six-membered ring

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formed has a distorted structure, lowering the degree of flatness of the molecule. Thus, the concentration quenching is even less likely to occur.

Compounds belonging to group E are each a compound in which Y is selenium or tellurium in the compound represented by formula [1] or [2]. When Y is selenium or tellurium, the element has a d-orbital and metallic properties, thereby providing high electron mobility.

Compounds belonging to group F are each a compound in which Y is a CR_1R_2 group in the compound represented by formula [1] or [2]. When R_1 and R_2 are introduced, especially when R_1 and R_2 are groups other than hydrogen, the degree of flatness of the molecule is reduced. Thus, the concentration quenching is even less likely to occur.

Compounds belonging to group G are each a compound in which Y is a carbonyl group in the compound represented by formula [1] or [2]. The enhancement of the electron-withdrawing ability provides a stable compound that is less susceptible to oxidation.

G-7 Organic Light-Emitting Device

The organic light-emitting device according to the embodiment will be described below.

The organic light-emitting device according to the embodiment at least includes an anode and a cathode, which are a pair of electrodes, and an organic compound layer disposed between these electrodes. In the organic light-emitting device according to the embodiment, the organic compound layer may be formed of a single layer or a multilayer stack including multiple layers, as long as it includes a light-emitting layer. When the organic compound layer is formed of a multilayer stack including multiple layers, the organic compound layer may include, in addition to the light-emitting layer, a hole injection layer, a hole transport layer, an electron-blocking layer, a hole/exciton-blocking layer, an electron transport layer, and an electron injection layer, for example. The light-emitting layer may be formed of a single layer or a multilayer stack including multiple layers.

In the organic light-emitting device according to the embodiment, at least one organic compound layer contains the organic compound according to the embodiment. Specifically, the organic compound according to the embodiment is contained in any of the light-emitting layer, the hole injection layer, the hole transport layer, the electron-blocking layer, the hole/exciton-blocking layer, the electron transport layer, the electron injection layer, and so forth described above. The organic compound according to the embodiment can be contained in the light-emitting layer. The light-emitting layer can emit green light or red light. The emission color is not limited thereto.

In the organic light-emitting device according to the embodiment, in the case where the organic compound according to the embodiment is contained in the light-emitting layer, the light-emitting layer may consist of only the organic compound according to the embodiment or may be composed of the organic compound according to the embodiment and another compound. In the case where the light-emitting layer is composed of the organic compound according to the embodiment and another compound, the organic compound according to the embodiment may be used as a host or a guest in the light-emitting layer. The organic compound may be used as an assist material that can be contained in the light-emitting layer. The term "host" used here refers to a compound having the highest proportion by mass in compounds constituting the light-emitting layer. The term "guest" refers to a compound that has a lower proportion by mass than the host in the compounds

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constituting the light-emitting layer and that is responsible for main light emission. The term “assist material” refers to a compound that has a lower proportion by mass than the host in the compounds constituting the light-emitting layer and that assists the light emission of the guest.

In the case where the organic compound according to the embodiment is used as a guest in the light-emitting layer, the concentration of the guest is preferably 0.01% or more by mass and 20% or less by mass, more preferably 1% or more by mass and 15% or less by mass, based on the entire light-emitting layer. In the case where the organic compound according to the embodiment is used as an assist material in the light-emitting layer, the concentration of the assist material is preferably 0.1% or more by mass and 45% or less by mass, more preferably 1% or more by mass and 30% or less by mass, based on the entire light-emitting layer.

In the case where the organic compound according to the embodiment is used as a guest in the light-emitting layer, a material having a higher LUMO level than the organic compound according to the embodiment (a material having a LUMO level closer to the vacuum level) can be used as a host. The reason for this is as follows: The organic compound according to the embodiment tends to have a low LUMO level. Thus, when a material having a higher LUMO level than the organic compound according to the embodiment is used as a host, the organic compound according to the embodiment can receive more electrons supplied to the host of the light-emitting layer.

In the case where the organic compound according to the embodiment is used as an assist material in the light-emitting layer, a material having a higher LUMO level than the organic compound according to the embodiment (a material having a LUMO level closer to the vacuum level) can be used as a guest. The reason for this is as follows: The organic compound according to the embodiment tends to have a low LUMO level. Thus, when a material having a higher LUMO level than the organic compound according to the embodiment is used as a light-emitting material (guest), the organic compound according to the embodiment receives more electrons supplied to the host of the light-emitting layer, and the assist material is responsible for exciton recombination. This enables efficient energy transfer to the light-emitting material (guest).

The inventors have conducted various studies and have found that when the organic compound according to the embodiment is used as a host, guest, or assist material of a light-emitting layer, especially as a guest of a light-emitting layer, a device that emits light with high efficiency and high

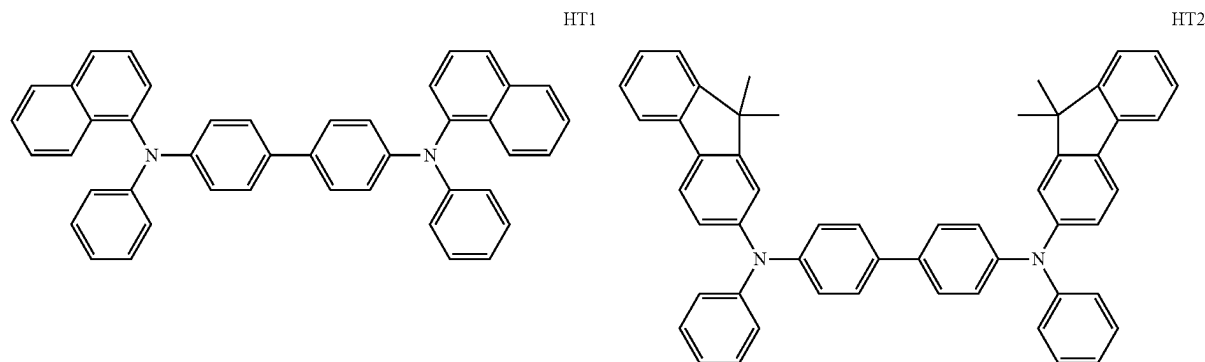
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luminance, and is extremely durable can be provided. The inventors have further found that when the organic compound according to the embodiment is used as an assist material in the light-emitting layer, a device that emits light with high efficiency and high luminance, and is extremely durable can be provided. The light-emitting layer may be formed of a single layer or multiple layers, and can contain multiple light-emitting materials. The term “multiple layers” may include a state in which the light-emitting layer and another light-emitting layer are stacked, or a state in which an intermediate layer is stacked between multiple light-emitting layers. Tandem devices or stacked devices are also acceptable. In these cases, the emission color of the organic light-emitting device is not limited to a single color. More specifically, the emission color may be white or an intermediate color. A film-forming method is vapor deposition or coating. Details will be described in examples below.

The organic compound according to the embodiment can be used as a constituent material of an organic compound layer other than the light-emitting layer included in the organic light-emitting device according to the embodiment. Specifically, the organic compound may be used as a constituent material of the electron transport layer, the electron injection layer, the hole transport layer, the hole injection layer, the hole-blocking layer, and so forth.

For example, a hole injection compound, a hole transport compound, a compound to be used as a host, a light-emitting compound, an electron injection compound, or an electron transport compound, which is known and has a low or high molecular weight, can be used together with the organic compound according to the embodiment, as needed. Examples of these compounds will be described below.

As a hole injection-transport material, a material having a high hole mobility can be used so as to facilitate the injection of holes from the anode and to transport the injected holes to the light-emitting layer. To reduce a deterioration in film quality, such as crystallization, in the organic light-emitting device, a material having a high glass transition temperature can be used. Examples of a low- or high-molecular-weight material having the ability to inject and transport holes include triarylamine derivatives, aryl carbazole derivatives, phenylenediamine derivatives, stilbene derivatives, phthalocyanine derivatives, porphyrin derivatives, poly(vinyl carbazole), polythiophene, and other conductive polymers. Moreover, the hole injection-transport material can be used for the electron-blocking layer. Non-limiting specific examples of a compound used as the hole injection-transport material will be illustrated below.

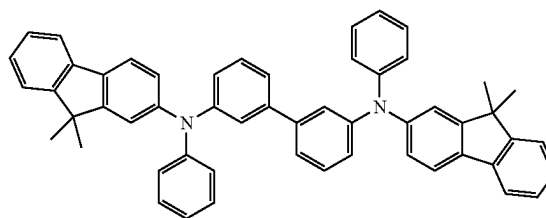
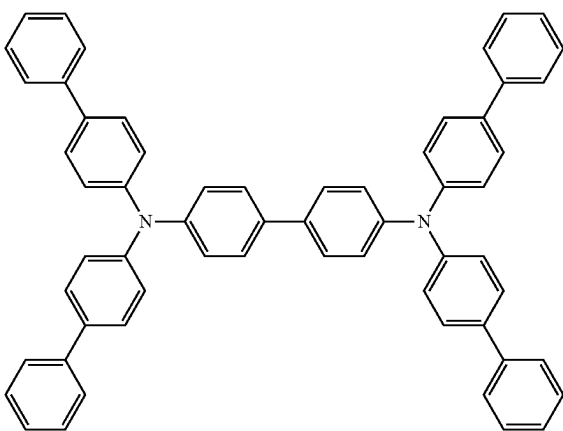


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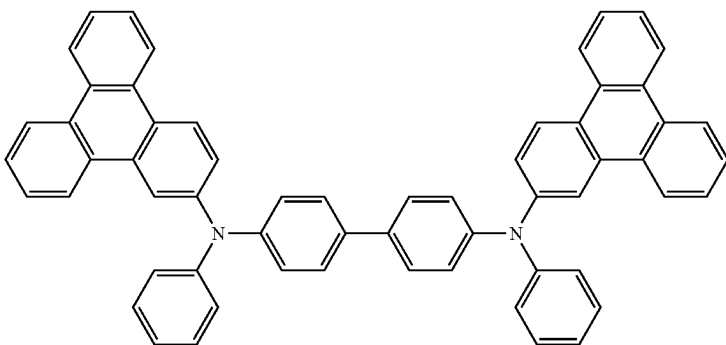
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HT3

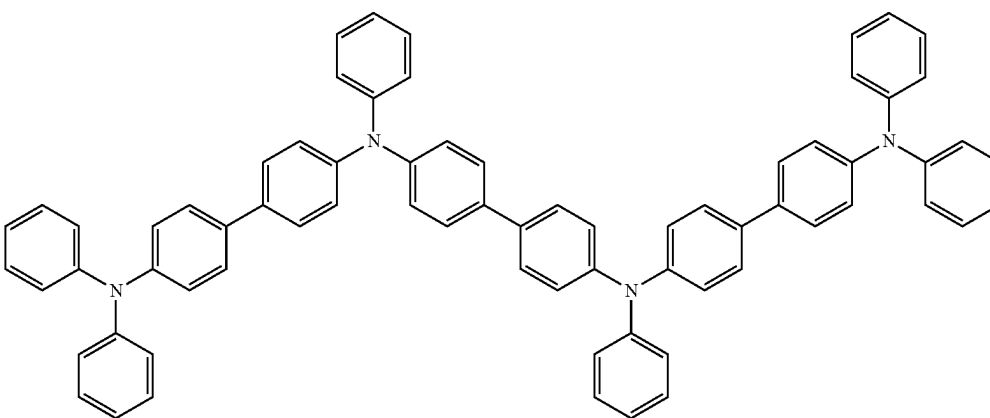
HT4



HT5



HT6

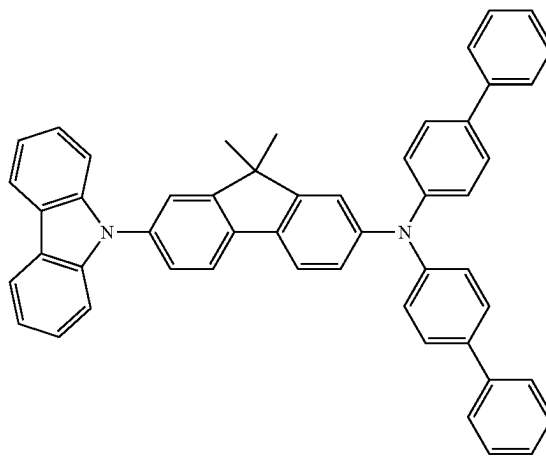
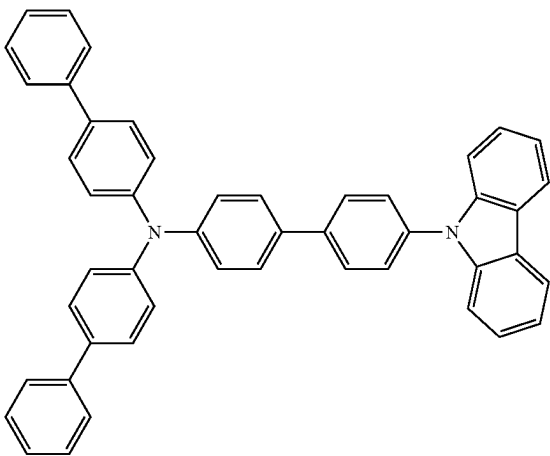


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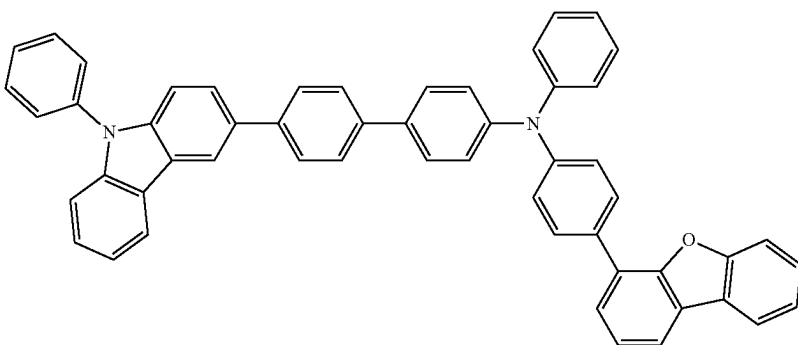
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HT7

HT8

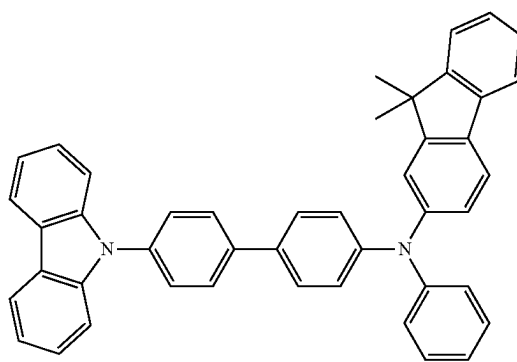
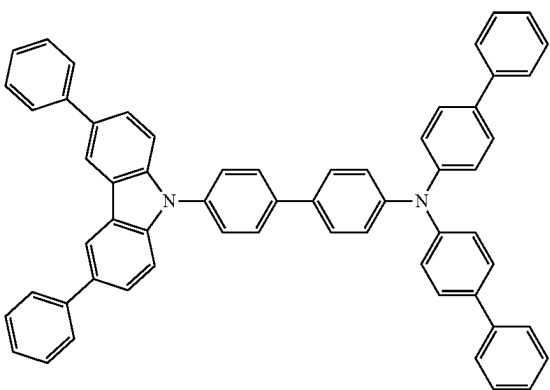


HT9



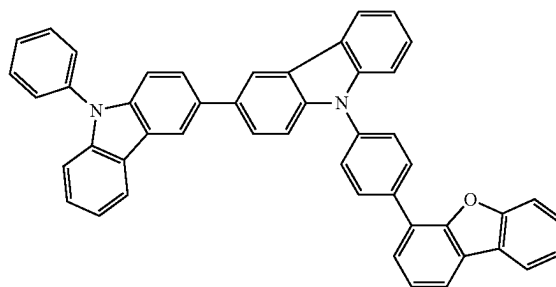
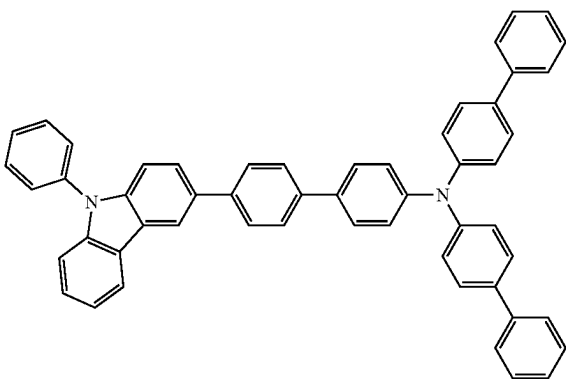
HT10

HT11

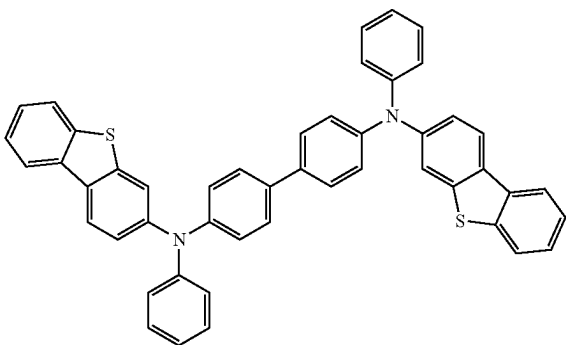


HT12

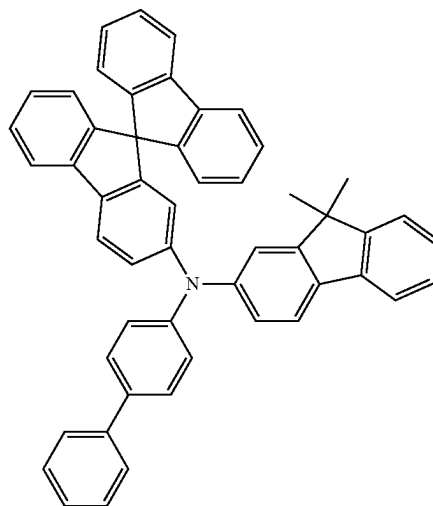
HT13



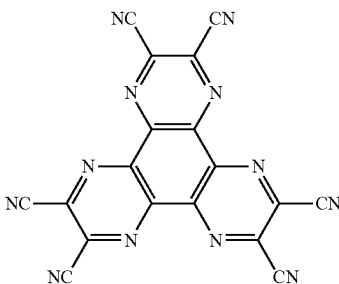
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HT14

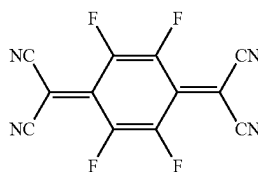
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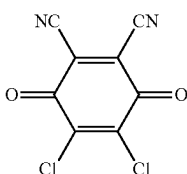
HT15



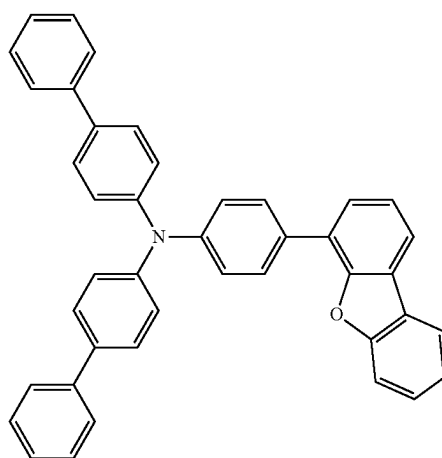
HT16



HT17



HT18

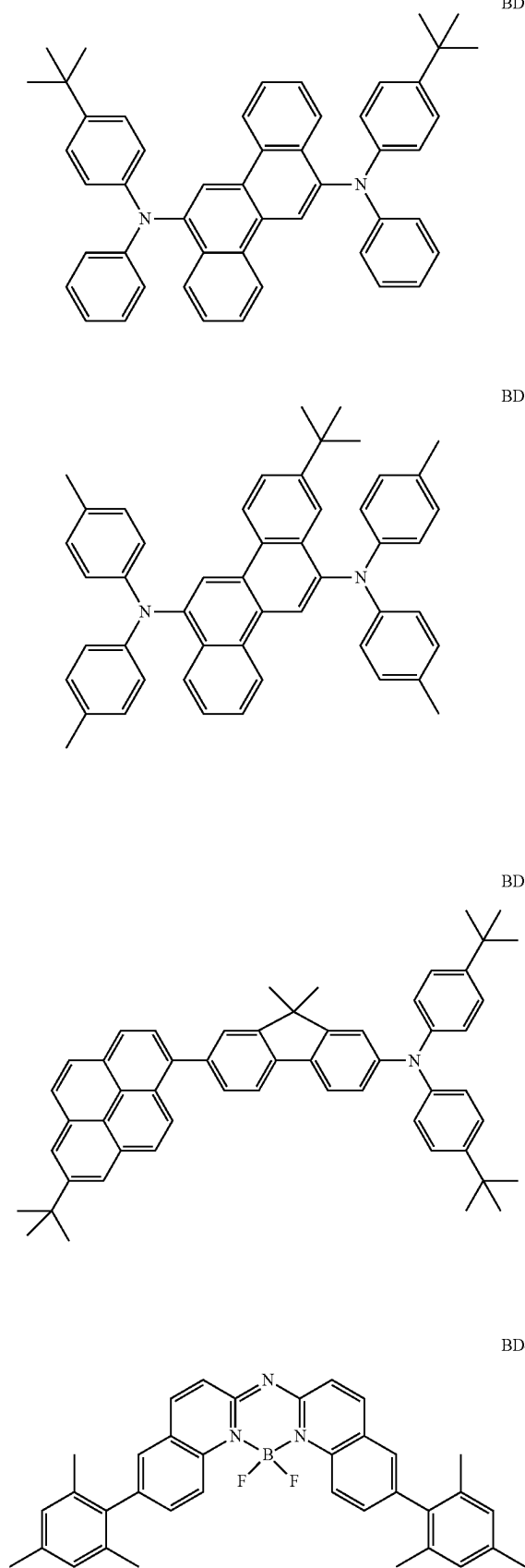


HT19

Among the hole transport materials illustrated above, HT16 to HT18 can be used in the layer in contact with the anode to reduce the driving voltage. HT16 is widely used in organic light-emitting devices. HT2, HT3, HT4, HT5, HT6, HT10, and HT12 may be used in an organic compound layer adjacent to HT16. Multiple materials may be used in a single organic compound layer.

Examples of a light-emitting material mainly associated with a light-emitting function include, in addition to the organic compounds represented by formulae [1] and [2], fused-ring compounds, such as fluorene derivatives, naph-

thalene derivatives, pyrene derivatives, perylene derivatives, tetracene derivatives, anthracene compounds, and rubrene, quinacridone derivatives, coumarin derivatives, stilbene derivatives, organoaluminum complexes, such as tris(8-quinolinolato)aluminum, iridium complexes, platinum complexes, rhenium complexes, copper complexes, europium complexes, ruthenium complexes, and polymer derivatives, such as poly(phenylene vinylene) derivatives, polyfluorene derivatives, and polyphenylene derivatives. Non-limiting specific examples of a compound used as a light-emitting material are illustrated below.

57**58**

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BD1

BD5

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BD2

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BD3

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BD4

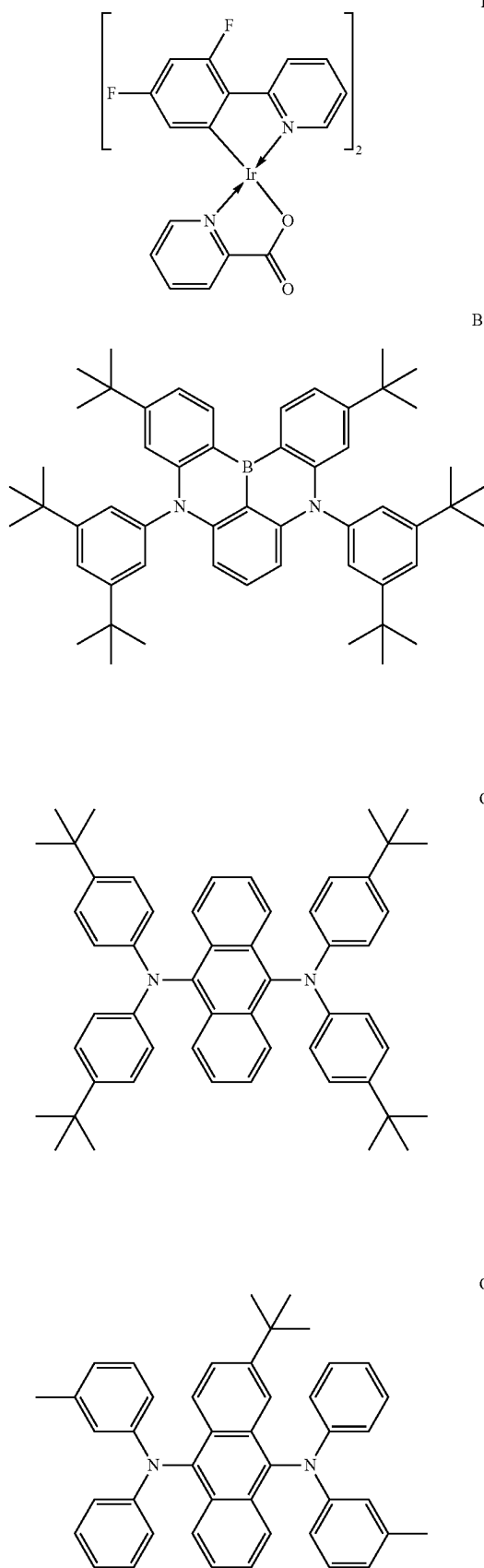
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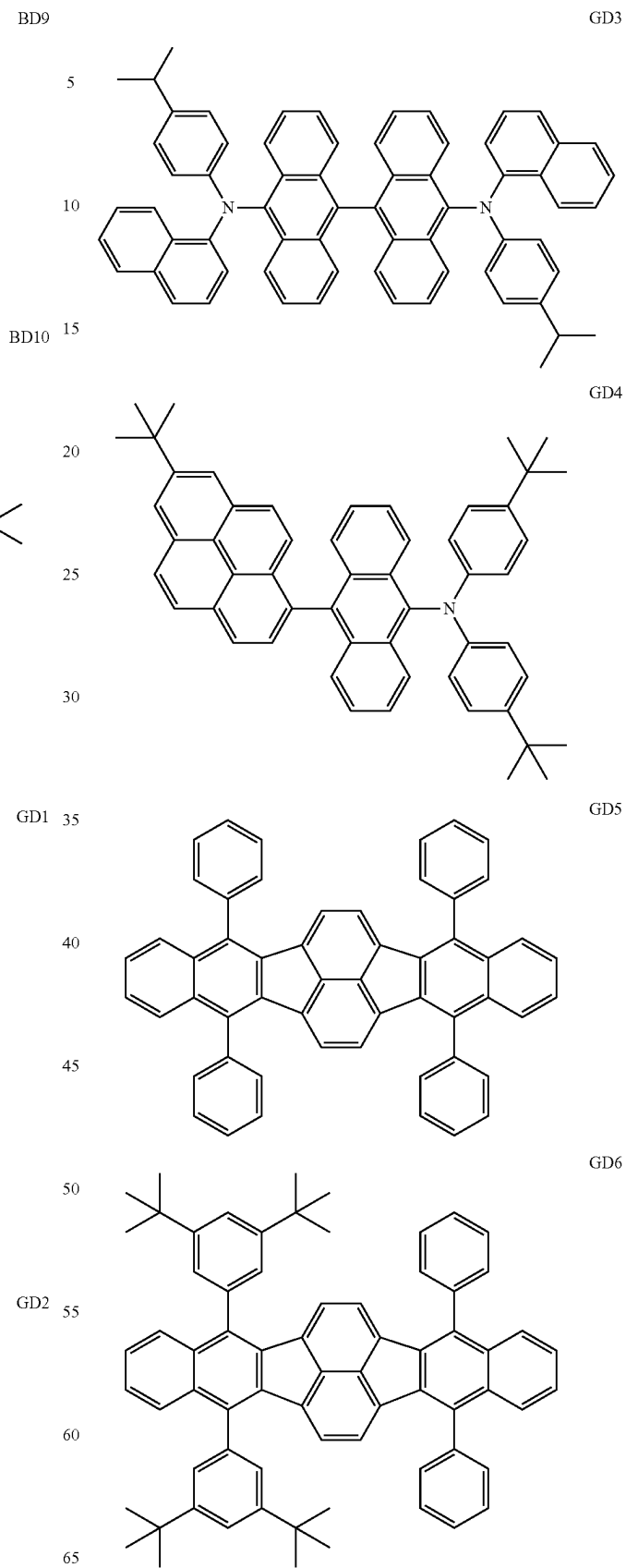
BD8

59

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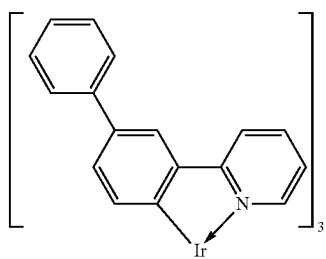
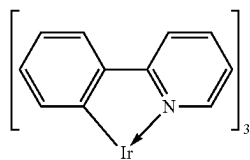
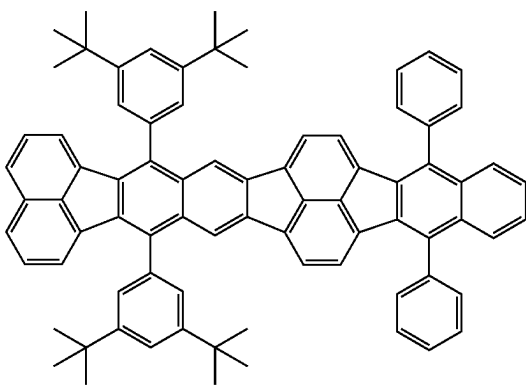
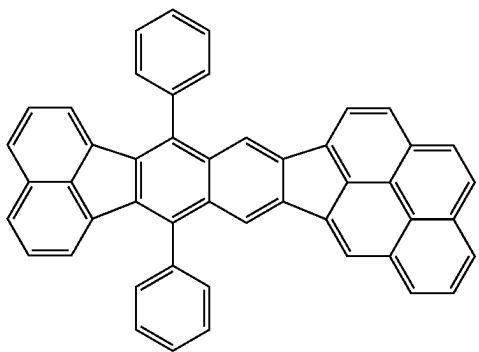
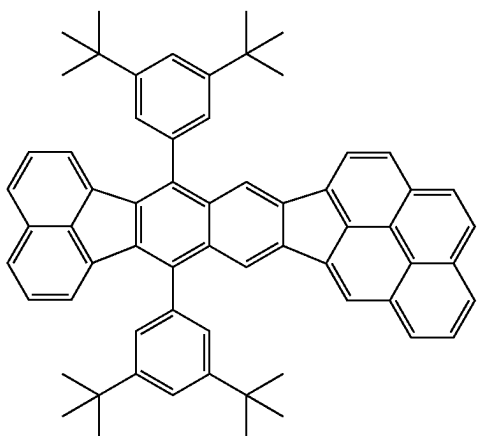
**60**

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**62**

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GD7

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GD8

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GD9

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GD10

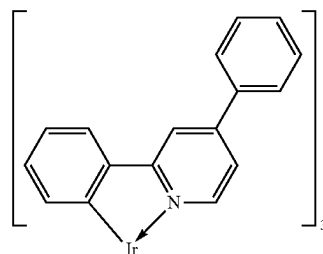
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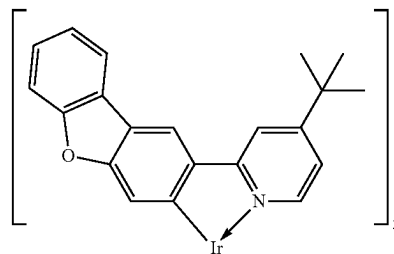
GD11

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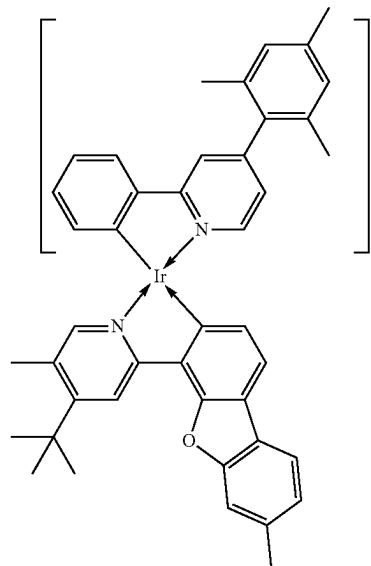


GD12

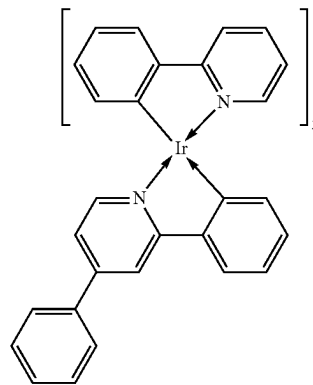


GD13

GD14

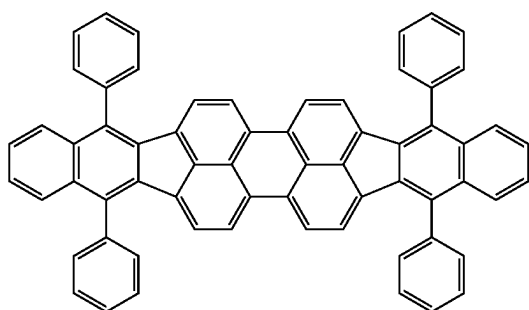


GD15



63

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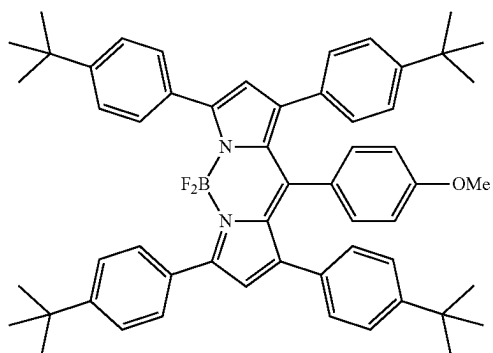
RD1

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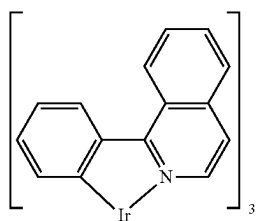
RD2



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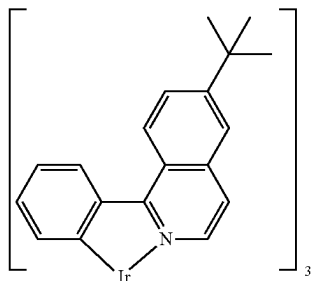
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RD3

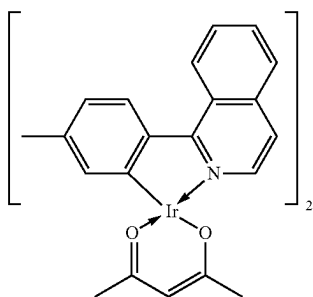


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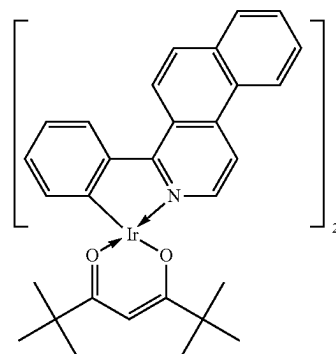
RD4



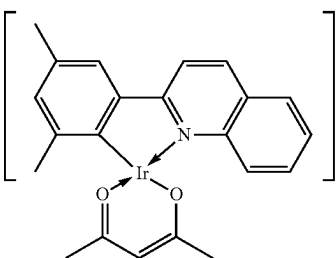
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**64**

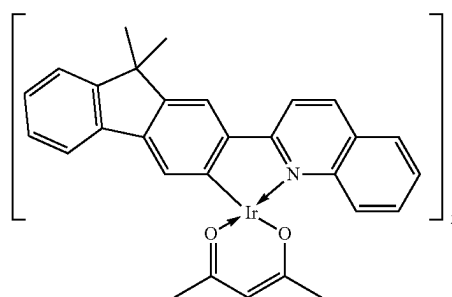
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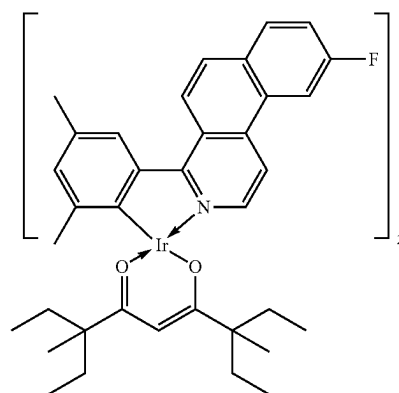
RD6



RD7



RD8



RD9

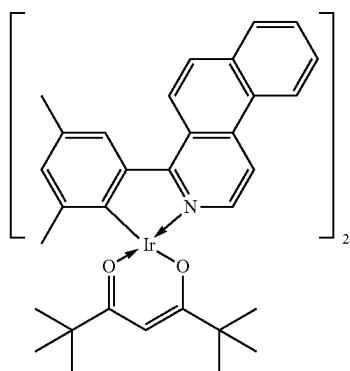
RD5

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When the light-emitting material is a hydrocarbon compound, the material can prevent a deterioration in luminous

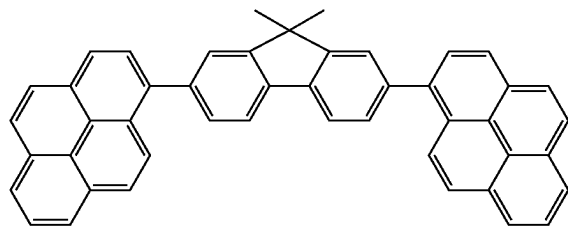
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RD10

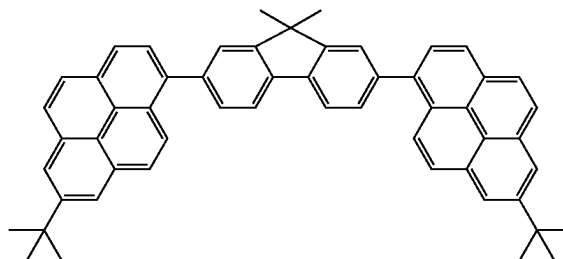
efficiency due to exciplex formation and a deterioration in color purity due to changes in the emission spectrum of the light-emitting material. The term "hydrocarbon compound" refers to a compound consisting of only carbon and hydrogen, and BD7, BD8, GD5 to GD9, and RD1 are hydrocarbon compounds. When the light-emitting material is a five-membered ring-containing fused polycyclic compound, the material has a high ionization potential and high resistance to oxidation. This can provide a highly durable device with a long lifetime. BD7, BD8, GD5 to GD9, and RD1 are five-membered ring-containing fused polycyclic compounds.

Examples of a host or an assist material in the light-emitting layer include aromatic hydrocarbon compounds and derivatives thereof, carbazole derivatives, dibenzofuran derivatives, dibenzothiophene derivatives, organoaluminum complexes, such as tris(8-quinolinolato)aluminum, and organoberyllium complexes. Non-limiting specific examples of a compound used as a host or an assist material in the light-emitting layer will be illustrated below.

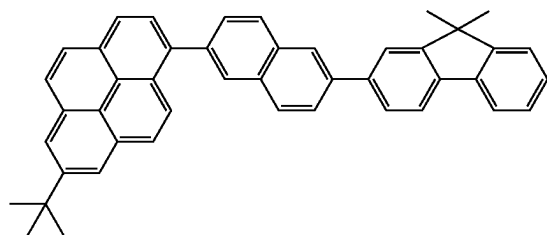
EM1



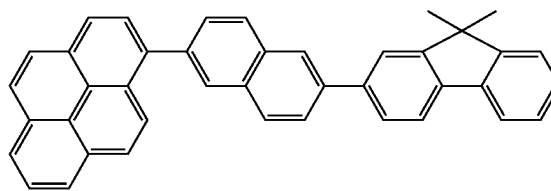
EM2



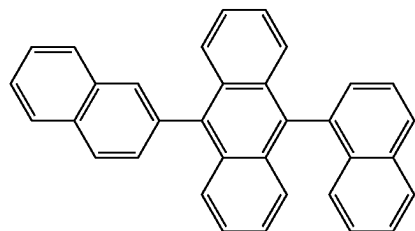
EM3



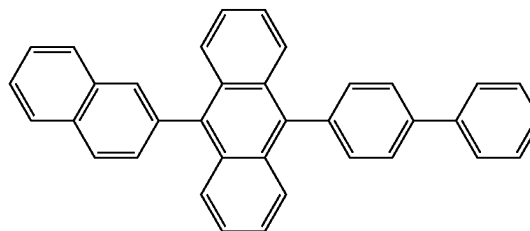
EM4



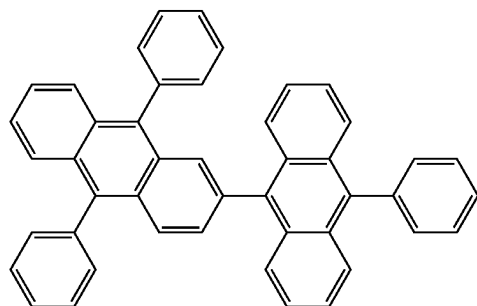
EM5



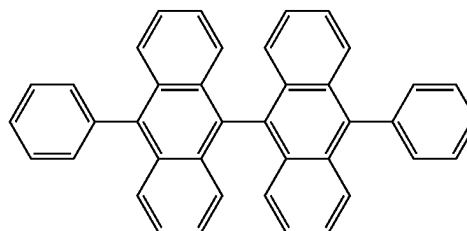
EM6



EM7



EM8

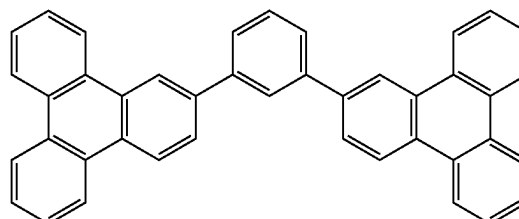
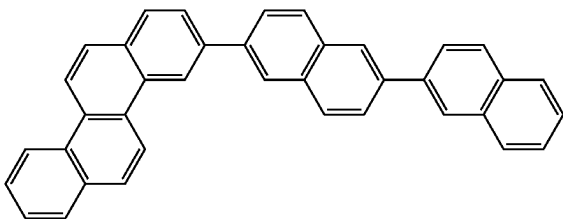


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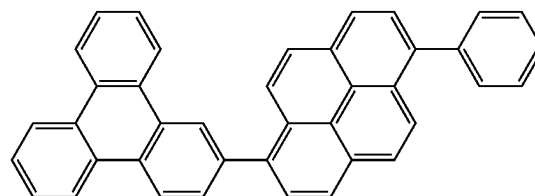
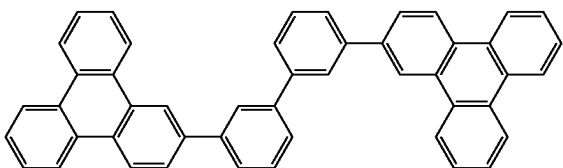
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EM9

EM10



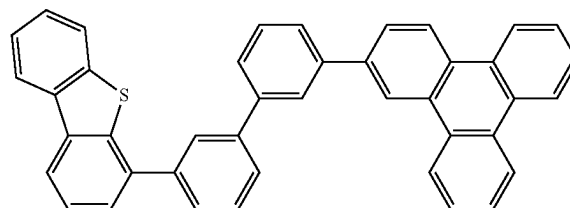
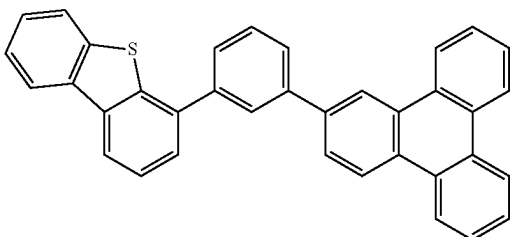
EM11

EM12

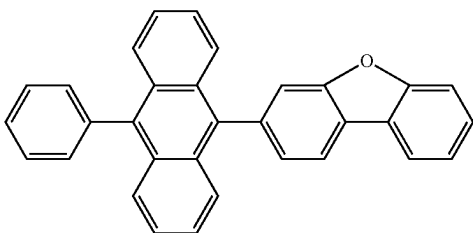


EM13

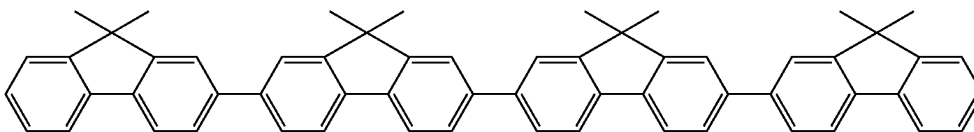
EM14



EM15

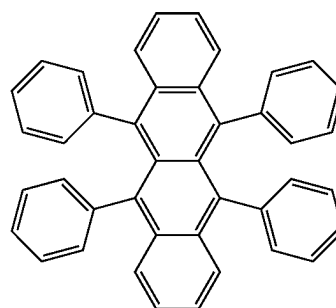
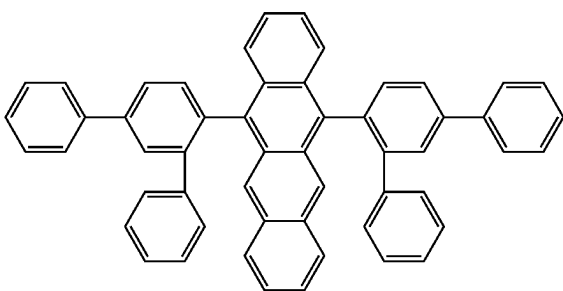


EM16

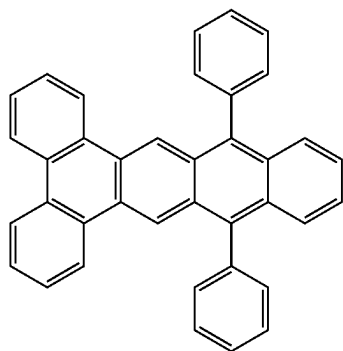


EM17

EM18

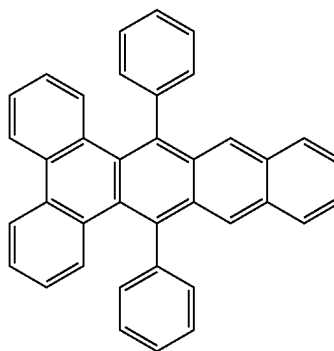


69



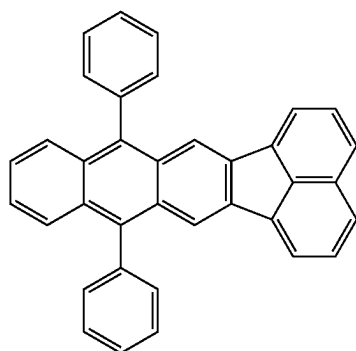
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EM19

70

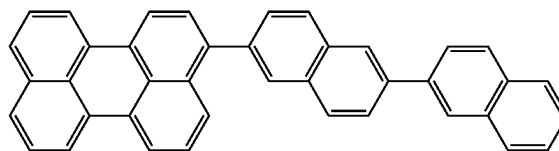


EM20

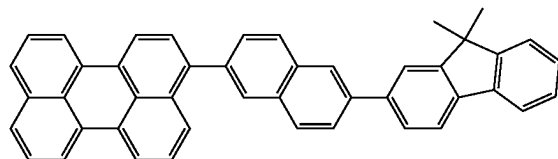
EM21



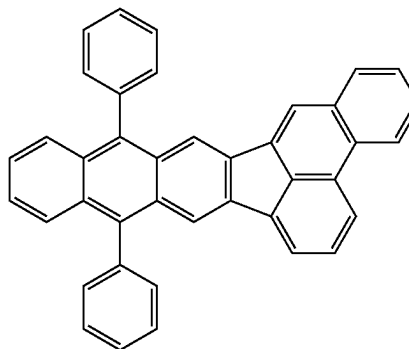
EM22



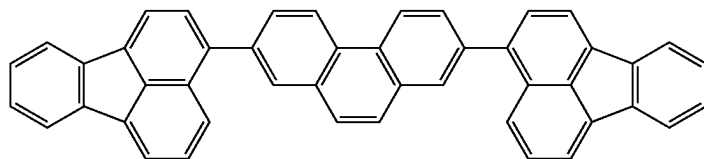
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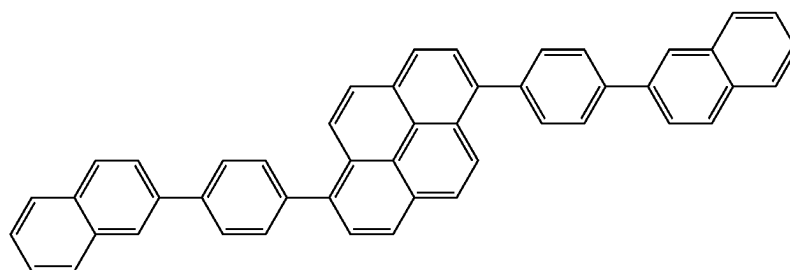
EM24



EM25



EM26

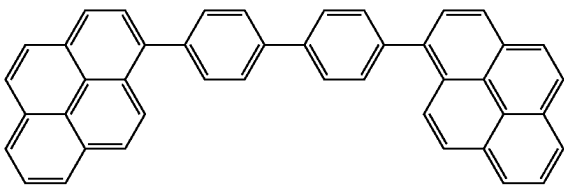


71

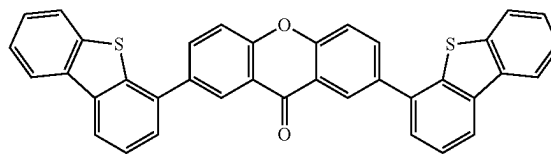
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EM27

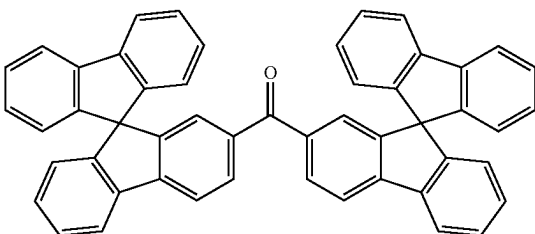
EM28



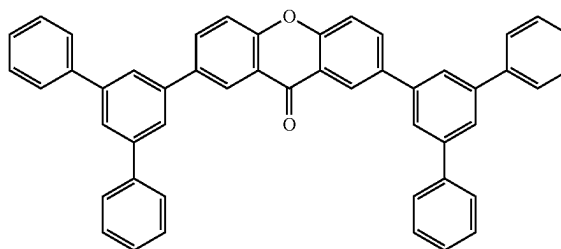
EM29



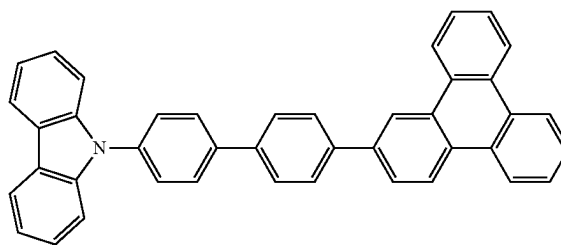
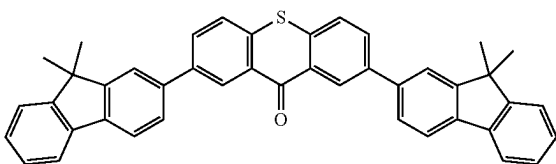
EM30



EM31

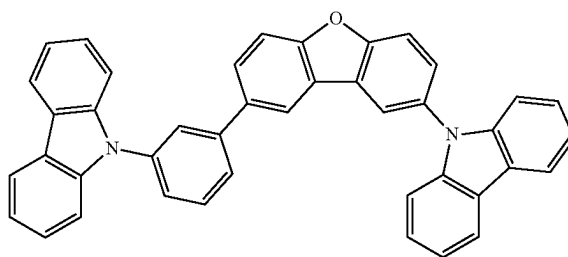
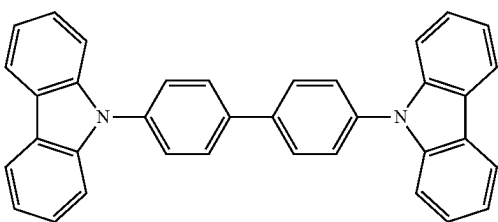


EM32



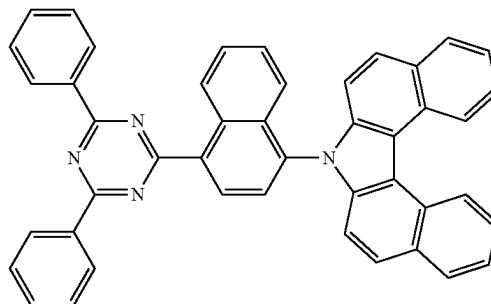
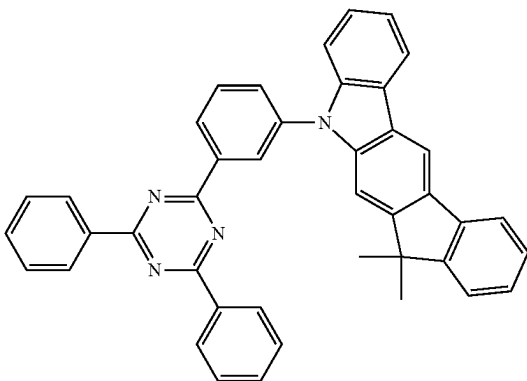
EM33

EM34

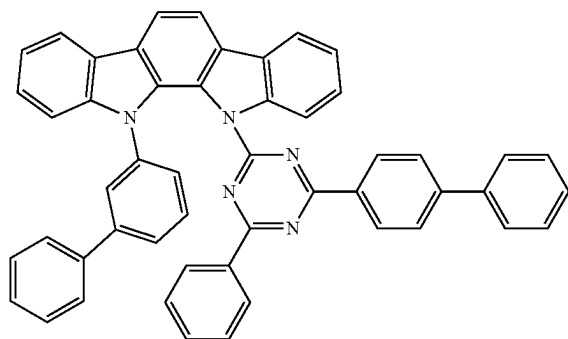


EM35

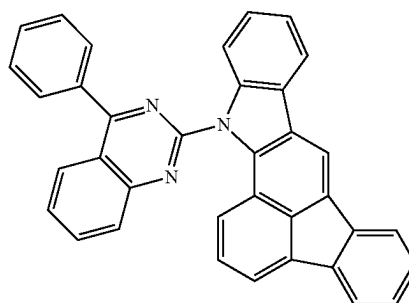
EM36



73

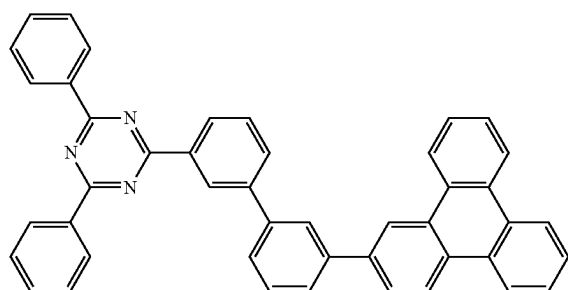
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EM37

74

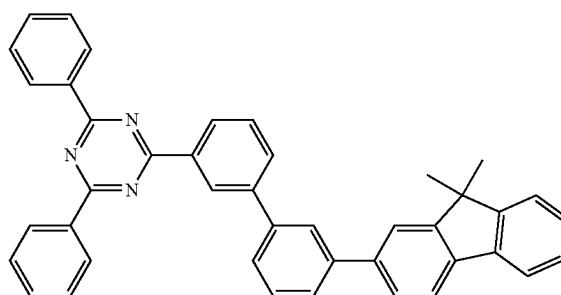


EM38

EM39



EM40



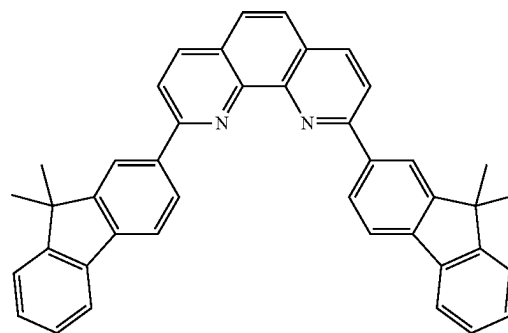
30

When the host material is a hydrocarbon compound, the compound according to the embodiment can easily trap electrons and holes to contribute to higher efficiency. The term "hydrocarbon compound" refers to a compound consisting of only carbon and hydrogen, and EM1 to EM12 and EM16 to EM27 are hydrocarbon compounds.

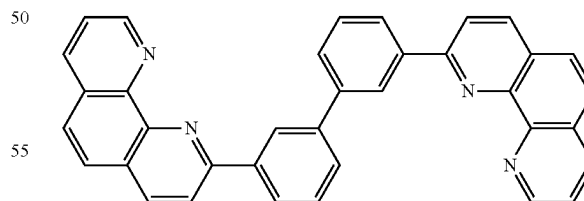
The electron transport material can be freely-selected from materials capable of transporting electrons injected from the cathode to the light-emitting layer and is selected in consideration of, for example, the balance with the hole mobility of the hole transport material. Examples of a material having the ability to transport electrons include oxadiazole derivatives, oxazole derivatives, pyrazine derivatives, triazole derivatives, triazine derivatives, quinoline derivatives, quinoxaline derivatives, phenanthroline derivatives, organoaluminum complexes, and condensed-ring compounds, such as fluorene derivatives, naphthalene derivatives, chrysene derivatives, and anthracene derivatives. The electron transport materials can be used for the hole-blocking layer. Non-limiting specific examples of a compound used as the electron transport material will be illustrated below.

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ET2

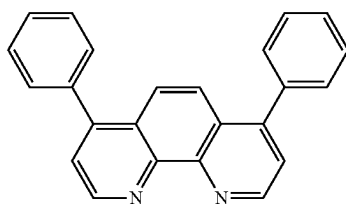


ET3



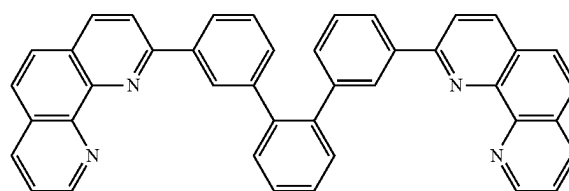
ET4

ET1



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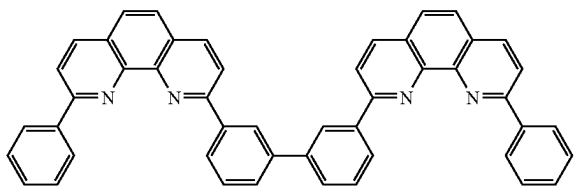
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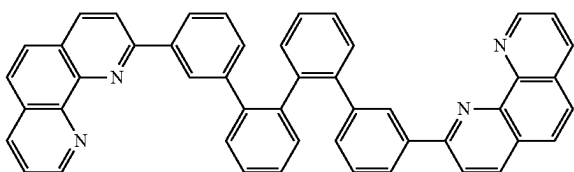
ET5



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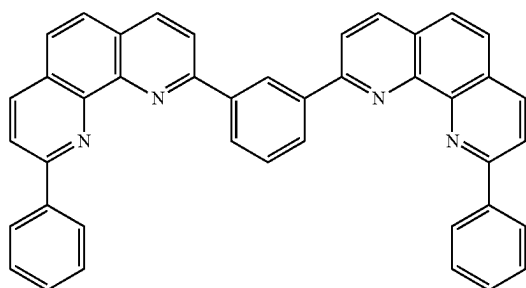
ET6



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EM7

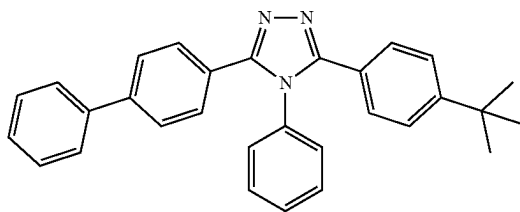


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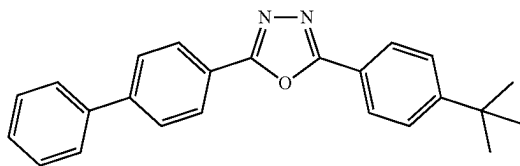
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EM8



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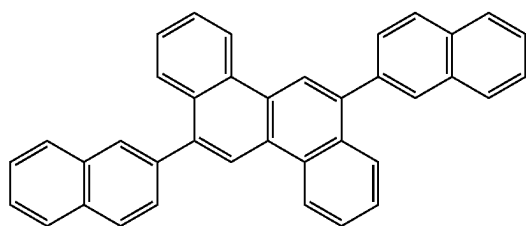
EM9



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EM10



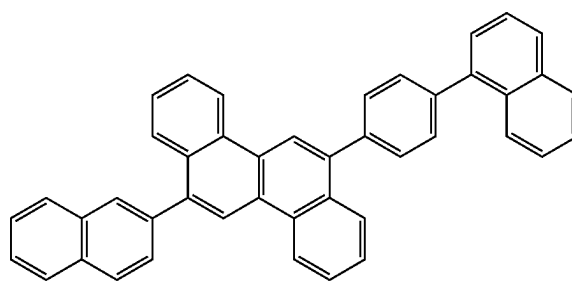
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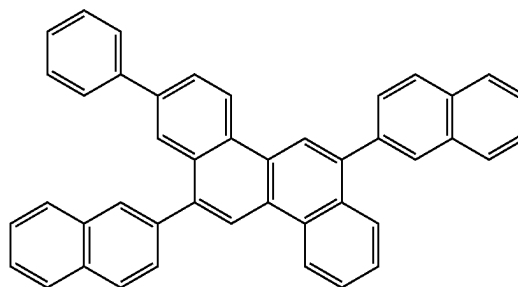
76

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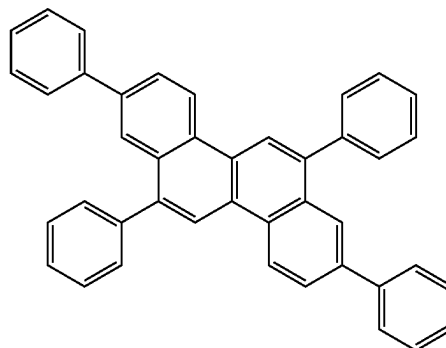
EM11



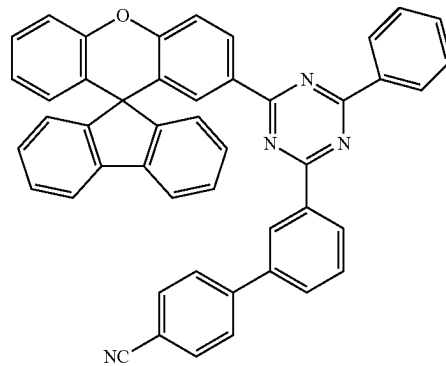
ET12



ET13

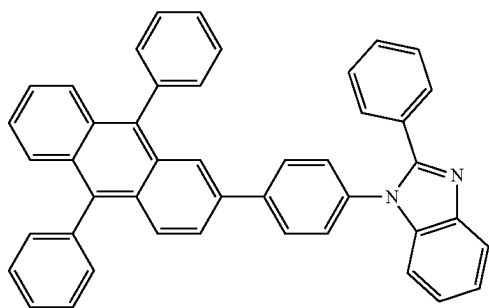
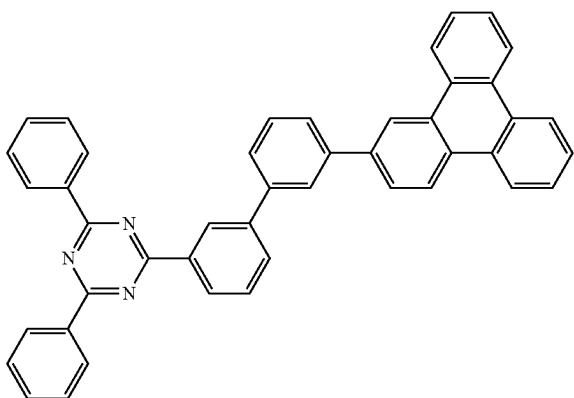
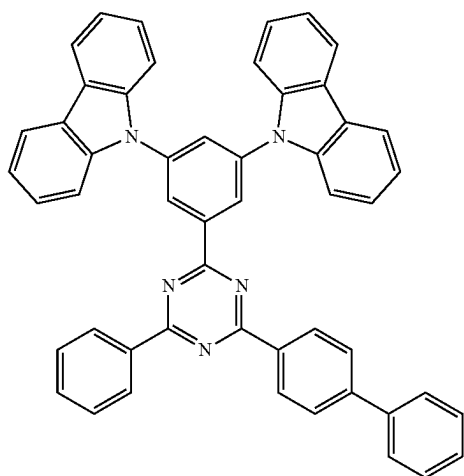
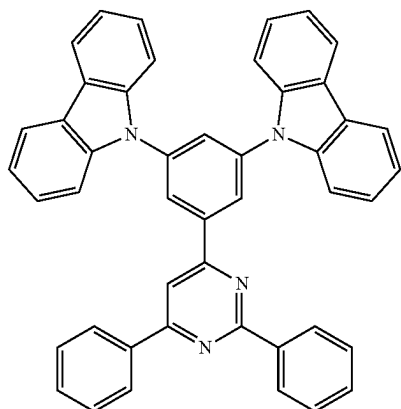


ET14



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**78**

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ET15

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ET16

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ET17

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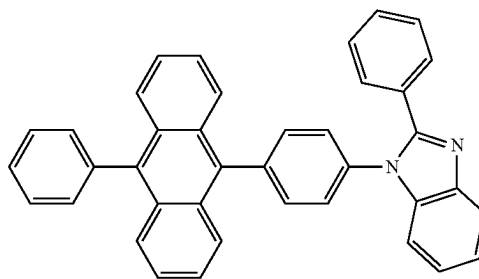
ET18

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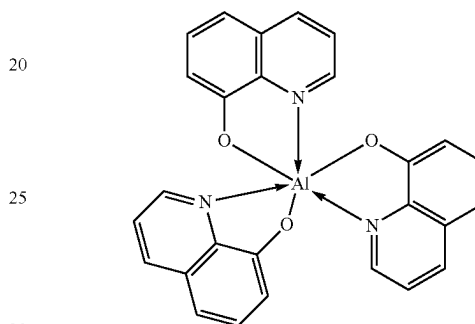
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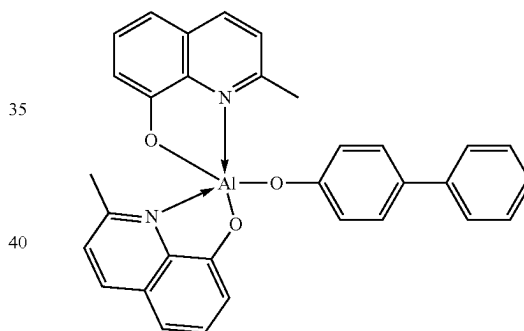
ET19



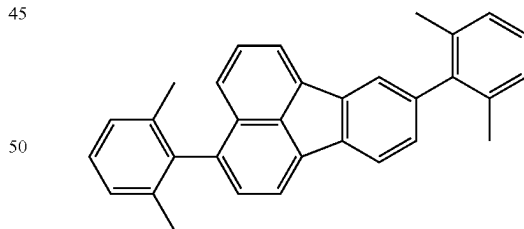
ET20



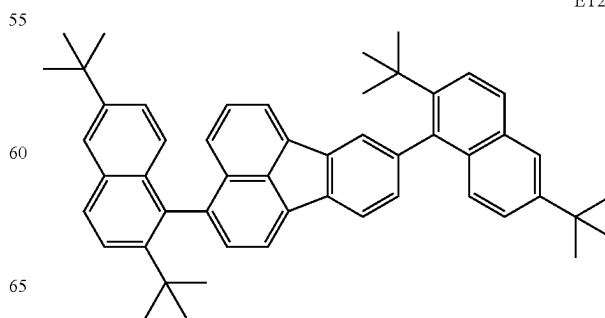
ET21



ET22

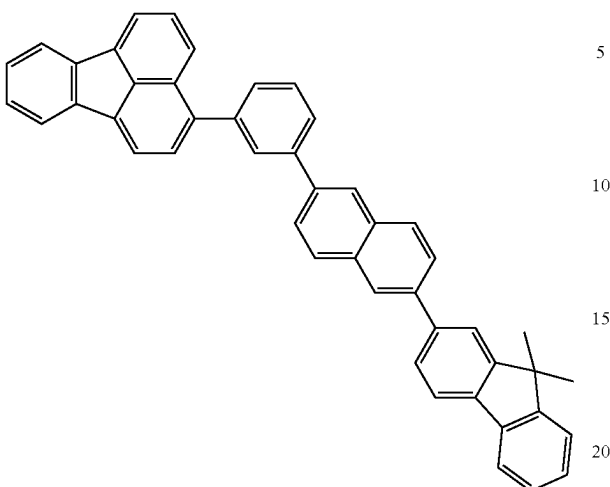


ET23



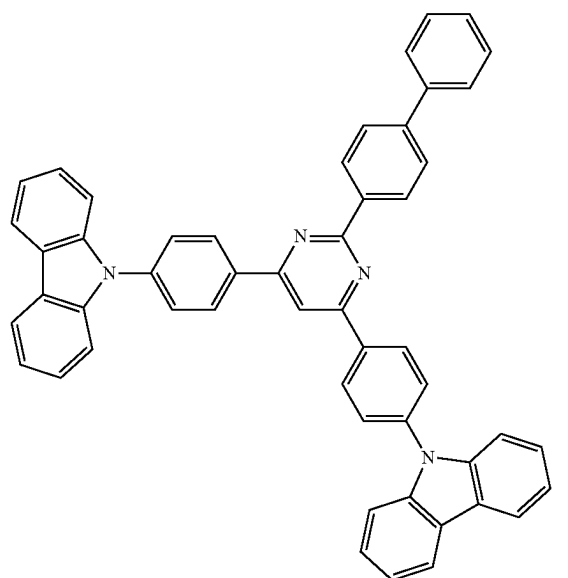
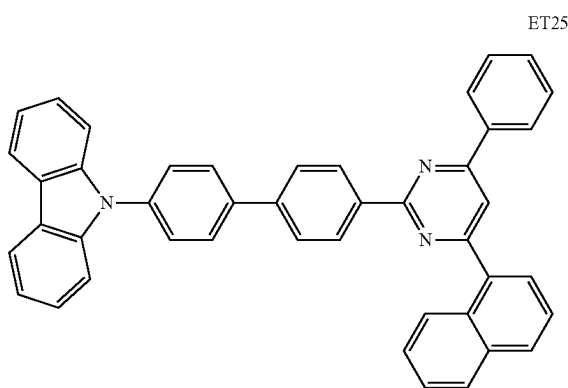
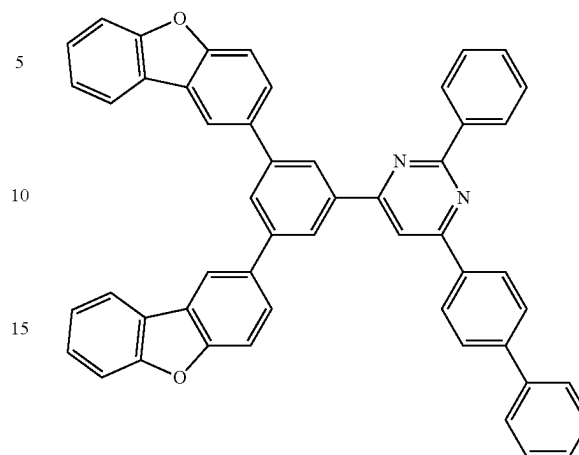
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An electron injection material can be freely-selected from materials capable of easily injecting electrons from the cathode and is selected in consideration of, for example, the balance with the hole-injecting properties. As the organic compound, n-type dopants and reducing dopants are also included. Examples thereof include alkali metal-containing compounds, such as lithium fluoride, lithium complexes, such as lithium quinolinolate, benzimidazolidene derivatives, imidazolidene derivatives, fulvalene derivatives, and acridine derivatives.

Configuration of Organic Light-Emitting Device

The organic light-emitting device is provided by disposing an anode, the organic compound layer, and a cathode on a substrate. A protective layer, a color filter, and so forth may be disposed on the cathode. In the case of disposing the color filter, a planarization layer may be disposed between the protective layer and the color filter. The planarization layer can be composed of, for example, an acrylic resin.

Substrate

Examples of the substrate include silicon wafers, quartz substrates, glass substrates, resin substrates, and metal substrates. The substrate may include switching devices such as a transistor, a line, and an insulating layer thereon. As the insulating layer, any material can be used as long as a contact hole can be formed to establish the electrical connection between the anode and the line and as long as insulation with a non-connected line can be ensured. For example, a resin such as polyimide, silicon oxide, or silicon nitride can be used.

Electrode

A pair of electrodes can be used. The pair of electrodes may be an anode and a cathode.

In the case where an electric field is applied in the direction in which the organic light-emitting device emits light, an electrode having a higher potential is the anode, and the other is the cathode. It can also be said that the electrode that supplies holes to the light-emitting layer is the anode and that the electrode that supplies electrons is the cathode.

As the constituent material of the anode, a material having a work function as high as possible can be used. Examples of the material that can be used include elemental metals, such as gold, platinum, silver, copper, nickel, palladium, cobalt, selenium, vanadium, and tungsten, mixtures thereof, alloys of combinations thereof, and metal oxides, such as tin oxide, zinc oxide, indium oxide, indium-tin oxide (ITO), and

indium-zinc oxide. Additionally, conductive polymers, such as polyaniline, polypyrrole, and polythiophene, may be used.

These electrode materials may be used alone or in combination of two or more. The anode may be formed of a single layer or multiple layers.

In the case where the anode is used as a reflective electrode, for example, chromium, aluminum, silver, titanium, tungsten, molybdenum, an alloy thereof, or a stack thereof may be used. In the case where the anode is used as a transparent electrode, a transparent conductive oxide layer composed of, for example, indium-tin oxide (ITO) or indium-zinc oxide may be used; however, the anode is not limited thereto. The electrode may be formed by photolithography.

As the constituent material of the cathode, a material having a lower work function can be used. Examples thereof include elemental metals such as alkali metals, e.g., lithium, alkaline-earth metals, e.g., calcium, aluminum, titanium, manganese, silver, lead, and chromium, and mixtures thereof. Alloys of combinations of these elemental metals may also be used. For example, magnesium-silver, aluminum-lithium, aluminum-magnesium, silver-copper, and zinc-silver may be used. Metal oxides such as indium-tin oxide (ITO) may also be used. These electrode materials may be used alone or in combination of two or more. The cathode may have a single-layer structure or a multilayer structure. In particular, silver can be used. To reduce the aggregation of silver, a silver alloy can be used. Any alloy ratio may be used as long as the aggregation of silver can be reduced. For example, 1:1 may be used.

A top emission device may be provided using the cathode formed of a conductive oxide layer composed of, for example, ITO. A bottom emission device may be provided using the cathode formed of a reflective electrode composed of, for example, aluminum (Al). The cathode is not particularly limited. Any method for forming the cathode may be used. For example, a direct-current or alternating-current sputtering technique can be employed because good film coverage is obtained and thus the resistance is easily reduced.

Protective Layer

A protective layer may be disposed on the cathode. For example, a glass member provided with a moisture absorbent can be bonded to the cathode to reduce the entry of, for example, water into the organic compound layer, thereby suppressing the occurrence of display defects. In another embodiment, a passivation film composed of, for example, silicon nitride may be disposed on the cathode to reduce the entry of, for example, water into the organic compound layer. For example, after the formation of the cathode, the substrate may be transported to another chamber without breaking the vacuum, and a silicon nitride film having a thickness of 2 μm may be formed by a chemical vapor deposition (CVD) method to provide a protective layer. After the film deposition by the CVD method, a protective layer may be formed by an atomic layer deposition (ALD) method.

Color Filter

A color filter may be disposed on the protective layer. For example, a color filter may be disposed on another substrate in consideration of the size of the organic light-emitting device and bonded to the substrate provided with the organic light-emitting device. A color filter may be formed by patterning on the protective layer using photolithography. The color filter may be composed of a polymer.

Planarization Layer

A planarization layer may be disposed between the color filter and the protective layer. The planarization layer may be composed of an organic compound. A low- or high-molecular-weight organic compound may be used. A high-molecular-weight organic compound can be used.

The planarization layers may be disposed above and below (or on) the color filter and may be composed of the same or different materials. Specific examples thereof include poly(vinyl carbazole) resins, polycarbonate resins, polyester resins, acrylonitrile butadiene styrene (ABS) resins, acrylic resins, polyimide resins, phenolic resins, epoxy resins, silicone resins, and urea resins.

Opposite Substrate

An opposite substrate may be disposed on the planarization layer. The opposite substrate is disposed at a position corresponding to the substrate described above and thus is called an opposite substrate. The opposite substrate may be composed of the same material as the substrate described above.

Organic Layer

The organic compound layer, such as the hole injection layer, the hole transport layer, the electron-blocking layer, the light-emitting layer, the hole-blocking layer, the electron transport layer, or the electron injection layer, included in the organic light-emitting device according to an embodiment of the present disclosure is formed by a method described below.

For the organic compound layer included in the organic light-emitting device according to an embodiment of the present disclosure, a dry process, such as a vacuum evaporation method, an ionized evaporation method, sputtering, or plasma, may be employed. Alternatively, instead of the dry process, it is also possible to employ a wet process in which a material is dissolved in an appropriate solvent and then a film is formed by a known coating method, such as spin coating, dipping, a casting method, a Langmuir-Blodgett (LB) technique, or an ink jet method.

In the case where the layer is formed by, for example, the vacuum evaporation method or the solution coating method, crystallization and so forth are less likely to occur, and good stability with time is obtained. In the case of forming a film by the coating method, the film may be formed in combination with an appropriate binder resin.

Non-limiting examples of the binder resin include poly(vinyl carbazole) resins, polycarbonate resins, polyester resins, acrylonitrile butadiene styrene (ABS) resins, acrylic resins, polyimide resins, phenolic resins, epoxy resins, silicone resins, and urea resins.

These binder resins may be used alone as a homopolymer or copolymer or in combination as a mixture of two or more. Furthermore, additives, such as a known plasticizer, antioxidant, and ultraviolet absorber, may be used, as needed.

Application of Organic Light-Emitting Device According to Embodiment of the Present Disclosure

The organic light-emitting device according to an embodiment can be used as a component member of a display apparatus or lighting apparatus. Other applications include exposure light sources for electrophotographic image-forming apparatuses, backlights for liquid crystal displays, and light-emitting devices including white-light sources and color filters.

The display apparatus may be an image information-processing unit having an image input unit that receives image information from an area or linear CCD sensor, a memory card, or any other source, an information-processing unit that processes the input information, and a display

unit that displays the input image. The display apparatus includes multiple pixels, and at least one of the multiple pixels may include the organic light-emitting device according to the embodiment and a transistor coupled to the organic light-emitting device.

The display unit of an image pickup apparatus or an inkjet printer may have a touch panel function. The driving mode of the touch panel function may be, but is not particularly limited to, an infrared mode, an electrostatic capacitance mode, a resistive film mode, or an electromagnetic inductive mode. The display apparatus may also be used for a display unit of a multifunction printer.

The following describes a display apparatus according to the embodiment with reference to the attached drawings. FIGS. 2A and 2B are each a schematic cross-sectional view of an example of a display apparatus including organic light-emitting devices and transistors coupled to the respective organic light-emitting devices. Each of the transistors is an example of an active element. The transistors may be thin-film transistors (TFTs).

FIG. 2A is an example of pixels that are components of the display apparatus according to the embodiment. Each of the pixels includes subpixels 10. The subpixels are separated into 10R, 10G, and 10B according to their light emission. The emission color may be distinguished based on the wavelength of light emitted from the light-emitting layer. Alternatively, light emitted from the subpixels may be selectively transmitted or color-converted with, for example, a color filter. Each subpixels 10 includes a reflective electrode serving as a first electrode 2, an insulating layer 3 covering the edge of the first electrode 2, an organic compound layer 4 covering the first electrode 2 and the insulating layer 3, a transparent electrode serving as a second electrode 5, a protective layer 6, and a color filter 7 over an interlayer insulating layer 1.

The transistors and capacitive elements may be disposed under or in the interlayer insulating layer 1.

Each transistor may be electrically coupled to a corresponding one of the first electrodes 2 through a contact hole (not illustrated).

The insulating layer 3 is also called a bank or pixel separation film. The insulating layer 3 covers the edge of each first electrode 2 and surrounds the first electrode 2. Portions that are not covered with the insulating layer 3 are in contact with the organic compound layer 4 and serve as light-emitting regions.

The organic compound layer 4 includes a hole injection layer 41, a hole transport layer 42, a first light-emitting layer 43, a second light-emitting layer 44, and an electron transport layer 45.

The second electrode 5 may be a transparent electrode, a reflective electrode, or a semi-transparent electrode.

The protective layer 6 reduces the penetration of moisture into the organic compound layer 4. Although the protective layer 6 is illustrated as a single layer, the protective layer 6 may include multiple layers, and each layer may be an inorganic compound layer or an organic compound layer.

The color filter 7 is separated into 7R, 7G, and 7B according to its color. The color filter 7 may be disposed on a planarization film (not illustrated). A resin protective layer (not illustrated) may be disposed on the color filter 7. The color filter 7 may be disposed on the protective layer 6. Alternatively, the color filter 7 may be disposed on an opposite substrate, such as a glass substrate, and then bonded.

A display apparatus 100 illustrated in FIG. 2B includes organic light-emitting devices 26 and TFTs 18 as an example

of transistors. A substrate 11 composed of a material, such as glass or silicon is provided, and an insulating layer 12 is disposed thereon. Active elements, such as the TFTs 18, are disposed on the insulating layer 12. The gate electrode 13, the gate insulating film 14, and the semiconductor layer 15 of each of the active elements are disposed thereon. Each TFT 18 further includes a drain electrode 16 and a source electrode 17. The TFTs 18 are overlaid with an insulating film 19. Anode 21 included in the organic light-emitting devices 26 is coupled to the source electrodes 17 through contact holes 20 provided in the insulating film 19.

The mode of electrical connection between the electrodes (anode 21 and cathode 23) included in each organic light-emitting device 26 and the electrodes (source electrode 17 and drain electrode 16) included in a corresponding one of the TFTs 18 is not limited to the mode illustrated in FIG. 2B. That is, it is sufficient that any one of the anode 21 and the cathode 23 is electrically coupled to any one of the source electrode 17 and the drain electrode 16 of the TFT 18. The term "TFT" refers to a thin-film transistor.

In the display apparatus 100 illustrated in FIG. 2B, although each organic compound layer 22 is illustrated as a single layer, the organic compound layer 22 may include multiple layers. To reduce the deterioration of the organic light-emitting devices 26, a first protective layer 24 and a second protective layer 25 are disposed on the cathodes 23.

In the display apparatus 100 illustrated in FIG. 2B, although the transistors are used as switching devices, other switching devices may be used instead.

The transistors used in the display apparatus 100 illustrated in FIG. 2B are not limited to transistors using a single-crystal silicon wafer, but may also be thin-film transistors including active layers on the insulating surface of a substrate. Examples of the material of the active layers include single-crystal silicon, non-single-crystal silicon, such as amorphous silicon and microcrystalline silicon; and non-single-crystal oxide semiconductors, such as indium zinc oxide and indium gallium zinc oxide. Thin-film transistors are also called TFT elements.

The transistors in the display apparatus 100 illustrated in FIG. 2B may be formed in the substrate, such as a Si substrate. The expression "formed in the substrate" indicates that the transistors are produced by processing the substrate, such as a Si substrate. In the case where the transistors are formed in the substrate, the substrate and the transistors can be deemed to be integrally formed.

In the organic light-emitting device according to the embodiment, the luminance is controlled by the TFT devices, which are an example of switching devices; thus, an image can be displayed at respective luminance levels by arranging multiple organic light-emitting devices in the plane. The switching devices according to the embodiment are not limited to the TFT devices and may be low-temperature polysilicon transistors or active-matrix drivers formed on a substrate such as a Si substrate. The expression "on a substrate" can also be said to be "in the substrate". Whether transistors are formed in the substrate or TFT devices are used is selected in accordance with the size of a display unit. For example, in the case where the display unit has a size of about 0.5 inches, organic light-emitting devices can be disposed on a Si substrate.

FIG. 3A is a schematic view of an example of an image-forming apparatus according to an embodiment of the present disclosure. An image-forming apparatus 40 is an electrophotographic image-forming apparatus and includes a photoconductor 27, an exposure light source 28, a charging unit 30, a developing unit 31, a transfer unit 32, a transport

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roller 33, and a fusing unit 35. The irradiation of light 29 is performed from the exposure light source 28 to form an electrostatic latent image on the surface of the photoconductor 27. The exposure light source 28 includes the organic light-emitting device according to the embodiment. The developing unit 31 contains, for example, a toner. The charging unit 30 charges the photoconductor 27. The transfer unit 32 transfers the developed image to a recording medium 34. The transport roller 33 transports the recording medium 34. The recording medium 34 is paper, for example. The fusing unit 35 fixes the image formed on the recording medium 34.

FIGS. 3B and 3C each illustrate the exposure light source 28 and are each a schematic view illustrating multiple light-emitting portions 36 arranged on a long substrate. Arrows 37 are parallel to the axis of the photoconductor and each represent the row direction in which the organic light-emitting devices are arranged. The row direction is the same as the direction of the axis on which the photoconductor 27 rotates. This direction can also be referred to as the long-axis direction of the photoconductor 27. FIG. 3B illustrates a configuration in which the light-emitting portions 36 are arranged in the long-axis direction of the photoconductor 27. FIG. 3C is different from FIG. 3B in that the light-emitting portions 36 are arranged alternately in the row direction in a first row and a second row. The first row and the second row are located at different positions in the column direction. In the first row, the multiple light-emitting portions 36 are spaced apart. The second row has the light-emitting portions 36 at positions corresponding to the positions between the light-emitting portions 36 in the first row.

In other words, the multiple light-emitting portions 36 are also spaced apart in the column direction. The arrangement in FIG. 3C can be rephrased as, for example, a lattice arrangement, a staggered arrangement, or a checkered pattern.

FIG. 4 is a schematic view illustrating an example of a display apparatus according to the embodiment. A display apparatus 1000 may include a touch panel 1003, a display panel 1005, a frame 1006, a circuit substrate 1007, and a battery 1008 disposed between an upper cover 1001 and a lower cover 1009. The touch panel 1003 and the display panel 1005 are coupled to flexible printed circuits FPCs 1002 and 1004, respectively. The circuit substrate 1007 includes printed transistors. The battery 1008 need not be provided unless the display apparatus is a portable apparatus. The battery 1008 may be disposed at a different position even if the display apparatus is a portable apparatus.

The display apparatus according to the embodiment may include a color filter having red, green, and blue portions. In the color filter, the red, green, and blue portions may be arranged in a delta arrangement.

The display apparatus according to the embodiment may be used for the display unit of a portable terminal. In that case, the display apparatus may have both a display function and an operation function. Examples of the portable terminal include mobile phones such as smartphones, tablets, and head-mounted displays.

The display apparatus according to the embodiment may be used for a display unit of an image pickup apparatus including an optical unit including multiple lenses and an image pickup device that receives light passing through the optical unit. The image pickup apparatus may include a display unit that displays information acquired by the image pickup device. The display unit may be a display unit exposed to the outside of the image pickup apparatus or a

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display unit disposed in a finder. The image pickup apparatus may be a digital camera or a digital camcorder.

FIG. 5A is a schematic view illustrating an example of an image pickup apparatus according to the embodiment. An image pickup apparatus 1100 may include a viewfinder 1101, a rear display 1102, an operation unit 1103, and a housing 1104. The viewfinder 1101 may include the display apparatus according to the embodiment. In this case, the display apparatus may display environmental information, imaging instructions, and so forth in addition to an image to be captured. The environmental information may include, for example, the intensity of external light, the direction of external light, the moving speed of a subject, and the possibility that a subject is shielded by a shielding material. The timing suitable for imaging is only for a short time; thus, the information may be displayed as soon as possible. The display apparatus including the organic light-emitting device can be used more suitably than liquid crystal displays because the organic light-emitting device has a fast response time. The display apparatus including the organic light-emitting device can be used more suitably than liquid crystal displays for such apparatuses required to have a high display speed.

The image pickup apparatus 1100 includes an optical unit (not illustrated). The optical unit includes multiple lenses and is configured to form an image on an image pickup element in the housing 1104. The relative positions of the multiple lenses can be adjusted to adjust the focal point. This operation can also be performed automatically. The image pickup apparatus may translate to a photoelectric conversion apparatus. Examples of an image capturing method employed in the photoelectric conversion apparatus may include a method for detecting a difference from the previous image and a method of cutting out an image from images always recorded, instead of sequentially capturing images.

FIG. 5B is a schematic view illustrating an example of an electronic apparatus according to the embodiment. An electronic apparatus 1200 includes a display unit 1201, an operation unit 1202, and a housing 1203. The housing 1203 may accommodate a circuit, a printed circuit board including the circuit, a battery, and a communication unit. The operation unit 1202 may be a button or a touch-screen-type reactive unit. The operation unit 1202 may be a biometric recognition unit that recognizes a fingerprint to release the lock or the like. An electronic apparatus having a communication unit can also be referred to as a communication apparatus. The electronic apparatus 1200 may further have a camera function by being equipped with a lens and an image pickup device. An image captured by the camera function is displayed on the display unit 1201. Examples of the electronic apparatus 1200 include smartphones and notebook computers.

FIG. 6A is a schematic view illustrating an example of the display apparatus according to the embodiment. FIG. 6A illustrates a display apparatus, such as a television monitor or a PC monitor. A display apparatus 1300 includes a frame 1301 and a display unit 1302. The light-emitting device according to the embodiment may be used for the display unit 1302. The display apparatus 1300 includes a base 1303 that supports the frame 1301 and the display unit 1302. The base 1303 is not limited to the structure illustrated in FIG. 6A. The lower side of the frame 1301 may also serve as a base. The frame 1301 and the display unit 1302 may be curved. These may have a radius of curvature of 5,000 mm or more and 6,000 mm or less.

FIG. 6B is a schematic view illustrating another example of a display apparatus according to the embodiment. A

display apparatus **1310** illustrated in FIG. 6B can be folded and is what is called a foldable display apparatus. The display apparatus **1310** includes a first display portion **1311**, a second display portion **1312**, a housing **1313**, and an inflection point **1314**. The first display portion **1311** and the second display portion **1312** may include the light-emitting device according to the embodiment. The first display portion **1311** and the second display portion **1312** may be a single, seamless display apparatus. The first display portion **1311** and the second display portion **1312** can be divided from each other at the inflection point. The first display portion **1311** and the second display portion **1312** may display different images. Alternatively, a single image may be displayed in the first and second display portions.

FIG. 7A is a schematic view illustrating an example of a lighting apparatus according to the embodiment. A lighting apparatus **1400** may include a housing **1401**, a light source **1402**, a circuit board **1403**, an optical filter **1404** that transmits light emitted from the light source **1402**, and a light diffusion unit **1405**. The light source **1402** may include an organic light-emitting device according to the embodiment. The optical filter **1404** may be a filter that improves the color rendering properties of the light source. The light diffusion unit **1405** can effectively diffuse light from the light source to deliver the light to a wide range when used for illumination and so forth. The optical filter **1404** and the light diffusion unit **1405** may be disposed at the light emission side of the lighting apparatus. A cover may be disposed at the outermost portion, as needed.

The lighting apparatus is, for example, an apparatus that lights a room. The lighting apparatus may emit light of white, neutral white, or any color from blue to red. A light control circuit that controls the light may be provided.

The lighting apparatus may include the organic light-emitting device according to the embodiment and a power supply circuit coupled thereto. The power supply circuit is a circuit that converts an AC voltage into a DC voltage. The color temperature of white is 4,200 K, and the color temperature of neutral white is 5,000 K. The lighting apparatus may include a color filter.

The lighting apparatus according to the embodiment may include a heat dissipation unit. The heat dissipation unit is configured to release heat in the device to the outside of the device and is composed of, for example, a metal having a high specific heat and liquid silicone.

FIG. 7B is a schematic view illustrating an automobile as an example of a moving object. The automobile includes a tail lamp, which is an example of lighting units. An automobile **1500** includes a tail lamp **1501** and may be configured to light the tail lamp when a brake operation or the like is performed.

The tail lamp **1501** may include an organic light-emitting device according to the embodiment. The tail lamp **1501** may include a protective member that protects the organic light-emitting device. The protective member may be composed of any transparent material having high strength to some extent and can be composed of, for example, polycarbonate. The polycarbonate may be mixed with, for example, a furandicarboxylic acid derivative or an acrylonitrile derivative.

The automobile **1500** may include an automobile body **1503** and windows **1502** attached thereto. The windows **1502** may be transparent displays if the windows are not used to check the front and back of the automobile. The transparent displays may include an organic light-emitting device according to the embodiment.

In this case, the components, such as the electrodes, of the organic light-emitting device are formed of transparent members.

The moving object according to the embodiment may be, for example, a ship, an aircraft, or a drone. The moving object may include a body and a lighting unit attached to the body. The lighting unit may emit light to indicate the position of the body. The lighting unit includes the organic light-emitting device according to the embodiment.

Examples of applications of the display apparatuses of the above embodiments will be described with reference to FIGS. 8A and 8B. The display apparatuses can be used for systems that can be worn as wearable devices, such as smart glasses, head-mounted displays (HMDs), and smart contacts. An image pickup and display apparatus used in such an example of the applications has an image pickup apparatus that can photoelectrically convert visible light and a display apparatus that can emit visible light.

FIG. 8A is a schematic view illustrating an example of a wearable device according to an embodiment of the present disclosure. Glasses **1600** (smart glasses) according to an example of applications will be described with reference to FIG. 8A. An image pickup apparatus **1602**, such as a complementary metal-oxide semiconductor (CMOS) sensor or a single-photon avalanche diode (SPAD), is provided on a front side of a lens **1601** of the glasses **1600**. The display apparatus according to any of the above-mentioned embodiments is provided on the back side of the lens **1601**.

The glasses **1600** further include a control unit **1603**. The control unit **1603** functions as a power source that supplies electric power to the image pickup apparatus **1602** and the display apparatus. The control unit **1603** controls the operation of the image pickup apparatus **1602** and the display apparatus. The lens **1601** has an optical system for focusing light on the image pickup apparatus **1602**.

FIG. 8B is a schematic view illustrating another example of a wearable device according to an embodiment of the present disclosure. Glasses **1610** (smart glasses) according to an example of applications will be described with reference to FIG. 8B. The glasses **1610** include a control unit **1612**. The control unit **1612** includes an image pickup apparatus corresponding to the image pickup apparatus **1602** illustrated in FIG. 8A and a display apparatus. A lens **1611** is provided with the image pickup apparatus in the control unit **1612** and an optical system that projects light emitted from the display apparatus. An image is projected onto the lens **1611**. The control unit **1612** functions as a power source that supplies electric power to the image pickup apparatus and the display apparatus and controls the operation of the image pickup apparatus and the display apparatus.

The control unit **1612** may include a gaze detection unit that detects the gaze of a wearer. Infrared light may be used for gaze detection. An infrared light-emitting unit emits infrared light to an eyeball of a user who is gazing at a displayed image. An image of the eyeball is captured by detecting the reflected infrared light from the eyeball with an image pickup unit having light-receiving elements. The deterioration of image quality is reduced by providing a reduction unit that reduces light from the infrared light-emitting unit to the display unit when viewed in plan. The user's gaze at the displayed image is detected from the image of the eyeball captured with the infrared light. Any known method can be employed to the gaze detection using the captured image of the eyeball. As an example, a gaze detection method based on a Purkinje image of the reflection of irradiation light on a cornea can be employed. More specifically, the gaze detection process is based on a pupil-

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corneal reflection method. Using the pupil-corneal reflection method, the user's gaze is detected by calculating a gaze vector representing the direction (rotation angle) of the eyeball based on the image of the pupil and the Purkinje image contained in the captured image of the eyeball.

A display apparatus according to an embodiment of the present disclosure may include an image pickup apparatus including light-receiving elements, and may control an image displayed on the display apparatus based on the gaze information of the user from the image pickup apparatus. Specifically, in the display apparatus, a first field of view at which the user gazes and a second field of view other than the first field of view are determined on the basis of the gaze information. The first field of view and the second field of view may be determined by the control unit of the display apparatus or may be determined by receiving those determined by an external control unit. In the display area of the display apparatus, the display resolution of the first field of view may be controlled to be higher than the display resolution of the second field of view. That is, the resolution of the second field of view may be lower than that of the first field of view.

The display area includes a first display area and a second display area different from the first display area. Based on the gaze information, an area of higher priority is determined from the first display area and the second display area. The first display area and the second display area may be determined by the control unit of the display apparatus or may be determined by receiving those determined by an external control unit. The resolution of an area of higher priority may be controlled to be higher than the resolution of an area other than the area of higher priority. In other words, the resolution of an area of a relatively low priority may be low.

Artificial intelligence (AI) may be used to determine the first field of view or the high-priority area. The AI may be a model configured to estimate the angle of gaze from the image of the eyeball and the distance to a target object located in the gaze direction, using the image of the eyeball and the actual direction of gaze of the eyeball in the image as teaching data. The AI program may be stored in the display apparatus, the image pickup apparatus, or an external apparatus. When the AI program is stored in the external apparatus, the AI program is transmitted to the display apparatus via communications.

In the case of controlling the display based on visual detection, smart glasses that further include an image pickup apparatus that captures an external image can be used. The smart glasses can display the captured external information in real time.

As described above, the use of an apparatus including the organic light-emitting device according to the embodiment enables a stable display with good image quality even for a long time.

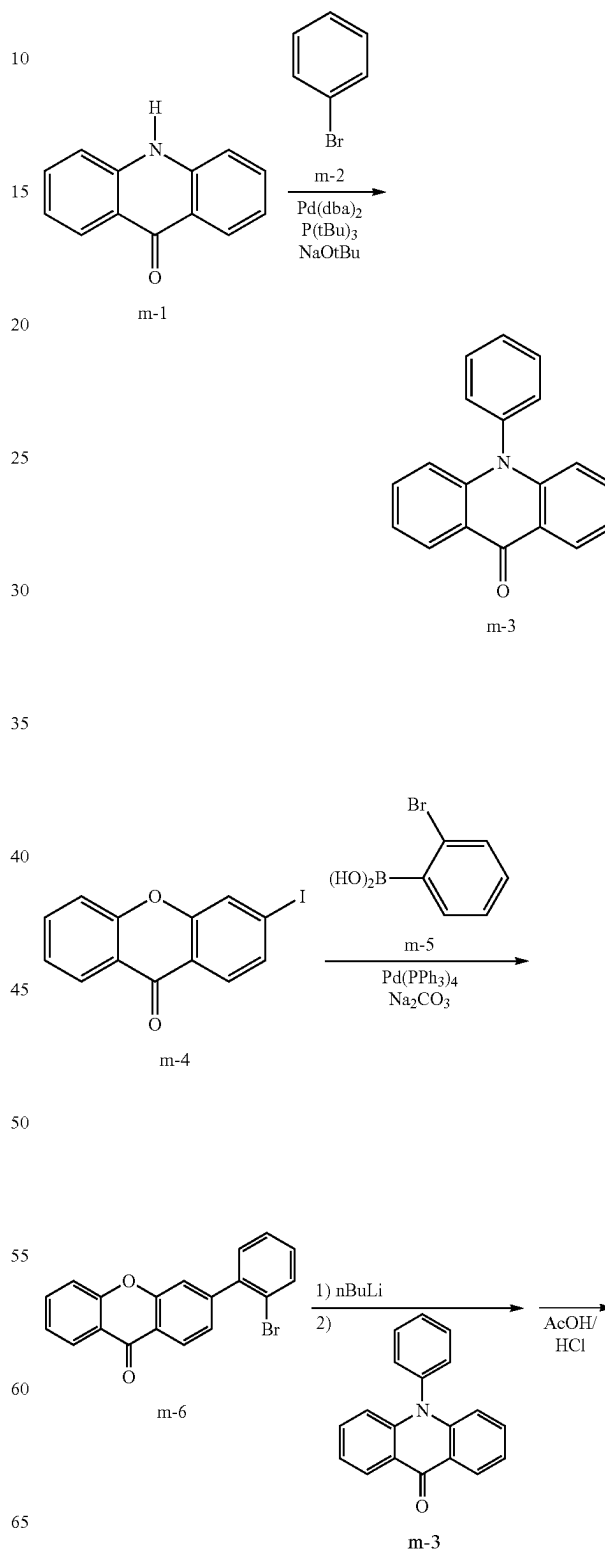
EXAMPLES

While the present disclosure will be described below by examples, the present disclosure is not limited to these examples.

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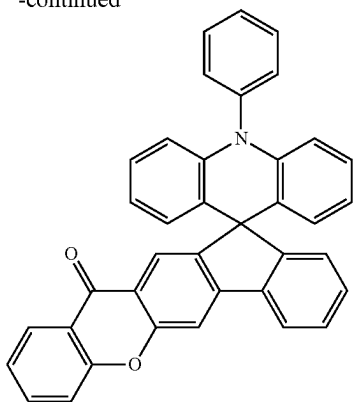
Example 1: Synthesis of Exemplified Compound C-1

Exemplified compound C-1 was synthesized according to the following scheme.



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-continued



C-1

(1) Synthesis of Compound m-3

The following reagents and solvent were placed in a 200-mL recovery flask.

Compound m-1: 3.9 g (20.0 mmol)

Compound m-2: 3.1 g (20.0 mmol)

Sodium tert-butoxide: 5.8 g (60.0 mmol)

Pd(dba)₃: 575 mg

Tri-tert-butylphosphine: 606 mg

o-Xylene: 60 mL

The reaction solution was heated and stirred at 140° C. for 5 hours under a stream of nitrogen. After the completion of the reaction, filtration was performed through Celite, and then the filtrate was concentrated to dryness. The resulting solid was purified by silica gel column chromatography (toluene-ethyl acetate mixture) to give 4.1 g of m-3 as a yellowish white solid (yield: 76%).

(2) Synthesis of Compound m-6

The following reagents and solvents were placed in a 200-mL recovery flask.

Compound m-4: 3.2 g (10.0 mmol)

Compound m-5: 2.2 g (11.0 mmol)

Sodium carbonate: 5.3 g (50.0 mmol)

Pd(PPh₃)₄: 478 mg

Toluene: 35 mL

Water: 35 mL

Ethanol: 10 mL

The reaction solution was heated and stirred at 60° C. for 5 hours under a stream of nitrogen. After the completion of

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the reaction, extraction was performed with toluene, and then the organic layer was concentrated to dryness. The resulting solid was purified by silica gel column chromatography (toluene-ethyl acetate mixture) to give 1.9 g of m-6 as a yellow solid (yield: 54%).

(3) Synthesis of Compound C-1

The following reagent and solvent were placed in a 200-mL recovery flask. Compound m-6: 1.8 g (5.0 mmol) THF: 70 mL

The reaction solution was cooled to -78° C. under a stream of nitrogen, and then 8.3 mL of n-BuLi (0.6 M) was added dropwise thereto. After the dropwise addition, the reaction solution was stirred at room temperature for 2 hours. The reaction mixture was again cooled to -78° C., and then 10 mL of a solution of 1.4 g (5.0 mmol) of compound m-3 in THF was added dropwise thereto. After the dropwise addition, the reaction mixture was stirred at room temperature for 4 hours. After the completion of the reaction, the reaction mixture was poured into ice water and extracted with toluene. The organic layer was concentrated to dryness to give a solid.

The resulting solid was dissolved in 80 mL of acetic acid under a stream of nitrogen. Then 1.5 mL of concentrated hydrochloric acid was added dropwise to the resulting solution. The reaction mixture was stirred at room temperature for 5 hours. After the completion of the reaction, the reaction mixture was poured into ice water, and the precipitated solid was filtered. The resulting solid was purified by silica gel column chromatography (toluene-ethyl acetate mixture) to give 1.2 g of exemplified compound C-1 (yield: 22%).

Exemplified compound C-1 was subjected to mass spectrometry with MALDI-TOF-MS (Bruker Autoflex LRF).

MALDI-TOF-MS

Measured value: m/z=526

Calculated value: C₃₈H₂₃NO₂=526

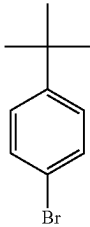
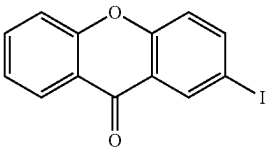
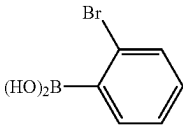
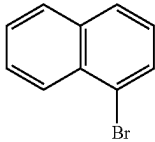
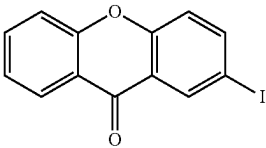
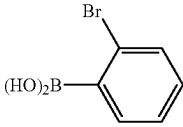
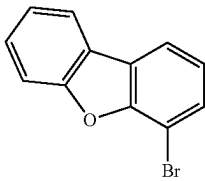
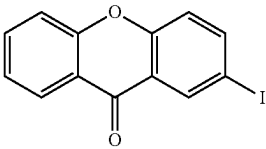
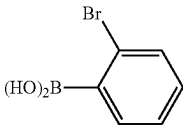
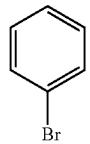
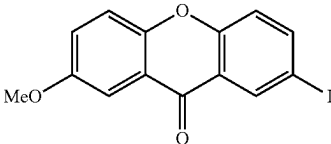
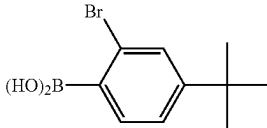
Examples 2 to 14: Synthesis of Exemplified Compounds

As presented in the following table, exemplified compounds of Examples 2 to 14 were synthesized as in Example 1, except that raw material m-2 of Example 1 was changed to raw material 1, raw material m-4 to raw material 2, and raw material m-5 to raw material 3. The resulting exemplified compounds were subjected to mass spectrometry as in Example 1. The measured values (m/z) are presented.

TABLE 1

Example	Exemplified compound	Raw material 1	Raw material 2	Raw material 3	m/z
2	C-2				554
3	C-13				526

TABLE 1-continued

Example	Exemplified compound	Raw material 1	Raw material 2	Raw material 3	m/z
4	C-15				582
5	C-18				576
6	C-21				616
7	C-24				706

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TABLE 2

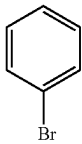
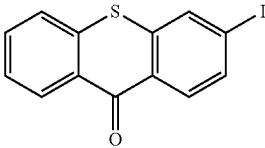
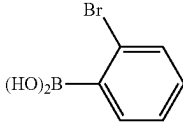
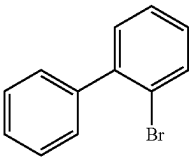
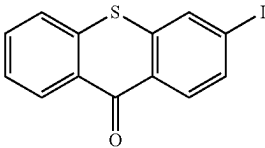
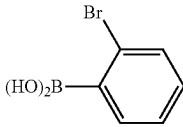
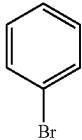
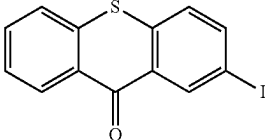
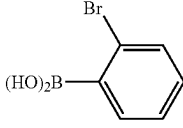
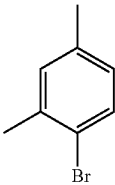
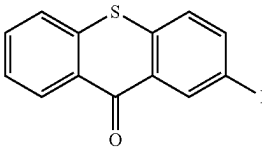
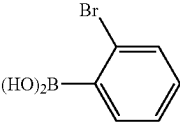
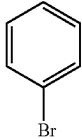
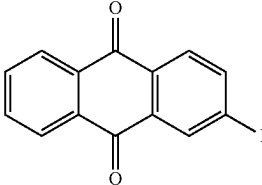
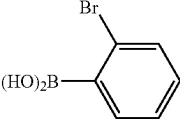
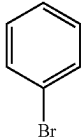
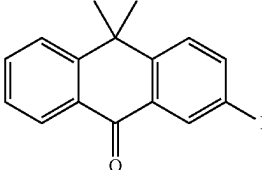
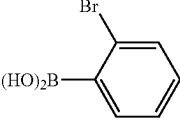
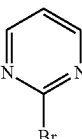
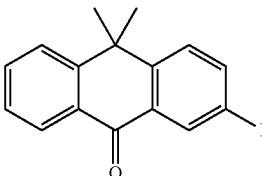
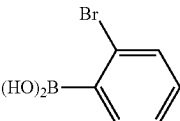
Example	Exemplified compound	Raw material 1	Raw material 2	Raw material 3	m/z
8	D-1				542
9	D-4				618
10	D-13				542

TABLE 2-continued

Example	Exemplified compound	Raw material 1	Raw material 2	Raw material 3	m/z
11	D-14				570
12	G-1				578
13	F-13				537
14	F-22				554

Example 15

In this Example, an organic light-emitting device having a bottom-emission structure was produced in which an anode, a hole injection layer, a hole transport layer, an electron-blocking layer, a light-emitting layer, a hole-blocking layer, an electron transport layer, an electron injection layer, and a cathode were sequentially formed on a substrate.

An ITO film was formed on a glass substrate and subjected to desired patterning to form an ITO electrode (anode). The ITO electrode had a thickness of 100 nm. The substrate on which the ITO electrode had been formed in this way was used as an ITO substrate in the following steps. Next, vacuum evaporation was performed by resistance heating in a vacuum chamber to continuously form organic compound layers and an electrode layer presented in Table 3 on the ITO substrate. Here, the opposing electrode (metal electrode layer, cathode) had an electrode area of 3 mm². The "percentage (%)" in Table 3 is percentage by mass.

TABLE 3

	Material		Thickness (nm)
	Cathode	Al	100
	Electron injection layer (EIL)	LiF	1
50	Electron transport layer (ETL)	ET2	15
	Hole-blocking layer (HBL)	ET12	15
	light-emitting material		
	host		
55	Light-emitting layer (EML)	EM10	20
	Light-emitting layer, percentage (%)	88	12
	Electron-blocking layer (EBL)	HT13	15
	Hole transport layer (HTL)	HT2	30
60	Hole injection layer (HIL)	HT16	5

The characteristics of the resulting device were measured and evaluated. As the initial characteristics associated with the light emission, green light emission with a maximum external quantum efficiency (E.Q.E.) of 5.8% was obtained. With regard to measurement instruments, specifically, the current-voltage characteristics were measured with a Hewlett-Packard 4140B microammeter, and the luminance was

measured with a Topcon BM7. The device was subjected to a continuous operation test at a current density of 50 mA/cm². The time when the percentage of luminance degradation reached 5% (LT95) was measured to be 122 hours.

Examples 16 to 20

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Organic light-emitting devices were produced in the same manner as in Example 15, except that the compounds used in Example 15 were changed to compounds listed in Table 4 as appropriate. The characteristics of the resulting device were measured and evaluated as in Example 15. Table 4 presents the measurement results.

TABLE 4

	EML				HBL	ETL	E.Q.E. [%]	LT95 [h]	Emission color
	HTL	EBL	Host	Light-emitting material					
Example 16	HT2	HT12	EM11	C-2	ET12	ET2	5.9	118	green
Example 17	HT3	HT11	EM9	D-1	ET12	ET2	5.8	123	green
Example 18	HT3	HT12	EM9	D-4	ET12	ET2	5.9	109	green
Example 19	HT2	HT11	EM14	C-13	ET12	ET2	5.4	102	blue
Example 20	HT2	HT11	EM32	D-14	ET12	ET5	5.4	103	blue

Example 21

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An organic light-emitting device was produced in the same manner as in Example 15, except that the organic compound layers and the electrode layer listed in Table 5 were continuously deposited. The “percentage (%)” in Table 5 is percentage by mass.

TABLE 5

	Material		Thickness (nm)	
Cathode	Al		100	
Electron injection layer (EIL)	LiF		1	
Electron transport layer (ETL)	ET2		15	45
Hole-blocking layer (HBL)	ET11		15	
	assist host	light-emitting material		
Light-emitting layer (EML)	EM11	C-1	GD6	20
Light-emitting layer, percentage (%)	82	15	3	
Electron-blocking layer (EBL)	HT13		15	55
Hole transport layer (HTL)	HT2		30	
Hole injection layer (HIL)	HT16		5	

The characteristics of the resulting device were measured and evaluated as in Example 20. As the initial characteristics associated with the light emission, green light emission with a maximum external quantum efficiency (E.Q.E.) of 6.9% was obtained. The device was subjected to a continuous operation test at a current density of 50 mA/cm². The time when the percentage of luminance degradation reached 5% (LT95) was measured to be 158 hours.

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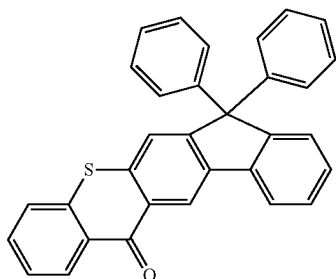
Examples 22 to 38 and Comparative Examples 1 and 2

Organic light-emitting devices were produced in the same manner as in Example 21, except that the compounds used

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in Example 21 were changed to compounds listed in Table 6 as appropriate. The characteristics of the resulting devices were measured and evaluated as in Example 21. Table 6 presents the measurement results. The guest materials used in the comparative examples are illustrated below.

Comparative compound J-1



Comparative compound J-2

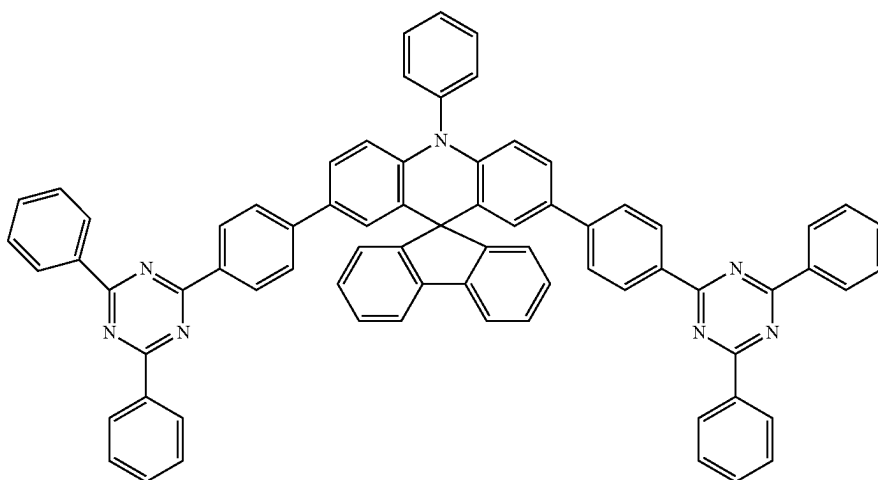


TABLE 6

	EML									
	HTL	EBL	Host	Assist	Light-emitting material	HBL	ETL	E.Q.E [%]	LT95 [h]	Emission color
Example 22	HT2	HT10	EM11	C-2	GD6	ET11	ET4	6.9	156	green
Example 23	HT3	HT11	EM11	C-15	GD6	ET11	ET2	6.8	161	green
Example 24	HT2	HT12	EM10	C-13	GD8	ET11	ET2	6.8	160	green
Example 25	HT2	HT11	EM13	D-1	GD8	ET12	ET2	6.7	155	green
Example 26	HT2	HT10	EM32	C-1	GD7	ET12	ET5	6.9	124	green
Example 27	HT6	HT11	EM32	D-1	GD9	ET12	ET2	7.0	132	green
Example 28	HT2	HT12	EM11	F-13	GD1	ET11	ET2	6.4	92	green
Example 29	HT3	HT11	EM14	D-1	GD1	ET12	ET2	6.3	89	green
Example 30	HT3	HT10	EM32	F-13	GD4	ET11	ET2	6.2	75	green
Example 31	HT2	HT12	EM11	F-13	GD2	ET12	ET2	6.3	91	green
Example 32	HT2	HT12	EM9	C-2	RD1	ET12	ET4	7.0	180	red
Example 33	HT3	HT10	EM9	C-1	RD1	ET12	ET2	6.8	181	red
Example 34	HT2	HT12	EM14	D-1	RD1	ET11	ET5	7.2	175	red
Example 35	HT3	HT10	EM32	D-1	RD1	ET12	ET2	7.1	154	red
Example 36	HT2	HT12	EM32	F-13	RD1	ET11	ET5	7.0	150	red
Example 37	HT3	HT11	EM11	G-1	RD2	ET11	ET2	6.4	125	red
Example 38	HT3	HT12	EM14	G-1	RD2	ET12	ET2	6.3	105	red
Comparative example 1	HT2	HT11	EM11	J-1	GD6	ET12	ET2	3.8	38	green
Comparative example 2	HT2	HT11	EM11	J-2	GD6	ET12	ET2	3.9	35	green

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Table 6 indicates that in each of Comparative examples 1 and 2, the maximum external quantum efficiency (E.Q.E.) was as low as 4.0 or less. The reason for this is that the large difference between S_1 and T_1 results in the absence of an emission component based on delayed fluorescence. Each of the devices containing the compounds according to embodiments of the present disclosure had a small difference between S_1 and T_1 because of the presence of the acridine ring and the carbonyl group-containing ring via the spiro structure, and exhibited high luminous efficiency owing to delayed fluorescence. In each of the devices containing the compounds according to embodiments of the present disclosure, the 5% degradation lifetime (LT95) was 100 hours or more, indicating good durability characteristics.

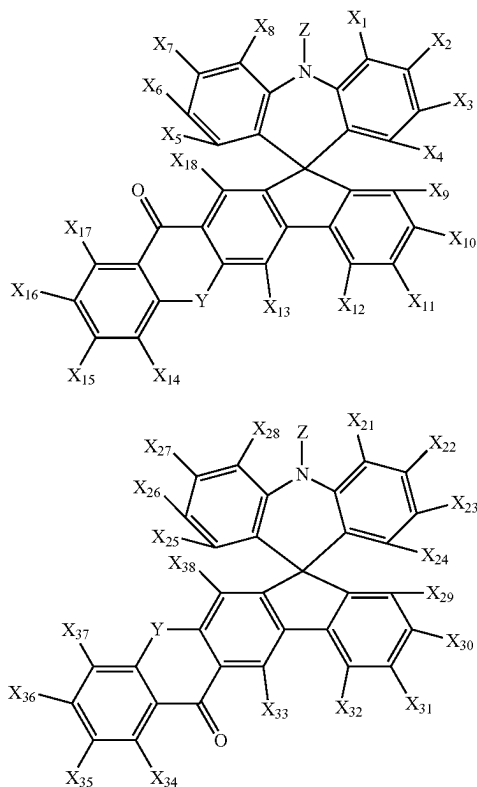
The organic compounds according to the embodiments of the present disclosure are less likely to cause molecular association, and thus concentration quenching can be reduced. Thus, when the organic compounds according to embodiments of the present disclosure are used in organic light-emitting devices, it is possible to provide the organic light-emitting devices having superior luminous efficiency and driving durability characteristics.

While the present disclosure has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2021-018115 filed Feb. 8, 2021, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An organic compound represented by formula [1] or [2]:



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where in formulae [1] and [2], X_1 to X_{18} and X_{21} to X_{38} are each independently selected from the group consisting of a hydrogen atom, a halogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted amino group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, a substituted or unsubstituted aryloxy group, a substituted or unsubstituted heteroaryloxy group, a silyl group, and a cyano group,

Y is oxygen, sulfur, selenium, tellurium, a CR_1R_2 group, or a carbonyl group, where R_1 and R_2 are each independently selected from the group consisting of a hydrogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted amino group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, a substituted or unsubstituted aryloxy group, a substituted or unsubstituted heteroaryloxy group, a silyl group, and a cyano group, and

Z is a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic group.

2. The organic compound according to claim 1, wherein Y is oxygen or sulfur.

3. The organic compound according to claim 1, wherein Z is a substituted or unsubstituted aryl group.

4. An organic light-emitting device, comprising:

a first electrode;

a second electrode; and

at least one organic compound layer disposed between the first electrode and the second electrode,

wherein at least one layer of the at least one organic compound layer contains the organic compound according to claim 1.

5. The organic light-emitting device according to claim 4, wherein the at least one layer containing the organic compound is a light-emitting layer.

6. The organic light-emitting device according to claim 5, wherein the light-emitting layer contains a host material having a higher lowest excited singlet level than the organic compound.

7. The organic light-emitting device according to claim 6, wherein the host material is a hydrocarbon compound.

8. The organic light-emitting device according to claim 6, wherein the light-emitting layer contains a light-emitting material.

9. The organic light-emitting device according to claim 8, wherein the light-emitting material is a hydrocarbon compound.

10. The organic light-emitting device according to claim 5, wherein the light-emitting layer emits green light or red light.

11. A display apparatus, comprising:

multiple pixels,

at least one of the multiple pixels including:

the organic light-emitting device according to claim 4, and

an active element coupled to the organic light-emitting device.

12. A photoelectric conversion apparatus, comprising:

an optical unit including multiple lenses;

an image pickup device configured to receive light passing through the optical unit; and

a display unit configured to display an image captured by the image pickup device,

wherein the display unit includes the organic light-emitting device according to claim 4.

13. An electronic apparatus, comprising:

a display unit including the organic light-emitting device according to claim 4;

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a housing provided with the display unit; and

a communication unit being disposed in the housing and communicating with an outside unit.

14. A lighting apparatus, comprising:

a light source including the organic light-emitting device according to claim 4; and

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a light diffusion unit or an optical filter configured to transmit light emitted from the light source.

15. A moving object, comprising:

a lighting unit including the organic light-emitting device according to claim 4; and

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a body provided with the lighting unit.

16. An exposure light source for an electrophotographic image-forming apparatus, comprising:

the organic light-emitting device according to claim 4.

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* * * * *