

(19)



(11)

EP 2 372 804 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:

05.10.2011 Bulletin 2011/40

(51) Int Cl.:

H01L 51/50 ^(2006.01) **C07C 13/66** ^(2006.01)
C07C 15/30 ^(2006.01) **C07C 15/38** ^(2006.01)
C07F 7/08 ^(2006.01) **C09K 11/06** ^(2006.01)

(21) Application number: **09834978.0**

(22) Date of filing: **24.12.2009**

(86) International application number:

PCT/JP2009/071501

(87) International publication number:

WO 2010/074181 (01.07.2010 Gazette 2010/26)

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL
PT RO SE SI SK SM TR**

(30) Priority: **26.12.2008 JP 2008334927**

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(54) **ORGANIC ELECTROLUMINESCENCE ELEMENT AND COMPOUND**

(57) An organic electroluminescence device composed of a cathode, an anode, and an organic thin film layer between the cathode and the anode. The organic thin film layer includes one or more layers. At least one layer of the organic thin film layer is a light emitting layer and at least one light emitting layer contains a compound

which is asymmetric with respect to the central benzene ring and a phosphorescent emitting material. The compound provides an organic electroluminescence device with long lifetime and high current efficiency.

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Description

TECHNICAL FIELD

[0001] The present invention relates to an organic electroluminescence device (may be referred to as "organic EL device") and a compound, and particularly relates to an organic electroluminescence device having a red-emitting layer and the compound.

BACKGROUND ART

[0002] An organic electroluminescence device, which has an organic thin film layer including a light emitting layer between an anode and a cathode and which emits light from an exciton energy resulted from the recombination of holes and electrons injected into the light emitting layer, has been known.

Sine the organic electroluminescence device is a spontaneous emitting device, it has been expected to be applicable, using its advantages, to a light emitting device with high current efficiency, high image quality, low power consumption and wide design freedom for thinner products.

[0003] The organic electroluminescence device has been still required to be further improved in its properties, for example, in the current efficiency.

In this regard, to enhance the internal quantum efficiency, a light emitting material (phosphorescent material) which emits light from triplet exciton has been developed, and a phosphorescent organic electroluminescence device are reported in recent years.

By forming a light emitting layer (phosphorescent layer) using the above phosphorescent material, an internal quantum efficiency of 75 % or more, theoretically about 100 % is obtained, to realize an organic electroluminescence device having high efficiency and low power consumption.

[0004] Further, a doping method in which a light emitting material is doped as a dopant into a host material for forming a light emitting layer is known.

In a doped light emitting layer, excitons can be efficiently generated from charges injected into a host material. The exciton energy of generated excitons is transferred to a dopant, and this allows the dopant to emit light in high efficiency. To intermolecularly transfer the energy from a host material to a phosphorescent dopant, the excited triplet energy E_{gH} of the host material has to be larger than the excited triplet energy E_{gD} of the phosphorescent dopant.

[0005] CBP (4,4'-bis(N-carbazolyl)biphenyl) is a well known material which has an effectively large excited triplet energy (Patent Document 1).

If CBP is used as a host material, the energy can be transferred to a phosphorescent dopant which emits light with a specific wavelength (for example, green and red), and an organic electroluminescence device having high efficiency can be obtained.

When CBP is used as a host material, the current efficiency is drastically enhanced by phosphorescent emission on one hand, but the lifetime is very short to make the device unsuitable for practical use on the other hand.

This may be because that CBP has a molecular structure less resistant to oxidation and therefore its molecule is largely degraded by holes.

Patent Document 2 discloses a technique in which a condensed ring derivative having a nitrogen-containing ring such as carbazole is used as a host material for a red-emitting phosphorescent layer. This technique enables the improvement of current efficiency and lifetime, but is not satisfactory for practical application in some cases.

[0006] A wide variety of fluorescent host materials (fluorescent hosts) for a fluorescent dopant is known, and various host materials which can form, in combination with a fluorescent dopant, a fluorescent layer excellent in current efficiency and lifetime are proposed.

The excited singlet energy $E_g(S)$ of a fluorescent host is larger than that of a fluorescent dopant, but its excited triplet energy $E_g(T)$ is not necessarily large. Therefore, the fluorescent host cannot be simply used as a host material (phosphorescent host) for a phosphorescent layer.

[0007] For example, an anthracene derivative is well known as a fluorescent host. However, the excited triplet energy $E_g(T)$ of anthracene derivative is as relatively small as about 1.9 eV. Therefore, the energy transfer to a phosphorescent dopant having an emission wavelength in a visible light region of 520 to 720 nm can not be secured. Further, the anthracene derivative cannot confine the excited triplet energy within a light emitting layer.

Therefore, the anthracene derivative is unsuitable as a phosphorescent host.

Further, perylene derivatives, pyrene derivatives and naphthacene derivatives are not preferred as a phosphorescent host for the same reason.

[0008] Patent Document 3 proposes to use an aromatic hydrocarbon compound as a phosphorescent host, which has a central benzene skeleton having two aromatic substituents at its meta positions.

However, the aromatic hydrocarbon compound described in Patent Document 3 has a molecular structure which bilat-

erally symmetrically extends with respect to the central benzene skeleton. Therefore, the light emitting layer would be likely to crystallize.

Patent Documents 4 to 9 disclose organic electroluminescence devices each employing an aromatic hydrocarbon compound. However, these documents are completely silent about the effectiveness of these compounds as a phosphorescent host.

[0009] Patent Document 10 discloses an organic EL device employing an aromatic hydrocarbon compound and a green-emitting Ir metal complex.

[0010]

Patent Document 1: US 2002/182441
 Patent Document 2: WO 2005/112519
 Patent Document 3: JP 2003-142267A
 Patent Document 4: WO 2007/046658
 Patent Document 5: JP2006-151966A
 Patent Document 6: JP2005-8588A
 Patent Document 7: JP2005-19219A
 Patent Document 8: JP2005-197262A
 Patent Document 9: JP2004-75567A
 Patent Document 10: JP2003-142267A

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0011] The aromatic hydrocarbon compound of Patent Document 10 has an essential structure composed of 5 aromatic rings, in which two aromatic hydrocarbon rings which are linked to each other are bonded to the central benzene ring at each of 1- and 3-positions or 1- and 2-positions. The inventors have found that the proposed compounds are easy to crystallize because of their symmetric structure with respect to the central benzene ring, and the compounds give uneven films particularly formed into films at 70°C to reduce the lifetime of device at room temperature.

As described above, a host material capable of efficiently causing a phosphorescent emitting material to emit and having a long practical lifetime has not yet been known, thereby preventing the application of the phosphorescent emitting material to practical devices.

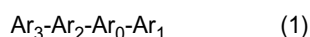
An object of the invention is to provide a phosphorescent organic electroluminescence device and compound with high efficiency and long lifetime.

MEANS FOR SOLVING THE PROBLEMS

[0012] As a result of extensive research for achieving the above object, the inventors have found that a phosphorescent organic electroluminescence device with high efficiency and long lifetime is obtained by using the compound represented by the following formula (1).

[0013] Namely, the present invention provides:

1. an organic electroluminescence device comprising a cathode, an anode, and an organic thin film layer between the cathode and the anode, wherein the organic thin film layer comprises one or more layers, at least one layer of the organic thin film layer is a light emitting layer, and at least one light emitting layer comprises a phosphorescent emitting material and a compound represented by formula (1):



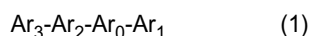
wherein Ar₀ is a substituted or unsubstituted benzene ring;

Ar₁ to Ar₃ are each independently a substituted or unsubstituted condensed aromatic hydrocarbon ring, the condensed aromatic hydrocarbon ring being selected from naphthalene ring, chrysene ring, fluoranthene ring, triphenylene ring, phenanthrene ring, benzophenanthrene ring, dibenzophenanthrene ring, benzotriphenylene ring, benzochrysene ring, benzo[b]fluoranthene ring, and picene ring, with the proviso that Ar₁ and Ar₂ are the same condensed aromatic hydrocarbon ring, numbers of substituents of Ar₁ and Ar₂ may be the same or different, and kinds of substituents of Ar₁ and Ar₂ may be the same or different;

Ar₀, Ar₁, Ar₂, and Ar₃ may be substituted by at least one group selected from an alkyl group having 1 to 20

carbon atoms, a haloalkyl group having 1 to 20 carbon atoms, a cycloalkyl group having 5 to 18 carbon atoms, a silyl group having 3 to 20 carbon atoms, a fluorene skeleton-containing group having 13 to 35 carbon atoms, dibenzofuranyl group, cyano group, and halogen atom; and
 when Ar₂ is naphthalene ring, Ar₀ and Ar₃ do not bond to 2- and 7-positions of the naphthalene ring;

2. the organic electroluminescence device of 1, wherein Ar₃ is a group selected from a substituted or unsubstituted phenanthrene ring, a substituted or unsubstituted fluoranthene ring, a substituted or unsubstituted benzophenanthrene ring, and a substituted or unsubstituted benzochrysene ring;
3. the organic electroluminescence device of 1, wherein an excited triplet energy of the compound is 2.0 eV or more and 2.8 eV or less;
4. the organic electroluminescence device of 1, wherein the phosphorescent emitting material comprises a metal complex which comprises a metal atom selected from Ir, Pt, Os, Au, Cu, Re, and Ru and a ligand;
5. the organic electroluminescence device of 4, wherein the ligand is an orthometalated ligand;
6. the organic electroluminescence device of 1, wherein at least one of the phosphorescent emitting materials emits light with a maximum wavelength of 520 nm or more and 720 nm or less;
7. the organic electroluminescence device of 1, wherein an electron transporting layer or an electron injecting layer is disposed as the organic thin film layer between the cathode and the light emitting layer, and the electron transporting layer or the electron injecting layer contains the compound represented by formula (1);
8. the organic electroluminescence device of 1, wherein an electron transporting layer or an electron injecting layer is disposed as the organic thin film layer between the cathode and the light emitting layer, and the electron transporting layer or the electron injecting layer contains an aromatic compound having a nitrogen-containing 6- or 5-membered ring or a condensed aromatic compound having a nitrogen-containing 6- or 5-membered ring;
9. the organic electroluminescence device of 1, wherein an interfacial region between the cathode and the organic thin film layer contains a reduction-causing dopant;
10. a compound represented by formula (1):



wherein Ar₀ is a substituted or unsubstituted benzene ring;
 Ar₁ to Ar₃ are each independently a substituted or unsubstituted condensed aromatic hydrocarbon ring, the condensed aromatic hydrocarbon ring being selected from naphthalene ring, chrysene ring, fluoranthene ring, triphenylene ring, phenanthrene ring, benzophenanthrene ring, dibenzophenanthrene ring, benzotriphenylene ring, benzochrysene ring, benzo[b]fluoranthene ring, and picene ring, with the proviso that Ar₁ and Ar₂ are the same condensed aromatic hydrocarbon ring, numbers of substituents of Ar₁ and Ar₂ may be the same or different, and kinds of substituents of Ar₁ and Ar₂ may be the same or different;
 Ar₀, Ar₁, Ar₂, and Ar₃ may be substituted by at least one group selected from an alkyl group having 1 to 20 carbon atoms, a haloalkyl group having 1 to 20 carbon atoms, a cycloalkyl group having 5 to 18 carbon atoms, a silyl group having 3 to 20 carbon atoms, a fluorene skeleton-containing group having 13 to 35 carbon atoms, dibenzofuranyl group, cyano group, and halogen atom; and
 when Ar₂ is naphthalene ring, Ar₀ and Ar₃ do not bond to 2- and 7-positions of the naphthalene ring; and

11. the compound of 10, wherein Ar₃ is a group selected from a substituted or unsubstituted phenanthrene ring, a substituted or unsubstituted fluoranthene ring, a substituted or unsubstituted benzophenanthrene ring, and a substituted or unsubstituted benzochrysene ring.

EFFECT OF THE INVENTION

[0014] According to the present invention, a phosphorescent organic electroluminescence device with high efficiency and long lifetime is obtained by using the compound represented by formula (1).

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a schematic illustration showing an embodiment of architecture of the organic electroluminescence device according to the present invention.

REFERENCE NUMERALS

[0016]

- 1: Organic electroluminescence device
- 2: Substrate
- 3: Anode
- 4: Cathode
- 5: Phosphorescent emitting layer
- 6: Hole injecting/transporting layer
- 7: Electron injecting/transporting layer
- 10: Organic thin film layer

BEST MODE FOR CARRYING OUT THE INVENTION

[0017] The embodiment of the present invention will be described below.

Device Architecture

[0018] First, the architecture of the organic electroluminescence device will be described. Representative architecture of the organic electroluminescence device includes, but not limited to,

- (1) anode/light emitting layer/cathode,
- (2) anode/hole injecting layer/light emitting layer/cathode,
- (3) anode/light emitting layer/electron injecting/transporting layer/cathode,
- (4) anode/hole injecting layer/light emitting layer/electron injecting/transporting layer/cathode,
- (5) anode/organic semiconductor layer/light emitting layer/cathode,
- (6) anode/organic semiconductor layer/electron blocking layer/light emitting layer/cathode,
- (7) anode/organic semiconductor layer/light emitting layer/adhesion improving layer/cathode,
- (8) anode/hole injecting/transporting layer/light emitting layer/electron injecting/transporting layer/cathode,
- (9) anode/insulating layer/light emitting layer/insulating layer/cathode,
- (10) anode/inorganic semiconductor layer/insulating layer/light emitting layer/insulating layer/cathode,
- (11) anode/organic semiconductor layer/insulating layer/light emitting layer/insulating layer/cathode,
- (12) anode/insulating layer/hole injecting/transporting layer/light emitting layer/insulating layer/cathode, and
- (13) anode/insulating layer/hole injecting/transporting layer/light emitting layer/electron injecting/transporting layer/cathode,

with the device architecture (8) being preferably used.

[0019] An example of the architecture of the organic electroluminescence device according to the present invention is schematically shown in Fig. 1.

The organic electroluminescence device 1 comprises a transparent substrate 2, an anode 3, a cathode 4, and an organic thin film layer 10 disposed between the anode 3 and the cathode 4.

The organic thin film layer 10 includes a phosphorescent emitting layer 5 comprising a phosphorescent host and a phosphorescent dopant. A hole injecting/transporting layer 6 may be disposed between the phosphorescent emitting layer 5 and the anode 3, and an electron injecting/transporting layer 7 may be disposed between the phosphorescent emitting layer 5 and the cathode 4.

An electron blocking layer may be formed on the side of the phosphorescent emitting layer 5 facing the anode 3, and a hole blocking layer may be formed on the side of the phosphorescent emitting layer 5 facing the cathode 4.

With such layers, electrons and holes are confined in the phosphorescent emitting layer 5, to facilitate the formation of excitons in the phosphorescent emitting layer 5.

[0020] In the present invention, the host is referred to as a fluorescent host when combinedly used with a fluorescent dopant and as a phosphorescent host when combinedly used with a phosphorescent dopant. Therefore, the fluorescent host and the phosphorescent host are not distinguished from each other merely by the difference in their molecular structures.

Namely, the term "fluorescent host" means a material for constituting a fluorescent emitting layer containing a fluorescent dopant and does not mean a material usable only as a host of a fluorescent material.

Similarly, the term "phosphorescent host" means a material for constituting a phosphorescent emitting layer containing a phosphorescent dopant and does not mean a material usable only as a host of a phosphorescent material.

[0021] In the present invention, the term "hole injecting/transporting layer" means a hole injecting layer, a hole transporting layer, or both, and the term "electron injecting/transporting layer" means an electron injecting layer, an electron transporting layer, or both.

Light-Transmissive Substrate

[0022] The organic electroluminescence device of the invention is formed on a light-transmissive substrate. The light-transmissive substrate serves as a support for the organic electroluminescence device and preferably a flat substrate having a transmittance of 50% or more to 400 to 700 nm visible light.

Examples of the substrate include a plate of glass and a plate of polymer.

The plate of glass may include a plate made of soda-lime glass, barium-strontium-containing glass, lead glass, aluminosilicate glass, borosilicate glass, barium borosilicate glass, or quartz.

The plate of polymer may include a plate made of polycarbonate resin, acrylic resin, polyethylene terephthalate resin, polyether sulfide resin, or polysulfone resin.

Anode and Cathode

[0023] The anode of the organic electroluminescence device injects holes to the hole injecting layer, the hole transporting layer or the light emitting layer, and an anode having a work function of 4.5 eV or more is effective.

Examples of material for anode include indium tin oxide alloy (ITO), tin oxide (NESA), indium zinc oxide alloy, gold, silver, platinum, and copper.

The anode is formed by making the electrode material into a thin film by a method, such as a vapor deposition method or a sputtering method.

When getting the light emitted from the light emitting layer through the anode as employed in the embodiments of the present invention, the transmittance of anode to visible light is preferably 10% or more. The sheet resistance of anode is preferably several hundreds Ω / or less. The film thickness of anode depends upon the kind of material and generally 10 nm to 1 μ m, preferably 10 to 200 nm.

[0024] The cathode is formed preferably from a material having a small work function in view of injecting electrons to the electron injecting layer, the electron transporting layer or the light emitting layer.

Examples of the material for cathode include, but not limited to, indium, aluminum, magnesium, magnesium-indium alloy, magnesium-aluminum alloy, aluminum-lithium alloy, aluminum-scandium-lithium alloy, and magnesium-silver alloy.

Like the anode, the cathode is formed by making the material into a thin film by a method, such as the vapor deposition method and the sputtering method. The emitted light may be taken from the side of cathode.

Light Emitting Layer

[0025] The light emitting layer of organic electroluminescence device combines the following function:

- (1) Injection function: allowing holes to be injected from the anode or hole injecting layer, and allowing electrons to be injected from the cathode or electron injecting layer, by the action of electric field;
- (2) Transporting function: transporting the injected charges (holes and electrons) by the force of electric field; and
- (iii) Emission function: providing a zone for recombination of electrons and holes to cause the emission.

[0026] The light emitting layer may be different in the hole injection ability and the electron injection ability, and also in the hole transporting ability and the electron transporting ability each being expressed by mobility.

[0027] The light emitting layer is formed, for example, by a known method, such as a vapor deposition method, a spin coating method, and LB method.

The light emitting layer is preferably a molecular deposit film.

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

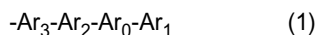
[0028] The light emitting layer can be also formed by making a solution of a binder, such as a resin, and its material in a solvent into a thin film by a spin coating method, as disclosed in JP 57-51781A.

The thickness of the light emitting layer is preferably 5 to 50 nm, more preferably 7 to 50 nm, and most preferably 10 to 50 nm. If being less than 5 nm, the light emitting layer is difficult to form and the control of color is difficult. If exceeding 50 nm, the driving voltage may increase.

Compound

[0029] The light emitting layer contains at least one kind of phosphorescent material and the compound represented by formula (1).

[0030]



[0031] wherein Ar_0 is a substituted or unsubstituted benzene ring;

Ar_1 to Ar_3 are independently a substituted or unsubstituted condensed aromatic hydrocarbon ring, the condensed aromatic hydrocarbon ring being selected from naphthalene ring, chrysene ring, fluoranthene ring, triphenylene ring, phenanthrene ring, benzophenanthrene ring, dibenzophenanthrene ring, benzotriphenylene ring, benzo[*b*]fluoranthene ring, and picene ring, with the proviso that Ar_1 and Ar_2 are the same condensed aromatic hydrocarbon ring, numbers of substituents of Ar_1 and Ar_2 may be the same or different, and kinds of substituents of Ar_1 and Ar_2 may be the same or different;

Ar_0 , Ar_1 , Ar_2 , and Ar_3 may be substituted by at least one group selected from an alkyl group having 1 to 20 carbon atoms, a haloalkyl group having 1 to 20 carbon atoms, a cycloalkyl group having 5 to 18 carbon atoms, a silyl group having 3 to 20 carbon atoms, a fluorene skeleton-containing group having 13 to 35 carbon atoms, dibenzofuranyl group, cyano group, and halogen atom; and

when Ar_2 is naphthalene ring, Ar_0 and Ar_3 do not bond to 2- and 7-positions of the naphthalene ring.

[0032] Ar_1 and Ar_2 exhibit the same ring structure selected from the condensed aromatic hydrocarbon rings recited above. A compound having a structure of $\text{Ar}_2-\text{Ar}_0-\text{Ar}_1$ is symmetric with respect to the central benzene ring, and therefore, easily crystallizes when made into a film, to shorten the lifetime of a device. In contrast, since the compound represented by formula (1) has Ar_3 group, the compound is asymmetric with respect to the benzene ring. Therefore, an organic EL device having such compound in its light emitting layer has a lifetime which is drastically improve.

[0033] Since the compound represented by formula (1) has a large triplet energy gap (excited triplet energy), the energy is transferred from the compound to a phosphorescent dopant, to cause the phosphorescent emission.

An anthracene derivative well known as a fluorescent host is unsuitable as a host of a red-emitting phosphorescent dopant. In contrast, the compound of the invention allows a red-emitting phosphorescent dopant to effectively emit because of its large triplet energy gap.

CBP, a well-known phosphorescent host, is usable as a host of a phosphorescent dopant which emits light having a wavelength shorter than that of green light. However, the compound of the invention is usable as a host of a phosphorescent dopant which emits green light or light having a longer wavelength.

In the present invention, the stability of molecule is enhanced to prolong the lifetime of device by constituting the skeleton of the compound from polycondensed rings containing no nitrogen atom.

When the number of ring atoms of the skeleton is excessively small, the stability of the compound is not sufficient. When the number of rings in the polycondensed rings constituting the skeleton is excessively large, the triplet energy gap is narrow for the wavelength of desired emission, because the HOMO to LUMO gap is narrow because of a long conjugated system. In this regard, since the compound of formula (1) has a moderate number of ring atoms, the compound is suitably used as a phosphorescent host for a phosphorescent emitting layer, which allows the emission of desired wavelength and is highly stable.

[0034] Conventionally, a host material applicable to a wide range of phosphorescent dopants emitting lights of wide range of wavelengths from green to red has been selected. Therefore, a compound, such as CBP, having a wide triplet energy gap has been used as the host material.

Although the triplet energy gap $E_g(T)$ of CBP is wide, CBP involves a problem of short lifetime.

[0035] Although not applicable as a host of a phosphorescent dopant having a wide gap corresponding to blue light, the compound of the invention works as a host of a red- or green-emitting phosphorescent dopant. If the triplet energy gap is excessively wide as in CBP, the energy is not effectively transferred to a red-emitting phosphorescent dopant because of an excessively large difference in the energy gaps. In contrast, when the host of the invention is used, the energy is effectively transferred from the exciton of host to a red- or green-emitting phosphorescent dopant because their energy gaps are matched, giving a phosphorescent emitting layer with extremely high efficiency.

Thus, according to the present invention, a phosphorescent emitting layer with high efficiency and long lifetime is obtained.

[0036] The triplet energy gap $E_g(T)$ of the material for an organic electroluminescence device is determined, for example, from the phosphorescent emission spectrum. In the present invention, it is determined, for example, as described below.

A sample for phosphorescent measurement is prepared by dissolving a test material in EPA solvent (diethyl ether: isopentane:ethanol = 5:5:2 by volume) at 10 $\mu\text{mol/L}$.

The sample for phosphorescent measurement is charged into a quartz cell, cooled to 77 K, and irradiated with exciting

light, and the wavelength of emitted phosphorescent light was measured.

A line tangent to the rising portion at the short-wavelength side of the obtained phosphorescent emission spectrum is drawn, and the wavelength at the intersection of the tangent line and the base line is converted to a value of energy unit, employing the converted value as the triplet energy gap $E_g(T)$.

The phosphorescent measurement is carried out, for example, by using a commercially available apparatus, such as F-4500 (manufactured by Hitachi, Ltd.).

The triplet energy gap may be determined in different manner without departing from the spirit and scope of the present invention.

[0037] Ar_0 , Ar_1 , Ar_2 , and Ar_3 may have one or more substituents which are selected from an alkyl group having 1 to 20 carbon atoms, a haloalkyl group having 1 to 20 carbon atoms, a cycloalkyl group having 5 to 18 carbon atoms, a silyl group having 3 to 20 carbon atoms, a fluorene skeleton-containing group having 13 to 35 carbon atoms, dibenzofuranyl group, cyano group, and halogen atom.

Since these substituents do not include nitrogen atom, the stability of the compound is further enhanced and the lifetime of device is prolonged.

The number of substituents of each of Ar_0 , Ar_1 , Ar_2 , and Ar_3 is preferably two or less and more preferably one or less.

[0038] Examples of the alkyl group having 1 to 20 carbon atoms include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group, n-dodecyl group, n-tridecyl group, n-tetradecyl group, n-pentadecyl group, n-hexadecyl group, n-heptadecyl group, n-octadecyl group, neopentyl group, 1-methylpentyl group, 2-methylpentyl group, 1-pentylhexyl group, 1-butylpentyl group, 1-heptyloctyl group, and 3-methylpentyl group.

[0039] Examples of the haloalkyl group having 1 to 20 carbon atoms include chloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 2-chloroisobutyl group, 1,2-dichloroethyl group, 1,3-dichloroisopropyl group, 2,3-dichlorot-butyl group, 1,2,3-trichloropropyl group, bromomethyl group, 1-bromoethyl group, 2-bromoethyl group, 2-bromoisobutyl group, 1,2-dibromoethyl group, 1,3-dibromoisopropyl group, 2,3-dibromot-butyl group, 1,2,3-tribromopropyl group, iodomethyl group, 1-iodoethyl group, 2-iodoethyl group, 2-iodoisobutyl group, 1,2-diiodoethyl group, 1,3-diiodoisopropyl group, 2,3-diiodot-butyl group, and 1,2,3-triiodopropyl group.

[0040] Examples of the cycloalkyl group having 5 to 18 carbon atoms include cyclopentyl group, cyclohexyl group, cyclooctyl group, and 3,5-tetramethylcyclohexyl group.

[0041] The silyl group having 3 to 20 carbon atoms is preferably an alkylsilyl group, an arylsilyl group, or an aralkylsilyl group. Examples thereof include trimethylsilyl group, triethylsilyl group, tributylsilyl group, trioctylsilyl group, triisobutylsilyl group, dimethylethylsilyl group, dimethylisopropylsilyl group, dimethylpropylsilyl group, dimethylbutylsilyl group, dimethyl-t-butylsilyl group, diethylisopropylsilyl group, phenyldimethylsilyl group, diphenylmethylsilyl group, diphenyl-t-butylsilyl group, and triphenylsilyl group.

Examples of the halogen atom include fluorine atom, chlorine atom, bromine atom, and iodine atom.

[0042] Examples of the fluorene skeleton-containing group having 13 to 35 carbon atoms include 9,9-dimethyl fluorene, 9,9-diethyl fluorene, 9,9-dibutyl fluorene, 9,9-dipentyl fluorene, 9,9-didecylfluorene, 9,9-diheptylfluorene, 9,9-dicyclohexylfluorene, 9,9-dicyclopentylfluorene, and 9,9-diphenylfluorene.

[0043] In the asymmetric material represented by formula (1), the terminal Ar_3 is preferably a group having good heat resistance selected from a substituted or unsubstituted phenanthrene ring, a substituted or unsubstituted fluoranthene ring, a substituted or unsubstituted benzophenanthrene ring, and a substituted or unsubstituted benzochrysene ring.

The compound having the ring structure selected as mentioned above form a highly stable thin film for an organic electroluminescence device, and provides a device with high efficiency and long lifetime, in particular, when combinedly used with a red-emitting phosphorescent material.

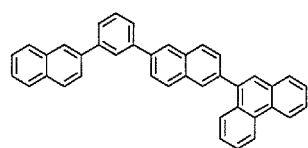
[0044] The excited triplet energy of the compound of the invention is preferably 2.0 eV or more and 2.8 eV or less.

If being 2.0 eV or more, the energy can be transferred to a phosphorescent emitting material which emits light of 520 nm or longer and 720 nm or shorter. If being 2.8 eV or less, the problem of failing to efficient emission due the energy gap excessively large for a red-emitting phosphorescent dopant is avoided.

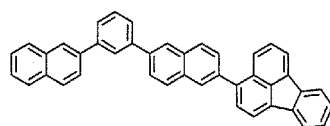
The excited triplet energy of the compound is more preferably 2.0 eV or more and 2.7 eV or less, and still more preferably 2.1 eV or more and 2.7 eV or less.

[0045] The compound of the invention is exemplified below. In formula (1) to (59), Me is methyl group and tBu is t-butyl group.

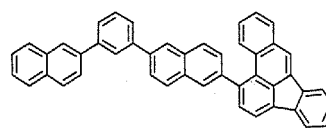
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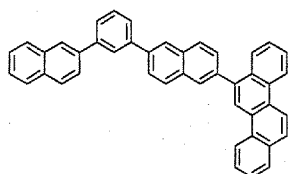
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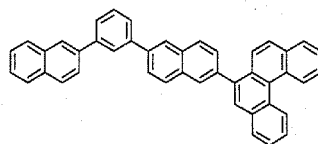
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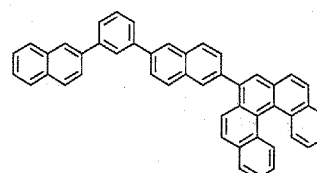
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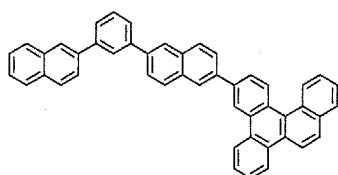
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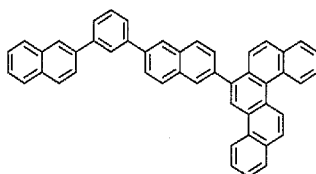
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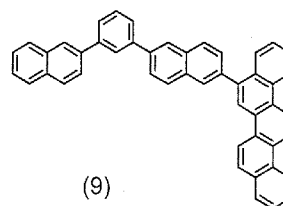
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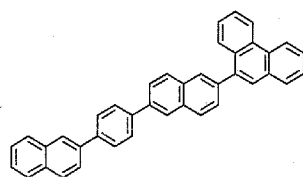
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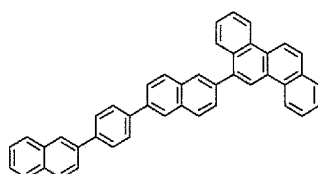
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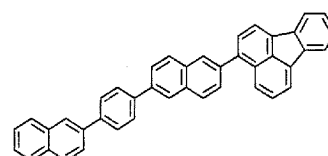
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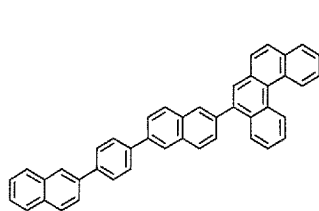
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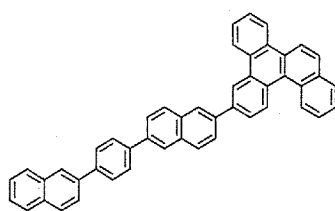
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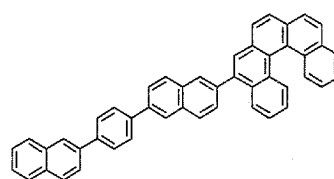
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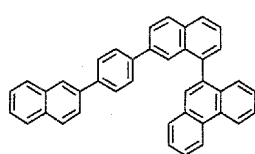


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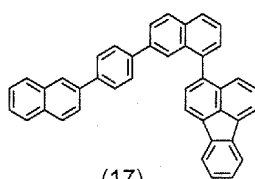


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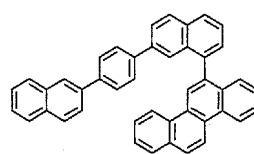
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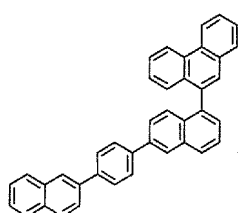
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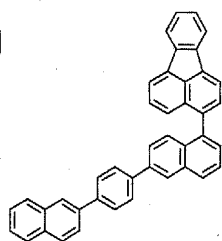
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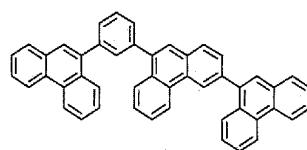
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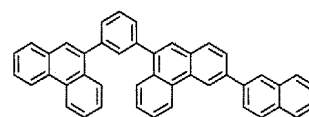
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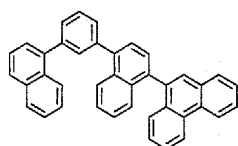
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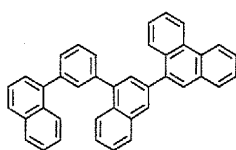
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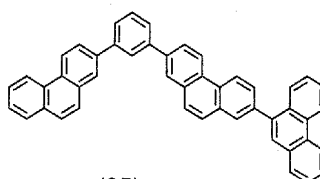
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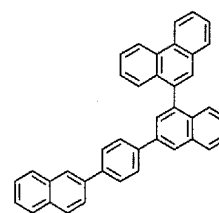
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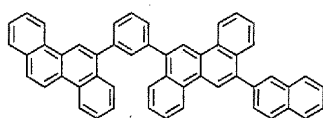
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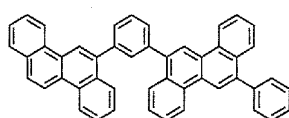
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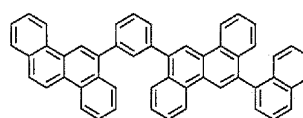
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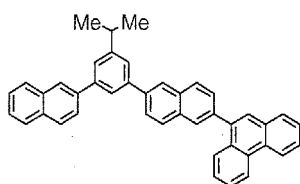


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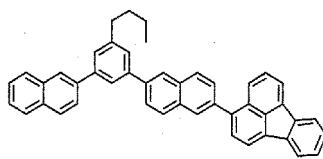


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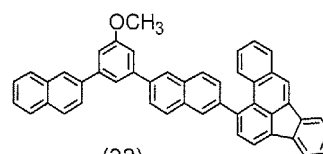
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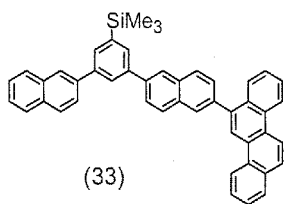
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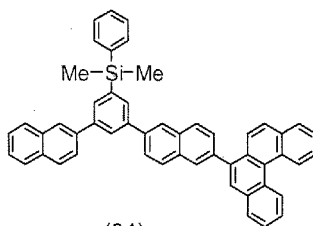
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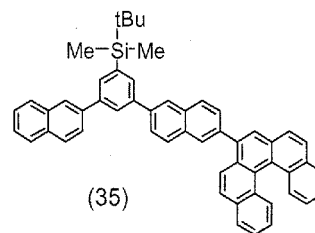
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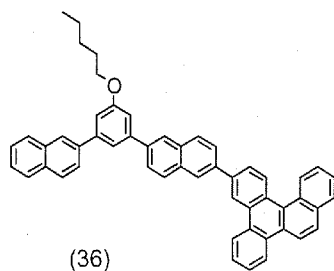
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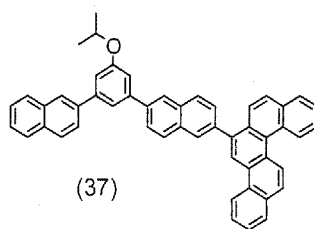
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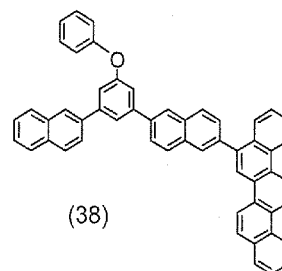
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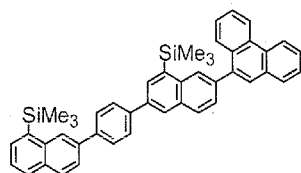
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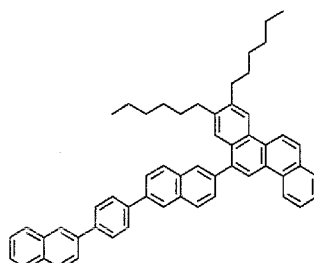
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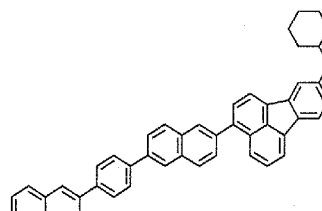
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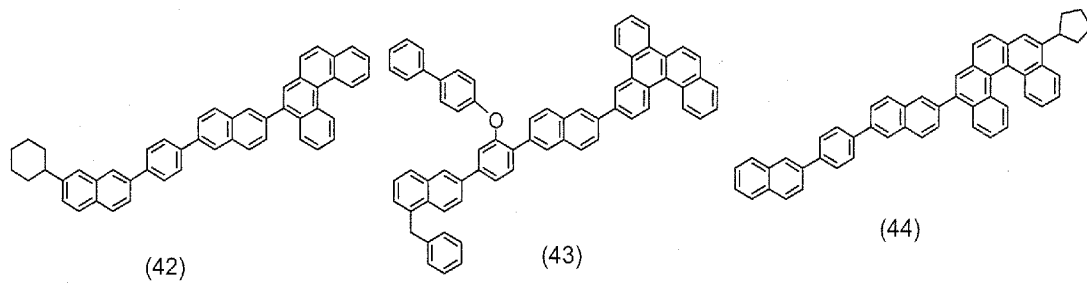
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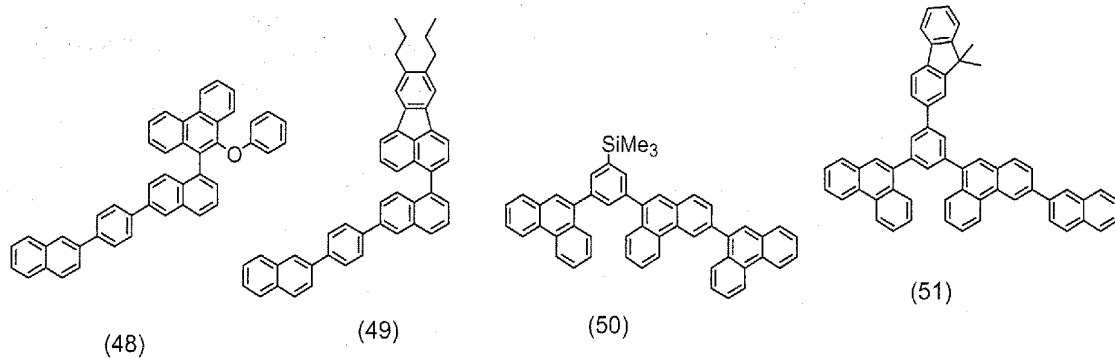
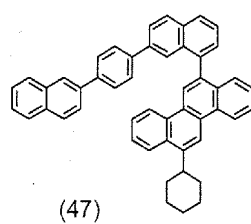
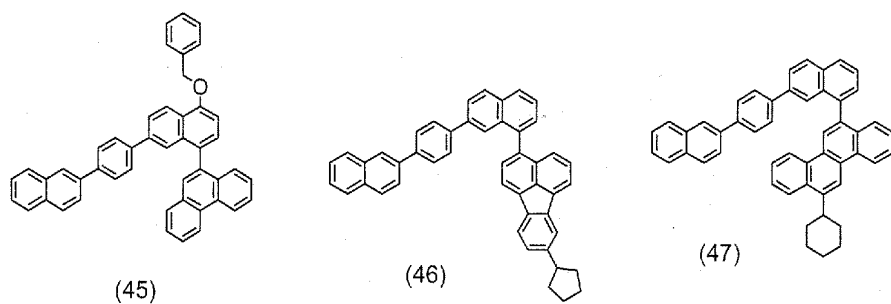
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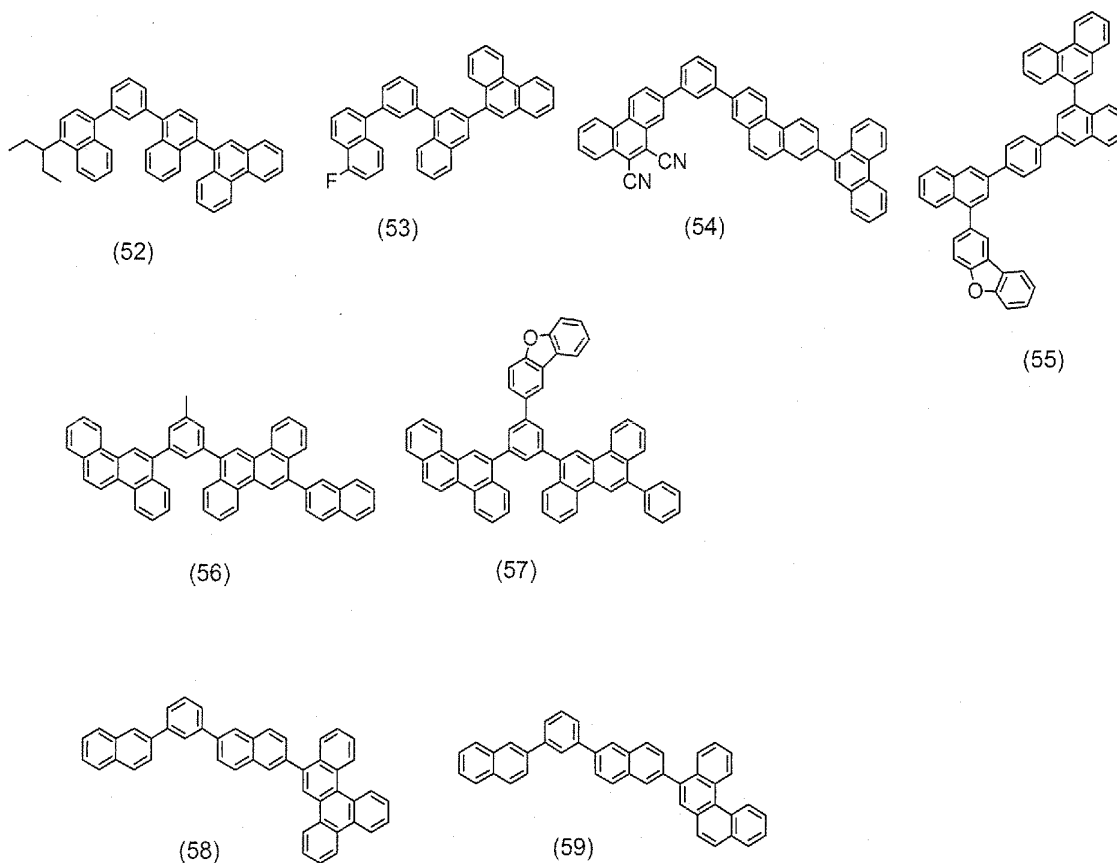


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[0049]





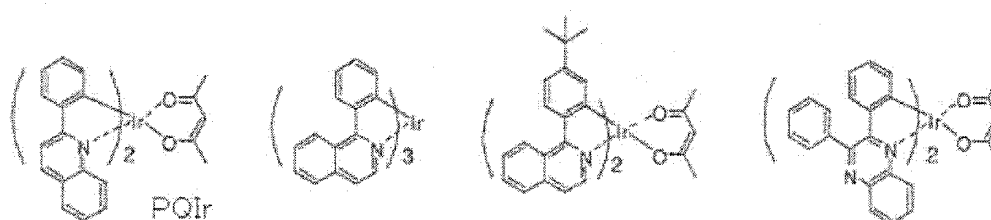
Phosphorescent Emitting Material

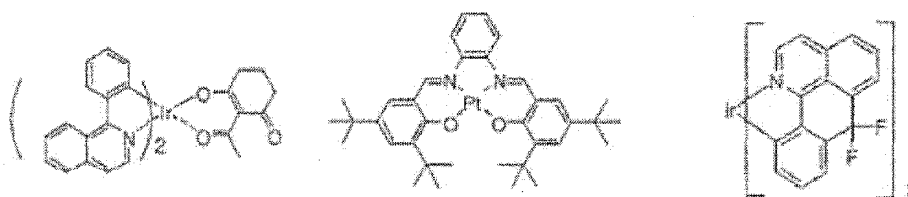
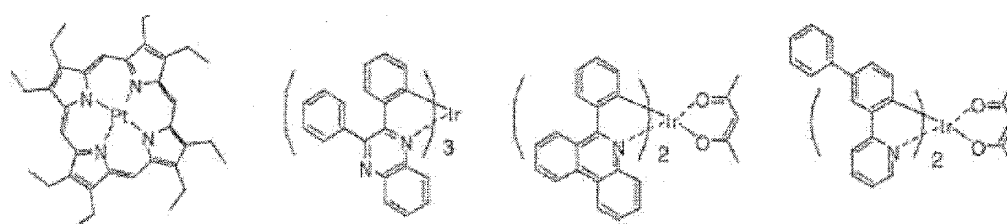
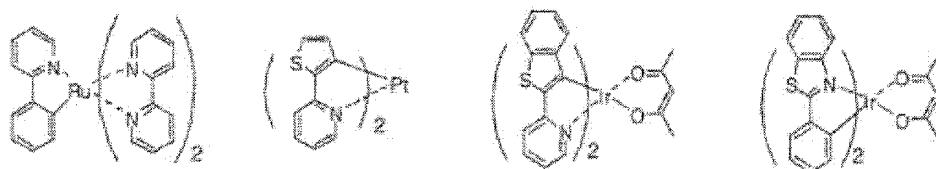
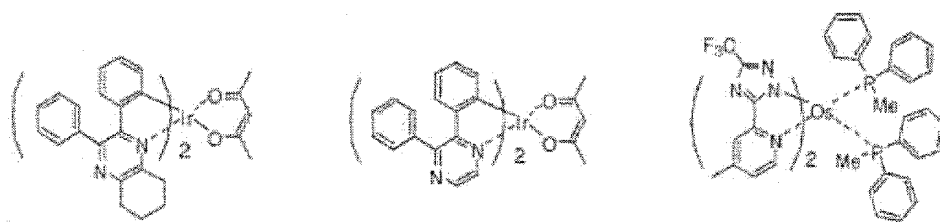
[0050] The phosphorescent emitting material used in the invention preferably comprises a metal complex. The metal complex preferably comprises a metal atom selected from Ir, Pt, Os, Au, Cu, Re, and Ru and a ligand. A ligand having an ortho metal bond is particularly preferred.

In view of obtaining a high phosphorescent quantum efficiency and further improving the external quantum efficiency of electroluminescence device, a compound comprising a metal selected from iridium (Ir), osmium (Os), and platinum (Pt) is preferred, with a metal complex, such as iridium complex, osmium complex, and platinum, being more preferred, iridium complex and platinum complex being still more preferred, and an ortho metallated iridium complex being most preferred.

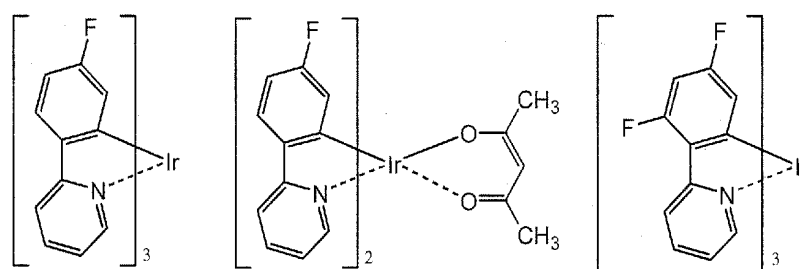
Examples of the metal complex are shown below, among which green-to red-emitting metal complexes are preferred.

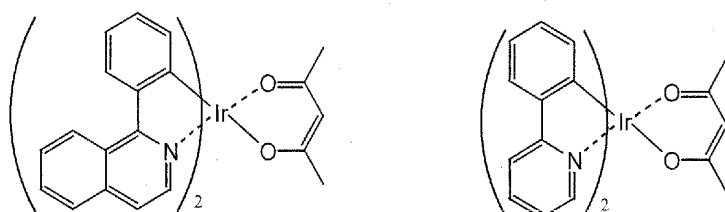
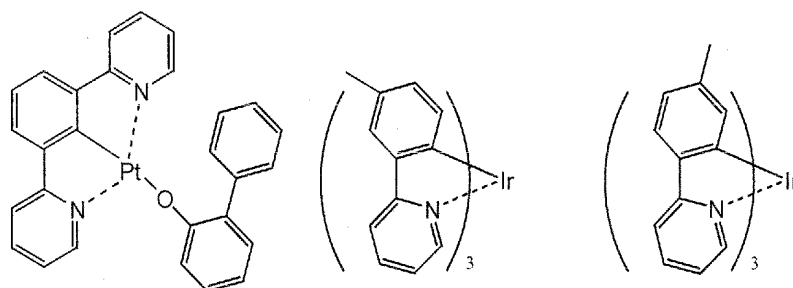
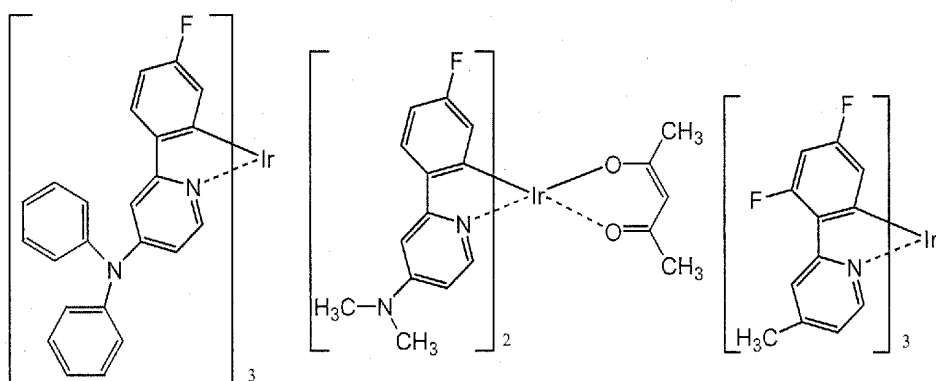
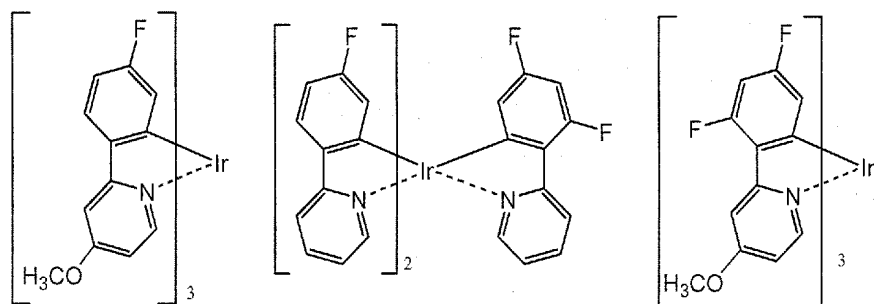
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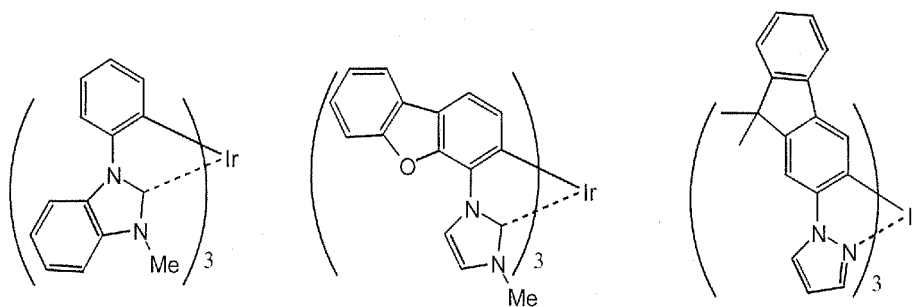
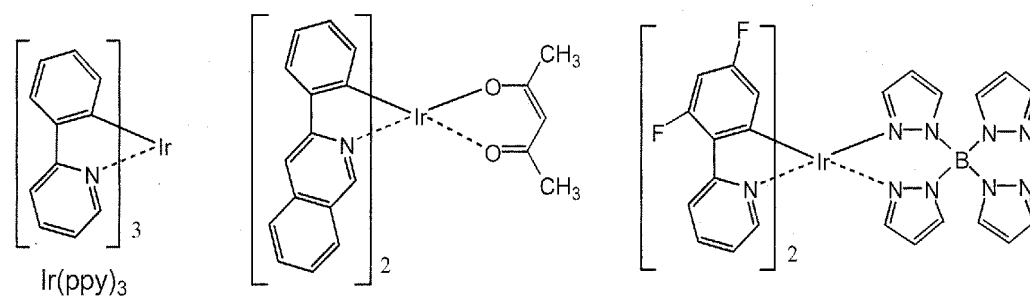
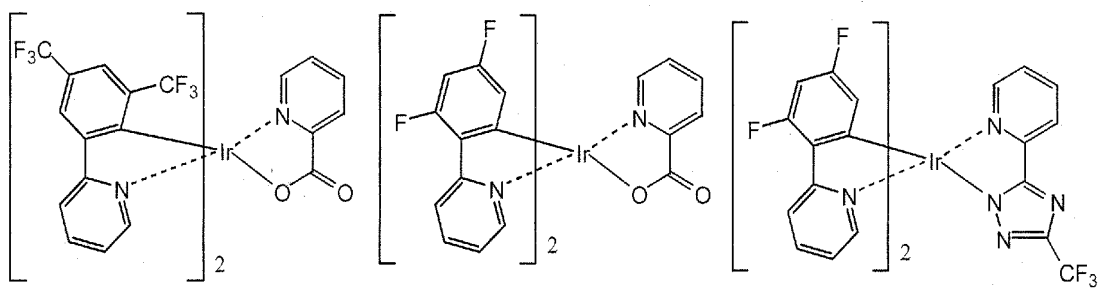


[0052]

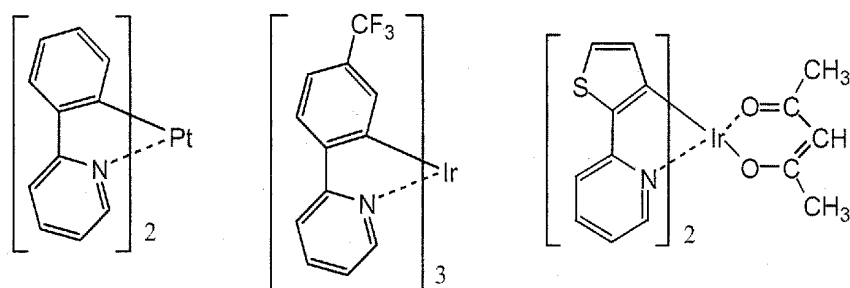


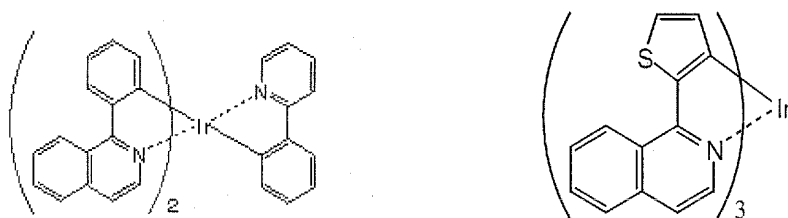
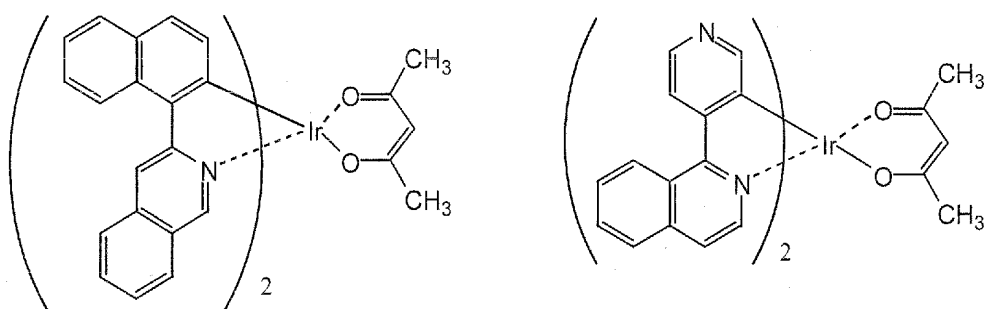
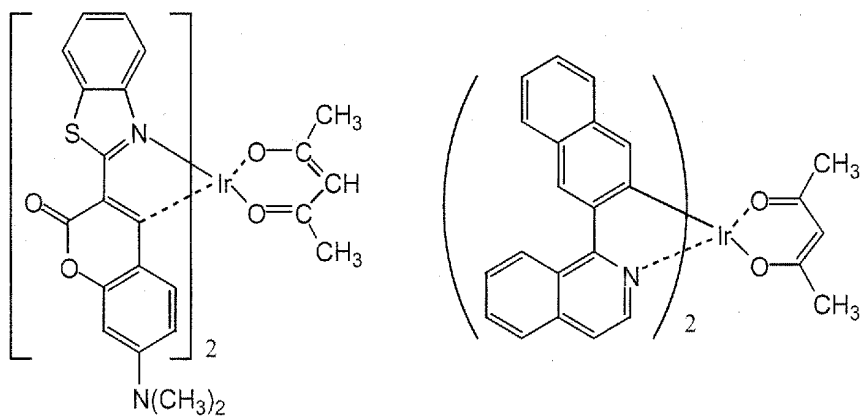
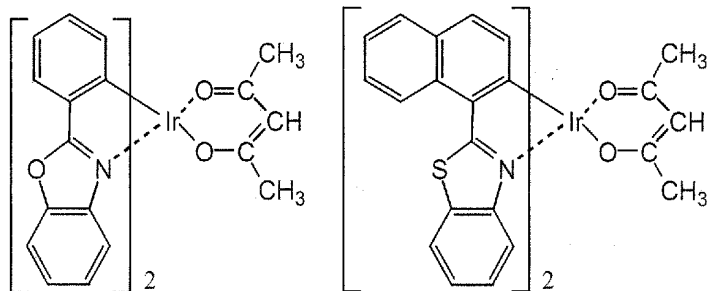


[0053]

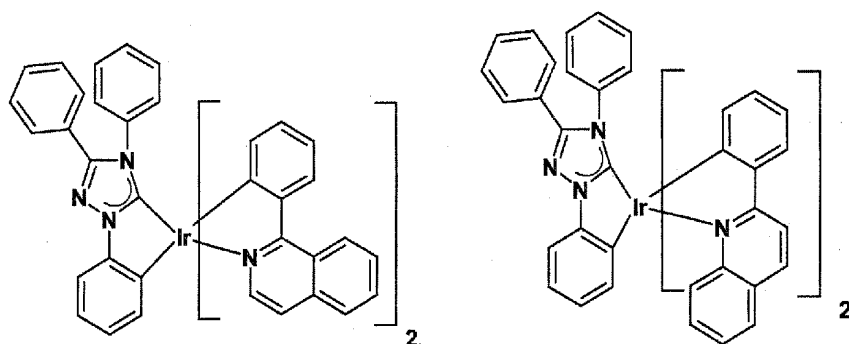


[0054]





[0055]



[0056] In the present invention, at least one of the phosphorescent emitting materials in the light emitting layer shows emission maximum in a range preferably 520 nm or more and 720 nm or less and more preferably 570 nm or more and 720 nm or less.

A highly efficient organic electroluminescence device is obtained by forming the light emitting layer comprising the specific compound of the invention which is doped with the phosphorescent emitting material (phosphorescent dopant) showing such emission wavelength.

[0057] The organic electroluminescence device of the invention may have a hole transporting layer (hole injecting layer), and the hole transporting layer (hole injecting layer), each preferably containing the compound represented by formula (1). In addition, the organic electroluminescence device of the invention may have an electron transporting layer and/or a hole blocking layer, and the electron transporting layer and/or the hole blocking layer preferably contains the compound represented by formula (1).

[0058] It is also preferred for the organic electroluminescence device of the invention to contain a reduction-causing dopant in the interfacial region between the cathode and the organic thin film layer.

With such a construction, the organic electroluminescence device has an improved luminance and an elongated lifetime. Examples of the reduction-causing dopant include at least one selected from alkali metal, alkali metal complex, alkali metal compound, alkaline earth metal, alkaline earth metal complex, alkaline earth metal compound, rare earth metal, rare earth metal complex, and rare earth metal compound.

[0059] Examples of the alkali metal include Na (work function: 2.36 eV), K (work function: 2.28 eV), Rb (work function: 2.16 eV), and Cs (work function: 1.95 eV), with those having a work function of 2.9 eV or less being particularly preferred. Of the above, preferred are K, Rb, and Cs, more preferred are Rb and Cs, and most preferred is Cs.

Examples of the alkaline earth metal include Ca (work function: 2.9 eV), Sr (work function: 2.0 to 2.5 eV), and Ba (work function: 2.52 eV), with those having a work function of 2.9 eV or less being particularly preferred.

Examples of the rare earth metal include Sc, Y, Ce, Tb, and Yb, with those having a work function of 2.9 eV or less being particularly preferred.

Since the preferred metals mentioned above has a particularly high reductivity, an organic electroluminescence device having an improved luminance and an elongated lifetime can be obtained by its addition to the electron injecting region in a relatively small amount.

[0060] Examples of the alkali metal compound include alkali oxide, such as Li_2O , Cs_2O , K_2O , and alkali halide, such as LiF, NaF, CsF, and KF, with LiF, Li_2O , and NaF being preferred.

Examples of the alkaline earth metal compound include BaO, SrO, CaO, and mixture thereof, such as $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$) and $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$), with BaO, SrO, and CaO being preferred.

Examples of the rare earth metal compound include YbF_3 , ScF_3 , ScO_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 , with YbF_3 , ScF_3 , and TbF_3 being preferred.

[0061] Examples of the alkali metal complex, alkaline earth metal complex, and rare earth metal are not particularly limited as long as containing at least one metal ion selected from alkali metal ions, alkaline earth metal ions, rare earth metal ions, respectively. The ligand is preferably, but limited to, quinolinol, benzoquinolinol, acridinol, phenanthridinol, hydroxyphenyloxazole, hydroxyphenyl-thiazole, hydroxydiaryloxadiazole, hydroxydiarylthiadiazole, hydroxyphenylpyridine, hydroxyphenylbenzimidazole, hydroxybenzotriazole, hydroxyfulborane, bipyridyl, phenanthroline, phthalocyanine, porphyrin, cyclopentadiene, β -diketones, azomethines, and derivative thereof.

[0062] The reduction-causing dopant is formed in the interfacial region preferably into a form of layer or island. The reduction-causing dopant is added preferably by co-depositing the reduction-causing dopant and the organic material for forming the interfacial region, such as a light emitting material and an electron injecting material, by a resistance heating deposition method, thereby dispersing the reduction-causing dopant into the organic material. The disperse concentration expressed by the molar ratio of the organic material and the reduction-causing dopant is 100:1 to 1:100 and preferably 5:1 to 1:5.

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

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

The molar ratio of the main component and the reduction-causing dopant in the organic electroluminescence device of the invention is preferably 5:1 to 1:5 and more preferably 2:1 to 1:2.

[0063] It is preferred for the organic electroluminescence device of the invention that an electron injecting layer is disposed between the light emitting layer and the cathode, and the electron injecting layer contains a nitrogen-containing ring derivative as a main component. The electron injecting layer may work as an electron transporting layer

The term "main component" referred to herein means that 50% by mass or more of the electron injecting layer is the nitrogen-containing ring derivative.

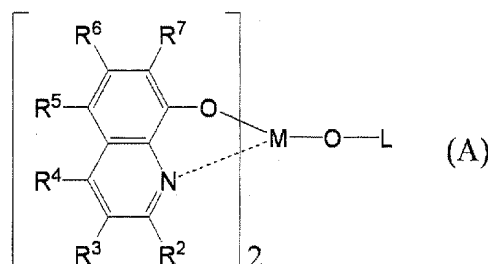
The electron injecting layer or the electron transporting layer is a layer for facilitating the injection of electrons into the light emitting layer and has large electron mobility. The electron injecting layer is formed to adjust the energy level, for example, by reducing the abrupt change in energy level.

An aromatic heterocyclic compound having one or more heteroatoms in its molecule is preferably used as the electron injecting material for the electron injecting layer, with a nitrogen-containing ring derivative being particularly preferred.

The nitrogen-containing ring derivative is preferably an aromatic ring compound having a nitrogen-containing 6- or 5-membered ring or a condensed aromatic ring compound having a nitrogen-containing 6- or 5-membered ring.

[0064] The nitrogen-containing ring derivative is preferably, for example, a chelate metal complex having a nitrogen-containing ring represented by formula (A):

[0065]



[0066] R^2 to R^7 are each independently hydrogen atom, a halogen atom, hydroxyl group, amino group, a hydrocarbon group having 1 to 40 carbon atoms, an alkoxy group, an aryloxy group, an alkoxy carbonyl group, or a heterocyclic group, each being optionally substituted.

The halogen atom may include fluorine, chlorine, bromine, and iodine. The substituted amino group may include an alkylamino group, an arylamino group, and an aralkylamino group.

The hydrocarbon group having 1 to 40 carbon atoms may include an alkyl group, an alkenyl group, a cycloalkyl group, an aryl group, and an aralkyl group, each being substituted or unsubstituted.

[0067] Examples of the alkyl group include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group, n-dodecyl group, n-tridecyl group, n-tetradecyl group, n-pentadecyl group, n-hexadecyl group, n-heptadecyl group, n-octadecyl group, neopentyl group, 1-methylpentyl group, 2-methylpentyl group, 1-pentylhexyl group, 1-butylpentyl group, 1-heptyloctyl group, 3-methylpentyl group, hydroxymethyl group, 1-hydroxyethyl group, 2-hydroxyethyl group, 2-hydroxyisobutyl group, 1,2-dihydroxyethyl group, 1,3-dihydroxyisopropyl group, 2,3-dihydroxyt-butyl group, 1,2,3-trihydroxypropyl group, chloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 2-chloroisobutyl group, 1,2-dichloroethyl group, 1,3-dichloroisopropyl group, 2,3-dichlorot-butyl group, 1,2,3-trichloropropyl group, bromomethyl group, 1-bromoethyl group, 2-bromoethyl group, 2-bromoisobutyl group, 1,2-dibromoethyl group, 1,3-dibromoisopropyl group, 2,3-dibromot-butyl group, 1,2,3-tribromopropyl group, iodomethyl group, 1-iodoethyl group, 2-iodoethyl group, 2-iodoisobutyl group, 1,2-diiodoethyl group, 1,3-diiodoisopropyl group, 2,3-diiodot-butyl group, 1,2,3-triiodopropyl group, aminomethyl group, 1-aminoethyl group, 2-aminoethyl group, 2-aminoisobutyl group, 1,2-diaminoethyl group, 1,3-diaminoisopropyl group, 2,3-diamino-t-butyl group, 1,2,3-triaminopropyl group, cyanomethyl group, 1-cyanoethyl group, 2-cyanoethyl group, 2-cyanoisobutyl group, 1,2-dicyanoethyl group, 1,3-dicyanoisopropyl group, 2,3-

dicyano-t-butyl group, 1,2,3-tricyanopropyl group, nitromethyl group, 1-nitroethyl group, 2-nitroethyl group, 1,2-dinitroethyl group, 2,3-dinitro-t-butyl group, and 1,2,3-trinitropropyl group.

[0068] Of the above, preferred are methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group, n-dodecyl group, n-tridecyl group, n-tetradecyl group, n-pentadecyl group, n-hexadecyl group, n-heptadecyl group, n-octadecyl group, neopentyl group, 1-methylpentyl group, 1-pentylhexyl group, 1-butylpentyl group, and 1-heptyloctyl group.

[0069] Examples of the alkenyl group include vinyl group, allyl group, 1-butenyl group, 2-butenyl group, 3-butenyl group, 1,3-butadienyl group, 1-methylvinyl group, styryl group, 2,2-diphenylvinyl group, 1,2-diphenylvinyl group, 1-methylallyl group, 1,1-dimethylallyl group, 2-methylallyl group, 1-phenylallyl group, 2-phenylallyl group, 3-phenylallyl group, 3,3-diphenylallyl group, 1,2-dimethylallyl group, 1-phenyl-1-butenyl group, and 3-phenyl-1-butenyl group, with styryl group, 2,2-diphenylvinyl group, and 1,2-diphenylvinyl group being preferred.

[0070] Examples of the cycloalkyl group include cyclopentyl group, cyclohexyl group, cyclooctyl group, and 3,5-tetramethylcyclohexyl group, with cyclohexyl group, cyclooctyl group, and 3,5-tetramethylcyclohexyl group being preferred.

The alkoxy group is represented by -OY, wherein Y is an alkyl group. Examples and preferred examples thereof are the same as those described above.

[0071] Examples of the non-condensed aryl group include phenyl group, biphenyl-2-yl group, biphenyl-3-yl group, biphenyl-4-yl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-phenylpropyl)phenyl group, 4'-methylbiphenyl group, 4"-t-butylp-terphenyl-4-yl group, o-cumenyl group, m-cumenyl group, p-cumenyl group, 2,3-xylyl group, 3,4-xylyl group, 2,5-xylyl group, mesityl group, and m-quaterphenyl group.

[0072] Of the above, preferred are phenyl group, biphenyl-2-yl group, biphenyl-3-yl group, biphenyl-4-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, p-tolyl group, 3,4-xylyl group, and m-quaterphenyl-2-yl group.

Examples of the condensed aryl group include 1-naphthyl group, 2-naphthyl group.

[0073] The heterocyclic group may be monocyclic or condensed and has preferably 1 to 20 ring carbon atoms, more preferably 1 to 12 ring carbon atoms, and more preferably 1 to 10 ring carbon atoms. The heterocyclic group is preferably an aromatic heterocyclic group having at least one heteroatom selected from nitrogen atom, oxygen atom, sulfur atom, and selenium atom. Examples of the heterocyclic group include the residues derived from pyrrolidine, piperidine, piperazine, morpholine, thiophene, selenophene, furan, pyrrole, imidazole, pyrazole, pyridine, pyrazine, pyridazine, pyrimidine, triazole, triazine, indole, indazole, purine, thiazoline, thiazole, thiadiazole, oxazoline, oxazole, oxadiazole, quinoline, isoquinoline, phthalazine, naphthyridine, quinoxaline, quinazoline, cinnoline, pteridine, acridine, phenanthroline, phenazine, tetrazole, benzimidazole, benzoxazole, benzothiazole, benzotriazole, tetrazaindene, carbazole, and azepine, with the residues of furan, thiophene, pyridine, pyrazine, pyrimidine, pyridazine, triazine, quinoline, phthalazine, naphthyridine, quinoxaline, and quinazoline being preferred, the residues derived from furan, thiophene, pyridine, and quinoline being more preferred, and quinolinyl group being still more preferred.

[0074] Examples of the aralkyl group include benzyl group, 1-phenylethyl group, 2-phenylethyl group, 1-phenylisopropyl group, 2-phenylisopropyl group, phenyl-t-butyl group, α -naphthylmethyl group, 1- α -naphthylethyl group, 2- α -naphthylethyl group, 1- α -naphthylisopropyl group, 2- α -naphthylisopropyl group, β -naphthylmethyl group, 1- β -naphthylethyl group, 2- β -naphthylethyl group, 1- β -naphthylisopropyl group, 2- β -naphthylisopropyl group, p-methylbenzyl group, m-methylbenzyl group, o-methylbenzyl group, p-chlorobenzyl group, m-chlorobenzyl group, o-chlorobenzyl group, p-bromobenzyl group, m-bromobenzyl group, o-bromobenzyl group, p-iodobenzyl group, m-iodobenzyl group, o-iodobenzyl group, p-hydroxybenzyl group, m-hydroxybenzyl group, o-hydroxybenzyl group, p-aminobenzyl group, m-aminobenzyl group, o-aminobenzyl group, p-nitrobenzyl group, m-nitrobenzyl group, o-nitrobenzyl group, p-cyanobenzyl group, m-cyanobenzyl group, o-cyanobenzyl group, 1-hydroxy-2-phenylisopropyl group, and 1-chloro-2-phenylisopropyl group.

[0075] Of the above, preferred are benzyl group, p-cyanobenzyl group, m-cyanobenzyl group, o-cyanobenzyl group, 1-phenylethyl group, 2-phenylethyl group, 1-phenylisopropyl group, and 2-phenylisopropyl group.

[0076] The aryloxy group is represented by -OY' wherein Y' is phenyl group, 1-naphthyl group, 2-naphthyl group, 1-anthryl group, 2-anthryl group, 9-anthryl group, 1-phenanthryl group, 2-phenanthryl group, 3-phenanthryl group, 4-phenanthryl group, 9-phenanthryl group, 1-naphthacenyl group, 2-naphthacenyl group, 9-naphthacenyl group, 1-pyrenyl group, 2-pyrenyl group, 4-pyrenyl group, 2-biphenyl group, 3-biphenyl group, 4-biphenyl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-phenylpropyl)phenyl group, 3-methyl-2-naphthyl group, 4-methyl-1-naphthyl group, 4-methyl-1-anthryl group, 4'-methylbiphenyl group, or 4"-t-butyl-p-terphenyl-4-yl group.

[0077] The aryloxy group includes a heteroaryloxy group represented by -OZ', wherein Z' is 2-pyrrolyl group, 3-pyrrolyl group, pyrazinyl group, 2-pyridinyl group, 3-pyridinyl group, 4-pyridinyl group, 2-indolyl group, 3-indolyl group, 4-indolyl group, 5-indolyl group, 6-indolyl group, 7-indolyl group, 1-isindolyl group, 3-isindolyl group, 4-isindolyl group, 5-

isoidolyl group, 6-isoidolyl group, 7-isoidolyl group, 2-furyl group, 3-furyl group, 2-benzofuranyl group, 3-benzofuranyl group, 4-benzofuranyl group, 5-benzofuranyl group, 6-benzofuranyl group, 7-benzofuranyl group, 1-isobenzofuranyl group, 3-isobenzofuranyl group, 4-isobenzofuranyl group, 5-isobenzofuranyl group, 6-isobenzofuranyl group, 7-isobenzofuranyl group, 2-quinolyl group, 3-quinolyl group, 4-quinolyl group, 5-quinolyl group, 6-quinolyl group, 7-quinolyl group, 8-quinolyl group, 1-isoquinolyl group, 3-isoquinolyl group, 4-isoquinolyl group, 5-isoquinolyl group, 6-isoquinolyl group, 7-isoquinolyl group, 8-isoquinolyl group, 2-quinoxalyl group, 5-quinoxalyl group, 6-quinoxalyl group, 1-carbazolyl group, 2-carbazolyl group, 3-carbazolyl group, 4-carbazolyl group, 1-phenanthridinyl group, 2-phenanthridinyl group, 3-phenanthridinyl group, 4-phenanthridinyl group, 6-phenanthridinyl group, 7-phenanthridinyl group, 8-phenanthridinyl group, 9-phenanthridinyl group, 10-phenanthridinyl group, 1-acridinyl group, 2-acridinyl group, 3-acridinyl group, 4-acridinyl group, 9-acridinyl group, 1,7-phenanthroline-2-yl group, 1,7-phenanthroline-3-yl group, 1,7-phenanthroline-4-yl group, 1,7-phenanthroline-5-yl group, 1,7-phenanthroline-6-yl group, 1,7-phenanthroline-8-yl group, 1,7-phenanthroline-9-yl group, 1,7-phenanthroline-10-yl group, 1,8-phenanthroline-2-yl group, 1,8-phenanthroline-3-yl group, 1,8-phenanthroline-4-yl group, 1,8-phenanthroline-5-yl group, 1,8-phenanthroline-6-yl group, 1,8-phenanthroline-7-yl group, 1,8-phenanthroline-9-yl group, 1,8-phenanthroline-10-yl group, 1,9-phenanthroline-2-yl group, 1,9-phenanthroline-3-yl group, 1,9-phenanthroline-4-yl group, 1,9-phenanthroline-5-yl group, 1,9-phenanthroline-6-yl group, 1,9-phenanthroline-7-yl group, 1,9-phenanthroline-8-yl group, 1,9-phenanthroline-10-yl group, 1,10-phenanthroline-2-yl group, 1,10-phenanthroline-3-yl group, 1,10-phenanthroline-4-yl group, 1,10-phenanthroline-5-yl group, 2,9-phenanthroline-1-yl group, 2,9-phenanthroline-3-yl group, 2,9-phenanthroline-4-yl group, 2,9-phenanthroline-5-yl group, 2,9-phenanthroline-6-yl group, 2,9-phenanthroline-7-yl group, 2,9-phenanthroline-8-yl group, 2,9-phenanthroline-10-yl group, 2,8-phenanthroline-1-yl group, 2,8-phenanthroline-3-yl group, 2,8-phenanthroline-4-yl group, 2,8-phenanthroline-5-yl group, 2,8-phenanthroline-6-yl group, 2,8-phenanthroline-7-yl group, 2,8-phenanthroline-9-yl group, 2,8-phenanthroline-10-yl group, 2,7-phenanthroline-2-yl group, 2,7-phenanthroline-3-yl group, 2,7-phenanthroline-4-yl group, 2,7-phenanthroline-5-yl group, 2,7-phenanthroline-6-yl group, 2,7-phenanthroline-8-yl group, 2,7-phenanthroline-9-yl group, 2,7-phenanthroline-10-yl group, 1-phenazinyl group, 2-phenazinyl group, 1-phenothiazinyl group, 2-phenothiazinyl group, 3-phenothiazinyl group, 4-phenothiazinyl group, 1-phenoxazinyl group, 2-phenoxazinyl group, 3-phenoxazinyl group, 4-phenoxazinyl group, 2-oxazolyl group, 4-oxazolyl group, 5-oxazolyl group, 2-oxadiazolyl group, 5-oxadiazolyl group, 3-furazanyl group, 2-thienyl group, 3-thienyl group, 2-methylpyrrole-1-yl group, 2-methylpyrrole-8-yl group, 2-methylpyrrole-4-yl group, 2-methylpyrrole-5-yl group, 3-methylpyrrole-1-yl group, 3-methylpyrrole-2-yl group, 3-methylpyrrole-4-yl group, 3-methylpyrrole-5-yl group, 2-t-butylpyrrole-4-yl group, 3-(2-phenylpropyl)pyrrole-1-yl group, 2-methyl-1-indolyl group, 4-methyl-1-indolyl group, 2-methyl-3-indolyl group, 4-methyl-1-3-indolyl group, 2-t-butyl-1-indolyl group, 4-t-butyl-1-indolyl group, 2-t-butyl-3-indolyl group, and 4-t-butyl-3-indolyl group.

[0078] The alkoxycarbonyl group is represented by $-COOY'$, wherein Y' is an alkyl group and examples thereof are selected from those described above.

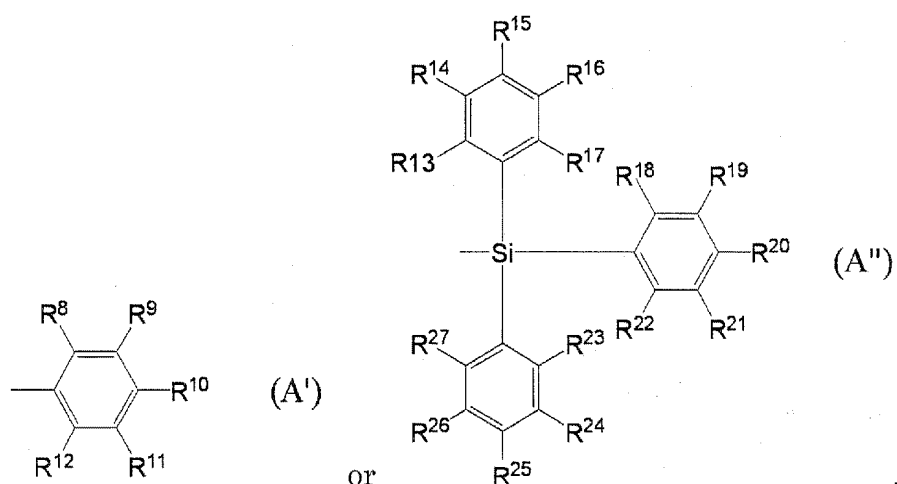
[0079] The alkylamino group and the aralkylamino group are represented by $-NQ^1Q^2$, wherein Q^1 and Q^2 are each independently an alkyl group or an aralkyl group, examples and preferred examples being the same as those described above. One of Q^1 and Q^2 may be hydrogen atom.

The arylamino group represented by $-NAr^1Ar^2$, wherein Ar^1 and Ar^2 are each independently a non-condensed aryl group or a condensed aryl group, examples thereof being the same as those described above. One of Ar^1 and Ar^2 may be hydrogen atom.

[0080] M is aluminum (Al), gallium (Ga), or indium (In), with In being preferred.

L in formula (A) is a group represented by formula (A') or (A''):

[0081]



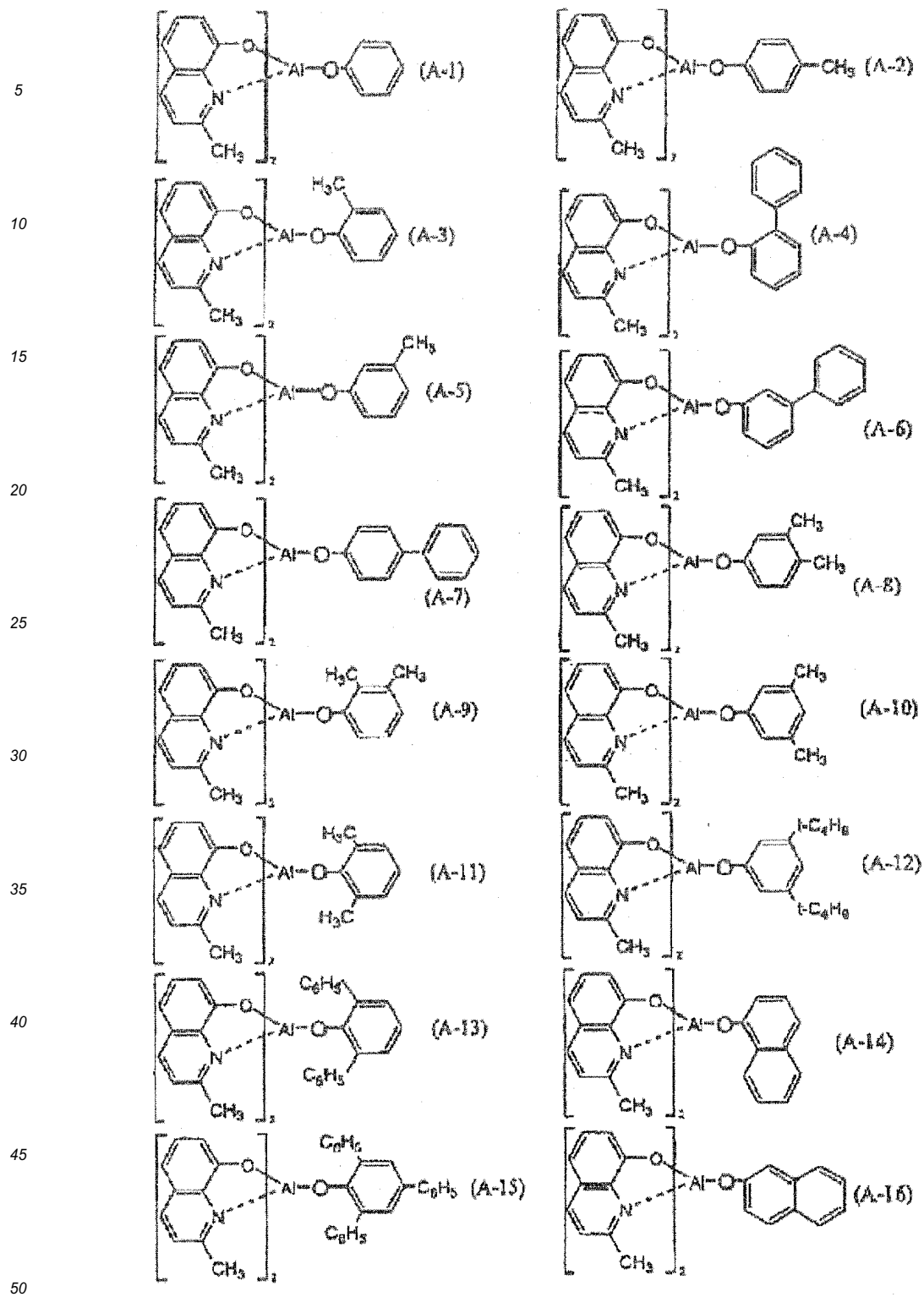
[0082] In the above formulae, R⁸ to R¹² are each independently hydrogen atom or a substituted or unsubstituted hydrocarbon group having 1 to 40 carbon atoms. The adjacent two groups may form a ring structure. R¹³ to R²⁷ are each independently hydrogen atom or a substituted or unsubstituted hydrocarbon group having 1 to 40 carbon atoms. The adjacent two groups may form a ring structure.

[0083] Examples of the hydrocarbon group having 1 to 40 carbon atoms for R⁸ to R¹² and R¹³ to R²⁷ in formulae (A') and (A'') are the same as those described above with respect to R² to R⁷.

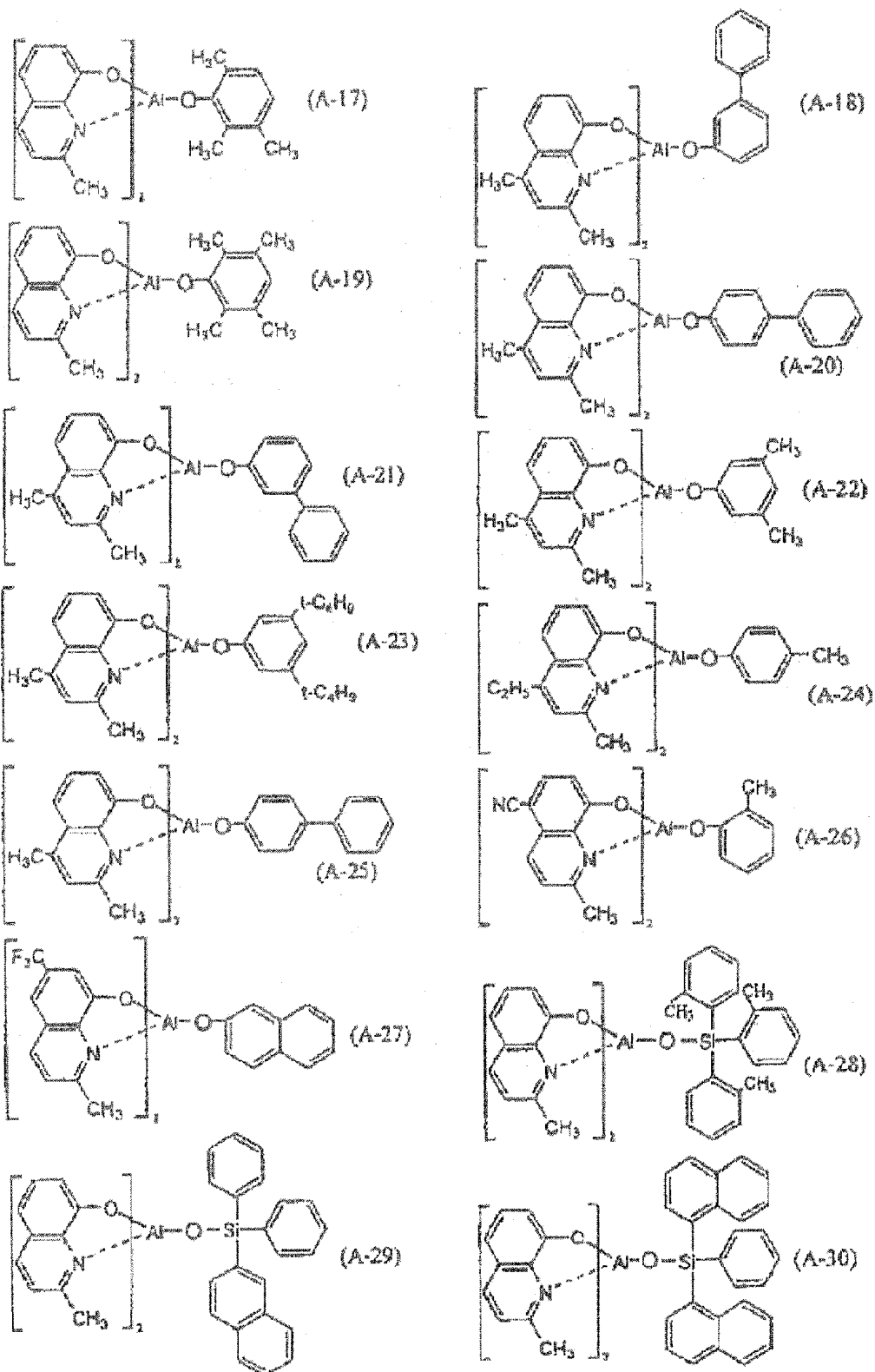
Examples of the divalent group formed by the adjacent groups of R⁸ to R¹² and R¹³ to R²⁷ which completes the ring structure include tetramethylene group, pentamethylene group, hexamethylene group, diphenylmethane-2,2'-diyl group, diphenylethane-3,3'-diyl group, and diphenylpropane-4,4'-diyl group.

[0084] Specific examples of the chelate metal complex having a nitrogen-containing ring represented by formula (A) are shown below, although not limited thereto.

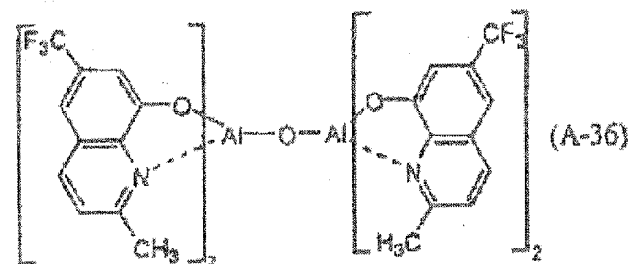
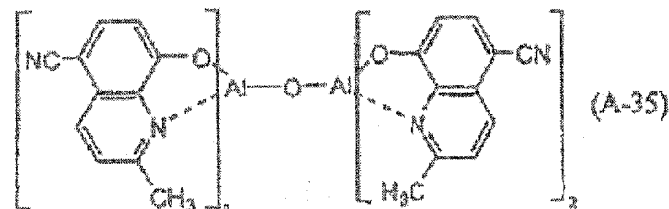
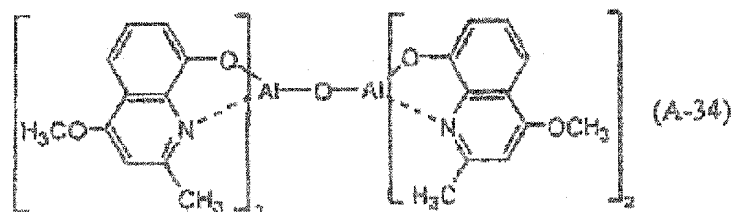
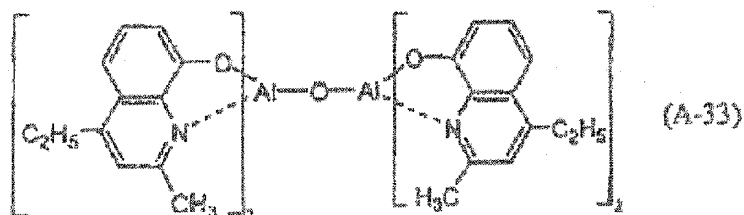
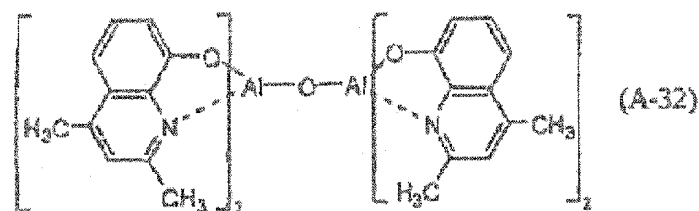
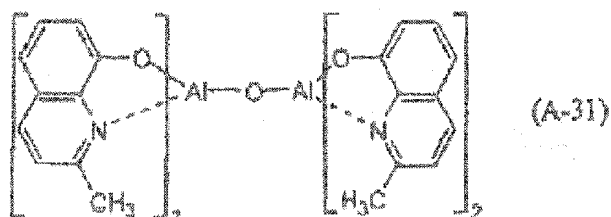
[0085]



[0086]



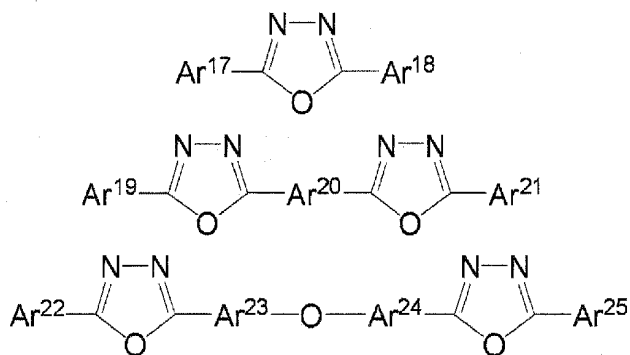
[0087]



[0088] In the present invention, the electron injecting layer and the electron transporting layer preferably contain a nitrogen-containing heterocyclic derivative.

[0089] The electron injecting layer or the electron transporting layer is a layer for facilitating the injection of electrons into the light emitting layer and have large electron mobility. The electron injecting layer is formed to adjust the energy level, for example, by reducing the abrupt change in energy level. The material for the electron injecting layer or the electron transporting layer is preferably a metal complex including 8-hydroxyquinoline or its derivative, an oxadiazole derivative, and a nitrogen-containing heterocyclic derivative. Examples of the metal complex including 8-hydroxyquinoline or its derivative include a metal chelate oxinoid including a chelated oxine (generally, 8-quinolinol or 8-hydroxyquinoline), for example, tris(8-quinolinol)aluminum. Examples of the oxadiazole derivative are shown below.

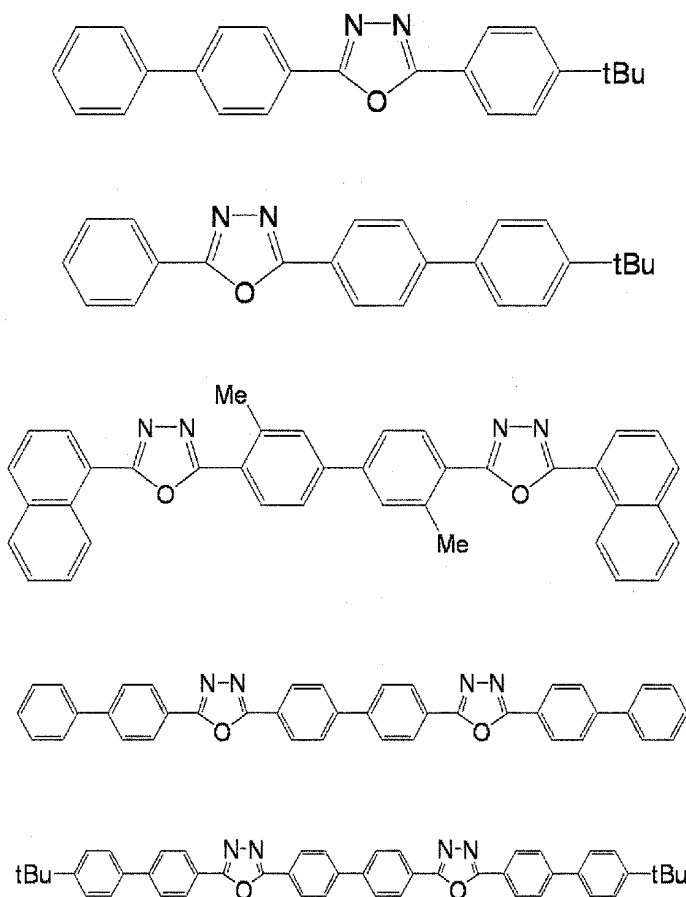
[0090]

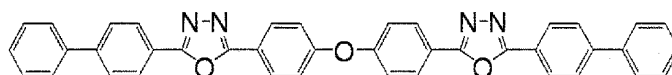


[0091] In the above formulae, each of Ar¹⁷, Ar¹⁸, Ar¹⁹, Ar²¹, Ar²², and Ar²⁵ is a substituted or unsubstituted aryl group, and Ar¹⁷ and Ar¹⁸, Ar¹⁹ and Ar²¹, and Ar²² and Ar²⁵ may be the same or different. Each of Ar²⁰, Ar²³, and Ar²⁴ is a substituted or unsubstituted arylene group, and Ar²³ and Ar²⁴ may be the same or different.

Examples of the arylene group include phenylene group, naphthylene group, biphenylene group, anthracenylene group, perylenylene group, and pyrenylene group. Examples of the substituent include an alkyl group having 1 to 10 carbon atoms, an alkoxy group having 1 to 10 carbon atoms, and cyano group. Electron transporting compounds which have a good thin film-forming property are preferably used. Examples of the electron transporting compound are shown below.

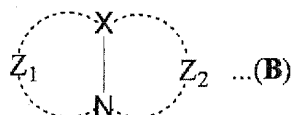
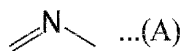
[0092]





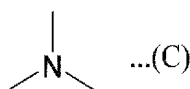
[0093] Examples of the nitrogen-containing heterocyclic derivative include a nitrogen-containing heterocyclic derivative having the following formulae but exclusive of metal complex, for example, a nitrogen-containing having a 5- or 6-membered ring having the skeleton represented by formula (A) or having the structure represented by formula (B).

[0094]



[0095] In formula (B), X is carbon atom or nitrogen atom. Z₁ and Z₂ are each independently a group of atoms for completing the nitrogen-containing heteroring.

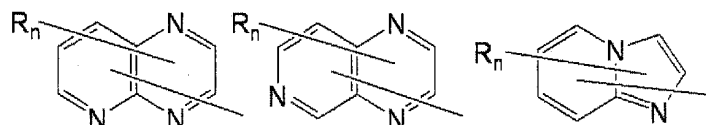
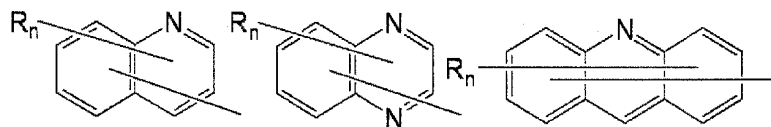
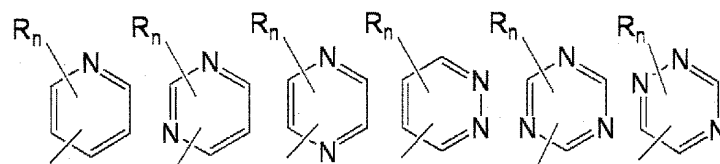
[0096]

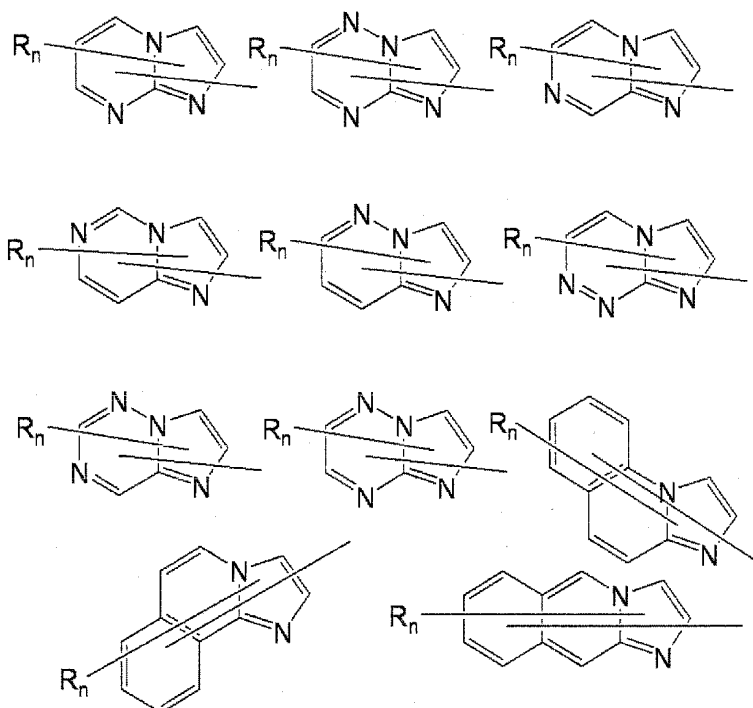


[0097] A nitrogen-containing aromatic polycyclic compound having a 5- or 6-membered ring is preferred. If two or more nitrogen atoms are included, the nitrogen-containing aromatic polycyclic compound preferably has a skeleton of a combination of (A) and (B) or a combination of (A) and (C).

[0098] The nitrogen-containing group of the nitrogen-containing organic compound is selected from the nitrogen-containing heterocyclic groups shown below.

[0099]

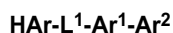




[0100] In the above formulae, R is an aryl group having 6 to 40 carbon atoms, a heteroaryl group having 3 to 40 carbon atoms, an alkyl group having 1 to 20 carbon atoms, or an alkoxy group having 1 to 20 carbon atoms; and n is an integer of 0 to 5. If n is an integer of 2 or more, R groups may be the same or different.

[0101] More preferred is a nitrogen-containing heterocyclic derivative represented by the following formula:

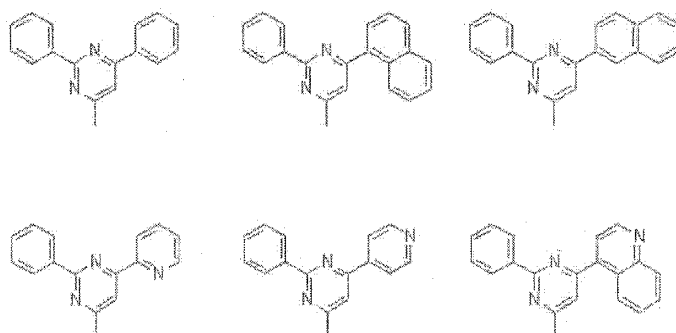
[0102]

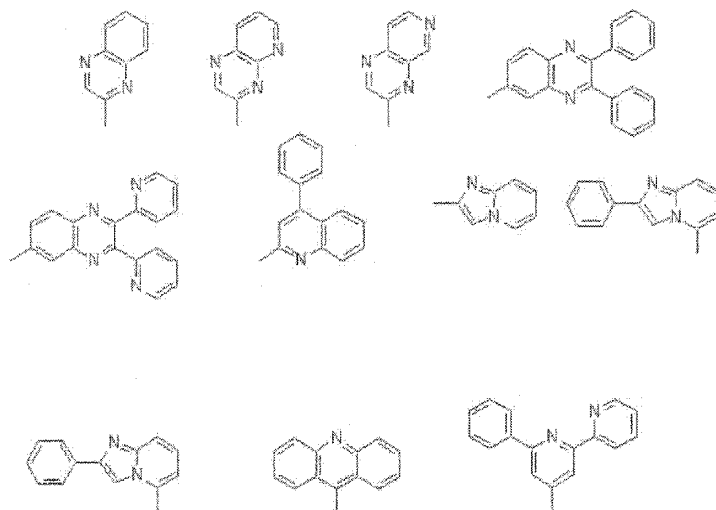
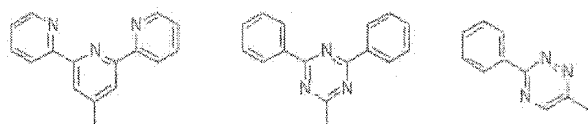


[0103] In the above formula, HAr is a substitute or unsubstituted nitrogen-containing heteroring having 3 to 40 carbon atoms; L^1 is a single bond, a substituted or unsubstituted arylene group having 6 to 40 carbon atoms, or a substituted or unsubstituted heteroarylene group having 3 to 40 carbon atoms; Ar^1 is a substitute or unsubstituted divalent aromatic hydrocarbon group having 6 to 40 carbon atoms; and Ar^2 is a substitute or unsubstituted aryl group having 6 to 40 carbon atoms or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms.

[0104] HAr is selected, for example, from the following group:

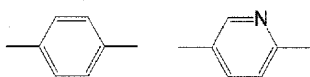
[0105]





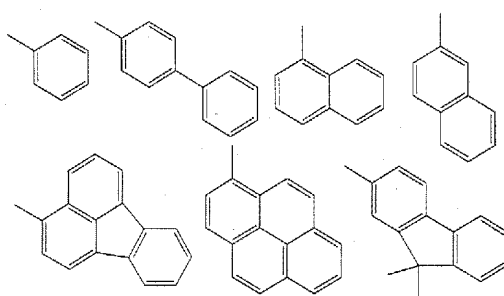
[0106] L¹ is selected, for example, from the following group:

[0107]



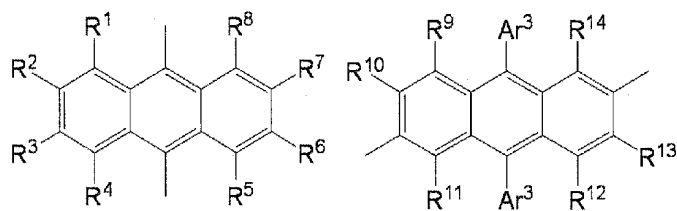
[0108] Ar² is selected, for example, from the following group:

[0109]



[0110] Ar¹ is selected, for example, from the following arylanthranly groups:

[0111]

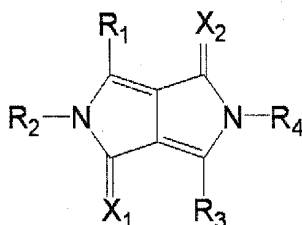


[0112] In the above formulae, R¹ to R¹⁴ are each independently hydrogen atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, or a heteroaryl group having 3 to 40 carbon atoms; and Ar³ is a substituted or unsubstituted aryl group having 6 to 40 carbon atoms or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms.

A nitrogen-containing heterocyclic derivative having Ar¹ wherein R¹ to R⁸ are all hydrogen atoms is preferred.

[0113] In addition, the following compound (JP 9-3448A) is preferred.

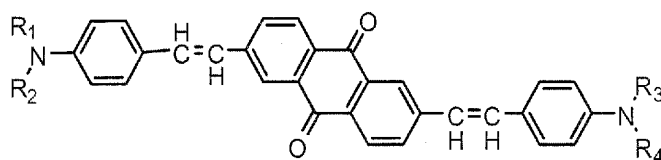
[0114]



[0115] In the above formula, R₁ to R₄ are each independently hydrogen atom, a substituted or unsubstituted aliphatic group, a substituted or unsubstituted alicyclic group, a substituted or unsubstituted carbocyclic aromatic group, or a substituted or unsubstituted heterocyclic group; and X₁ and X₂ are each independently oxygen atom, sulfur atom, or dicyanomethylene group.

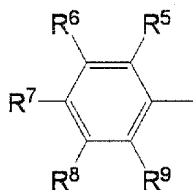
[0116] Further, the following compound (JP 2000-173774A) is also preferred.

[0117]



[0118] In the above formula, R¹, R², R³, and R⁴ may be the same or different and each represents an aryl group represented by the following formula:

[0119]



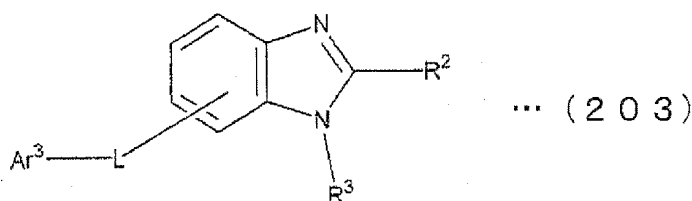
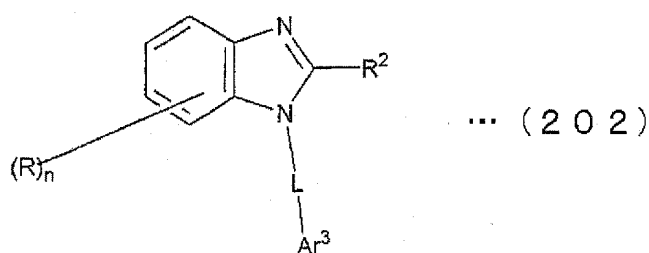
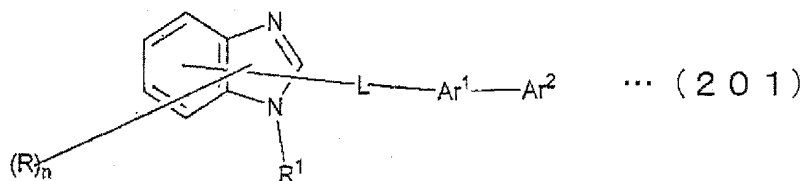
[0120] wherein R⁵, R⁶, R⁷, R⁸, and R⁹ may be the same or different and represent hydrogen atoms or at least one thereof is a saturated or unsaturated alkoxy group, an alkyl group, amino group, or an alkylamino group.

[0121] Further, a high molecular compound having the nitrogen-containing heterocyclic group or the nitrogen-con-

taining heterocyclic derivative is also usable.

[0122] It is preferred for the electron transporting layer to contain any one of the nitrogen-containing heterocyclic derivatives represented by the following formulae (201) to (203):

[0123]



[0124] wherein R is hydrogen atom, a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms; n is an integer of 0 to 4; R¹ is a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or an alkoxy group having 1 to 20 carbon atoms; R² and R³ are each independently hydrogen atom, a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms; L is a substituted or unsubstituted arylene group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridinylene group, a substituted or unsubstituted quinolinylene group, or a substituted or unsubstituted fluorenylene group; Ar¹ is a substituted or unsubstituted arylene group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridinylene group, or a substituted or unsubstituted quinolinylene group; and Ar² is a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms.

Ar³ is a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, or a group represented by -Ar¹-Ar² wherein Ar¹ and Ar² are as defined above.

[0125] In formulae (201) to (203), R is hydrogen atom, a substituted or unsubstituted aryl group having 6 to 60 carbon

atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms.

[0126] Examples of the aryl group having 6 to 60 carbon atoms, preferably 6 to 40 carbon atoms, and more preferably 6 to 20 carbon atoms include phenyl group, naphthyl group, anthryl group, phenanthryl group, naphthacenyl group, chrysenyl group, pyrenyl group, biphenyl group, terphenyl group, tolyl group, t-butylphenyl group, (2-phenylpropyl)phenyl group, fluoranthenyl group, fluorenyl group, a monovalent residue of spirobifluorene, perfluorophenyl group, perfluoronaphthyl group, perfluoroanthryl group, perfluorobiphenyl group, a monovalent residue of 9-phenylanthracene, a monovalent residue of 9-(1'-naphthyl)anthracene, a monovalent residue of 9-(2'-naphthyl)anthracene, a monovalent residue of 6-phenylchrysene, and a monovalent residue of 9-[4-(diphenylamino)phenyl]anthracene, with phenyl group, naphthyl group, biphenyl group, terphenyl group, 9-(10-phenyl)anthryl group, 9-[10-(1'-naphthyl)]anthryl group, and 9-[10-(2'-naphthyl)]anthryl group being preferred.

[0127] Examples of the alkyl group having 1 to 20 carbon atoms, preferably 1 to 6 carbon atoms include methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, and a haloalkyl group, such as trifluoromethyl group. The alkyl group having 3 or more carbon atoms may be linear, cyclic or branched.

Examples of the alkoxy group having 1 to 20 carbon atoms, preferably 1 to 6 carbon atoms include methoxy group, ethoxy group, propoxy group, butoxy group, pentyloxy group, and hexyloxy group. The alkoxy group having 3 or more carbon atoms may be linear, cyclic or branched.

[0128] Examples of the substituent represented by R include a halogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, a substituted or unsubstituted aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, and a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms.

Examples of the halogen atom include fluorine, chlorine, bromine, and iodine.

Examples of the alkyl group having 1 to 20 carbon atoms, the alkoxy group having 1 to 20 carbon atoms, and the aryl group having 6 to 40 carbon atoms are the same as those described above.

[0129] Examples of the aryloxy group having 6 to 40 carbon atoms include phenoxy group and biphenyloxy group. Examples of the heteroaryl group having 3 to 40 carbon atoms include pyrrolyl group, furyl group, thienyl group, silolyl group, pyridyl group, quinolyl group, isoquinolyl group, benzofuryl group, imidazolyl group, pyrimidyl group, carbazolyl group, selenophenyl group, oxadiazolyl group, and triazolyl group.

n is an integer of 0 to 4, preferably 0 to 2.

[0130] In formula (201), R¹ is a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or an alkoxy group having 1 to 20 carbon atoms.

Examples, preferred examples, and preferred carbon numbers of the above groups are the same as those described with respect to R.

[0131] In formulae (202) and (203), R² and R³ are each independently hydrogen atom, a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms.

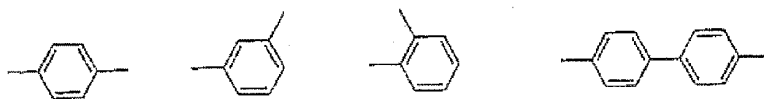
Examples of each group, preferred carbon numbers, and examples of substituent are the same as those described with respect to R.

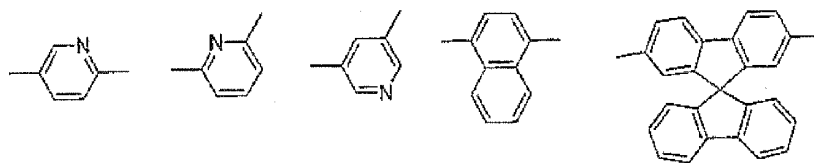
[0132] In formulae (201) to (203), L is a substituted or unsubstituted arylene group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridinylene group, a substituted or unsubstituted quinolinylenylene group, or a substituted or unsubstituted fluorenylene group.

Preferably the arylene group has 6 to 40 carbon atoms and more preferably 6 to 20 carbon atoms. Examples thereof include divalent groups formed by removing one hydrogen atom from the aryl groups described with respect to R. Examples of the substituent of each group represented by L are the same as those described with respect to R.

[0133] L is preferably selected from the following group:

[0134]

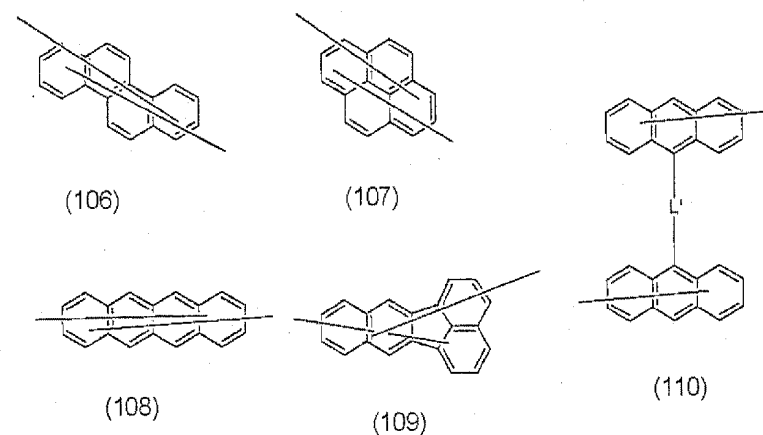
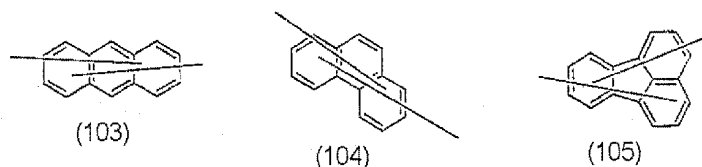
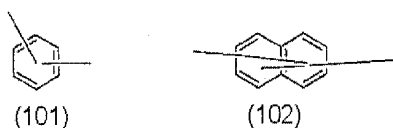




[0135] In formula (201), Ar¹ is a substituted or unsubstituted arylene group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridinylene group, or a substituted or unsubstituted quinolinylene group. Examples of the substituent of each group represented by Ar¹ and Ar³ are the same as those described with respect to R.

Ar¹ is preferably any one of condensed groups represented by the following formulae (101) to (110):

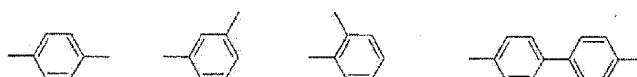
[0136]

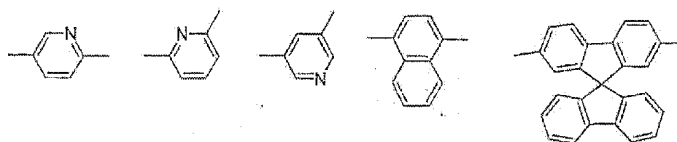


[0137] In formulae (101) to (110), each condensed ring may be substituted by a halogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, a substituted or unsubstituted aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms. If substituted by two or more groups, the substituents may be the same or different. Examples of the substituent are the same as those described above.

In formula (110), L' is a single bond or a group selected from the following group:

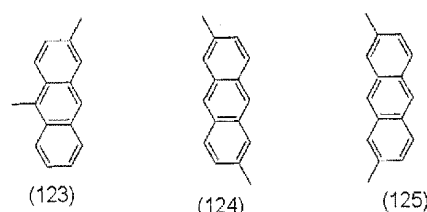
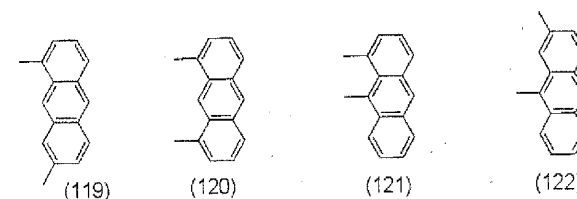
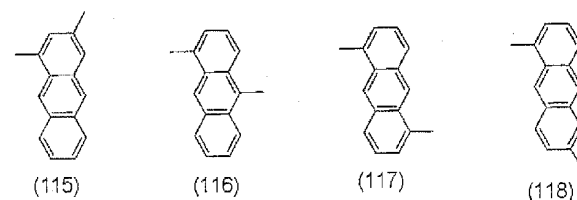
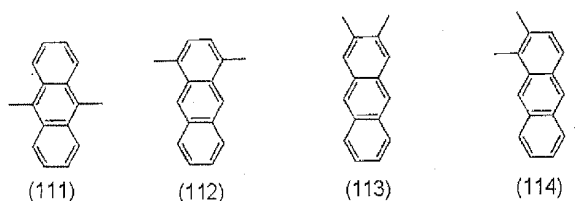
[0138]





[0139] Formula (103) represented by Ar^1 is preferably the condensed ring group represented by the following formulae (111) to (125):

[0140]



[0141] In formulae (111) to (125), each condensed ring may be substituted by a halogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, a substituted or unsubstituted aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms. If substituted by two or more groups, the substituents may be the same or different. Examples of the substituent are the same as those described above.

[0142] In formula (201), Ar^2 is a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, or a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms.

Examples of each group, preferred carbon numbers, and examples of substituent are the same as those described with respect to R.

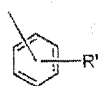
[0143] In formulae (202) and (203), Ar^3 is a substituted or unsubstituted aryl group having 6 to 60 carbon atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted

alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, or a group represented by $-\text{Ar}^1-\text{Ar}^2$ wherein Ar^1 and Ar^2 are as defined above.

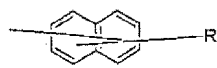
Examples of each group, preferred carbon numbers, and examples of substituent are the same as those described with respect to R.

Ar^3 is preferably any one of condensed ring groups represented by the following formulae (126) to (135):

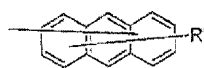
[0144]



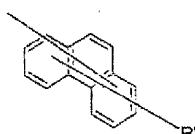
(126)



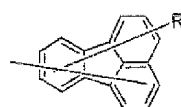
(127)



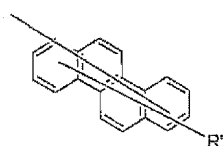
(128)



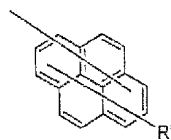
(129)



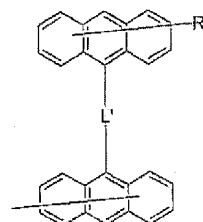
(130)



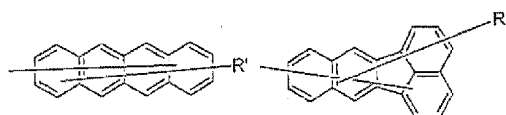
(131)



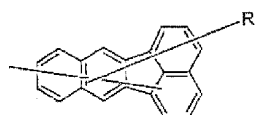
(132)



(135)



(133)



(134)

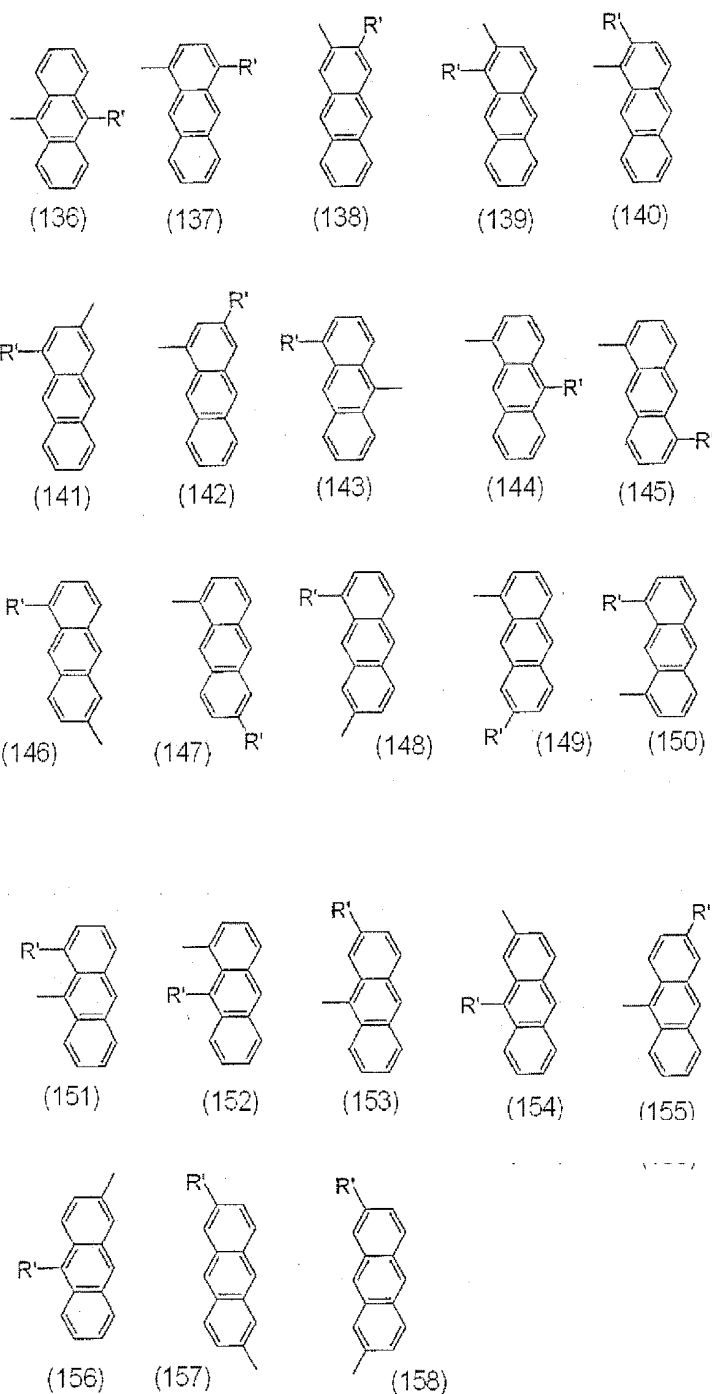
[0145] In formulae (126) to (135), each condensed ring may be substituted by a halogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, a substituted or unsubstituted aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms. If substituted by two or more groups, the substituents may be the same or different. Examples of the substituent are the same as those described above.

In formula (135), L' is as defined above.

In formulae (126) to (135), R' is hydrogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms. Examples thereof are the same as those described above.

Formula (128) represented by Ar^3 is preferably the condensed ring group represented by the following formulae (136) to (158):

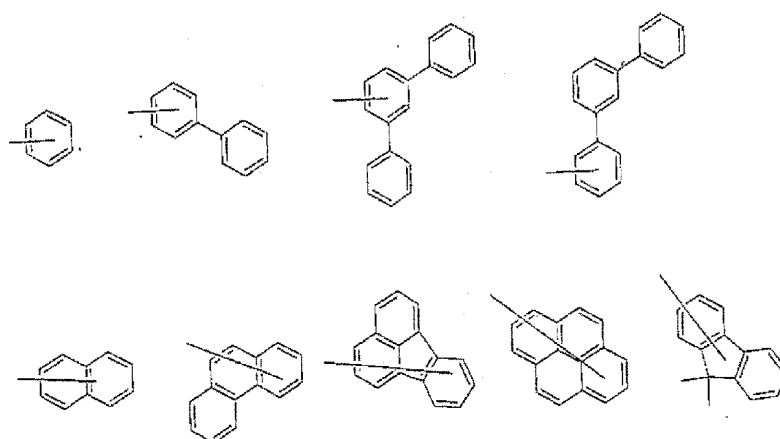
[0146]



[0147] In formulae (136) to (158), each condensed ring may be substituted by a halogen atom, a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 20 carbon atoms, a substituted or unsubstituted aryloxy group having 6 to 40 carbon atoms, a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, or a substituted or unsubstituted heteroaryl group having 3 to 40 carbon atoms. If substituted by two or more groups, the substituents may be the same or different. Examples of the substituent are the same as those described above.

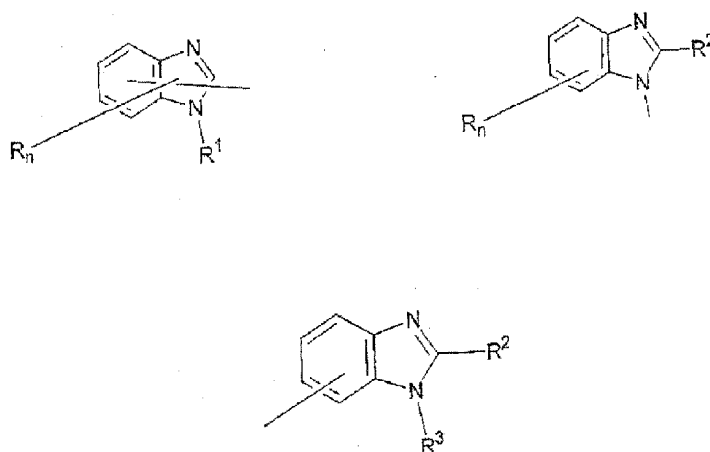
Each of Ar² and Ar³ is preferably selected from the following group:

[0148]

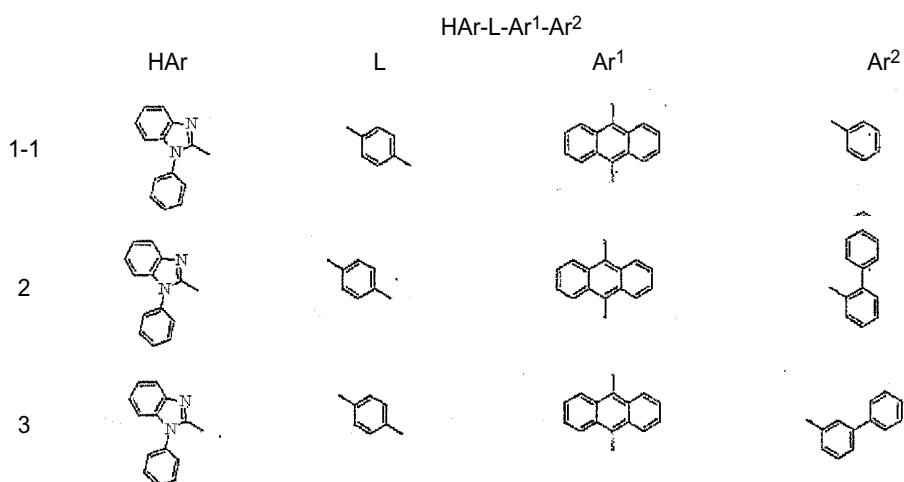


[0149] Examples of the nitrogen-containing heterocyclic derivative represented by formulae (201) to (203) are shown below. The nitrogen-containing heterocyclic derivative is, however, not limited to the following exemplary compounds. In the following tables, HAr is the following structure in formulae (201) to (203).

[0150]



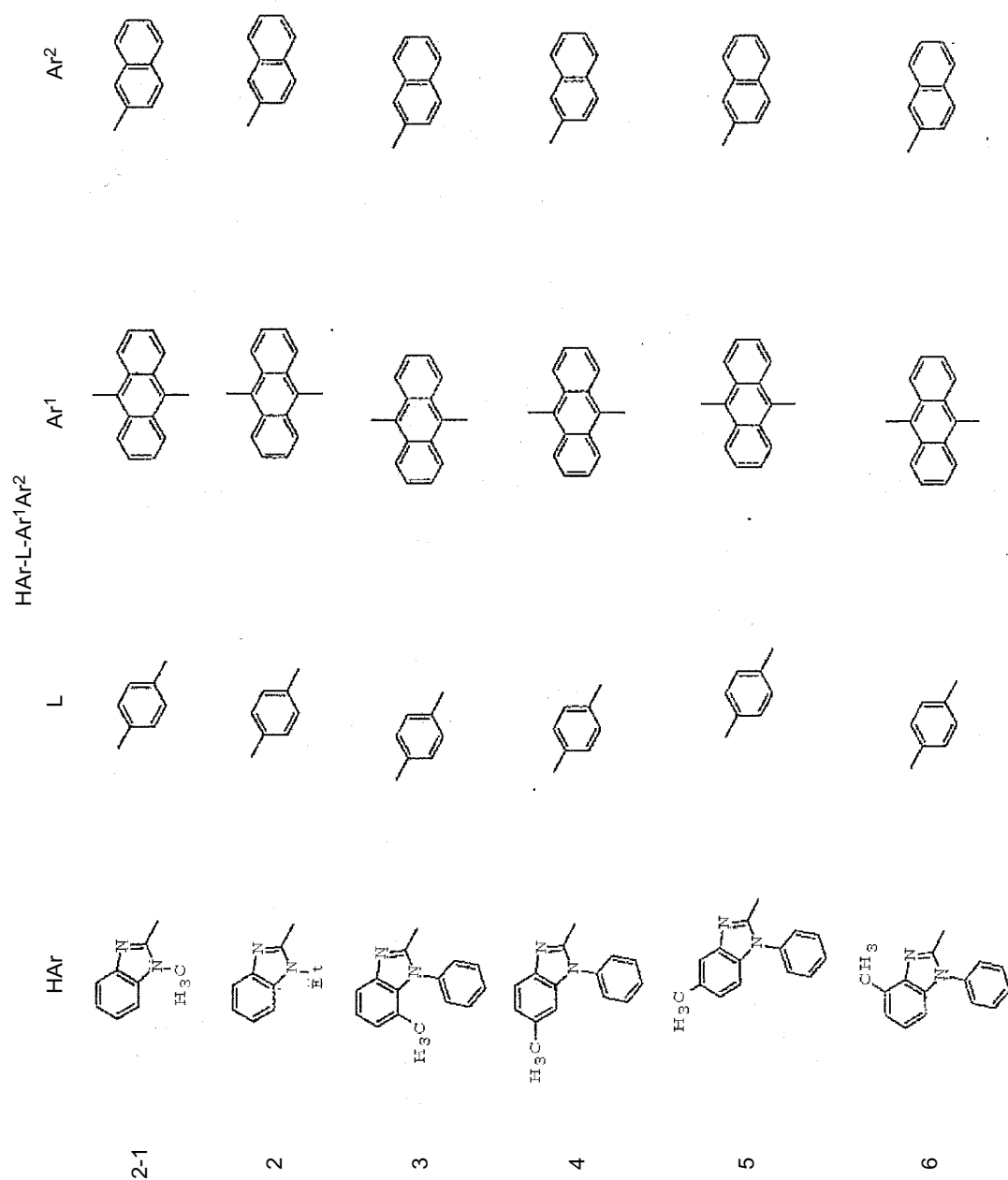
[0151]



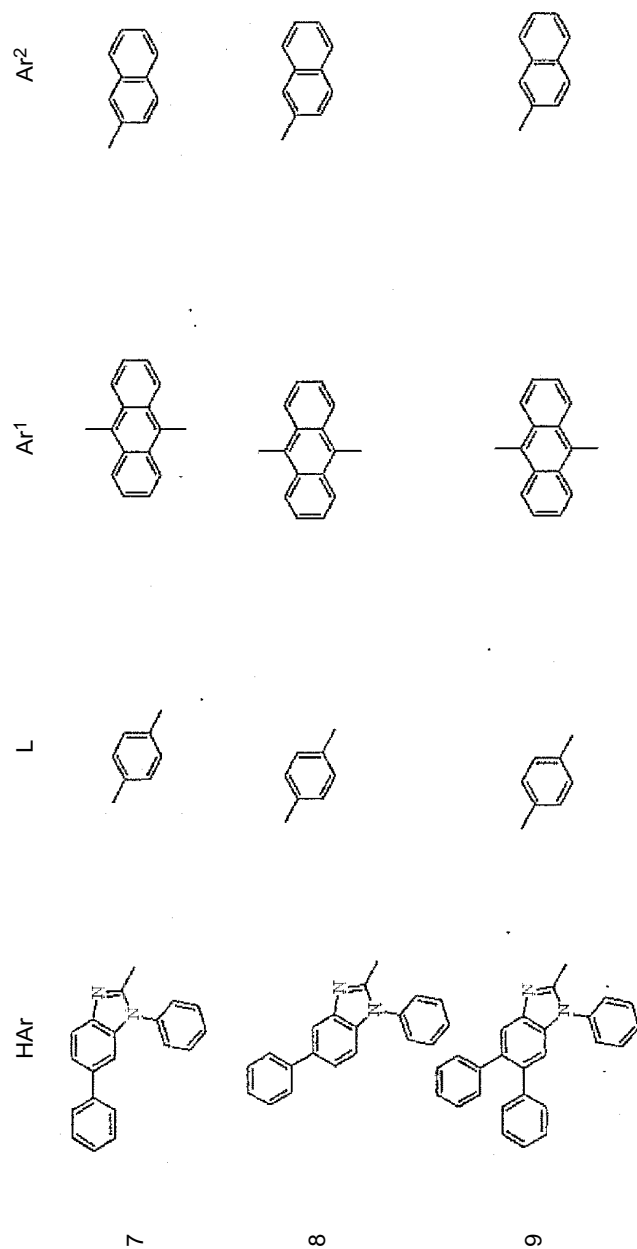
(continued)

HAr-L-Ar¹-Ar²

[0152]



(continued)
HAr-L-Ar¹Ar²



[0153]

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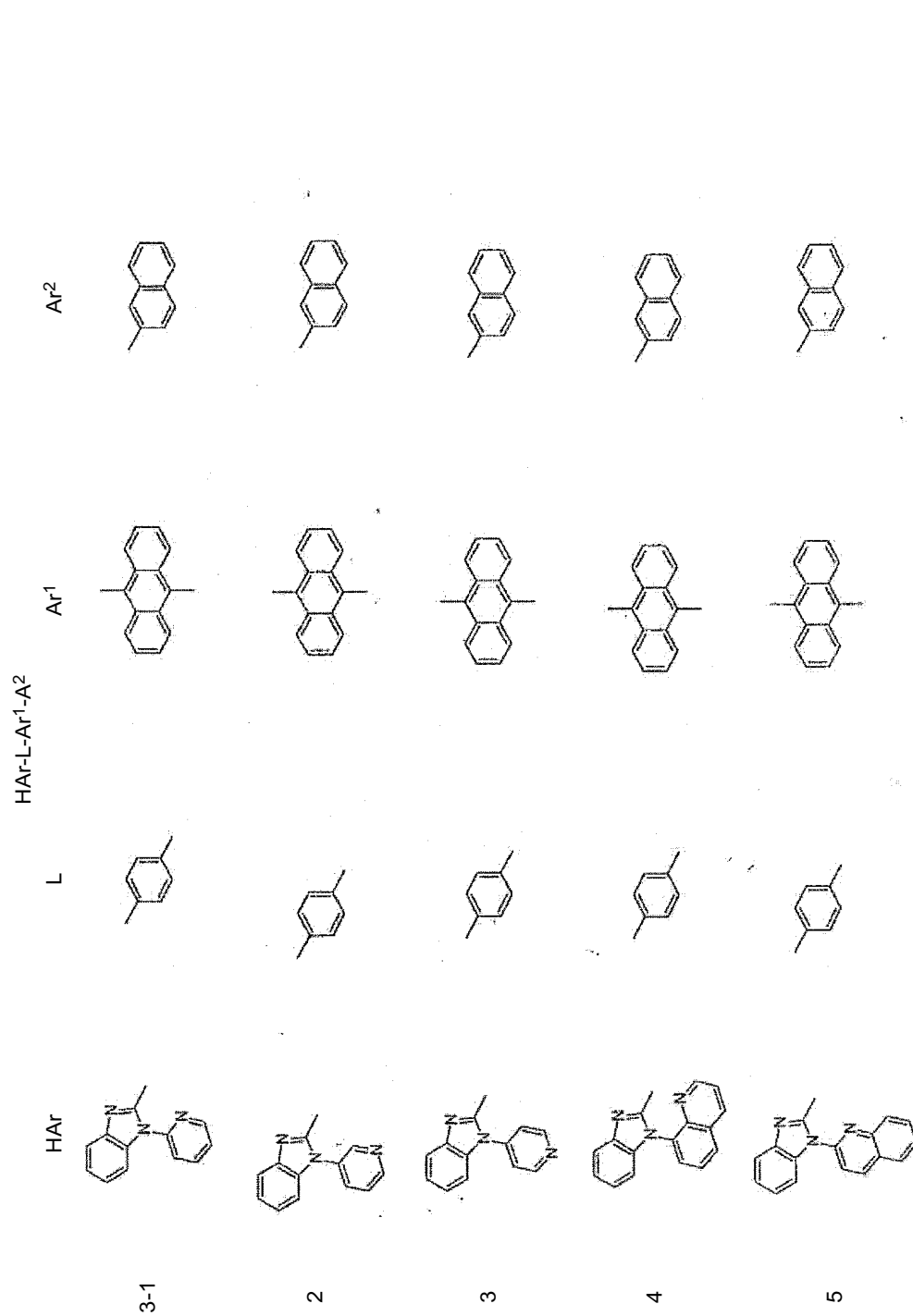
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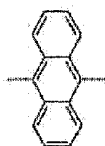
Ar²



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Ar¹



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(continued)

HAr-L-Ar¹-A²

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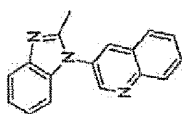
L



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HAr

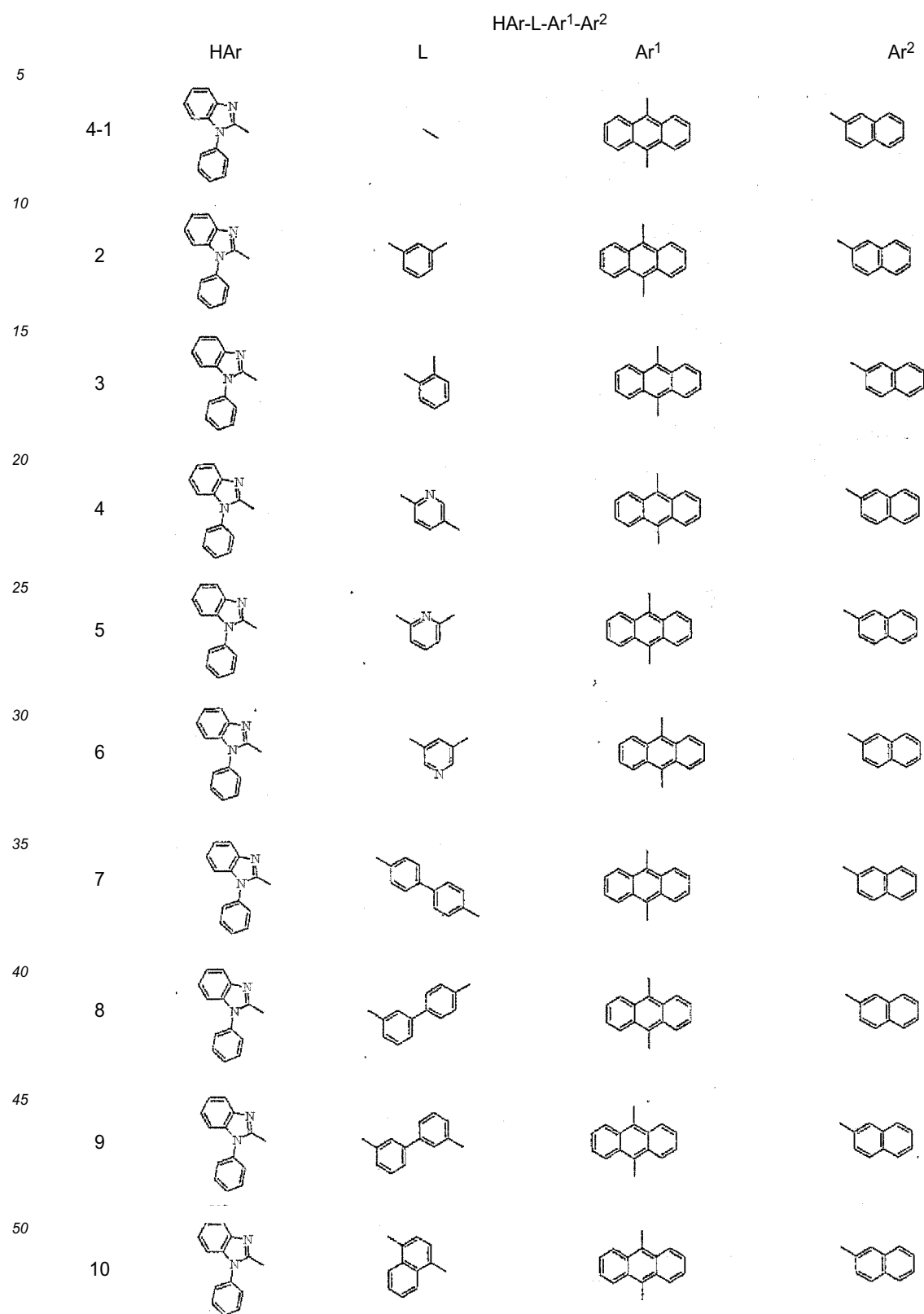


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[0154]



(continued)

HAr-L-Ar¹-Ar²

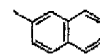
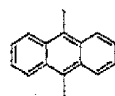
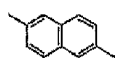
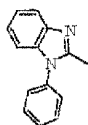
HAr

L

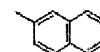
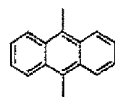
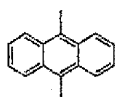
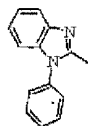
Ar¹

Ar²

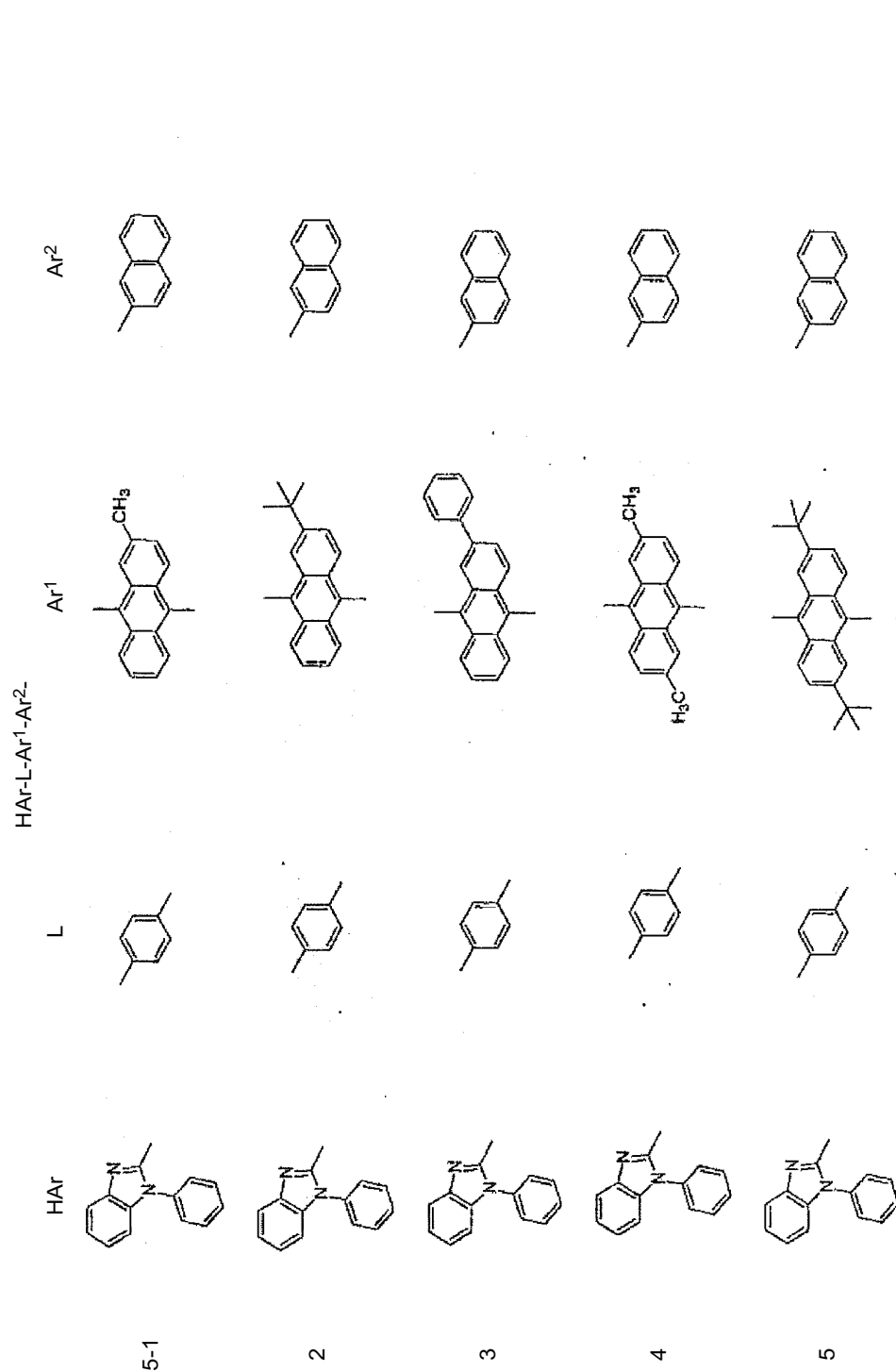
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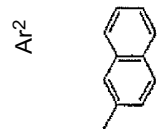
[0155]



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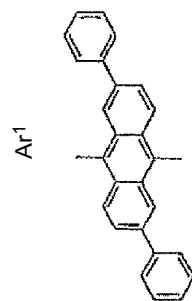
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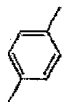
(continued)

HAr-L-Ar¹-Ar²-



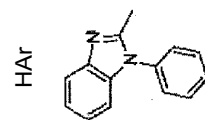
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L



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[0156]

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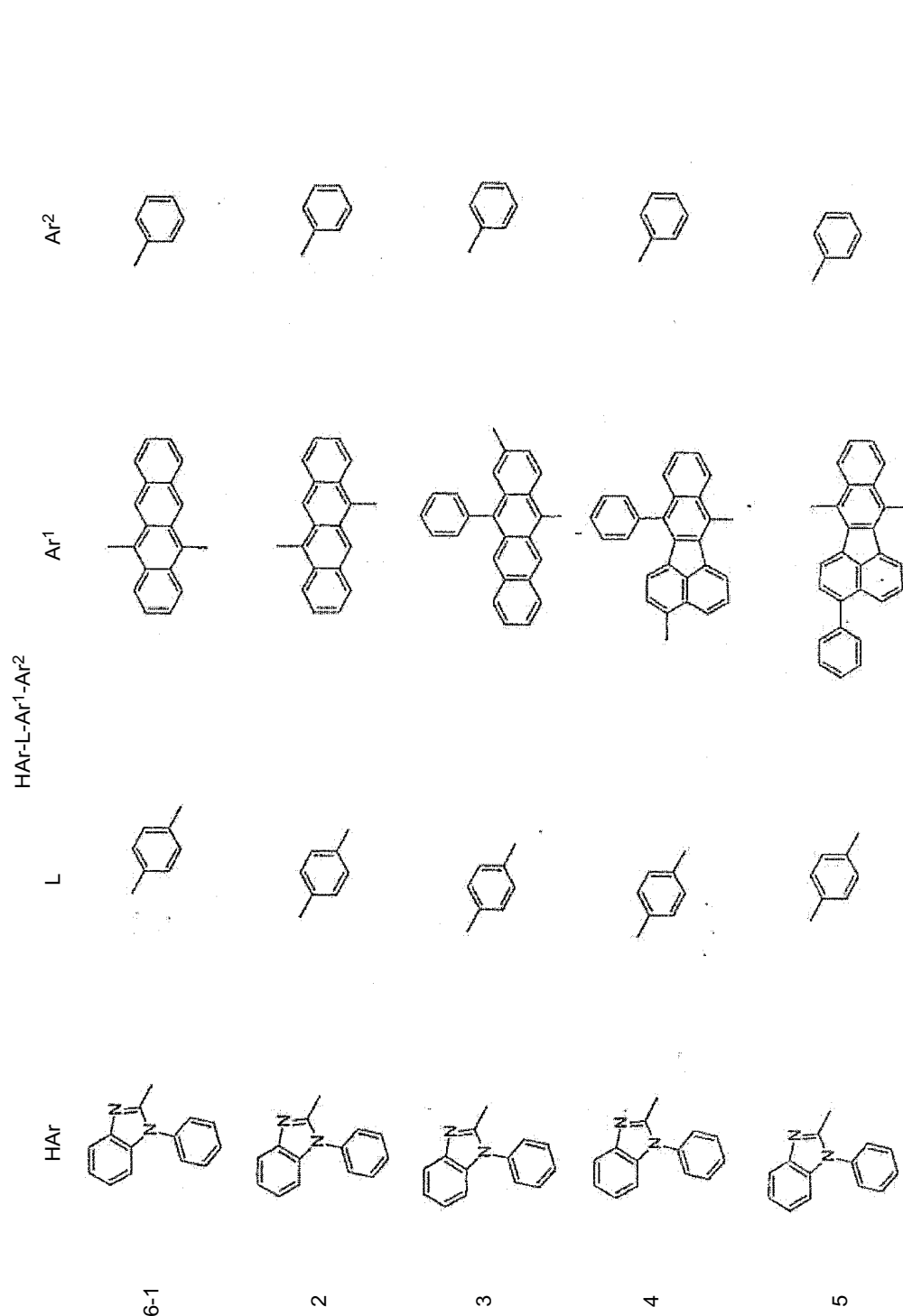
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[0157]



(continued)

HAr-L-Ar¹-Ar²

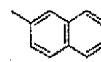
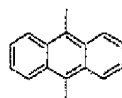
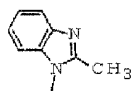
HAr

L

Ar¹

Ar²

10



[0158]

HAr-L-Ar¹-Ar²

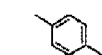
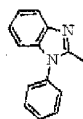
HAr

L

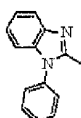
Ar¹

Ar²

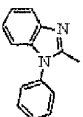
8-1



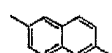
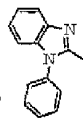
2



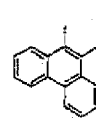
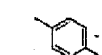
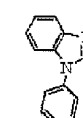
3



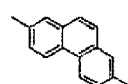
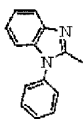
4



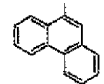
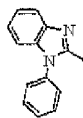
5



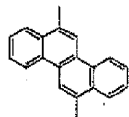
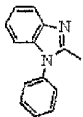
6



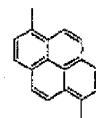
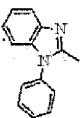
7



B

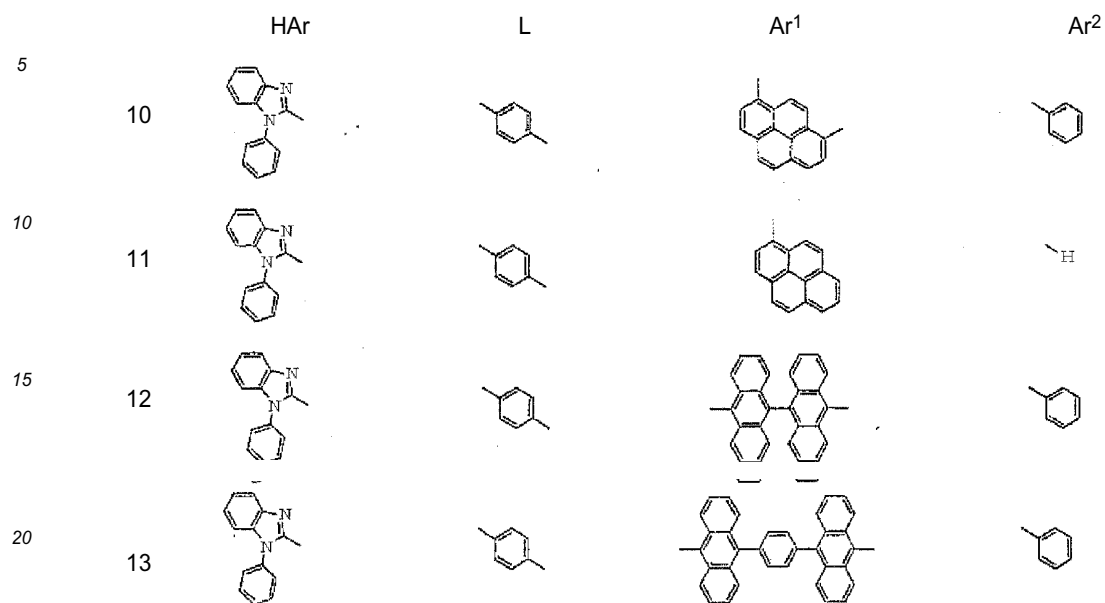


9



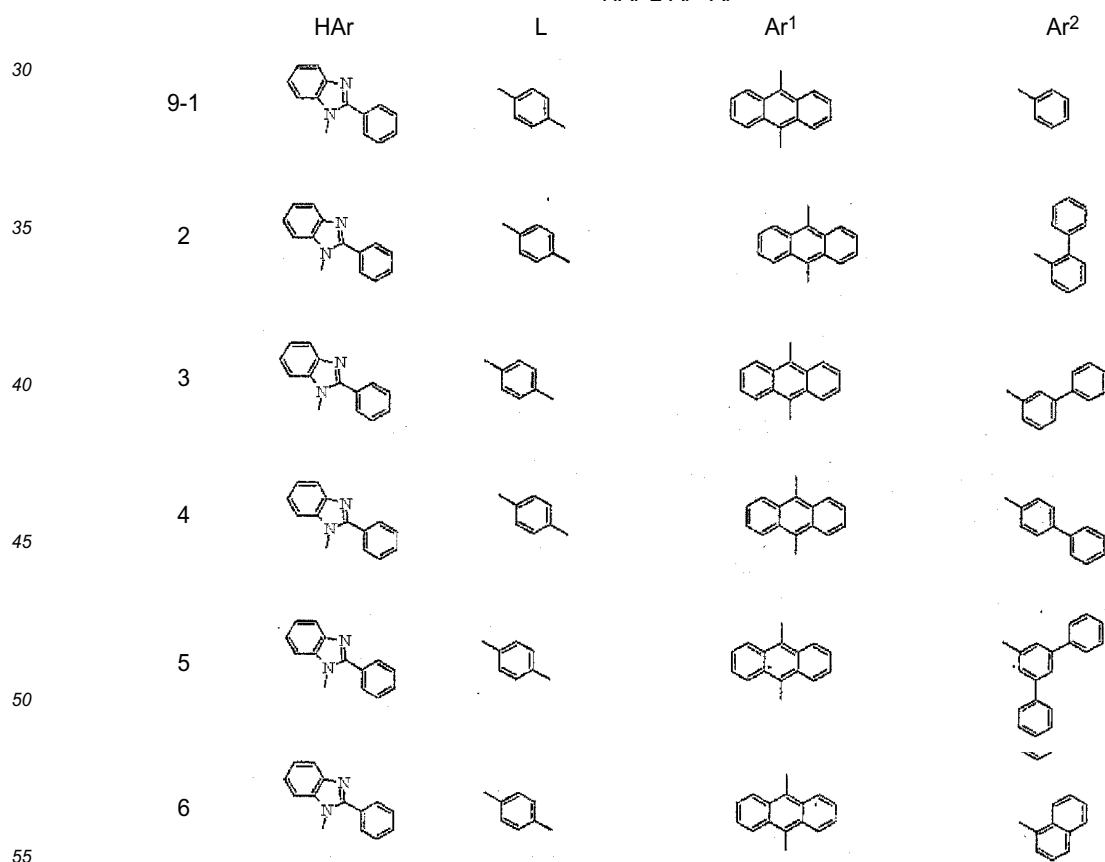
(continued)

HAr-L-Ar¹-Ar²



[0159]

HAr-L-Ar¹-Ar²



(continued)

HAr-L-Ar¹-Ar²

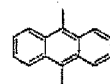
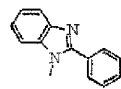
HAr

L

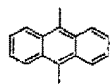
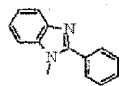
Ar¹

Ar²

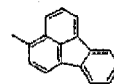
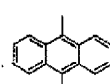
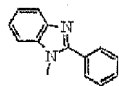
7



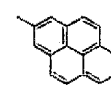
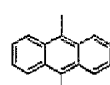
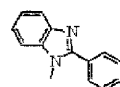
8



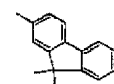
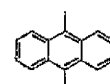
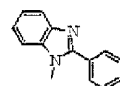
9



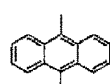
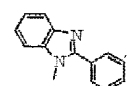
10



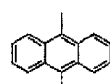
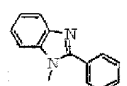
11



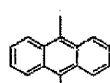
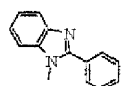
12



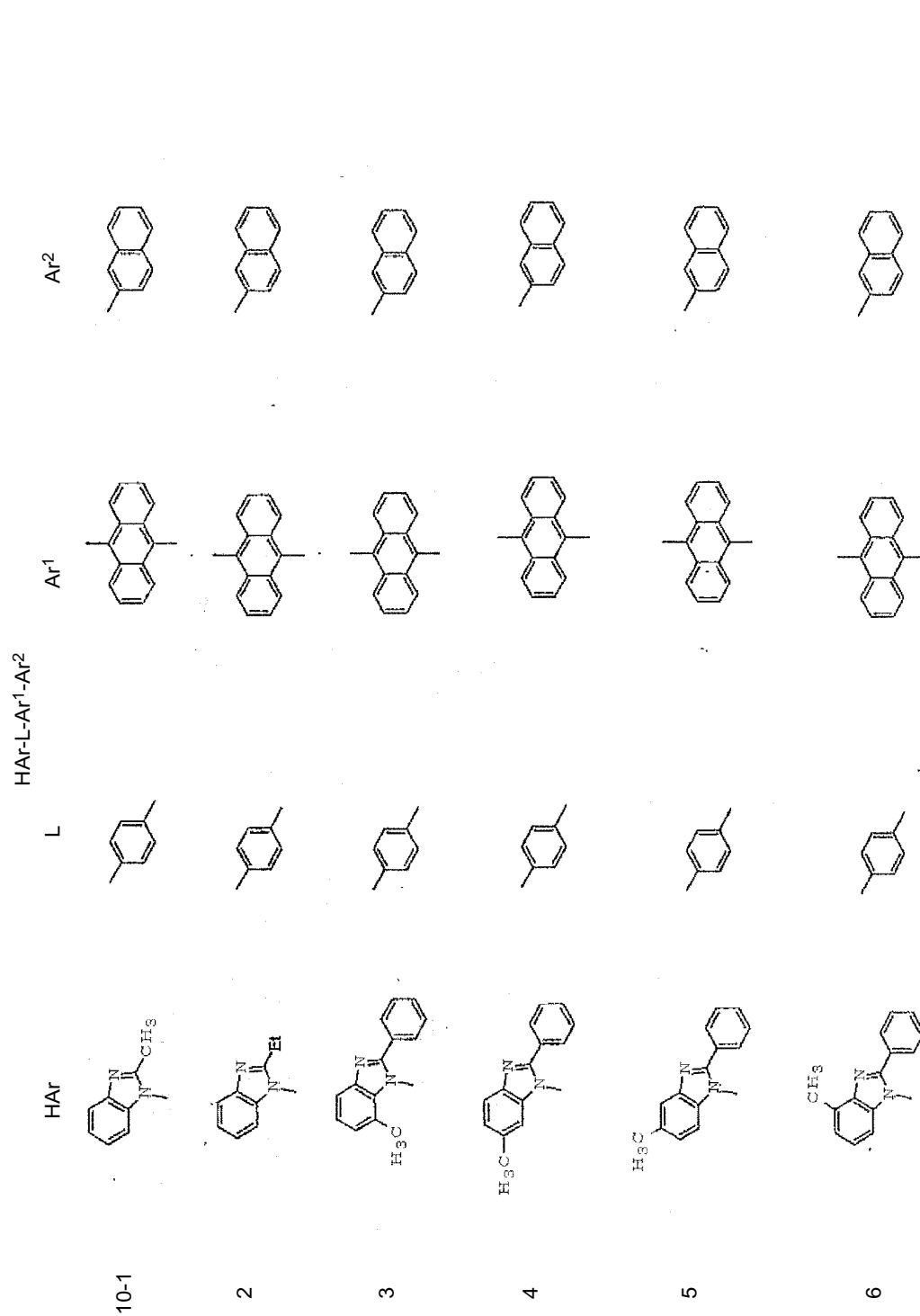
13



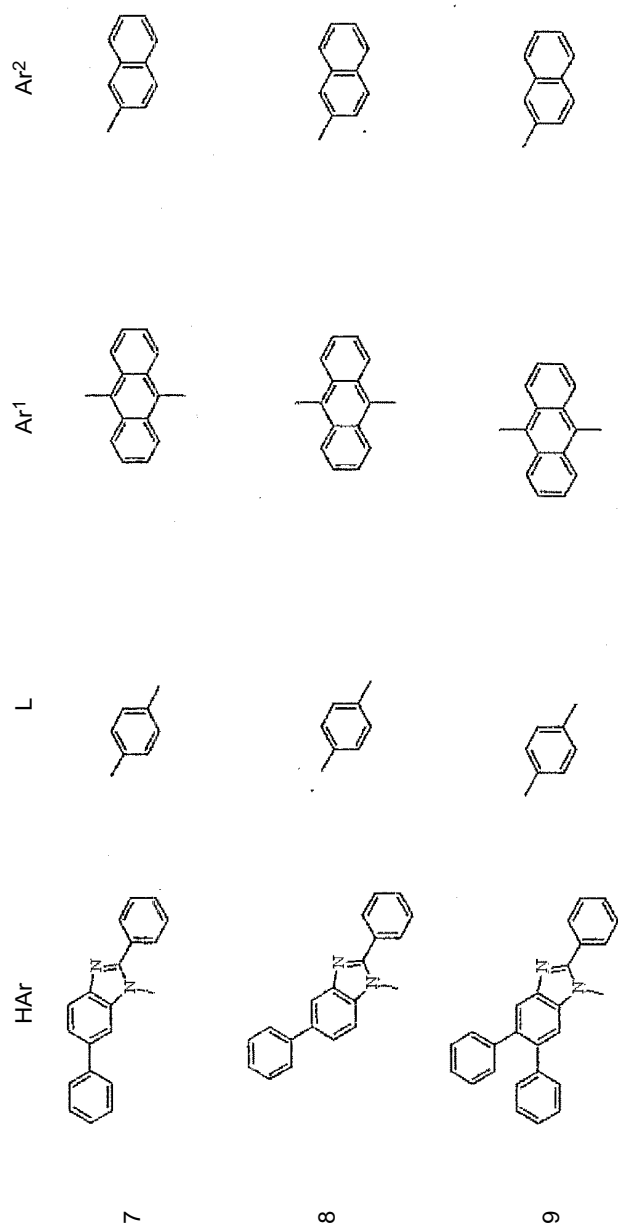
14



[0160]



(continued)
HAr-L-Ar¹-Ar²



[0161]

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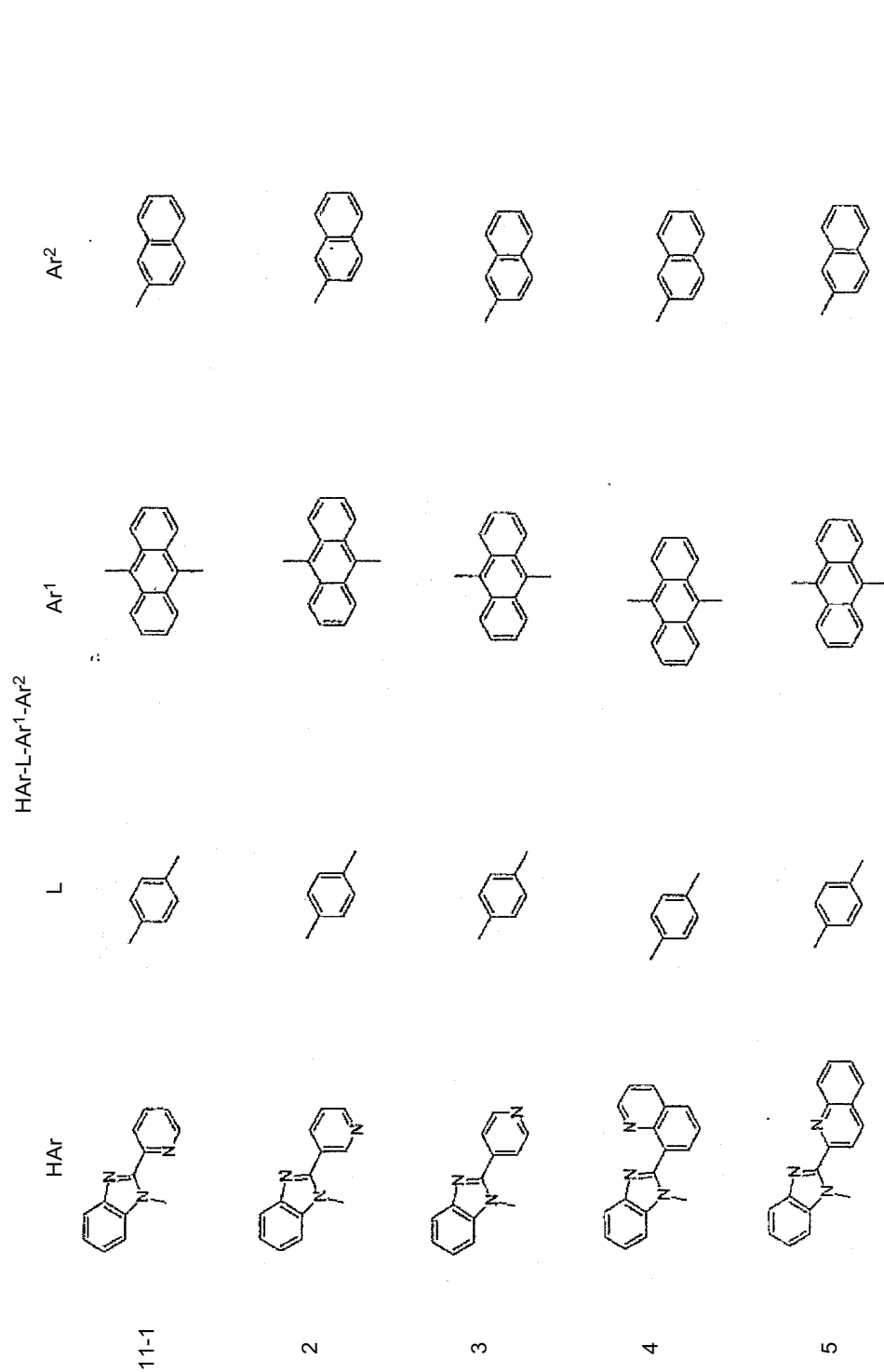
35

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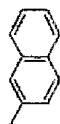


5

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15

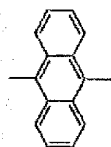
Ar²



20

25

Ar¹



30

(continued)

HAr-L-Ar¹-Ar²

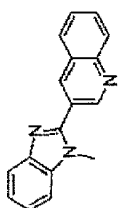
35

L



40

HAr



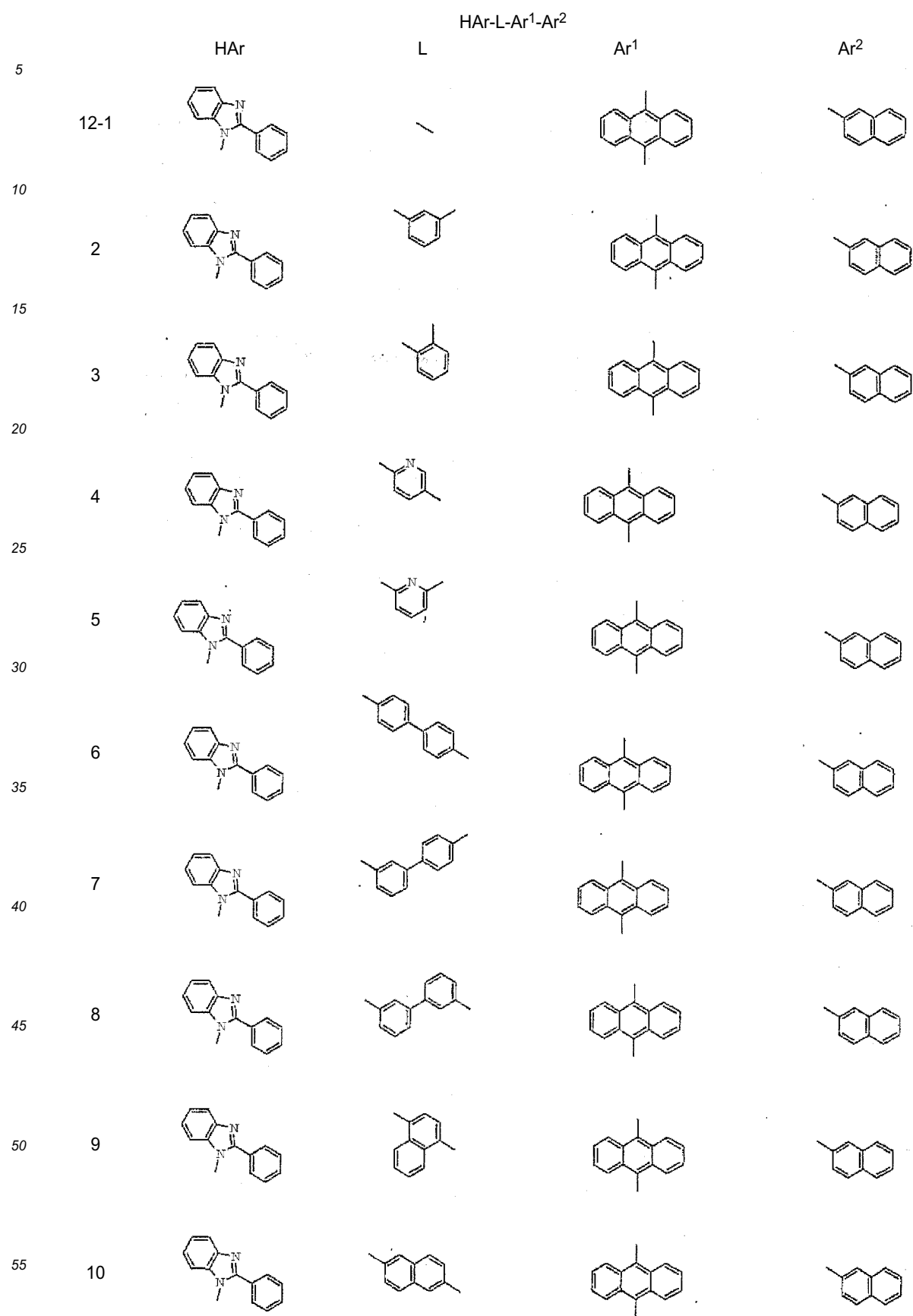
45

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6

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[0162]



(continued)

HAr-L-Ar¹-Ar²

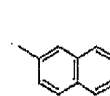
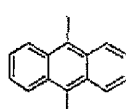
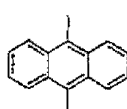
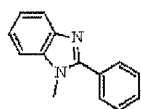
HAr

L

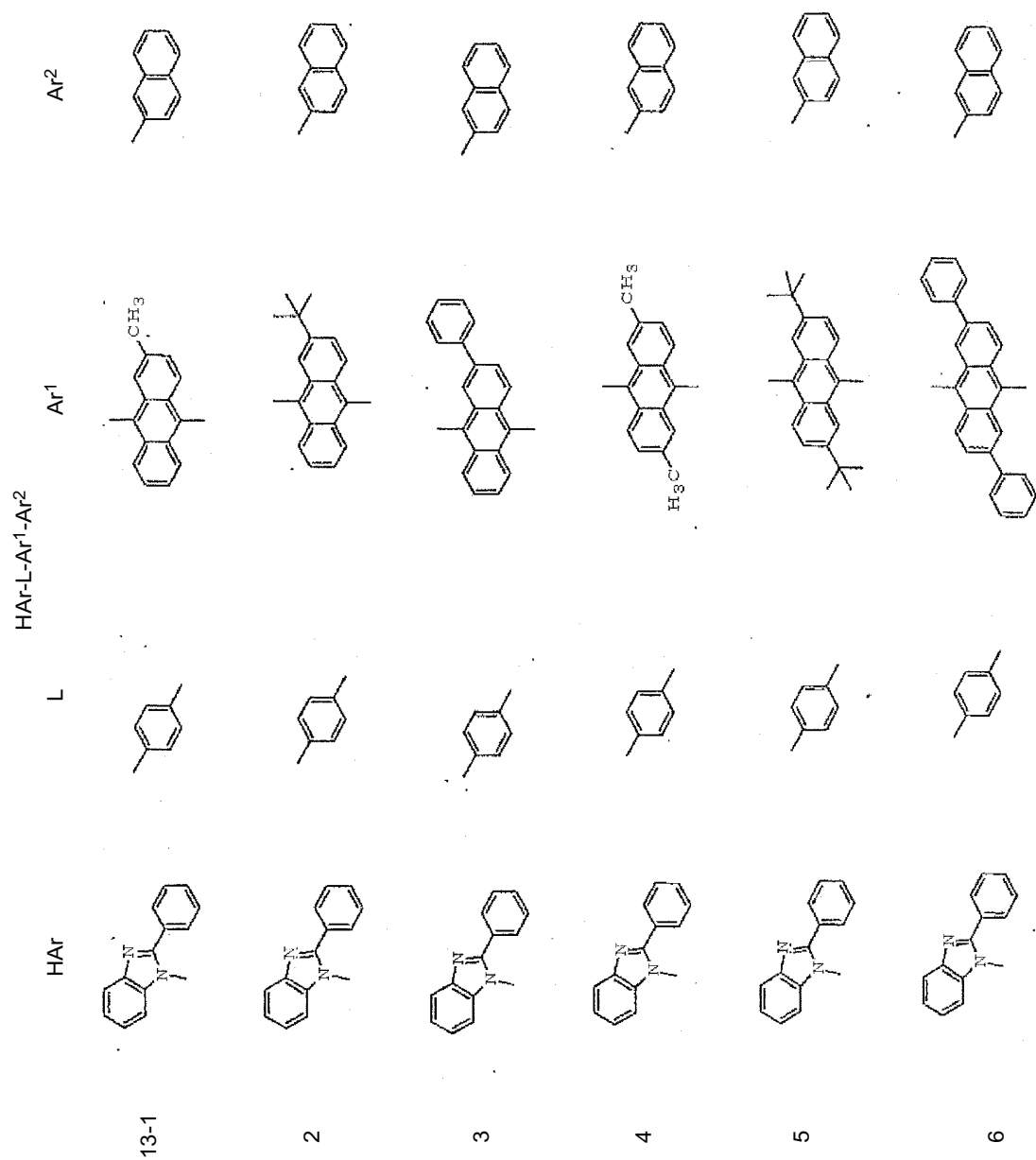
Ar¹

Ar²

11



[0163]



[0164]

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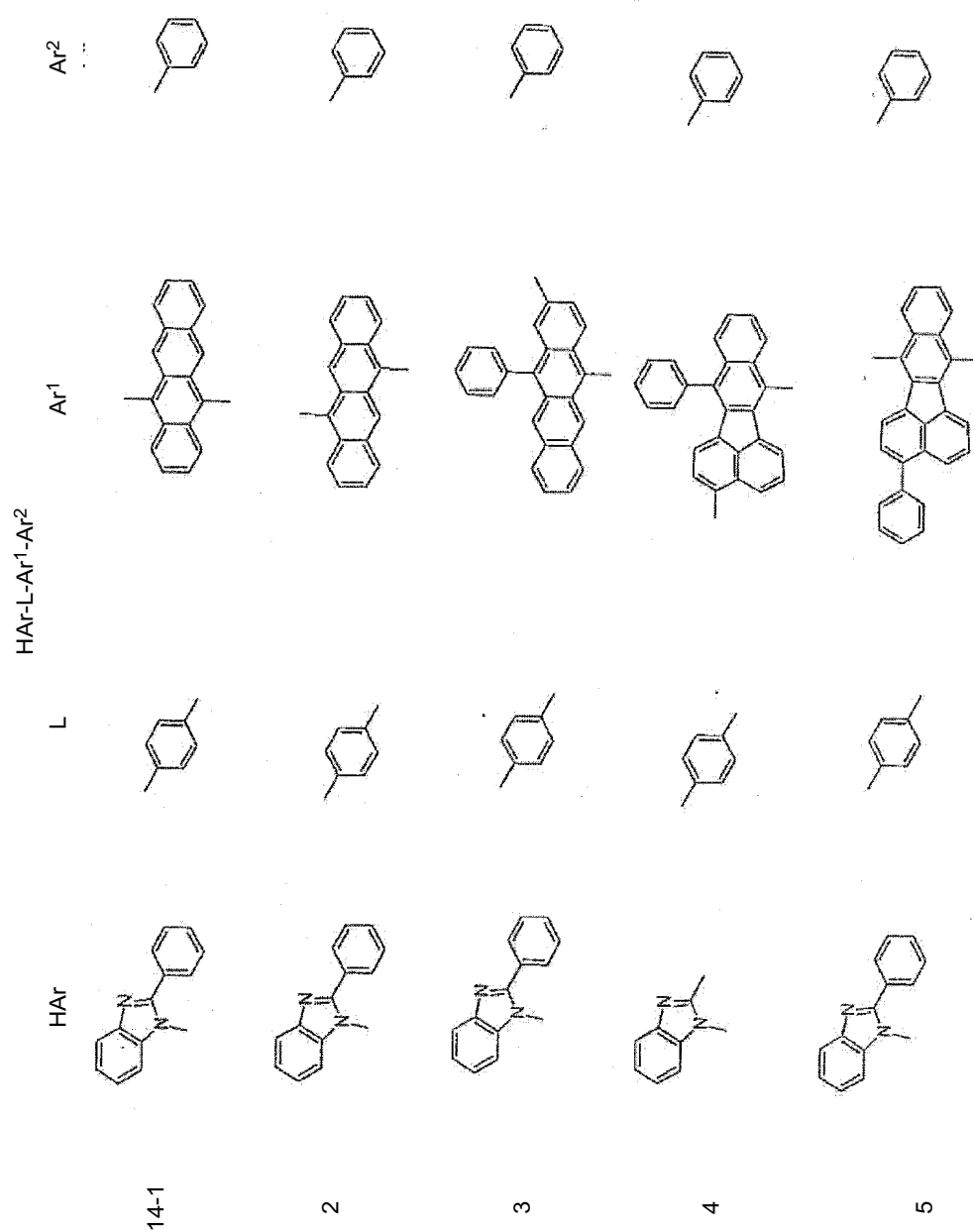
35

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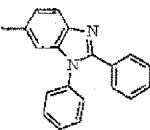
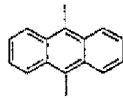
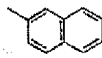
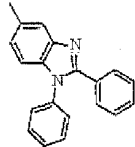
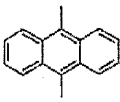
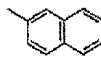
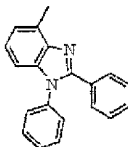
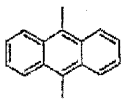
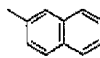
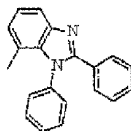
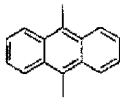
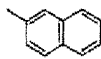
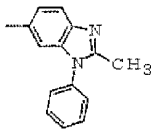
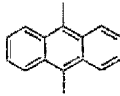
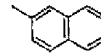
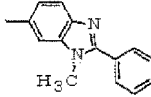
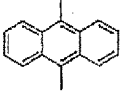
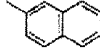
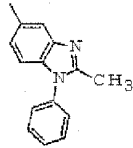
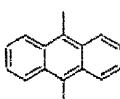
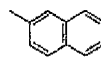
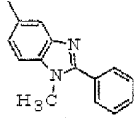
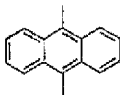
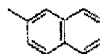
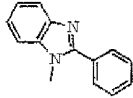
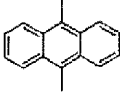
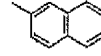
45

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[0165]

	HAr	L	Ar ¹	Ar ²
5				
15-1				
10				
2				
15				
3				
20				
4				
25				
5				
30				
6				
35				
7				
40				
8				
45				
9				
50				
55				

(continued)

HAr-L-Ar¹-Ar²

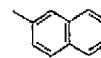
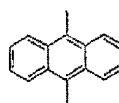
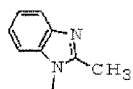
HAr

L

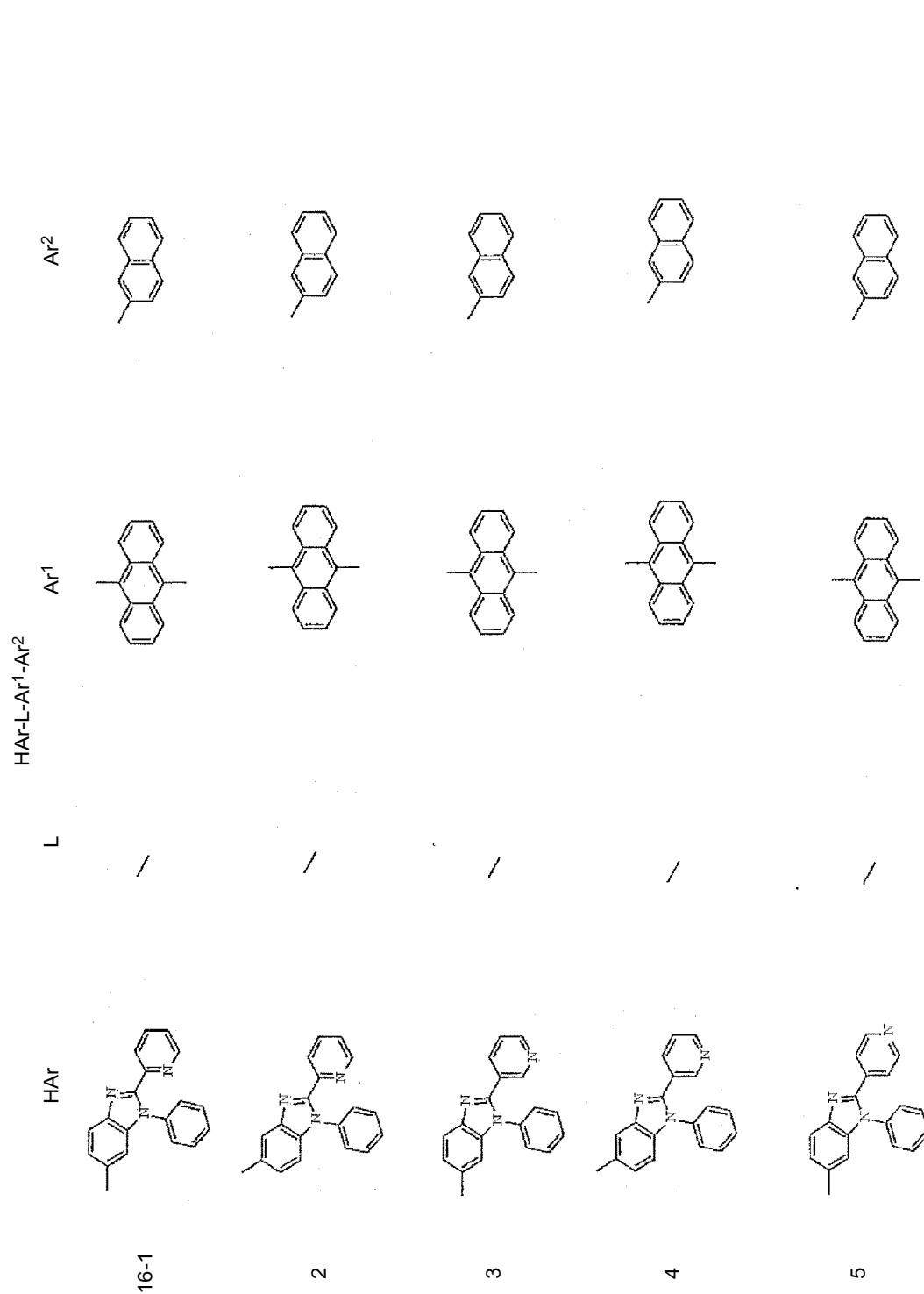
Ar¹

Ar²

10



[0166]



5

10

15

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25

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35

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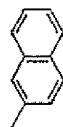
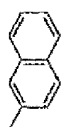
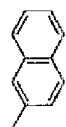
50

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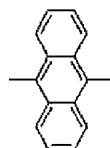
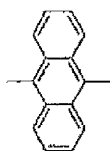
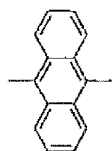
(continued)

HAr-L-Ar¹-Ar²

Ar²



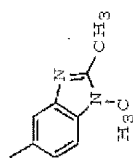
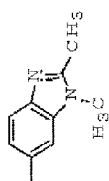
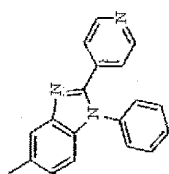
Ar¹



L



HAr



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[0167]

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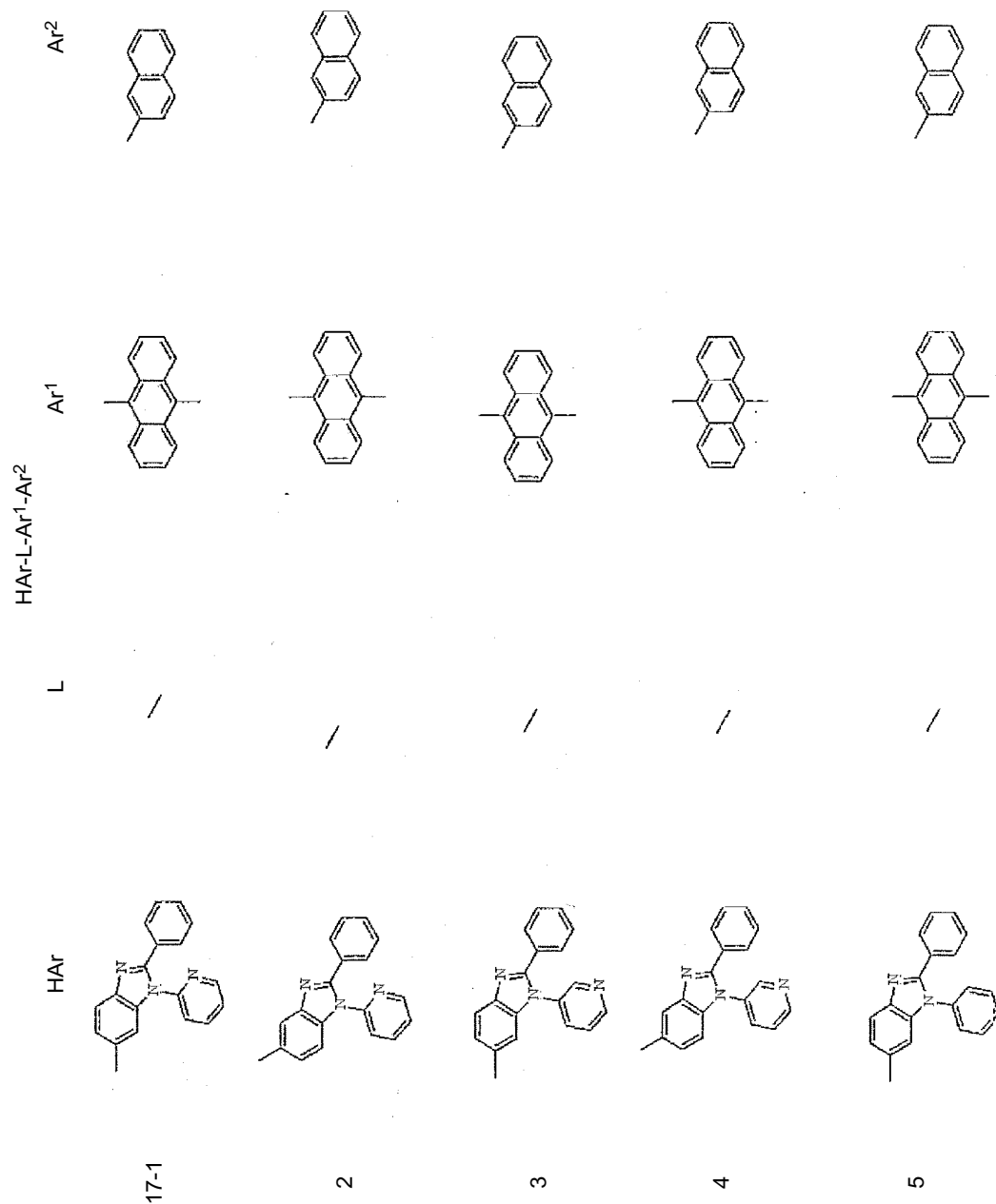
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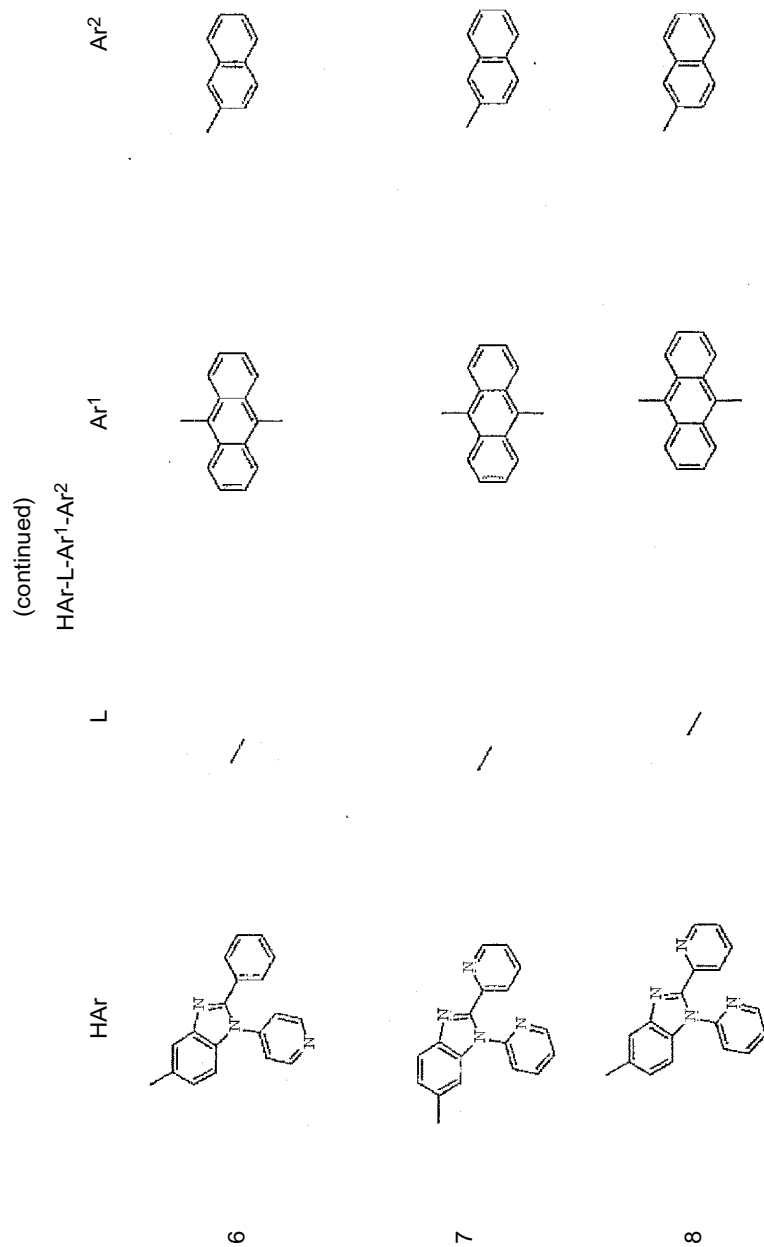
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[0168] Of the above exemplary compounds, particularly preferred are the compounds (1-1), (1-5), (1-7), (2-1), (3-1), (4-2), (4-6), (7-2), (7-7), (7-8), (7-9), (9-1), and (9-7).

[0169] The thickness of the electron injecting layer and the electron transporting layer is preferably, but not particularly limited to, 1 to 100 nm.

[0170] It is preferred that the electron injecting layer is constituted by an inorganic compound, such as an insulating material and a semiconductor, in addition to the nitrogen-containing ring derivative. The electron injecting layer containing the insulating material or the semiconductor effectively prevents the leak of electric current to enhance the electron injecting properties.

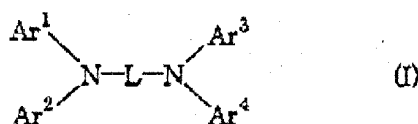
The insulating material is preferably at least one metal compound selected from the group consisting of alkali metal chalcogenides, alkaline earth metal chalcogenides, alkali metal halides and alkaline earth metal halides. The alkali metal chalcogenide, etc. mentioned above are preferred because the electron injecting properties of the electron injecting layer are further enhance. Examples of preferred alkali metal chalcogenide include Li_2O , K_2O , Na_2S , Na_2Se and Na_2O , and examples of preferred alkaline earth metal chalcogenide include CaO , BaO , SrO , BeO , BaS and CaSe . Examples of preferred alkali metal halide include LiF , NaF , KF , LiCl , KCl and NaCl . Examples of the alkaline earth metal halide include fluorides, such as CaF_2 , BaF_2 , SrF_2 , MgF_2 and BeF_2 , and halides other than fluorides.

Examples of the semiconductor include oxides, nitrides or oxynitrides of at least one element selected from the group consisting of Ba, Ca, Sr, Yb, Al, Ga, In, Li, Na, Cd, Mg, Si, Ta, Sb and Zn. The semiconductor may be used alone or in combination of two or more. The inorganic compound included in the electron injecting layer preferably forms a micro-crystalline or amorphous insulating thin film. If the electron injecting layer is formed from such an insulating thin film, the pixel defects, such as dark spots, can be decreased because a more uniform thin film is formed. Examples of such inorganic compound include the alkali metal chalcogenide, the alkaline earth metal chalcogenide, the alkali metal halide and the alkaline earth metal halide.

When using the insulating material or the semiconductor, the thickness of its layer is preferably about 0.1 to 15 nm. The electron injecting layer in the invention may contain the reduction-causing dopant mentioned above.

[0171] The hole injecting layer or the hole transporting layer (inclusive of a hole injecting/transporting layer) is preferably formed from an aromatic amine compound, for example, an aromatic amine derivative represented by the following formula (I):

[0172]



[0173] In formula (I), each of Ar^1 to Ar^4 is a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms, a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms, or a group formed by bonding the preceding aryl group and heteroaryl group to each other.

[0174] Examples of the substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms include phenyl group, 1-naphthyl group, 2-naphthyl group, 1-anthryl group, 2-anthryl group, 9-anthryl group, 1-phenanthryl group, 2-phenanthryl group, 3-phenanthryl group, 4-phenanthryl group, 9-phenanthryl group, 1-naphthacenyl group, 2-naphthacenyl group, 9-naphthacenyl group, 1-pyrenyl group, 2-pyrenyl group, 4-pyrenyl group, 2-biphenyl group, 3-biphenyl group, 4-biphenyl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-phenylpropyl)phenyl group, 3-methyl-2-naphthyl group, 4-methyl-1-naphthyl group, 4-methyl-1-anthryl group, 4'-methylbiphenyl group, 4"-t-butyl-p-terphenyl-4-yl group, fluoranthenyl group, and fluorenyl group.

[0175] Examples of the substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms include 1-pyrrolyl group, 2-pyrrolyl group, 3-pyrrolyl group, pyrazinyl group, 2-pyridinyl group, 3-pyridinyl group, 4-pyridinyl group, 1-indolyl group, 2-indolyl group, 3-indolyl group, 4-indolyl group, 5-indolyl group, 6-indolyl group, 7-indolyl group, 1-isoindolyl group, 2-isoindolyl group, 3-isoindolyl group, 4-isoindolyl group, 5-isoindolyl group, 6-isoindolyl group, 7-isoindolyl group, 2-furyl group, 3-furyl group, 2-benzofuranyl group, 3-benzofuranyl group, 4-benzofuranyl group, 5-benzofuranyl group, 6-benzofuranyl group, 7-benzofuranyl group, 1-isobenzofuranyl group, 3-isobenzofuranyl group, 4-isobenzofuranyl group, 5-isobenzofuranyl group, 6-isobenzofuranyl group, 7-isobenzofuranyl group, quinolyl group, 3-quinolyl group, 4-quinolyl group, 5-quinolyl group, 6-quinolyl group, 7-quinolyl group, 8-quinolyl group, 1-isoquinolyl group, 3-isoquinolyl group, 4-isoquinolyl group, 5-isoquinolyl group, 6-isoquinolyl group, 7-isoquinolyl group, 8-isoquinolyl group, 2-quinoxal-yl group, 5-quinoxal-yl group, 6-quinoxal-yl group, 1-carbazolyl group, 2-carbazolyl group, 3-carbazolyl group, 4-carbazolyl group, 9-carbazolyl group, 1-phenanthridinyl group, 2-phenanthridinyl group, 3-phenanthridinyl group, 4-

phenanthridinyl group, 6-phenanthridinyl group, 7-phenanthridinyl group, 8-phenanthridinyl group, 9-phenanthridinyl group, 10-phenanthridinyl group, 1-acridinyl group, 2-acridinyl group, 3-acridinyl group, 4-acridinyl group, 9-acridinyl group, 1, 7-phenanthroline-2-yl group, 1,7-phenanthroline-3-yl group, 1,7-phenanthroline-4-yl group, 1,7-phenanthroline-5-yl group, 1,7-phenanthroline-6-yl group, 1,7-phenanthroline-8-yl group, 1,7-phenanthroline-9-yl group, 1,7-phenanthroline-10-yl group, 1,8-phenanthroline-2-yl group, 1,8-phenanthroline-3-yl group, 1,8-phenanthroline-4-yl group, 1,8-phenanthroline-5-yl group, 1,8-phenanthroline-6-yl group, 1,8-phenanthroline-7-yl group, 1,8-phenanthroline-9-yl group, 1,8-phenanthroline-10-yl group, 1,9-phenanthroline-2-yl group, 1,9-phenanthroline-3-yl group, 1,9-phenanthroline-4-yl group, 1,9-phenanthroline-5-yl group, 1,9-phenanthroline-6-yl group, 1,9-phenanthroline-7-yl group, 1,9-phenanthroline-8-yl group, 1,9-phenanthroline-10-yl group, 1,10-phenanthroline-2-yl group, 1,10-phenanthroline-3-yl group, 1,10-phenanthroline-4-yl group, 1,10-phenanthroline-5-yl group, 2,9-phenanthroline-1-yl group, 2,9-phenanthroline-3-yl group, 2,9-phenanthroline-4-yl group, 2,9-phenanthroline-5-yl group, 2,9-phenanthroline-6-yl group, 2,9-phenanthroline-7-yl group, 2,9-phenanthroline-8-yl group, 2,9-phenanthroline-10-yl group, 2,8-phenanthroline-1-yl group, 2,8-phenanthroline-3-yl group, 2,8-phenanthroline-4-yl group, 2,8-phenanthroline-5-yl group, 2,8-phenanthroline-6-yl group, 2,8-phenanthroline-7-yl group, 2,8-phenanthroline-9-yl group, 2,8-phenanthroline-10-yl group, 2,7-phenanthroline-1-yl group, 2,7-phenanthroline-3-yl group, 2,7-phenanthroline-4-yl group, 2,7-phenanthroline-5-yl group, 2,7-phenanthroline-6-yl group, 2,7-phenanthroline-8-yl group, 2,7-phenanthroline-9-yl group, 2,7-phenanthroline-10-yl group, 1-phenazinyl group, 2-phenazinyl group, 1-phenothiazinyl group, 2-phenothiazinyl group, 3-phenothiazinyl group, 4-phenothiazinyl group, 10-phenothiazinyl group, 1-phenoxazinyl group, 2-phenoxazinyl group, 3-phenoxazinyl group, 4-phenoxazinyl group, 10-phenoxazinyl group, 2-oxazolyl group, 4-oxazolyl group, 5-oxazolyl group, 2-oxadiazolyl group, 5-oxadiazolyl group, 3-furazanyl group, 2-thienyl group, 3-thienyl group, 2-methylpyrrole-1-yl group, 2-methylpyrrole-3-yl group, 2-methylpyrrole-4-yl group, 2-methylpyrrole-5-yl group, 3-methylpyrrole-1-yl group, 3-methylpyrrole-2-yl group, 3-methylpyrrole-4-yl group, 3-methylpyrrole-5-yl group, 2-t-butylpyrrole-4-yl group, 3-(2-phenylpropyl)pyrrole-1-yl group, 2-methyl-1-indolyl group, 4-methyl-1-indolyl group, 2-methyl-3-indolyl group, 4-methyl-3-indolyl group, 2-t-butyl-1-indolyl group, 4-t-butyl-1-indolyl group, 2-t-butyl-3-indolyl group, and 4-t-butyl-3-indolyl group, with phenyl group, naphthyl group, biphenyl group, anthranyl group, phenanthryl group, pyrenyl group, chrysenyl group, fluoranthenyl group, and fluorenyl group being preferred.

[0176] L is a linking group, for example, a substituted or unsubstituted arylene group having 6 to 50 ring carbon atoms, a substituted or unsubstituted heteroarylene group having 5 to 50 ring atoms, or a divalent group derived from two or more arylene groups or heteroarylene groups by bonding these groups via a single bond, an ether bond, a thioether bond, an alkylene group having 1 to 20 carbon atoms, an alkenylene group having 2 to 20 carbon atoms, or amino group. Examples of the arylene group having 6 to 50 ring carbon atoms include 1,4-phenylene group, 1,2-phenylene group, 1,3-phenylene group, 1,4-naphthylene group, 2,6-naphthylene group, 1,5-naphthylene group, 9,10-anthracenylene group, 9,10-phenanthrenylene group, 3,6-phenanthrenylene group, 1,6-pyrenylene group, 2,7-pyrenylene group, 6,12-chrysenylene group, 4,4'-biphenylene group, 3,3'-biphenylene group, 2,2'-biphenylene group, and 2,7-fluorenylene group. Examples of the heteroarylene group having 5 to 50 ring atoms include 2,5-thiophenylene group, 2,5-silolylene group, and 2,5-oxadiazolylene group. Of the above groups, preferred are 1,4-phenylene group, 1,2-phenylene group, 1,3-phenylene group, 1,4-naphthylene group, 9,10-anthracenylene group, 6,12-chrysenylene group, 4,4'-biphenylene group, 3,3'-biphenylene group, 2,2'-biphenylene group, and 2,7-fluorenylene group.

[0177] If L is a linking group having two or more arylene groups or heteroarylene groups, adjacent arylene groups or adjacent heteroarylene group may bond to each other via a divalent group to form a ring. Examples of the divalent group for completing such ring include tetramethylene group, pentamethylene group, hexamethylene group, diphenylmethane-2,2'-diyl group, diphenylethane-3,3'-diyl group, and diphenylpropane-4,4'-diyl group.

[0178] Examples of the substituent of Ar¹ to Ar⁴ and L include a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms, a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms, a substituted or unsubstituted alkyl group having 1 to 50 carbon atoms, a substituted or unsubstituted cycloalkyl group having 3 to 50 carbon atoms, a substituted or unsubstituted alkoxy group having 1 to 50 carbon atoms, a substituted or unsubstituted aralkyl group having 7 to 50 carbon atoms, a substituted or unsubstituted aryloxy group having 6 to 50 ring carbon atoms, a substituted or unsubstituted heteroaryloxy group having 5 to 50 ring atoms, a substituted or unsubstituted arylthio group having 6 to 50 ring carbon atoms, a substituted or unsubstituted heteroarylthio group having 5 to 50 ring atoms, a substituted or unsubstituted alkoxycarbonyl group having 2 to 50 carbon atoms, an amino group substituted by a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms or a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms, halogen atom, cyano group, nitro group, and hydroxyl group.

[0179] Examples of the substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms include phenyl group, 1-naphthyl group, 2-naphthyl group, 1-anthryl group, 2-anthryl group, 9-anthryl group, 1-phenanthryl group, 2-phenanthryl group, 3-phenanthryl group, 4-phenanthryl group, 9-phenanthryl group, 1-naphthacenyl group, 2-naphthacenyl group, 9-naphthacenyl group, 1-pyrenyl group, 2-pyrenyl group, 4-pyrenyl group, 2-biphenyl group, 3-biphenyl group, 4-biphenyl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-

phenylpropyl)phenyl group, 3-methyl-2-naphthyl group, 4-methyl-1-naphthyl group, 4-methyl-1-anthryl group, 4'-methylbiphenyl group, 4"-t-butyl-p-terphenyl-4-yl group, fluoranthenyl group, and fluorenyl group.

[0180] Examples of the substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms include 1-pyrrolyl group, 2-pyrrolyl group, 3-pyrrolyl group, pyrazinyl group, 2-pyridinyl group, 3-pyridinyl group, 4-pyridinyl group, 1-indolyl group, 2-indolyl group, 3-indolyl group, 4-indolyl group, 5-indolyl group, 6-indolyl group, 7-indolyl group, 1-isindolyl group, 2-isindolyl group, 3-isindolyl group, 4-isindolyl group, 5-isindolyl group, 6-isindolyl group, 7-isindolyl group, 2-furyl group, 3-furyl group, 2-benzofuranyl group, 3-benzofuranyl group, 4-benzofuranyl group, 5-benzofuranyl group, 6-benzofuranyl group, 7-benzofuranyl group, 1-isobenzofuranyl group, 3-isobenzofuranyl group, 4-isobenzofuranyl group, 5-isobenzofuranyl group, 6-isobenzofuranyl group, 7-isobenzofuranyl group, quinolyl group, 3-quinolyl group, 4-quinolyl group, 5-quinolyl group, 6-quinolyl group, 7-quinolyl group, 8-quinolyl group, 1-isoquinolyl group, 3-isoquinolyl group, 4-isoquinolyl group, 5-isoquinolyl group, 6-isoquinolyl group, 7-isoquinolyl group, 8-isoquinolyl group, 2-quinoxalyl group, 5-quinoxalyl group, 6-quinoxalyl group, 1-carbazolyl group, 2-carbazolyl group, 3-carbazolyl group, 4-carbazolyl group, 9-carbazolyl group, 1-phenanthridinyl group, 2-phenanthridinyl group, 3-phenanthridinyl group, 4-phenanthridinyl group, 6-phenanthridinyl group, 7-phenanthridinyl group, 8-phenanthridinyl group, 9-phenanthridinyl group, 10-phenanthridinyl group, 1-acridinyl group, 2-acridinyl group, 3-acridinyl group, 4-acridinyl group, 9-acridinyl group, 1,7-phenanthroline-2-yl group, 1,7-phenanthroline-3-yl group, 1,7-phenanthroline-4-yl group, 1,7-phenanthroline-5-yl group, 1,7-phenanthroline-6-yl group, 1,7-phenanthroline-8-yl group, 1,7-phenanthroline-9-yl group, 1,7-phenanthroline-10-yl group, 1,8-phenanthroline-2-yl group, 1,8-phenanthroline-3-yl group, 1,8-phenanthroline-4-yl group, 1,8-phenanthroline-5-yl group, 1,8-phenanthroline-6-yl group, 1,8-phenanthroline-7-yl group, 1,8-phenanthroline-9-yl group, 1,8-phenanthroline-10-yl group, 1,9-phenanthroline-2-yl group, 1,9-phenanthroline-3-yl group, 1,9-phenanthroline-4-yl group, 1,9-phenanthroline-5-yl group, 1,9-phenanthroline-6-yl group, 1,9-phenanthroline-7-yl group, 1,9-phenanthroline-8-yl group, 1,9-phenanthroline-10-yl group, 1,10-phenanthroline-2-yl group, 1,10-phenanthroline-3-yl group, 1,10-phenanthroline-4-yl group, 1,10-phenanthroline-5-yl group, 2,9-phenanthroline-1-yl group, 2,9-phenanthroline-3-yl group, 2,9-phenanthroline-4-yl group, 2,9-phenanthroline-5-yl group, 2,9-phenanthroline-6-yl group, 2,9-phenanthroline-7-yl group, 2,9-phenanthroline-8-yl group, 2,9-phenanthroline-10-yl group, 2,8-phenanthroline-1-yl group, 2,8-phenanthroline-3-yl group, 2,8-phenanthroline-4-yl group, 2,8-phenanthroline-5-yl group, 2,8-phenanthroline-6-yl group, 2,8-phenanthroline-7-yl group, 2,8-phenanthroline-9-yl group, 2,8-phenanthroline-10-yl group, 2,7-phenanthroline-1-yl group, 2,7-phenanthroline-3-yl group, 2,7-phenanthroline-4-yl group, 2,7-phenanthroline-5-yl group, 2,7-phenanthroline-6-yl group, 2,7-phenanthroline-8-yl group, 2,7-phenanthroline-9-yl group, 2,7-phenanthroline-10-yl group, 1-phenazinyl group, 2-phenazinyl group, 1-phenothiazinyl group, 2-phenothiazinyl group, 3-phenothiazinyl group, 4-phenothiazinyl group, 10-phenothiazinyl group, 1-phenoxazinyl group, 2-phenoxazinyl group, 3-phenoxazinyl group, 4-phenoxazinyl group, 10-phenoxazinyl group, 2-oxazolyl group, 4-oxazolyl group, 5-oxazolyl group, 2-oxadiazolyl group, 5-oxadiazolyl group, 3-furazanyl group, 2-thienyl group, 3-thienyl group, 2-methylpyrrole-1-yl group, 2-methylpyrrole-3-yl group, 2-methylpyrrole-4-yl group, 2-methylpyrrole-5-yl group, 3-methylpyrrole-1-yl group, 3-methylpyrrole-2-yl group, 3-methylpyrrole-4-yl group, 3-methylpyrrole-5-yl group, 2-t-butylpyrrole-4-yl group, 3-(2-phenylpropyl)pyrrole-1-yl group, 2-methyl-1-indolyl group, 4-methyl-1-indolyl group, 2-methyl-3-indolyl group, 4-methyl-3-indolyl group, 2-t-butyl-1-indolyl group, 4-t-butyl-1-indolyl group, 2-t-butyl-3-indolyl group, and 4-t-butyl-3-indolyl group.

[0181] Examples of the substituted or unsubstituted alkyl group having 1 to 50 carbon atoms include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, hydroxymethyl group, 1-hydroxyethyl group, 2-hydroxyethyl group, 2-hydroxyisobutyl group, 1,2-dihydroxyethyl group, 1,3-dihydroxyisopropyl group, 2,3-dihydroxyt-butyl group, 1,2,3-trihydroxypropyl group, chloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 2-chloroisobutyl group, 1,2-dichloroethyl group, 1,3-dichloroisopropyl group, 2,3-dichlorot-butyl group, 1,2,3-trichloropropyl group, bromomethyl group, 1-bromoethyl group, 2-bromoethyl group, 2-bromoisobutyl group, 1,2-dibromoethyl group, 1,3-dibromoisopropyl group, 2,3-dibromot-butyl group, 1,2,3-tribromopropyl group, iodomethyl group, 1-iodomethyl group, 2-iodoethyl group, 2-iodoisobutyl group, 1,2-diiodoethyl group, 1,3-diiodoisopropyl group, 2,3-diiodot-butyl group, 1,2,3-triiodopropyl group, aminomethyl group, 1-aminoethyl group, 2-aminoethyl group, 2-aminoisobutyl group, 1,2-diaminoethyl group, 1,3-diaminoisopropyl group, 2,3-diamino-t-butyl group, 1,2,3-triaminopropyl group, cyanomethyl group, 1-cyanoethyl group, 2-cyanoethyl group, 2-cyanoisobutyl group, 1,2-dicyanoethyl group, 1,3-dicyanoisopropyl group, 2,3-dicyano-t-butyl group, 1,2,3-tricyanopropyl group, nitromethyl group, 1-nitroethyl group, 2-nitroethyl group, 2-nitroisobutyl group, 1,2-dinitroethyl group, 1,3-dinitroisopropyl group, 2,3-dinitro-t-butyl group, and 1,2,3-trinitropropyl group.

[0182] Examples of the substituted or unsubstituted cycloalkyl group having 3 to 50 carbon atoms include cyclopropyl group, cyclobutyl group, cyclopentyl group, cyclohexyl group, 4-methylcyclohexyl group, 1-adamantyl group, 2-adamantyl group, 1-norbornyl group, and 2-norbornyl group.

[0183] The substituted or unsubstituted alkoxy group having 1 to 50 carbon atoms is represented by -OY. Examples of Y include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, hydroxymethyl group, 1-hydroxyethyl group, 2-hydroxyethyl group, 2-hydroxyisobutyl group, 1,2-dihydroxyethyl group, 1,3-dihydroxyisopropyl group, 2,3-dihydroxyt-

butyl group, 1,2,3-trihydroxypropyl group, chloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 2-chloroisobutyl group, 1,2-dichloroethyl group, 1,3-dichloroisopropyl group, 2,3-dichlorot-butyl group, 1,2,3-trichloropropyl group, bromomethyl group, 1-bromoethyl group, 2-bromoethyl group, 2-bromoisobutyl group, 1,2-dibromoethyl group, 1,3-dibromoisopropyl group, 2,3-dibromot-butyl group, 1,2,3-tribromopropyl group, iodomethyl group, 1-iodoethyl group, 2-iodoethyl group, 2-iodoisobutyl group, 1,2-diiodoethyl group, 1,3-diiodoisopropyl group, 2,3-diiodot-butyl group, 1,2,3-triiodopropyl group, aminomethyl group, 1-aminoethyl group, 2-aminoethyl group, 2-aminoisobutyl group, 1,2-diaminoethyl group, 1,3-diaminoisopropyl group, 2,3-diamino-t-butyl group, 1,2,3-triaminopropyl group, cyanomethyl group, 1-cyanoethyl group, 2-cyanoethyl group, 2-cyanoisobutyl group, 1,2-dicyanoethyl group, 1,3-dicyanoisopropyl group, 2,3-dicyano-t-butyl group, 1,2,3-tricyanopropyl group, nitromethyl group, 1-nitroethyl group, 2-nitroethyl group, 2-nitroisobutyl group, 1,2-dinitroethyl group, 1,3-dinitroisopropyl group, 2,3-dinitro-t-butyl group, and 1,2,3-trinitropropyl group.

[0184] Examples of the substituted or unsubstituted aralkyl group having 7 to 50 carbon atoms include benzyl group, 1-phenylethyl group, 2-phenylethyl group, 1-phenylisopropyl group, 2-phenylisopropyl group, phenyl-t-butyl group, α -naphthylmethyl group, 1- α -naphthylethyl group, 2- α -naphthylethyl group, 1- α -naphthylisopropyl group, 2- α -naphthylisopropyl group, β -naphthylmethyl group, 1-6-naphthylethyl group, 2- β -naphthylethyl group, 1- β -naphthylisopropyl group, 2- β -naphthylisopropyl group, 1-pyrrolylmethyl group, 2-(1-pyrrolyl)ethyl group, p-methylbenzyl group, m-methylbenzyl group, o-methylbenzyl group, p-chlorobenzyl group, m-chlorobenzyl group, o-chlorobenzyl group, p-bromobenzyl group, m-bromobenzyl group, o-bromobenzyl group, p-iodobenzyl group, m-iodobenzyl group, o-iodobenzyl group, p-hydroxybenzyl group, m-hydroxybenzyl group, o-hydroxybenzyl group, p-aminobenzyl group, m-aminobenzyl group, o-aminobenzyl group, p-nitrobenzyl group, m-nitrobenzyl group, o-nitrobenzyl group, p-cyanobenzyl group, m-cyanobenzyl group, o-cyanobenzyl group, 1-hydroxy-2-phenylisopropyl group, and 1-chloro-2-phenylisopropyl group.

[0185] The substituted or unsubstituted aryloxy group having 6 to 50 ring carbon atoms is represented by -OY'. Examples of Y' include phenyl group, 1-naphthyl group, 2-naphthyl group, 1-anthryl group, 2-anthryl group, 9-anthryl group, 1-phenanthryl group, 2-phenanthryl group, 3-phenanthryl group, 4-phenanthryl group, 9-phenanthryl group, 1-naphthacenyl group, 2-naphthacenyl group, 9-naphthacenyl group, 1-pyrenyl group, 2-pyrenyl group, 4-pyrenyl group, 2-biphenyl group, 3-biphenyl group, 4-biphenyl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-phenylpropyl)phenyl group, 3-methyl-2-naphthyl group, 4-methyl-1-naphthyl group, 4-methyl-1-anthryl group, 4'-methylbiphenyl group, and 4"-t-butyl-p-terphenyl-4-yl group.

The substituted or unsubstituted heteroaryloxy group having 5 to 50 ring atoms is represented by -OZ'. Examples of Z' include 2-pyrrolyl group, 3-pyrrolyl group, pyrazinyl group, 2-pyridinyl group, 3-pyridinyl group, 4-pyridinyl group, 2-indolyl group, 3-indolyl group, 4-indolyl group, 5-indolyl group, 6-indolyl group, 7-indolyl group, 1-isoindolyl group, 3-isoindolyl group, 4-isoindolyl group, 5-isoindolyl group, 6-isoindolyl group, 7-isoindolyl group, 2-furyl group, 3-furyl group, 2-benzofuranyl group, 3-benzofuranyl group, 4-benzofuranyl group, 5-benzofuranyl group, 6-benzofuranyl group, 7-benzofuranyl group, 1-isobenzofuranyl group, 3-isobenzofuranyl group, 4-isobenzofuranyl group, 5-isobenzofuranyl group, 6-isobenzofuranyl group, 7-isobenzofuranyl group, 2-quinolyl group, 3-quinolyl group, 4-quinolyl group, 5-quinolyl group, 6-quinolyl group, 7-quinolyl group, 8-quinolyl group, 1-isoquinolyl group, 3-isoquinolyl group, 4-isoquinolyl group, 5-isoquinolyl group, 6-isoquinolyl group, 7-isoquinolyl group, 8-isoquinolyl group, 2-quinoxalyl group, 5-quinoxalyl group, 6-quinoxalyl group, 1-carbazolyl group, 2-carbazolyl group, 3-carbazolyl group, 4-carbazolyl group, 1-phenanthridinyl group, 2-phenanthridinyl group, 3-phenanthridinyl group, 4-phenanthridinyl group, 6-phenanthridinyl group, 7-phenanthridinyl group, 8-phenanthridinyl group, 9-phenanthridinyl group, 10-phenanthridinyl group, 1-acridinyl group, 2-acridinyl group, 3-acridinyl group, 4-acridinyl group, 9-acridinyl group, 1,7-phenanthroline-2-yl group, 1,7-phenanthroline-3-yl group, 1,7-phenanthroline-4-yl group, 1,7-phenanthroline-5-yl group, 1,7-phenanthroline-6-yl group, 1,7-phenanthroline-8-yl group, 1,7-phenanthroline-9-yl group, 1,7-phenanthroline-10-yl group, 1,8-phenanthroline-2-yl group, 1,8-phenanthroline-3-yl group, 1,8-phenanthroline-4-yl group, 1,8-phenanthroline-5-yl group, 1,8-phenanthroline-6-yl group, 1,8-phenanthroline-7-yl group, 1,8-phenanthroline-9-yl group, 1,8-phenanthroline-10-yl group, 1,9-phenanthroline-2-yl group, 1,9-phenanthroline-3-yl group, 1,9-phenanthroline-4-yl group, 1,9-phenanthroline-5-yl group, 1,9-phenanthroline-6-yl group, 1,9-phenanthroline-7-yl group, 1,9-phenanthroline-8-yl group, 1,9-phenanthroline-10-yl group, 1,10-phenanthroline-2-yl group, 1,10-phenanthroline-3-yl group, 1,10-phenanthroline-4-yl group, 1,19-phenanthroline-5-yl group, 2,9-phenanthroline-1-yl group, 2,9-phenanthroline-3-yl group, 2,9-phenanthroline-4-yl group, 2,9-phenanthroline-5-yl group, 2,9-phenanthroline-6-yl group, 2,9-phenanthroline-7-yl group, 2,9-phenanthroline-8-yl group, 2,9-phenanthroline-10-yl group, 2,8-phenanthroline-1-yl group, 2,8-phenanthroline-3-yl group, 2,8-phenanthroline-4-yl group, 2,8-phenanthroline-5-yl group, 2,8-phenanthroline-6-yl group, 2,8-phenanthroline-7-yl group, 2,8-phenanthroline-9-yl group, 2,8-phenanthroline-10-yl group, 2,7-phenanthroline-1-yl group, 2,7-phenanthroline-3-yl group, 2,7-phenanthroline-4-yl group, 2,7-phenanthroline-5-yl group, 2,7-phenanthroline-6-yl group, 2,7-phenanthroline-8-yl group, 2,7-phenanthroline-9-yl group, 2,7-phenanthroline-10-yl group, 1-phenazinyl group, 2-phenazinyl group, 1-phenothiazinyl group, 2-phenothiazinyl group, 3-phenothiazinyl group, 4-phenothiazinyl group, 1-phenoxazinyl group, 2-phenoxazinyl group, 3-phenoxazinyl group, 4-phenoxazinyl group, 2-oxazolyl group, 4-oxazolyl group, 5-oxazolyl group, 2-oxadiazolyl group, 5-oxadiazolyl group, 3-furazanyl group, 2-thienyl group, 3-thienyl group, 2-methylpyrrole-1-yl group, 2-methyl-

pyrrole-3-yl group, 2-methylpyrrole-4-yl group, 2-methylpyrrole-5-yl group, 3-methylpyrrole-1-yl group, 3-methylpyrrole-2-yl group, 3-methylpyrrole-4-yl group, 3-methylpyrrole-5-yl group, 2-t-butylpyrrole-4-yl group, 3-(2-phenylpropyl)pyrrole-1-yl group, 2-methyl-1-indolyl group, 4-methyl-1-indolyl group, 2-methyl-3-indolyl group, 4-methyl-3-indolyl group, 2-t-butyl-1-indolyl group, 4-t-butyl-1-indolyl group, 2-t-butyl-3-indolyl group, and 4-t-butyl-3-indolyl group.

[0186] The substituted or unsubstituted arylthio group having 6 to 50 ring carbon atoms is represented by -SY^{'''}. Examples of Y^{'''} include phenyl group, 1-naphthyl group, 2-naphthyl group, 1-anthryl group, 2-anthryl group, 9-anthryl group, 1-phenanthryl group, 2-phenanthryl group, 3-phenanthryl group, 4-phenanthryl group, 9-phenanthryl group, 1-naphthacenyl group, 2-naphthacenyl group, 9-naphthacenyl group, 1-pyrenyl group, 2-pyrenyl group, 4-pyrenyl group, 2-biphenyl group, 3-biphenyl group, 4-biphenyl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-phenylpropyl)phenyl group, 3-methyl-2-naphthyl group, 4-methyl-1-naphthyl group, 4-methyl-1-anthryl group, 4'-methylbiphenyl group, and 4"-t-butyl-p-terphenyl-4-yl group.

[0187] The substituted or unsubstituted heteroarylthio group having 5 to 50 ring atoms is represented by -SZ^{''}. Examples of Z^{''} include 2-pyrrolyl group, 3-pyrrolyl group, pyrazinyl group, 2-pyridinyl group, 3-pyridinyl group, 4-pyridinyl group, 2-indolyl group, 3-indolyl group, 4-indolyl group, 5-indolyl group, 6-indolyl group, 7-indolyl group, 1-isoindolyl group, 3-isoindolyl group, 4-isoindolyl group, 5-isoindolyl group, 6-isoindolyl group, 7-isoindolyl group, 2-furyl group, 3-furyl group, 2-benzofuranyl group, 3-benzofuranyl group, 4-benzofuranyl group, 5-benzofuranyl group, 6-benzofuranyl group, 7-benzofuranyl group, 1-isobenzofuranyl group, 3-isobenzofuranyl group, 4-isobenzofuranyl group, 5-isobenzofuranyl group, 6-isobenzofuranyl group, 7-isobenzofuranyl group, 2-quinolyl group, 3-quinolyl group, 4-quinolyl group, 5-quinolyl group, 6-quinolyl group, 7-quinolyl group, 8-quinolyl group, 1-isoquinolyl group, 3-isoquinolyl group, 4-isoquinolyl group, 5-isoquinolyl group, 6-isoquinolyl group, 7-isoquinolyl group, 8-isoquinolyl group, 2-quinoxaliny group, 5-quinoxaliny group, 6-quinoxaliny group, 1-carbazolyl group, 2-carbazolyl group, 3-carbazolyl group, 4-carbazolyl group, 1-phenanthridinyl group, 2-phenanthridinyl group, 3-phenanthridinyl group, 4-phenanthridinyl group, 6-phenanthridinyl group, 7-phenanthridinyl group, 8-phenanthridinyl group, 9-phenanthridinyl group, 10-phenanthridinyl group, 1-acridinyl group, 2-acridinyl group, 3-acridinyl group, 4-acridinyl group, 9-acridinyl group, 1,7-phenanthroline-2-yl group, 1,7-phenanthroline-3-yl group, 1,7-phenanthroline-4-yl group, 1,7-phenanthroline-5-yl group, 1,7-phenanthroline-6-yl group, 1,7-phenanthroline-8-yl group, 1,7-phenanthroline-9-yl group, 1,7-phenanthroline-10-yl group, 1,8-phenanthroline-2-yl group, 1,8-phenanthroline-3-yl group, 1,8-phenanthroline-4-yl group, 1,8-phenanthroline-5-yl group, 1,8-phenanthroline-6-yl group, 1,8-phenanthroline-7-yl group, 1,8-phenanthroline-9-yl group, 1,8-phenanthroline-10-yl group, 1,9-phenanthroline-2-yl group, 1,9-phenanthroline-3-yl group, 1,9-phenanthroline-4-yl group, 1,9-phenanthroline-5-yl group, 1,9-phenanthroline-6-yl group, 1,9-phenanthroline-7-yl group, 1,9-phenanthroline-8-yl group, 1,9-phenanthroline, 10-yl group, 1,10-phenanthroline-2-yl group, 1,10-phenanthroline-3-yl group, 1,10-phenanthroline-4-yl group, 1,10-phenanthroline-5-yl group, 2,9-phenanthroline-1-yl group, 2,9-phenanthroline-3-yl group, 2,9-phenanthroline-4-yl group, 2,9-phenanthroline-5-yl group, 2,9-phenanthroline-6-yl group, 2,9-phenanthroline-7-yl group, 2,9-phenanthroline-8-yl group, 2,9-phenanthroline-10-yl group, 2,8-phenanthroline-1-yl group, 2,8-phenanthroline-3-yl group, 2,8-phenanthroline-4-yl group, 2,8-phenanthroline-5-yl group, 2,8-phenanthroline-6-yl group, 2,8-phenanthroline-7-yl group, 2,8-phenanthroline-9-yl group, 2,8-phenanthroline-10-yl group, 2,7-phenanthroline-1-yl group, 2,7-phenanthroline-3-yl group, 2,7-phenanthroline-4-yl group, 2,7-phenanthroline-5-yl group, 2,7-phenanthroline-6-yl group, 2,7-phenanthroline-8-yl group, 2,7-phenanthroline-9-yl group, 2,7-phenanthroline-10-yl group, 1-phenazinyl group, 2-phenazinyl group, 1-phenothiazinyl group, 2-phenothiazinyl group, 3-phenothiazinyl group, 4-phenothiazinyl group, 1-phenoxazinyl group, 2-phenoxazinyl group, 3-phenoxazinyl group, 4-phenoxazinyl group, 2-oxazolyl group, 4-oxazolyl group, 5-oxazolyl group, 2-oxadiazolyl group, 5-oxadiazolyl group, 3-furazanyl group, 2-thienyl group, 3-thienyl group, 2-methylpyrrole-1-yl group, 2-methylpyrrole-3-yl group, 2-methylpyrrole-4-yl group, 2-methylpyrrole-5-yl group, 3-methylpyrrole-1-yl group, 3-methylpyrrole-2-yl group, 3-methylpyrrole-4-yl group, 3-methylpyrrole-5-yl group, 2-t-butylpyrrole-4-yl group, 3-(2-phenylpropyl)pyrrole-1-yl group, 2-methyl-1-indolyl group, 4-methyl-1-indolyl group, 2-methyl-3-indolyl group, 4-methyl-3-indolyl group, 2-t-butyl-1-indolyl group, 4-t-butyl-1-indolyl group, 2-t-butyl-3-indolyl group, and 4-t-butyl-3-indolyl group.

[0188] The substituted or unsubstituted alkoxycarbonyl group having 2 to 50 carbon atoms is represented by -COOZ. Examples of Z include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, s-butyl group, isobutyl group, t-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, hydroxymethyl group, 1-hydroxyethyl group, 2-hydroxyethyl group, 2-hydroxyisobutyl group, 1,2-dihydroxyethyl group, 1,3-dihydroxyisopropyl group, 2,3-dihydroxyt-butyl group, 1,2,3-trihydroxypropyl group, chloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 2-chloroisobutyl group, 1,2-dichloroethyl group, 1,3-dichloroisopropyl group, 2,3-dichlorot-butyl group, 1,2,3-trichloropropyl group, bromomethyl group, 1-bromoethyl group, 2-bromoethyl group, 2-bromoisobutyl group, 1,2-dibromoethyl group, 1,3-dibromoisopropyl group, 2,3-dibromot-butyl group, 1,2,3-tribromopropyl group, iodomethyl group, 1-iodoethyl group, 2-iodoethyl group, 2-iodoisobutyl group, 1,2-diiodoethyl group, 1,3-diiodoisopropyl group, 2,3-diiodot-butyl group, 1,2,3-triiodopropyl group, aminomethyl group, 1-aminoethyl group, 2-aminoethyl group, 2-aminoisobutyl group, 1,2-diaminoethyl group, 1,3-diaminoisopropyl group, 2,3-diamino-t-butyl group, 1,2,3-triaminopropyl group, cyanomethyl group, 1-cyanoethyl group, 2-cyanoethyl group, 2-cyanoisobutyl group, 1,2-dicyanoethyl group, 1,3-dicyanoisopropyl group, 2,3-

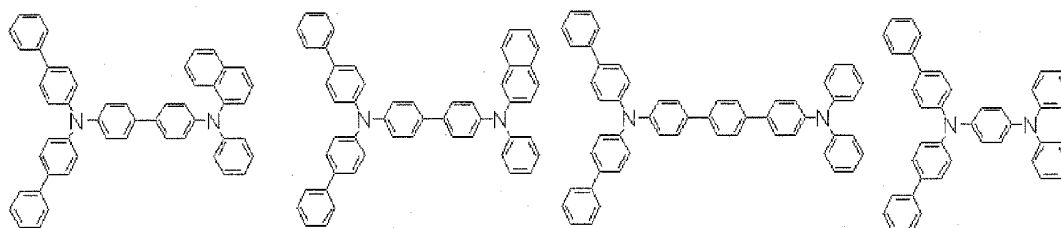
dicyano-t-butyl group, 1,2,3-tricyanopropyl group, nitromethyl group, 1-nitroethyl group, 2-nitroethyl group, 2-nitroisobutyl group, 1,2-dinitroethyl group, 1,3-dinitroisopropyl group, 2,3-dinitro-t-butyl group, and 1,2,3-trinitropropyl group.

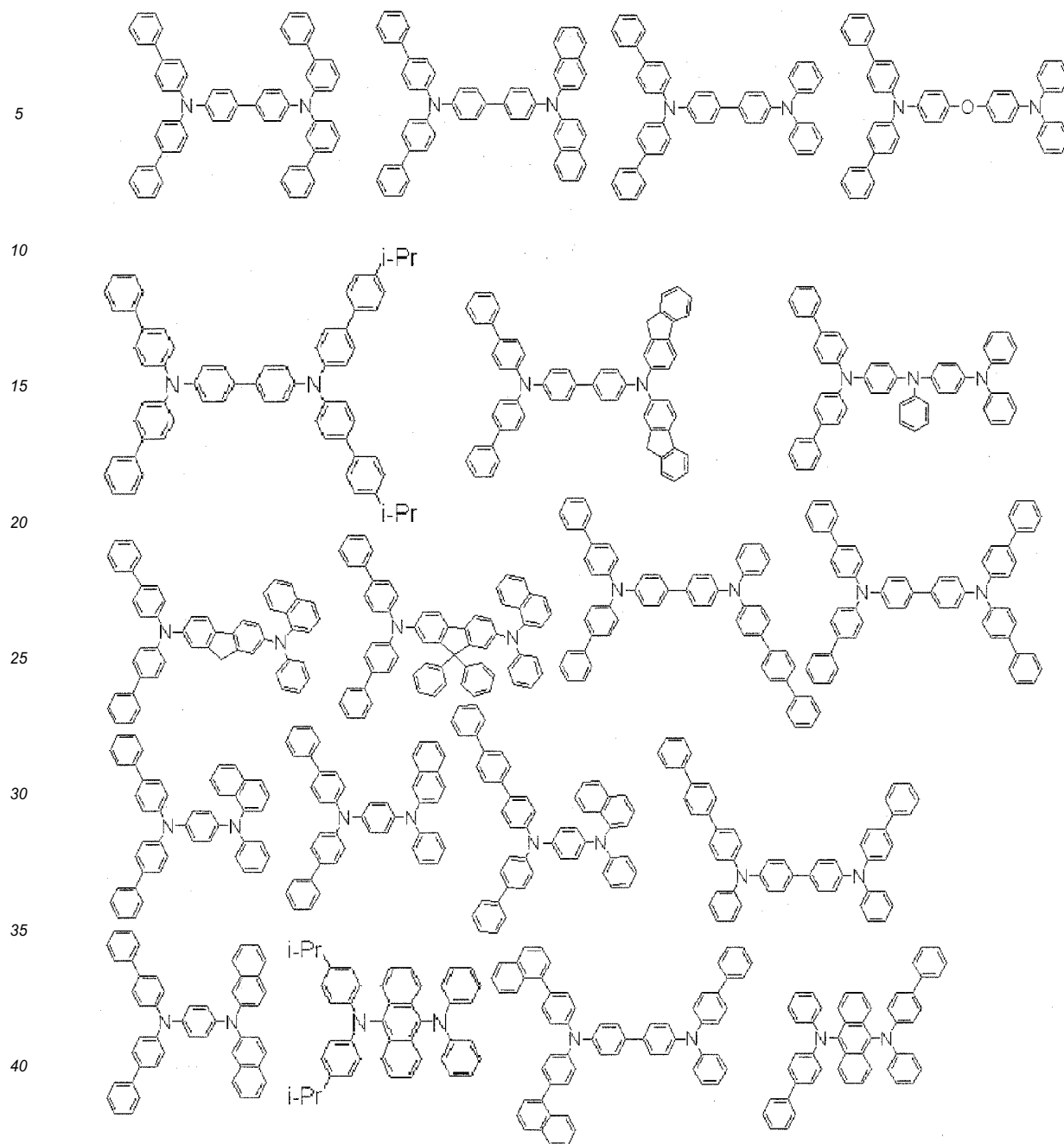
[0189] The amino group substituted by a substituted or unsubstituted aryl group having 6 to 50 ring carbon atoms or a substituted or unsubstituted heteroaryl group having 5 to 50 ring atoms is represented by -NPQ. Examples of P and

Q include phenyl group, 1-naphthyl group, 2-naphthyl group, 1-anthryl group, 2-anthryl group, 9-anthryl group, 1-phenanthryl group, 2-phenanthryl group, 3-phenanthryl group, 4-phenanthryl group, 9-phenanthryl group, 1-naphthacenyl group, 2-naphthacenyl group, 9-naphthacenyl group, 1-pyrenyl group, 2-pyrenyl group, 4-pyrenyl group, 2-biphenyl group, 3-biphenyl group, 4-biphenyl group, p-terphenyl-4-yl group, p-terphenyl-3-yl group, p-terphenyl-2-yl group, m-terphenyl-4-yl group, m-terphenyl-3-yl group, m-terphenyl-2-yl group, o-tolyl group, m-tolyl group, p-tolyl group, p-t-butylphenyl group, p-(2-phenylpropyl)phenyl group, 3-methyl-2-naphthyl group, 4-methyl-1-naphthyl group, 4-methyl-1-anthryl group, 4'-methylbiphenyl group, 4"-t-butyl-p-terphenyl-4-yl group, 2-pyrrolyl group, 3-pyrrolyl group, pyrazinyl group, 2-pyridinyl group, 3-pyridinyl group, 4-pyridinyl group, 2-indolyl group, 3-indolyl group, 4-indolyl group, 5-indolyl group, 6-indolyl group, 7-indolyl group, 1-isindolyl group, 3-isindolyl group, 4-isindolyl group, 5-isindolyl group, 6-isindolyl group, 7-isindolyl group, 2-furyl group, 3-furyl group, 2-benzofuranyl group, 3-benzofuranyl group, 4-benzofuranyl group, 5-benzofuranyl group, 6-benzofuranyl group, 7-benzofuranyl group, 1-isobenzofuranyl group, 3-isobenzofuranyl group, 4-isobenzofuranyl group, 5-isobenzofuranyl group, 6-isobenzofuranyl group, 7-isobenzofuranyl group, 2-quinolyl group, 3-quinolyl group, 4-quinolyl group, 5-quinolyl group, 6-quinolyl group, 7-quinolyl group, 8-quinolyl group, 1-isoquinolyl group, 3-isoquinolyl group, 4-isoquinolyl group, 5-isoquinolyl group, 6-isoquinolyl group, 7-isoquinolyl group, 8-isoquinolyl group, 2-quinoxalyl group, 5-quinoxalyl group, 6-quinoxalyl group, 1-carbazolyl group, 2-carbazolyl group, 3-carbazolyl group, 4-carbazolyl group, 1-phenanthridinyl group, 2-phenanthridinyl group, 3-phenanthridinyl group, 4-phenanthridinyl group, 6-phenanthridinyl group, 7-phenanthridinyl group, 8-phenanthridinyl group, 9-phenanthridinyl group, 10-phenanthridinyl group, 1-acridinyl group, 2-acridinyl group, 3-acridinyl group, 4-acridinyl group, 9-acridinyl group, 1,7-phenanthroline-2-yl group, 1,7-phenanthroline-3-yl group, 1,7-phenanthroline-4-yl group, 1,7-phenanthroline-5-yl group, 1,7-phenanthroline-6-yl group, 1,7-phenanthroline-8-yl group, 1,7-phenanthroline-9-yl group, 1,7-phenanthroline-10-yl group, 1,8-phenanthroline-2-yl group, 1,8-phenanthroline-3-yl group, 1,8-phenanthroline-4-yl group, 1,8-phenanthroline-5-yl group, 1,8-phenanthroline-6-yl group, 1,8-phenanthroline-7-yl group, 1,8-phenanthroline-9-yl group, 1,8-phenanthroline-10-yl group, 1,9-phenanthroline-2-yl group, 1,9-phenanthroline-3-yl group, 1,9-phenanthroline-4-yl group, 1,9-phenanthroline-5-yl group, 1,9-phenanthroline-6-yl group, 1,9-phenanthroline-7-yl group, 1,9-phenanthroline-8-yl group, 1,9-phenanthroline-10-yl group, 1,10-phenanthroline-2-yl group, 1,10-phenanthroline-3-yl group, 1,10-phenanthroline-4-yl group, 1,10-phenanthroline-5-yl group, 2,9-phenanthroline-1-yl group, 2,9-phenanthroline-3-yl group, 2,9-phenanthroline-4-yl group, 2,9-phenanthroline-5-yl group, 2,9-phenanthroline-6-yl group, 2,9-phenanthroline-7-yl group, 2,9-phenanthroline-8-yl group, 2,9-phenanthroline-10-yl group, 2,8-phenanthroline-1-yl group, 2,8-phenanthroline-3-yl group, 2,8-phenanthroline-4-yl group, 2,8-phenanthroline-5-yl group, 2,8-phenanthroline-6-yl group, 2,8-phenanthroline-7-yl group, 2,8-phenanthroline-9-yl group, 2,8-phenanthroline-10-yl group, 2,7-phenanthroline-1-yl group, 2,7-phenanthroline-3-yl group, 2,7-phenanthroline-4-yl group, 2,7-phenanthroline-5-yl group, 2,7-phenanthroline-6-yl group, 2,7-phenanthroline-8-yl group, 2,7-phenanthroline-9-yl group, 2,7-phenanthroline-10-yl group, 1-phenazinyl group, 2-phenazinyl group, 1-phenothiazinyl group, 2-phenothiazinyl group, 3-phenothiazinyl group, 4-phenothiazinyl group, 1-phenoxazinyl group, 2-phenoxazinyl group, 3-phenoxazinyl group, 4-phenoxazinyl group, 2-oxazolyl group, 4-oxazolyl group, 5-oxazolyl group, 2-oxadiazolyl group, 5-oxadiazolyl group, 3-furazanyl group, 2-thienyl group, 3-thienyl group, 2-methylpyrrole-1-yl group, 2-methylpyrrole-3-yl group, 2-methylpyrrole-4-yl group, 2-methylpyrrole-5-yl group, 3-methylpyrrole-1-yl group, 3-methylpyrrole-2-yl group, 3-methylpyrrole-4-yl group, 3-methylpyrrole-5-yl group, 2-t-butylpyrrole-4-yl group, 3-(2-phenylpropyl)pyrrole-1-yl group, 2-methyl-1-indolyl group, 4-methyl-1-indolyl group, 2-methyl-3-indolyl group, 4-methyl-3-indolyl group, 2-t-butyl-1-indolyl group, 4-t-butyl-1-indolyl group, 2-t-butyl-3-indolyl group, and 4-t-butyl-3-indolyl group.

[0190] Examples of the compound represented by formula (I) are shown below, although not limited thereto.

[0191]





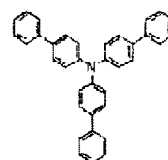
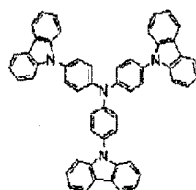
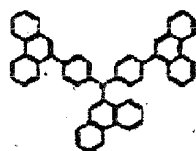
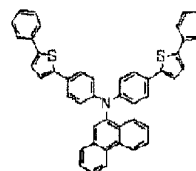
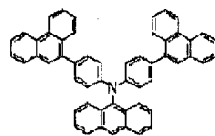
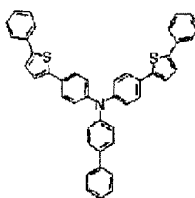
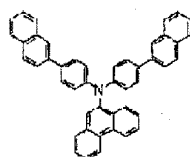
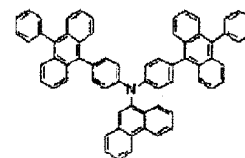
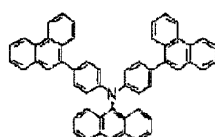
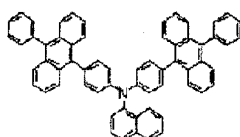
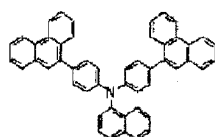
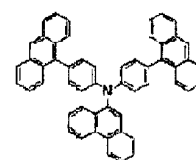
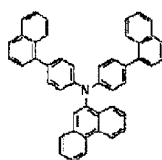
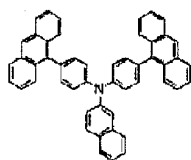
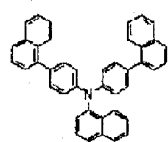
[0192] An aromatic amine represented by the following formula (II) is also preferably used to form the hole injecting layer or the hole transporting layer.

[0193]

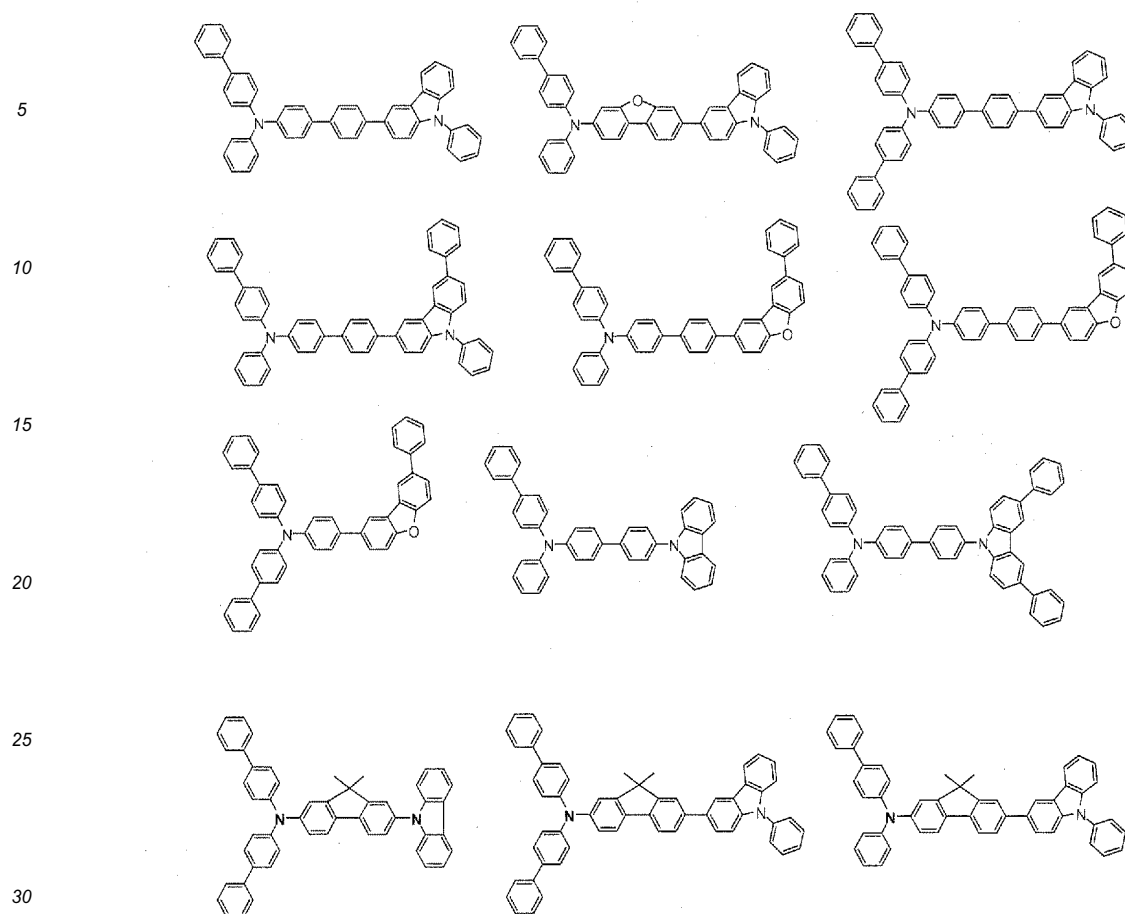


[0194] In formula (II), Ar¹ to Ar³ are the same as defined in Ar¹ to Ar¹ of formula (I). Examples of the compound represented by formula (II) are shown below, although not limited thereto.

[0195]



[0196]



[0197] The present invention is not limited to the embodiments described above, and variations and modifications can be effected within the spirit and scope of the invention.

For example, the following modification is a preferred embodiment of the invention.

It is also preferred that the light emitting layer of the invention contains a charge injecting aid.

When the light emitting layer is formed by using a host material having a wide energy gap, the difference between the ionization potential (Ip) of the host material and Ip of the hole injecting/transporting layer, etc., this being likely to make the injection of holes into the light emitting layer difficult to increase the driving voltage for obtaining sufficient luminance.

[0198] In this case, by incorporating a hole injecting/transporting charge injecting aid into the light emitting layer, the injection of holes into the light emitting layer is facilitated and the driving voltage is reduced.

For example, a hole injecting/transporting material generally known is usable as the charge injecting aid.

Examples thereof include triazole derivatives (US 3,112,197), oxadiazole derivatives (US 3,189,447), imidazole derivatives (JP 37-16096B), polyarylethane derivatives (US 3,615,402, US 3,820,989, US 3,542,544, JP 45-555B, JP 51-10983B, JP 51-93224A, JP 55-17105A, JP 56-4148A, JP 55-108667A, JP 55-156953A, JP 56-36656A), pyrazoline derivatives and pyrazolone derivatives (US 3,180,729, US 4,278,746, JP 55-88064A, JP 55-88065A, JP 49-105537A, JP 55-51086A, JP 56-80051A, JP 56-88141A, JP 57-45545A, JP 54-112637A, JP 55-74546A), phenylenediamine derivatives (US 3,615,404, JP 51-101058, JP 46-3712B, JP 47-25336B, JP 54-53435A, JP 54-110536A, JP 54-119925A), arylamine derivatives (US 3,567,450, US 3,180,703, US 3,240,597, US 3,658,520, US 4,232,103, US 4,175,961, US 4,012,376, JP 49-35702B, JP 39-27577B, JP 55-144250A, JP 56-119132A, JP 56-22437A, DE 1,110,518), amino-substituted chalcone derivatives (US 3,526,501), oxazole derivatives (US 3,257,203), styrylanthracene derivative (JP 56-46234A), fluorenone derivatives (JP 54-110837A), hydrazone derivatives (US 3,717,462, JP 54-59143A, JP 55-52063A, JP 55-52064A, JP 55-46760A, JP 55-85495A, JP 57-11350A, JP 57-148749A, JP 2-311591A), stilbene derivatives (JP 61-210363A, JP 61-228451A, JP 61-14642A, JP 61-72255A, JP 62-47646A, JP 62-36674A, JP 62-10652A, JP 62-30255A, JP 60-93455A, JP 60-94462A, JP 60-174749A, JP 60-175052A), silazane derivatives (US 4,950,950), polysilanes (JP 2-204996A), aniline-based copolymer (JP 2-282263A), and electroconductive high molecular weight oligomer (particularly, thiophene oligomer) disclosed in JP 1-211399A.

[0199] In addition to the hole injecting material mentioned above, porphyrin compounds (JP 63-295695A), and aromatic

tertiary amines and styryl amine compounds (US 4,127,412, JP 53-27033A, JP 54-58445A, JP 54-149634A, JP 54-64299A, JP 55-79450A, JP 55-144250A, JP 56-119132A, JP 61-295558A; JP 61-98353A, JP 63-295695A) are usable, with the aromatic tertiary amines being particularly preferred.

[0200] A compound having two condensed aromatic rings in its molecule described in US 5,061,569, for example, 4,4'-bis(N-(1-naphthyl)-N-phenylamino)biphenyl(NPD), and 4,4',4''-tris(N-(3-methylphenyl)-N-phenylamino)triphenylamine (MTDATA) in which three triphenylamine units are linked to each other in starburst configuration are also usable. Further, hexaazatriphenylene derivatives described in JP 3614405, JP 3571977, or US 4,780,536 are preferably used as the hole injecting material.

[0201] An organic compound, such as p-type Si and p-type SiC, is also usable as the hole injecting material.

[0202] The method of forming each layer of the organic electroluminescence device of the invention is not particularly limited, and each layer can be formed by a known method, such as a vacuum vapor deposition method and a spin coating method. The organic thin film layer in the organic electroluminescence device of the invention may be formed by a known method, for example, by a vacuum vapor deposition method, a molecular beam evaporation method (MBE method), and a coating method, such as a dipping method, a spin coating method, a casting method, a bar coating method and a roll coating method, each using a solvent solution.

The film thickness of each organic layer in the organic electroluminescence device of the invention is not particularly limited. Since defects, such as pinholes, are likely to be caused if the film thickness is excessively small and high applied voltage is required to reduce the efficiency if the film thickness is excessively large, the film thickness is preferably from several nanometers to 1 μm .

EXAMPLES

[0203] The present invention will be described in more detail with reference to examples and comparative examples. However, it should be noted that the scope of the present invention is not limited to the following examples.

The physical properties of each material shown in Table 1 were measured as follows.

The triplet energy gap E_g was determined from the phosphorescent emission spectrum as described below.

A sample for phosphorescent measurement was prepared by dissolving each material in EPA solvent (diethyl ether: isopentane:ethanol = 5:5:2 by volume) at 10 mol/L.

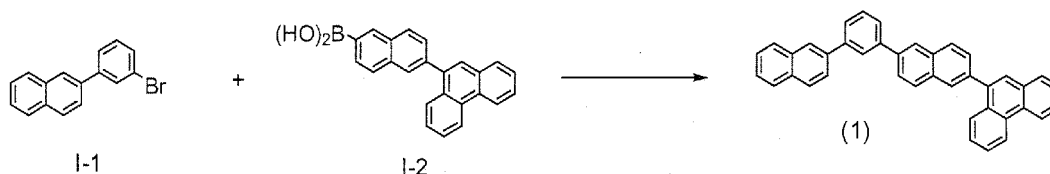
The sample for phosphorescent measurement was charged into a quartz cell, cooled to 77 K, and irradiated with exciting light, and the intensity of emitted phosphorescent light was measured at each wavelength.

A line tangent to the rising portion at the short-wavelength side of the obtained phosphorescent emission spectrum was drawn, and the wavelength at the intersection of the tangent line and the base line was converted to a value of energy unit, employing the converted value as the triplet energy gap $E_g(T)$.

The measurement was conducted by using a commercially available measuring apparatus F-4500 (manufactured by Hitachi, Ltd.).

Synthesis Example 1 (Synthesis of compound (1))

[0204]



[0205] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide I-1, 6.3 g (18 mmol) of boronic acid I-2, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0); 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 10 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 7.1 g (yield: 78%) of compound (1).

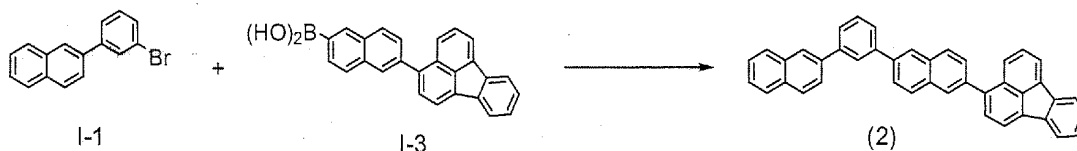
The mass spectrometric analysis showed a peak at $m/e = 506$ to the calculated molecular weight of 506.

Synthesis Example 2 (Synthesis of compound (2))

[0206]

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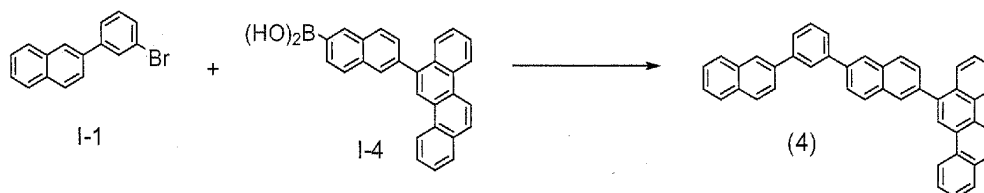
[0207] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide 1-1, 6.7 g (18 mmol) of boronic acid 1-3, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 5.8 g (yield: 61%) of compound (2). The mass spectrometric analysis showed a peak at $m/e = 530$ to the calculated molecular weight of 530.

Synthesis Example 3 (Synthesis of compound (4))

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[0208]

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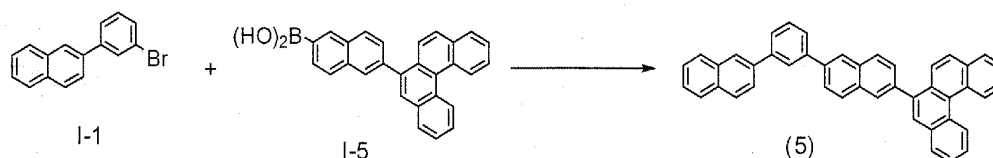
[0209] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide 1-1, 7.2 g (18 mmol) of boronic acid 1-4, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 14 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 5.9 g (yield: 61%) of compound (4). The mass spectrometric analysis showed a peak at $m/e = 556$ to the calculated molecular weight of 556.

Synthesis Example 4 (Synthesis of compound (5))

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[0210]

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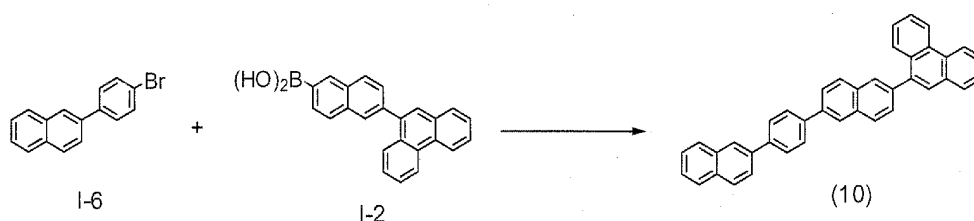
[0211] In argon atmosphere, a mixture of 4.5 g (16 mmol) of bromide 1-1, 6.4 g (16 mmol) of boronic acid 1-5, 374 mg (0.32 mmol) of tetrakis(triphenylphosphine)palladium(0), 100 ml of toluene, 35 ml of dimethoxyethane, and 23 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room

temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 4.6 g (yield: 52%) of compound (5).

The mass spectrometric analysis showed a peak at $m/e = 556$ to the calculated molecular weight of 556.

Synthesis Example 5 (Synthesis of compound (10))

[0212]

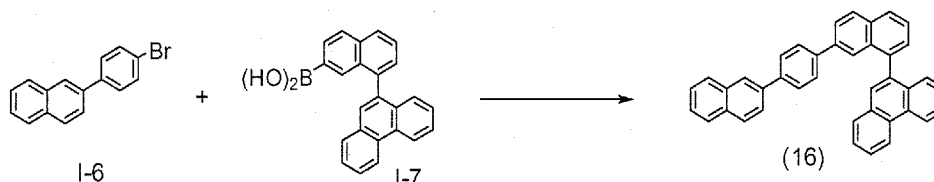


[0213] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide 1-6, 6.3 g (18 mmol) of boronic acid I-2, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 6.5 g (yield: 71%) of compound (10).

The mass spectrometric analysis showed a peak at $m/e = 506$ to the calculated molecular weight of 506.

Synthesis Example 6 (Synthesis of compound (16))

[0214]

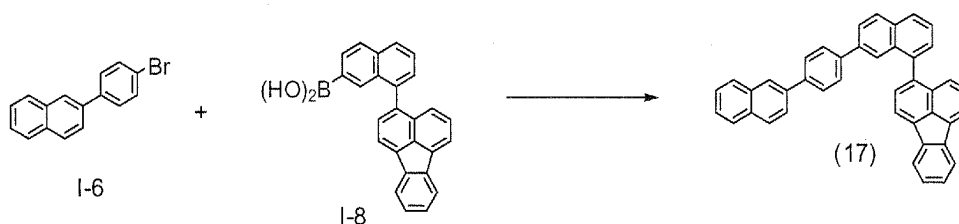


[0215] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide 1-6, 6.3 g (18 mmol) of boronic acid I-7, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C at 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 6.0 g (yield: 66%) of compound (16).

The mass spectrometric analysis showed a peak at $m/e = 506$ to the calculated molecular weight of 506.

Synthesis Example 7 (Synthesis of compound (17))

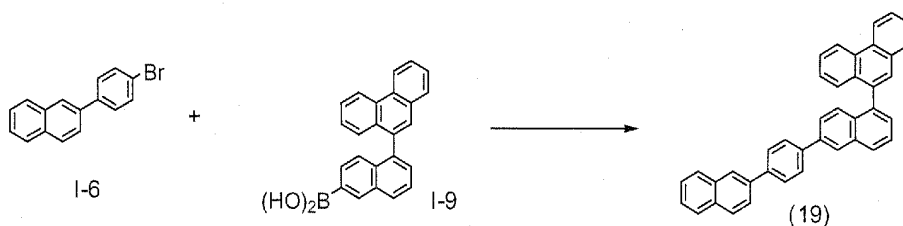
[0216]



[0217] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide 1-6, 6.7 g (18 mmol) of boronic acid 1-8, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 10 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 5.6 g (yield: 59%) of compound (17). The mass spectrometric analysis showed a peak at $m/e = 530$ to the calculated molecular weight of 530.

Synthesis Example 8 (Synthesis of compound (19))

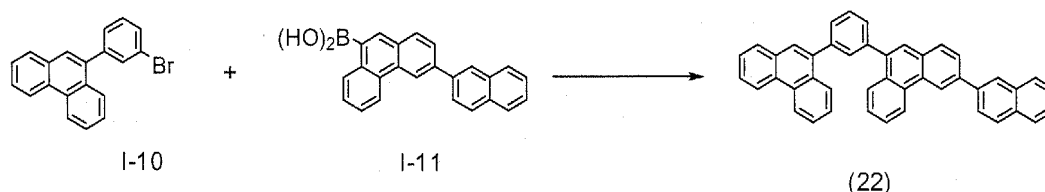
[0218]



[0219] In argon atmosphere, 5.0 g (18 mmol) of bromide 1-6, 6.3 g (18 mmol) of boronic acid 1-9, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 6.2 g (yield: 68%) of compound (19). The mass spectrometric analysis showed a peak at $m/e = 506$ to the calculated molecular weight of 506.

Synthesis Example 9 (Synthesis of compound (22))

[0220]

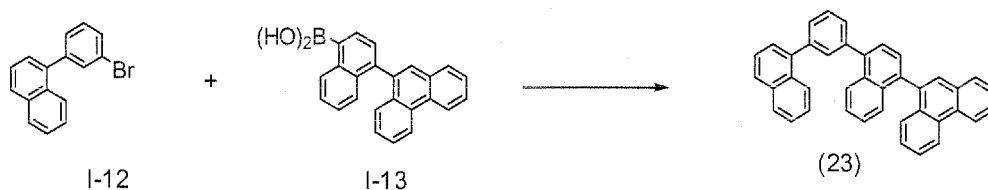


[0221] In argon atmosphere, a mixture of 4.0 g (12 mmol) of bromide 1-10, 4.2 g (12 mmol) of boronic acid 1-11, 280 mg (0.24 mmol) of tetrakis(triphenylphosphine)palladium(0), 90 ml of toluene, 30 ml of dimethoxyethane, and 17 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After

liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 3.5 g (yield: 52%) of compound (22). The mass spectrometric analysis showed a peak at $m/e = 556$ to the calculated molecular weight of 556.

Synthesis Example 10 (Synthesis of compound (23))

[0222]

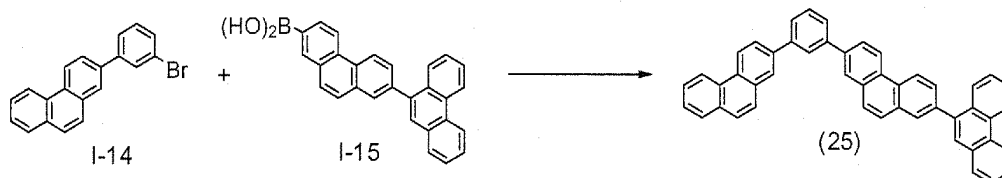


[0223] In argon atmosphere, a mixture of 5.0 g (18 mmol) of bromide I-12, 6.2 g (18 mmol) of boronic acid I-13, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 100 ml of toluene, 30 ml of dimethoxyethane, and 26 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 4.2 g (yield: 46%) of compound (23).

The mass spectrometric analysis showed a peak at $m/e = 506$ to the calculated molecular weight of 506.

Synthesis Example 11 (Synthesis of compound (25))

[0224]

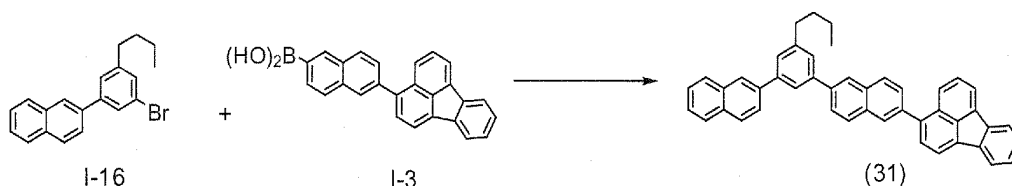


[0225] In argon atmosphere, a mixture of 5.0 g (15 mmol) of bromide I-14, 6.0 g (15 mmol) of boronic acid I-15, 350 mg (0.30 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 22 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 6.9 g (yield: 76%) of compound (25).

The mass spectrometric analysis showed a peak at $m/e = 606$ to the calculated molecular weight of 606.

Synthesis Example 12 (Synthesis of compound (31))

[0226]

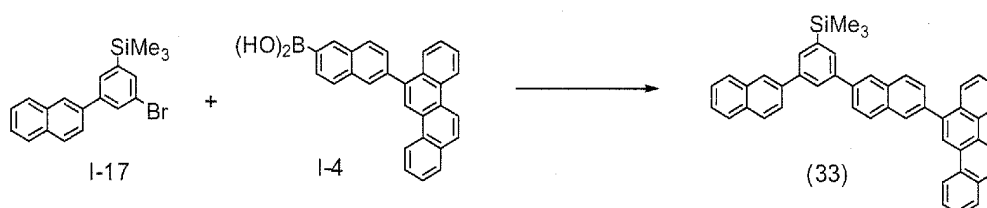


[0227] In argon atmosphere, 4.0 g (12 mmol) of bromide I-16, 4.5 g (12 mmol) of boronic acid 1-3, 280 mg (0.24 mmol) of tetrakis(triphenylphosphine)palladium(0), 90 ml of toluene, 30 ml of dimethoxyethane, and 17 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 14 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 4.1 g (yield: 58%) of compound (31).

The mass spectrometric analysis showed a peak at $m/e = 586$ to the calculated molecular weight of 586.

Synthesis Example 13 (Synthesis of compound (33))

[0228]

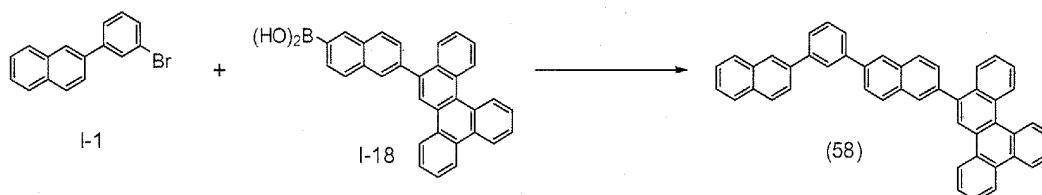


[0229] In argon atmosphere, a mixture of 5.0 g (14 mmol) of bromide I-17, 5.6 g (14 mmol) of boronic acid 1-9, 330 mg (0.28 mmol) of tetrakis(triphenylphosphine)palladium(0), 100 ml of toluene, 35 ml of dimethoxyethane, and 20 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 12 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 5.8 g (yield: 66%) of compound (33).

The mass spectrometric analysis showed a peak at $m/e = 628$ to the calculated molecular weight of 628.

Synthesis Example 14 (Synthesis of compound (58))

[0230]

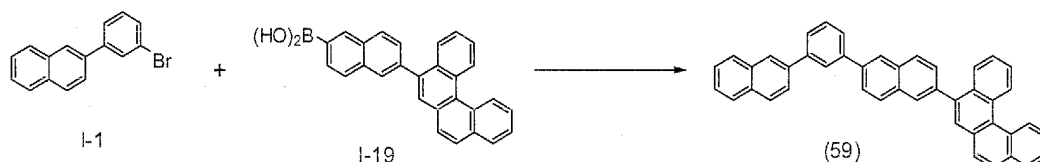


[0231] In argon atmosphere, a mixture of 5.1 g (18 mmol) of bromide I-1, 8.1 g (18 mmol) of boronic acid I-18, 420 mg (0.36 mmol) of tetrakis(triphenylphosphine)palladium(0), 120 ml of toluene, 40 ml of dimethoxyethane, and 25 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 13 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 4.1 g (yield 38%) of compound (58).

The mass spectrometric analysis showed a peak at $m/e = 606$ to the calculated molecular weight of 556.

Synthesis Example 15 (Synthesis of compound (59))

[0232]



[0233] In argon atmosphere, a mixture of 4.5 g (16 mmol) of bromide I-1, 6.4 g (16 mmol) of boronic acid I-19, 374 mg (0.32 mmol) of tetrakis(triphenylphosphine)palladium(0), 100 ml of toluene, 35 ml of dimethoxyethane, and 23 ml of 2 M aqueous solution of sodium carbonate was stirred at 90 °C for 15 h. The reaction mixture was allowed to cool to room temperature, added with water, stirred for one hour at room temperature, and then, extracted with toluene. After liquid-liquid separation, the organic phase was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. The solvent was evaporated off under reduced pressure, and the residue was purified by silica gel column chromatography and recrystallized from toluene, to obtain 4.2 g (yield: 47%) of compound (59). The mass spectrometric analysis showed a peak at $m/e = 556$ to the calculated molecular weight of 556.

EXAMPLE 1 (Production of organic EL device)

[0234] A glass substrate of 25 mm x 75 mm x 0.7 mm thickness having ITO transparent electrode (product of Asahi Glass Company Ltd.) was cleaned by ultrasonic cleaning in isopropyl alcohol for 5 min and then UV ozone cleaning for 30 min. The cleaned glass substrate was mounted to a substrate holder of a vacuum vapor deposition apparatus. HT1 was deposited into a film of 50 nm thick so as to cover the transparent electrode. The HT1 film worked as a hole injecting/transporting layer. Successively, compound (1) and 10% by mass of Ir(piq)₃ as a phosphorescent dopant were co-deposited into a film of 40 nm thick on the hole injecting/transporting layer by resistance heating method. The obtained film worked as a light emitting layer (phosphorescent emitting layer). Successively, ET1 was deposited into a film of 40 nm thick on the light emitting layer. The obtained film worked as an electron transporting layer. An electron injection electrode (cathode) was formed by depositing LiF into a film of 0.5 nm thick at a film-forming speed of 0.1 nm/min. Then, a metal cathode was formed on the LiF layer by vapor-depositing metallic Al into a film of 150 nm thick, thereby producing an organic electroluminescence device.

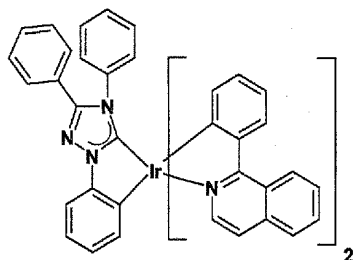
EXAMPLES 2 to 15 and COMPARATIVE EXAMPLES 1 to 5

[0235] Each organic electroluminescence device was produced in the same manner as in Example 1 except for using each compound shown in Table 1 in place of compound (1).

EXAMPLE 16

[0236] An organic electroluminescence device was produced in the same manner as in Example 14 except for using the following Complex A as the phosphorescent dopant in place of Ir(piq)₃.

[0237]

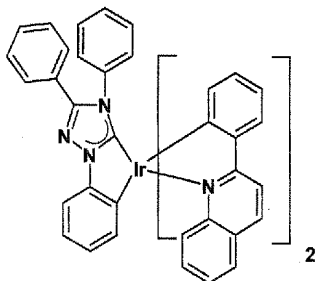


Complex A

EXAMPLE 17

[0238] An organic electroluminescence device was produced in the same manner as in Example 14 except for using the following Complex B as the phosphorescent dopant in place of Ir(piq)₃.

[0239]



Complex B

COMPARATIVE EXAMPLES 6

[0240] An organic electroluminescence device was produced in the same manner as in Example 16 except for using CBP in place of compound (58).

COMPARATIVE EXAMPLE 7

[0241] An organic electroluminescence device was produced in the same manner as in Example 17 except for using BAQ in place of compound (58).

Evaluation of emission performance of organic electroluminescence devices

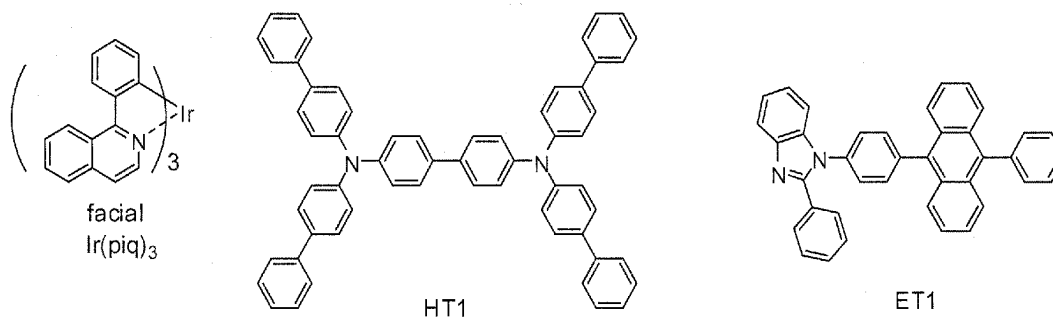
[0242] The organic EL devices produced in Examples 1 to 17 and Comparative Examples 1 to 7 were allowed to emit light by DC driving to measure the voltage, current efficiency and half lifetime of luminance (initial luminance: 3000 cd/m²) at a current density of 10 mA/cm².

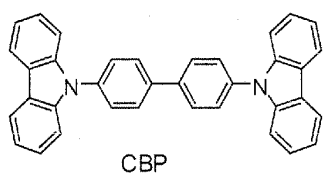
Further, the uniformity of pixel at 70 °C driving was visually evaluated, and rates as A when uniform and B when partly ununiform.

Separately, a sample for phosphorescent measurement was prepared by dissolving each material in EPA solvent (diethyl ether:isopentane:ethanol = 5:5:2 by volume) at 10 μmol/L. The sample for phosphorescent measurement was charged into a quartz cell, cooled to 77 K, and irradiated with exciting light, and the intensity of emitted phosphorescent light was measured at each wavelength.

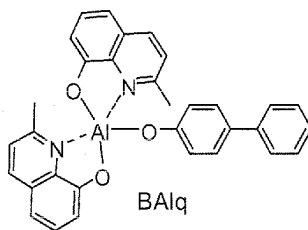
A line tangent to the rising portion at the short-wavelength side of the obtained phosphorescent emission spectrum was drawn, and the wavelength at the intersection of the tangent line and the base line was converted to a value of energy unit, to determine the excited triplet energy (Eg(T)) of the material for organic EL device. The samples used were purified by sublimation, etc. Results of evaluation are shown in Tables 1 and 2.

[0243]

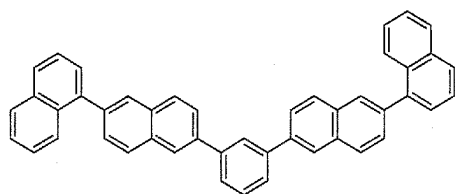




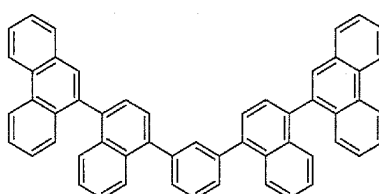
CBP



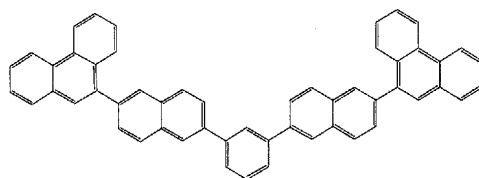
BAlq



(A)



(B)



[0244]

Table 1

	Material of organic EL device	Eg(T) of organic EL device (eV)	Voltage (V)	Current efficiency (cd/A)	Half lifetime of luminance (h)	Pixel uniformity, upon driving at 70 °C
Examples						
1	1	2.52	4.4	11.4	6700	A
2	2	2.28	3.9	12.0	8000	A
3	4	2.38	4.1	10.1	6800	A
4	5	2.42	4.0	11.5	8500	A
5	10	2.50	4.3	10.0	7600	A
6	16	2.50	4.5	9.3	7500	A
7	17	2.30	4.3	10.4	6900	A
8	19	2.55	4.3	11.0	6000	A
9	22	2.54	4.5	10.2	7400	A
10	23	2.52	4.6	9.2	6800	A
11	25	2.43	4.2	9.3	7100	A
12	31	2.28	4.0	10.6	6300	A
13	33	2.38	4.1	9.9	6200	A
14	58	2.36	4.3	11.3	8100	A
15	59	2.44	4.2	11.8	7900	A
Comparative Examples						
1	CBP	2.81	5.7	6.3	1200	B

(continued)

Comparative Examples						
2	BAIq	2.28	5.3	7.0	2300	B
3	A	2.51	5.2	7.5	3800	B
4	B	2.65	5.1	8.7	3400	B
5	C	2.50	4.8	9.1	2700	B

[0245]

Table 2

Dopant		Material of organic EL device	Voltage (V)	Current efficiency (cd/A)	Half lifetime of luminance (h)	Pixel uniformity upon driving at 70 °C
Examples						
16	Complex A	58	4.5	8.2	5200	A
17	Complex B	58	4.7	7.8	4100	A
Comparative Examples						
6	Complex A	CBP	5.9	4.3	1000	B
7	Complex B	BAIq	5.1	5.1	1800	B

[0246] The results of Tables 1 and 2 show that the organic electroluminescence devices of Examples 1 to 17 employing the compound of the invention have high external quantum efficiency and extremely long lifetime. In contrast, the devices of Comparative Examples 1 to 7 require relative high voltage and have low current efficiency, particularly, have extremely short lifetimes. The device of Comparative Example 1 has extremely low current efficiency and short lifetime. The devices of Comparative Examples 2 and 3 have current efficiency higher than that of Comparative Example 1, but have short lifetime. The devices of Comparative Examples 4 and 5 have high current efficiency and relatively long lifetime, but poor in the lifetime as compared with those of Examples 1 to 17. The current efficiency of the device of Comparative Example 5 is high, but its lifetime is not comparable to the long lifetime of the devices of Example 1 to 17. The pixel uniformity upon driving at 70 °C was poor in any of comparative examples as compared with examples.

[0247] The characteristic features of the combinations in the present invention are that:

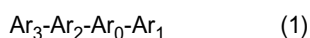
the triplet energy gap of the compound and the triplet energy gap of the dopants are suited to improve the current efficiency;
 since the compound is not substituted with a nitrogen-containing ring and a nitrogen atom, the light emitting material is highly resistant to holes and electrons, allowing the lifetime to be extended more than those of the combinations ever known; and
 the in-plane uniformity is stably obtained even when driving at 70 °C because the thin film has good heat stability.

INDUSTRIAL APPLICABILITY

[0248] The present invention provides an organic phosphorescent device with high efficiency and long lifetime.

Claims

1. An organic electroluminescence device comprising a cathode, an anode, and an organic thin film layer between the cathode and the anode, wherein the organic thin film layer comprises one or more layers, at least one layer of the organic thin film layer is a light emitting layer, and at least one light emitting layer comprises a phosphorescent emitting material and a compound represented by formula (1):



wherein Ar₀ is a substituted or unsubstituted benzene ring;

Ar₁ to Ar₃ are each independently a substituted or unsubstituted condensed aromatic hydrocarbon ring, the

condensed aromatic hydrocarbon ring being selected from naphthalene ring, chrysene ring, fluoranthene ring, triphenylene ring, phenanthrene ring, benzophenanthrene ring, dibenzophenanthrene ring, benzotriphenylene ring, benzochrysene ring, benzo[b]fluoranthene ring, and picene ring, with the proviso that Ar₁ and Ar₂ are the same condensed aromatic hydrocarbon ring, numbers of substituents of Ar₁ and Ar₂ may be the same or different, and kinds of substituents of Ar₁ and Ar₂ may be the same or different;

Ar₀, Ar₁, Ar₂, and Ar₃ may be substituted by at least one group selected from an alkyl group having 1 to 20 carbon atoms, a haloalkyl group having 1 to 20 carbon atoms, a cycloalkyl group having 5 to 18 carbon atoms, a silyl group having 3 to 20 carbon atoms, a fluorene skeleton-containing group having 13 to 35 carbon atoms, dibenzofuranyl group, cyano group, and halogen atom; and

when Ar₂ is naphthalene ring, Ar₀ and Ar₃ do not bond to 2- and 7-positions of the naphthalene ring.

2. The organic electroluminescence device according to claim 1, wherein Ar₃ is a group selected from a substituted or unsubstituted phenanthrene ring, a substituted or unsubstituted fluoranthene ring, a substituted or unsubstituted benzophenanthrene ring, and a substituted or unsubstituted benzochrysene ring.

3. The organic electroluminescence device according to claim 1, wherein an excited triplet energy of the compound is 2.0 eV or more and 2.8 eV or less.

4. The organic electroluminescence device according to claim 1, wherein the phosphorescent emitting material comprises a metal complex which comprises a metal atom selected from Ir, Pt, Os, Au, Cu, Re, and Ru and a ligand.

5. The organic electroluminescence device according to claim 4, wherein the ligand is an orthometalated ligand.

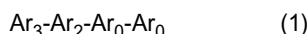
6. The organic electroluminescence device according to claim 1, wherein at least one of the phosphorescent emitting materials emits light with a maximum wavelength of 520 nm or more and 720 nm or less.

7. The organic electroluminescence device according to claim 1, wherein an electron transporting layer or an electron injecting layer is disposed as the organic thin film layer between the cathode and the light emitting layer, and the electron transporting layer or the electron injecting layer contains the compound represented by formula (1).

8. The organic electroluminescence device according to claim 1, wherein an electron transporting layer or an electron injecting layer is disposed as the organic thin film layer between the cathode and the light emitting layer, and the electron transporting layer or the electron injecting layer contains an aromatic compound having a nitrogen-containing 6- or 5-membered ring or a condensed aromatic compound having a nitrogen-containing 6- or 5-membered ring.

9. The organic electroluminescence device according to claim 1, wherein an interfacial region between the cathode and the organic thin film layer contains a reduction-causing dopant.

10. A compound represented by formula (1):



wherein Ar₀ is a substituted or unsubstituted benzene ring;

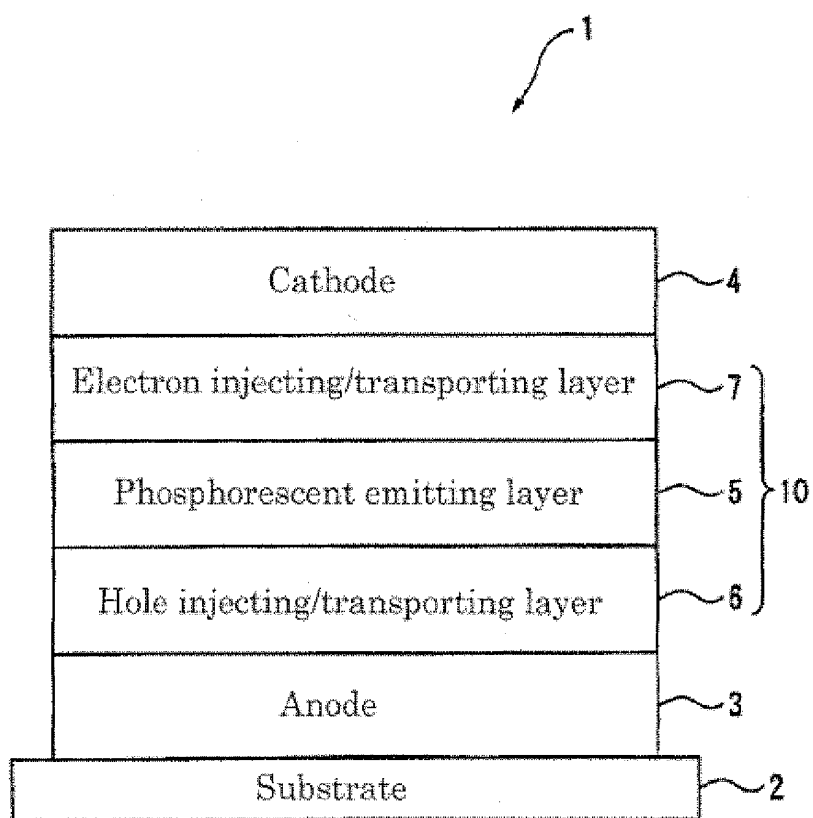
Ar₁ to Ar₃ are each independently a substituted or unsubstituted condensed aromatic hydrocarbon ring, the condensed aromatic hydrocarbon ring being selected from naphthalene ring, chrysene ring, fluoranthene ring, triphenylene ring, phenanthrene ring, benzophenanthrene ring, dibenzophenanthrene ring, benzotriphenylene ring, benzochrysene ring, benzo[b]fluoranthene ring, and picene ring, with the proviso that Ar₁ and Ar₂ are the same condensed aromatic hydrocarbon ring, numbers of substituents of Ar₁ and Ar₂ may be the same or different, and kinds of substituents of Ar₁ and Ar₂ may be the same or different;

Ar₀, Ar₁, Ar₂, and Ar₃ may be substituted by at least one group selected from an alkyl group having 1 to 20 carbon atoms, a haloalkyl group having 1 to 20 carbon atoms, a cycloalkyl group having 5 to 18 carbon atoms, a silyl group having 3 to 20 carbon atoms, a fluorene skeleton-containing group having 13 to 35 carbon atoms, dibenzofuranyl group, cyano group, and halogen atom; and

when Ar₂ is naphthalene ring, Ar₀ and Ar₃ do not bond to 2- and 7-positions of the naphthalene ring.

11. The compound according to claim 10, wherein Ar₃ is a group selected from a substituted or unsubstituted phenanthrene ring, a substituted or unsubstituted fluoranthene ring, a substituted or unsubstituted benzophenanthrene ring, and a substituted or unsubstituted benzochrysene ring.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/071501

A. CLASSIFICATION OF SUBJECT MATTER

H01L51/50(2006.01)i, C07C13/66(2006.01)i, C07C15/30(2006.01)i, C07C15/38(2006.01)i, C07F7/08(2006.01)i, C09K11/06(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L51/50, C07C13/66, C07C15/30, C07C15/38, C07F7/08, C09K11/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2010
Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CAPLUS (STN), REGISTRY (STN)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2007/114358 A1 (Idemitsu Kosan Co., Ltd.), 11 October 2007 (11.10.2007), claims 5, 6; paragraphs [0024], [0026], [0063] & JP 2007-277113 A & US 2007/0273272 A1 & EP 2003108 A1 & KR 10-2008-0114785 A & CN 101415663 A	10, 11 1-9
Y	WO 2008/123178 A1 (Idemitsu Kosan Co., Ltd.), 16 October 2008 (16.10.2008), paragraphs [0287], [0302] & EP 2133932 A	1-9
P, A	JP 2009-283899 A (Gracel Display Inc.), 03 December 2009 (03.12.2009), paragraphs [0049], [0052] & US 2009/0230852 A & EP 2100941 A2 & KR 10-0901887 B1 & CN 101531565 A	1-11

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
24 February, 2010 (24.02.10)

Date of mailing of the international search report
13 April, 2010 (13.04.10)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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专利名称(译)	有机电致发光元件和化合物		
公开(公告)号	EP2372804A1	公开(公告)日	2011-10-05
申请号	EP2009834978	申请日	2009-12-24
[标]申请(专利权)人(译)	出光兴产株式会社		
申请(专利权)人(译)	出光兴产股份有限公司.		
当前申请(专利权)人(译)	出光兴产股份有限公司.		
[标]发明人	IWAKUMA TOSHIHIRO TAKASHIMA YORIYUKI OGIWARA TOSHINARI		
发明人	IWAKUMA, TOSHIHIRO TAKASHIMA, YORIYUKI OGIWARA, TOSHINARI		
IPC分类号	H01L51/50 C07C13/66 C07C15/30 C07C15/38 C07F7/08 C09K11/06 C07C13/20 C07C13/38 C07C13/567 C07C13/62 C07C43/20 C07C43/205 C07C43/275 C07C255/52 C07D307/91 H01L51/00 H05B33/14		
CPC分类号	H01L51/0052 C07C13/28 C07C13/38 C07C13/567 C07C13/62 C07C13/66 C07C15/30 C07C15/38 C07C43/20 C07C43/202 C07C43/205 C07C43/275 C07C255/52 C07C2601/08 C07C2601/14 C07C2603/18 C07C2603/26 C07C2603/40 C07C2603/42 C07C2603/48 C07C2603/52 C07C2603/54 C07D307/91 C07F7/0805 C09K11/06 C09K2211/1059 C09K2211/185 H01L51/0054 H01L51/0055 H01L51/0071 H01L51/0079 H01L51/0085 H01L51/0087 H01L51/5016 H05B33/14		
代理机构(译)	RAUH , PETER		
优先权	2008334927 2008-12-26 JP		
其他公开文献	EP2372804B1 EP2372804A4		
外部链接	Espacenet		

摘要(译)

一种有机电致发光器件，由阴极，阳极和阴极与阳极之间的有机薄膜层组成。有机薄膜层包括一个或多个层。至少一层有机薄膜层是发光层，并且至少一个发光层含有相对于中心苯环不对称的化合物和磷光发光材料。该化合物提供了具有长寿命和高电流效率的有机电致发光器件。

