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(54) **MATERIAL FOR LIGHT-EMITTING ELEMENT AND LIGHT-EMITING ELEMENT**

(57) The purpose of the present invention is to provide an organic thin-film light-emitting element with improved luminous efficiency, drive voltage and durability life. This material for a light-emitting element is characterized by comprising a specific compound having a benzofluoranthene skeleton.

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a light-emitting device capable of converting electric energy into light, and a material to be used for the same. The present invention is capable of being used for areas such as display devices, flat-panel displays, backlight, lighting, interior design, labels, signboards, electrophotography machines, and light signal generators.

10 BACKGROUND ART

[0002] Researches on an organic thin-film light-emitting device in which electrons injected from a cathode and holes injected from an anode emit light when they are recombined in an organic fluorescent body held by both electrodes have been actively conducted in recent years. This light-emitting device is characteristic for high luminance light emission in the form of a thin type and under a low driving voltage, and multicolor light emission due to selection of a fluorescent material, and has been paid attention.

[0003] Such researches have undergone many studies for practical use since C. W. Tang et al. of Kodak Co., Ltd. showed that an organic thin-film device emits light at high luminance, and organic thin-film light-emitting devices have steadily come into practical use as they have been employed in main displays of mobile phones, and the like. However, there are still many technical problems and, especially, attainment of both increased efficiency and prolonged life of a device is one of the major problems.

[0004] For the organic thin-film light-emitting device, it is necessary to satisfy an improvement in luminous efficiency, a reduction in driving voltage and an improvement in durability. Particularly, realization of both luminous efficiency and durable life is a major problem. For example, a material having a benzofluoranthene skeleton (Patent Document 1) and a material having a nitrogen-containing heterocyclic ring (Patent Document 2) have been developed for improving luminous efficiency and durable life.

PRIOR ART DOCUMENTS

30 PATENT DOCUMENTS

[0005]

Patent Document 1: WO 2012/046839
 35 Patent Document 2: WO 2010/114264

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

40 **[0006]** However, conventional technologies were difficult to reduce the driving voltage of a device sufficiently, and even if they had been able to reduce the driving voltage, the luminous efficiency and the durable life of a device were insufficient. Thus, technologies capable of realizing all of high luminous efficiency, low driving voltage and durable life have not been found yet.

45 **[0007]** An object of the present invention is to solve such problems with the conventional technologies and provide an organic thin-film light-emitting device that has improved all of luminous efficiency, driving voltage and durable life.

SOLUTIONS TO THE PROBLEMS

50 **[0008]** The present invention provides a light-emitting device material including a compound represented by the following general formula (1):
 [Chemical Formula 1]



55 wherein Ar represents a group containing a benzofluoranthene skeleton, and Z is represented by the following general formula (2); L is a single bond, a substituted or unsubstituted arylene group, or a substituted or unsubstituted heteroarylene group; n is 1 or 2; and when n is 2, two Zs may be the same or different:

[Chemical Formula 2]



wherein ring A and ring B each represent a substituted or unsubstituted benzene ring, a substituted or unsubstituted fused aromatic hydrocarbon ring, a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsubstituted fused aromatic heterocyclic ring, with the proviso that at least one of atoms that form ring A and ring B is electron-accepting nitrogen; a substituent that ring A and ring B optionally have, and R¹ are each selected from the group consisting of an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³; R¹ may be hydrogen; R² and R³ are each an aryl group or a heteroaryl group; or R² and R³ may be fused to form a ring, with the proviso that the group is coupled to L at the position of any of R¹, ring A and ring B; and when n is 2, positions at which two Zs are coupled to L may be the same or different.

EFFECTS OF THE INVENTION

[0009] According to the present invention, there can be provided an organic thin-film light-emitting device that realizes all of luminous efficiency, driving voltage and durable life.

EMBODIMENTS OF THE INVENTION

[0010] The compound represented by the general formula (1) is described in detail below.
[Chemical Formula 3]



wherein Ar represents a group containing a benzofluoranthene skeleton, and Z is represented by the following general formula (2); L is a single bond, a substituted or unsubstituted arylene group, or a substituted or unsubstituted heteroarylene group; n is 1 or 2; and when n is 2, two Zs may be the same or different:

[Chemical Formula 4]



wherein ring A and ring B each represent a substituted or unsubstituted benzene ring, a substituted or unsubstituted fused aromatic hydrocarbon ring, a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsubstituted fused aromatic heterocyclic ring, with the proviso that at least one of atoms that form ring A and ring B is electron-accepting nitrogen; a substituent that ring A and ring B optionally have, and R¹ are each selected from the group consisting of an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³; R¹ may be hydrogen; R² and R³ are each an aryl group or a heteroaryl group; or R² and R³ may be fused to form a ring, with the proviso that the group is coupled to L at the position of any of R¹, ring A and ring B; and when n is 2, positions at

which two Zs are coupled to L may be the same or different.

[0011] In all the groups described above, hydrogen may be heavy hydrogen. The alkyl group denotes a saturated aliphatic hydrocarbon group, such as a methyl group, an ethyl group, a n-propyl group, an isopropyl group, a n-butyl group, a sec-butyl group, and a tert-butyl group, and it may or may not have a substituent. When the alkyl group is substituted, the additional substituent is not particularly limited, examples may include an alkyl group, an aryl group and a heteroaryl group, and the same holds true in the descriptions below. The number of carbon atoms in the alkyl group is not particularly limited, but from the viewpoints of easy availability and cost, it is preferably within the range of 1 or more and 20 or less, more preferably 1 or more and 8 or less.

[0012] The cycloalkyl group denotes a saturated alicyclic hydrocarbon group, such as a cyclopropyl group, a cyclohexyl group, a norbornyl group, and an adamantyl group, and this may or may not have a substituent. The number of carbon atoms in the alkyl group moiety is not particularly limited, but is preferably within the range of 3 or more and 20 or less.

[0013] The heterocyclic group denotes an aliphatic ring having an atom other than carbon in the ring, such as a pyran ring, a piperidine ring, and a cyclic amide, and this may or may not have a substituent. The number of carbon atoms in the heterocyclic group is not particularly limited, but is preferably within the range of 2 or more and 20 or less.

[0014] The alkenyl group denotes an unsaturated aliphatic hydrocarbon group containing a double bond, such as a vinyl group, an allyl group, and a butadienyl group, and this may or may not have a substituent. The number of carbon atoms in the alkenyl group is not particularly limited, but is preferably within the range of 2 or more and 20 or less.

[0015] The cycloalkenyl group denotes an unsaturated alicyclic hydrocarbon group containing a double bond, such as a cyclopentenyl group, a cyclopentadienyl group, and a cyclohexenyl group, and this may or may not have a substituent.

[0016] The alkynyl group denotes an unsaturated aliphatic hydrocarbon group containing a triple bond, such as an ethynyl group, and this may or may not have a substituent. The number of carbon atoms in the alkynyl group is not particularly limited, but is preferably within the range of 2 or more and 20 or less.

[0017] The alkoxy group denotes a functional group with an aliphatic hydrocarbon group bonded via an ether bond, such as a methoxy group, an ethoxy group, and a propoxy group, and this aliphatic hydrocarbon group may or may not have a substituent. The number of carbon atoms in the alkoxy group is not particularly limited, but is preferably within the range of 1 or more and 20 or less.

[0018] The alkylthio group denotes a group in which an oxygen atom of an ether bond in an alkoxy group is substituted with a sulfur atom. The hydrocarbon group of the alkylthio group may or may not have a substituent. The number of carbon atoms in the alkylthio group is not particularly limited, but is preferably within the range of 1 or more and 20 or less.

[0019] The aryl ether group denotes a functional group with an aromatic hydrocarbon group bonded via an ether bond, such as a phenoxy group, and the aromatic hydrocarbon group may or may not have a substituent. The number of carbon atoms in the aryl ether group is not particularly limited, but is preferably within the range of 6 or more and 40 or less.

[0020] The aryl thioether group denotes a group in which an oxygen atom of an ether bond in an aryl ether group is substituted with a sulfur atom. The aromatic hydrocarbon group in the aryl ether group may or may not have a substituent. The number of carbon atoms in the aryl ether group is not particularly limited, but is preferably within the range of 6 or more and 40 or less.

[0021] The aryl group denotes an aromatic hydrocarbon group, such as a phenyl group, a naphthyl group, a biphenyl group, a phenanthryl group, a terphenyl group, a pyrenyl group, and a fluoranthenyl group. The aryl group may or may not have a substituent. The number of carbon atoms in the aryl group is not particularly limited, but is preferably within the range of 6 or more and 40 or less.

[0022] The heteroaryl group denotes a cyclic aromatic group having one or a plurality of atoms other than carbon in the ring, such as a furanyl group, a thiophenyl group, a pyridyl group, a quinolinyl group, an isoquinolinyl group, a pyrazinyl group, a pyrimidyl group, a naphthyridyl group, a benzofuranyl group, a benzothiophenyl group, an indolyl group, a dibenzofuranyl group, and a carbazolyl group, and this may be unsubstituted or substituted. The number of carbon atoms in the heteroaryl group is not particularly limited, but is preferably within the range of 2 or more and 30 or less.

[0023] The halogen denotes an atom selected from fluorine, chlorine, bromine, and iodine.

[0024] The carbonyl group, the carboxyl group, the oxycarbonyl group, the carbamoyl group and the phosphine oxide group may or may not have a substituent. Here, examples of the substituent include an alkyl group, a cycloalkyl group, an aryl group and a heteroaryl group, and these substituents may be further substituted.

[0025] The arylene group denotes a divalent or trivalent group derived from an aromatic hydrocarbon group such as a phenyl group, a naphthyl group, and a biphenyl group, and this may or may not have a substituent. When the L in the general formula (1) is an arylene group, the number of nucleus carbon atoms is preferably within the range of 6 or more and 30 or less. Specific examples of the arylene group include a 1, 4-phenylene group, a 1, 3-phenylene group, a 1,2-phenylene group, a 4,4'-biphenylene group, a 4,3'-biphenylene group, a 3,3'-biphenylene group, a 1, 4-naphthylene group, a 1, 5-naphthylene group, a 2, 5-naphthylene group, a 2,6-naphthylene group and a 2,7-naphthylene group. A 1, 4-phenylene group and a 1, 3-phenylene group are more preferable.

[0026] The heteroarylene group denotes a divalent or trivalent group derived from an aromatic group having one or a plurality of atoms other than carbon in the ring, such as a pyridyl group, a quinolinyl group, a pyrimidinyl group, a

pyrazinyl group, a naphthyridyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a carbazolyl group, and this may or may not have a substituent. The number of carbon atoms in the heteroarylene group is not particularly limited, but is preferably within the range of 2 to 30.

[0027] Examples of the fused aromatic hydrocarbon ring include a naphthalene ring, an azulene ring, an anthracene ring, a phenanthrene ring, a pyrene ring, a chrysene ring, a naphthacene ring, a triphenylene ring, an acenaphthene ring, a coronene ring, a fluorene ring, a fluoranthene ring, a naphthacene ring, a pentacene ring, a perylene ring, a pentaphene ring, a picene ring, a pyranthrene and an anthraanthrene ring. Further, the fused aromatic hydrocarbon ring may have a substituent.

[0028] Examples of the monocyclic aromatic heterocyclic ring include a furan ring, a thiophene ring, a pyridine ring, a pyridazine ring, a pyrimidine ring, a pyrazine ring, an oxadiazole ring, a triazole ring, an imidazole ring, a pyrazole ring and a thiazole ring. Further, the monocyclic aromatic heterocyclic ring may have a substituent.

[0029] Examples of the fused aromatic heterocyclic ring include a quinoline ring, an isoquinoline ring, a quinoxaline ring, a benzimidazole ring, an indole ring, a benzimidazole ring, a benzothiazole ring, a benzoxazole ring, a quinoxaline ring, a quinazoline ring, a phthalazine ring, a carbazole ring, a carboline ring and a diazacarbazole ring (a ring in which one of carbon atoms of a hydrocarbon ring that forms a carboline ring is further substituted with a nitrogen atom). Further, the fused aromatic heterocyclic ring may have a substituent.

[0030] In the compound represented by the above general formula (1), L is a single bond, a substituted or unsubstituted arylene group, or a substituted or unsubstituted heteroarylene group. The group represented by Z represented by the above general formula (2) is coupled to L at the position of any of R¹, ring A and ring B. The group being coupled to L at the position of any of R¹, ring A and ring B has the following meaning. First, the group being coupled to L at the position of R¹ means that the nitrogen atom coupled to R¹ is directly bonded to L. The group being coupled to L at the position of either ring A or ring B means that for example when ring A is a benzene ring, L is directly bonded to any one of carbon atoms that form the benzene ring.

[0031] L is not particularly limited, but is preferably a single bond, or a substituted or unsubstituted arylene group. When L is a single bond, or a substituted or unsubstituted arylene group, conjugation is expanded to achieve high carrier mobility and high electron-accepting property. As a result, further low-voltage driving of the light-emitting device becomes possible, so that luminous efficiency can be further improved.

[0032] L is not particularly limited, but is preferably a substituted or unsubstituted arylene group. When L is a substituted or unsubstituted arylene group, conjugation is further expanded to achieve high carrier mobility and high electron-accepting property. As a result, further low-voltage driving of the light-emitting device becomes possible, so that luminous efficiency can be further improved. Crystallinity can be reduced and the glass transition temperature can be increased, so that stability of the film is improved, and therefore further improvement of life becomes possible when the compound is used for the light-emitting device.

[0033] In the compound represented by the above general formula (1), n is 1 or 2. That is, the compound represented by the general formula (1) has one or two groups represented by Z, and accordingly crystallinity is reduced and the glass transition temperature is increased, so that stability of the film is further improved. n is preferably 1. When n is 1, sublimability and deposition stability are further improved.

[0034] In the compound represented by the general formula (1), Ar is a group containing a benzofluoranthene skeleton, and the light-emitting device material of the present invention has a benzofluoranthene skeleton. The benzofluoranthene skeleton has a five-membered ring structure of 5 π electron system. When given one electron (when reduced), the five-membered ring structure of 5 π electron system turns to a 6 π electron system, so that aromatic stabilization occurs (Huckel rule). Thus, the five-membered ring structure of 5 π electron system shows high electron affinity, and the benzofluoranthene skeleton according to the present invention also has high electron affinity. Since anthracene and pyrene, generally famous fused ring aromatic skeletons, do not have a five-membered ring structure of 5 π electron system, there is no increase in electron affinity resulting from aromatic stabilization due to reduction, and such a phenomenon is a nature specific to a skeleton having a five-membered ring structure of 5 π electron system. Thus, when the light-emitting device material of the present invention is used for the light-emitting device, e.g., used for an electron transporting layer, proper electron injection property from the electrode is exhibited, so that the driving voltage of the light-emitting device can be reduced. As a result, luminous efficiency of the light-emitting device can be improved. The light-emitting device material also contributes to an increase in life.

[0035] The benzofluoranthene skeleton has high flatness, so that molecules are well superimposed on one another, and therefore high charge transporting property is achieved. Particularly, the benzofluoranthene skeleton has charge transporting property higher than that of, for example, fluoranthene owing to its high flatness. Thus, when the light-emitting device material of the present invention is used for any of the layers that form the light-emitting device, electrons generated from the cathode and holes generated from the anode can be efficiently transported, and therefore the driving voltage of the device can be reduced. As a result, luminous efficiency of the light-emitting device can be improved. The light-emitting device material also contributes to an increase in life.

[0036] The benzofluoranthene skeleton has high stability to charges, so that reduction by electrons and oxidation by

holes can be smoothly repeatedly performed. When the light-emitting device material of the present invention is used for the light-emitting device, life can be improved.

[0037] In Z represented by the above general formula (2), at least one of atoms that form ring A and ring B is electron-accepting nitrogen. Here, the electron-accepting nitrogen denotes a nitrogen atom which forms a multiple bond with an adjoining atom. Since nitrogen atoms have high electronegativity, the multiple bond has an electron-accepting nature. For this reason, z having electron-accepting nitrogen has high electron affinity. Thus, when the light-emitting device material of the present invention is used for the emissive layer and the electron transporting layer, proper electron injection property from the electrode is exhibited, so that the driving voltage of the light-emitting device can be reduced. As a result, luminous efficiency of the light-emitting device can be improved. The light-emitting device material also contributes to an increase in life.

[0038] In the group represented by Z, the number of electron-accepting nitrogen atoms that form ring A and ring B is preferably 1. When in Z, the number of electron-accepting nitrogen atoms that form ring A and ring B is 1, both electron injection property from the electrode and electron injection property to the emissive layer can be realized and thus the driving voltage of the light-emitting device can be further reduced when the light-emitting device material is used for the electron transporting layer. As a result, luminous efficiency of the light-emitting device can be improved.

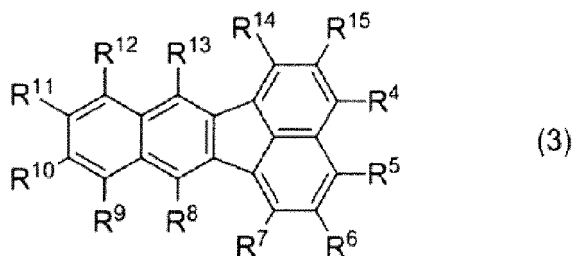
[0039] The group represented by Z has electron-donating nitrogen. Here, the electron-donating nitrogen denotes a nitrogen atom in which all the bonds with adjacent atoms are single bonds. In the group represented by Z, the nitrogen atom bonded to R¹ is the electron-donating nitrogen. The electron donating nitrogen has high stability to holes, so that oxidation by holes can be smoothly repeatedly performed. Accordingly, when the compound represented by the general formula (1) according to the present invention is used for the hole transporting layer, life can be improved.

[0040] When the light-emitting device material of the present invention has a group represented by Z, sublimability and deposition stability are improved, crystallinity is reduced, and stability of the film due to a high glass transition temperature is improved. Consequently, when the light-emitting device material of the present invention is used for the light-emitting device, life can be improved.

[0041] From the above, the light-emitting device material of the present invention has Ar, i.e., a group containing a benzo[fluoranthene] skeleton in the molecule, and a group represented by Z, and therefore has high electron injection/transporting properties, electrochemical stability, proper sublimability, proper deposition stability, proper film quality and a high glass transition temperature. Thus, when the light-emitting device material of the present invention is used for any of the layers that form the light-emitting device, an organic thin-film light-emitting device having all of high luminous efficiency, low driving voltage and durable life can be provided.

[0042] Examples of the benzo[fluoranthene] skeleton include a benzo[k]fluoranthene skeleton (8,9-benzo[fluoranthene] skeleton), benzo[j]fluoranthene skeleton (7,8-benzo[fluoranthene] skeleton), benzo[a]fluoranthene skeleton (1,2-benzo[fluoranthene] skeleton) and benzo[b]fluoranthene skeleton (2,3-benzo[fluoranthene] skeleton), and the group containing a benzo[fluoranthene] skeleton may be further modified with a fused ring as long as it contains a benzo[fluoranthene] skeleton. Among them, the benzo[k]fluoranthene skeleton is preferred. That is, Ar is preferably a group represented by the following general formula (3). When the benzo[fluoranthene] skeleton is represented by the general formula (3), conjugation is moderately expanded. Consequently, electrochemical stability becomes higher, and charge transporting property is further improved.

[Chemical Formula 5]



wherein R⁴ to R¹⁵ may be the same or different, and are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group and a carbamoyl group; and R⁴ to R¹⁵ may form a ring by adjacent substituents, with the proviso that the group is coupled to L at the position of any one of R⁴ to R¹⁵.

[0043] Preferably, R⁴ to R¹⁵ in the general formula (3) are each selected from the group consisting of hydrogen, an

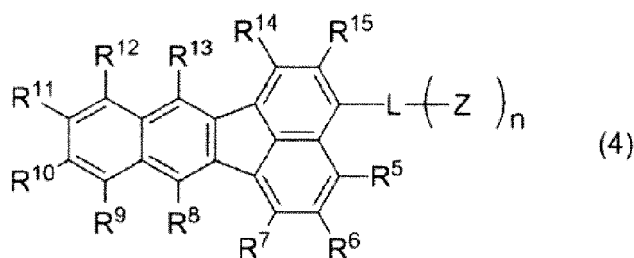
alkyl group, a cycloalkyl group, an aryl group, a heteroaryl group and halogen among the groups described above. When R^4 to R^{15} are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, an aryl group, a heteroaryl group and halogen, the glass transition temperature is increased, and thin-film stability is improved. When thin-film stability is improved, degeneration of the film is suppressed even when the light-emitting device is driven for a long period of time, and therefore durability is further improved. Since the substituent is hard to be decomposed under a high temperature, heat resistance is further improved. When heat resistance is improved, decomposition of the material during preparation of the device can be suppressed, and therefore durability is improved. Further, when the substituent is an aryl group or a heteroaryl group, conjugation is expanded, so that electrochemical stability becomes higher, and charge transporting property is further improved.

[0044] R^8 and R^{13} in the general formula (3) are each preferably a substituted or unsubstituted aryl group. When R^8 and R^{13} are each a substituted or unsubstituted aryl group, overlap of π conjugation planes between molecules can be moderately avoided. When R^8 and R^{13} are each a substituted or unsubstituted aryl group, heat resistance is further improved. As a result, without impairing high charge transporting property of the benzofluoranthene compound, improvement of sublimability, improvement of deposition stability, reduction of crystallinity and improvement of thin-film stability due to a high glass transition temperature are realized.

[0045] R^8 and R^{13} in the general formula (3) are each more preferably a substituted or unsubstituted phenyl group. When R^8 and R^{13} are each a substituted or unsubstituted phenyl group, overlap of π conjugation planes between molecules can be moderately avoided. Since the molecular weight becomes moderate, sublimability and deposition stability are further improved.

[0046] The compound represented by the general formula (1) is preferably a compound represented by the following general formula (4). In the benzofluoranthene, conjugation is easily expanded at the positions of R^4 and R^5 , and R^4 is used for coupling with L, so that conjugation is efficiently expanded. Consequently, the compound represented by the general formula (4) becomes more electrochemically stable, and charge transporting property is improved.

[Chemical Formula 6]

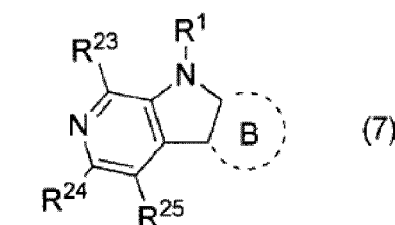
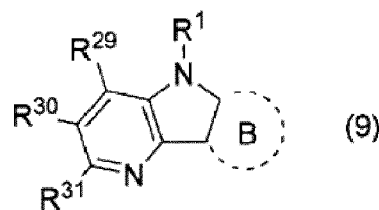
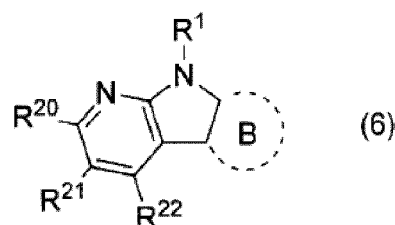
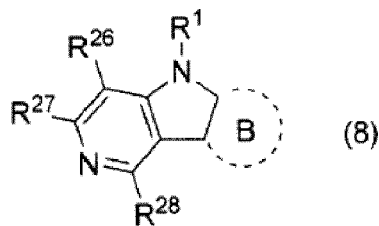
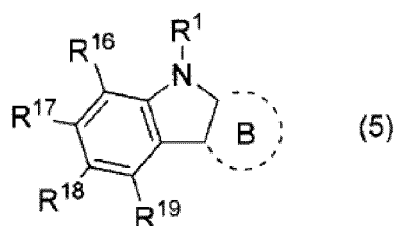


wherein R^5 to R^{15} may be the same or different, and are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group and a carbamoyl group; R^5 to R^{15} may form a ring by adjacent substituents; and L, Z and n are the same as in the general formula (1).

[0047] Preferably, R^5 to R^{15} in the general formula (4) are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, an aryl group, a heteroaryl group and halogen among the groups described above. When R^5 to R^{15} are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, an aryl group, a heteroaryl group and halogen, the glass transition temperature is further increased, and thin-film stability is further improved. Since the substituent is hard to be decomposed under a high temperature, heat resistance is further improved. Further, when the substituent is an aryl group or a heteroaryl group, conjugation is expanded, so that electrochemical stability becomes higher, and charge transporting property is further improved.

[0048] Z is preferably a group represented by any of the following general formulae (5) to (9). When Z is a group represented by any of the following general formulae (5) to (9), high electron mobility and high electron-accepting property are achieved, so that the driving voltage of the light-emitting device can be further reduced. As a result, luminous efficiency of the light-emitting device can be further improved. The light-emitting device material also contributes to an increase in life of the light-emitting device.

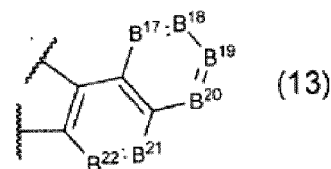
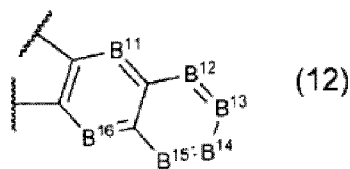
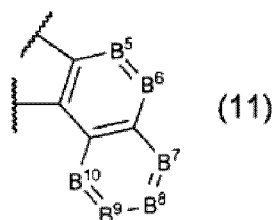
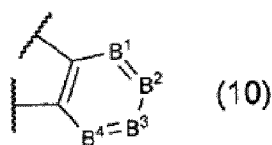
[Chemical Formula 7]



wherein ring B represents a substituted or unsubstituted benzene ring, a substituted or unsubstituted fused aromatic hydrocarbon ring, a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsubstituted fused aromatic heterocyclic ring, with the proviso that in the case of the general formula (5), ring B is a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsubstituted fused aromatic heterocyclic ring, and at least one of atoms that form ring B is electron-accepting nitrogen; a substituent that ring B optionally has, and R¹ are the same as in the general formula (2); and wherein R¹⁶ to R³¹ are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³, with the proviso that the group is coupled to L at the position of any of R¹, R¹⁶ to R¹⁹ and ring B in the case of the general formula (5), at the position of any of R¹, R²⁰ to R²² and ring B in the case of the general formula (6), at the position of any of R¹, R²³ to R²⁵ and ring B in the case of the general formula (7), at the position of any of R¹, R²⁶ to R²⁸ and ring B in the case of the general formula (8), and at the position of any of R¹, R²⁹ to R³¹ and ring B in the case of the general formula (9).

[0049] Ring B is preferably a structure represented by any of the following general formulae (10) to (13). When ring B is a structure represented by any of the following general formulae (10) to (13), high carrier mobility and high electron-accepting property are achieved. As a result, further low-voltage driving of the light-emitting device becomes possible, so that luminous efficiency can be improved. Improvement of sublimability, improvement of deposition stability, reduction of crystallinity and improvement of stability of the film due to a high glass transition temperature are realized.

[Chemical Formula 8]

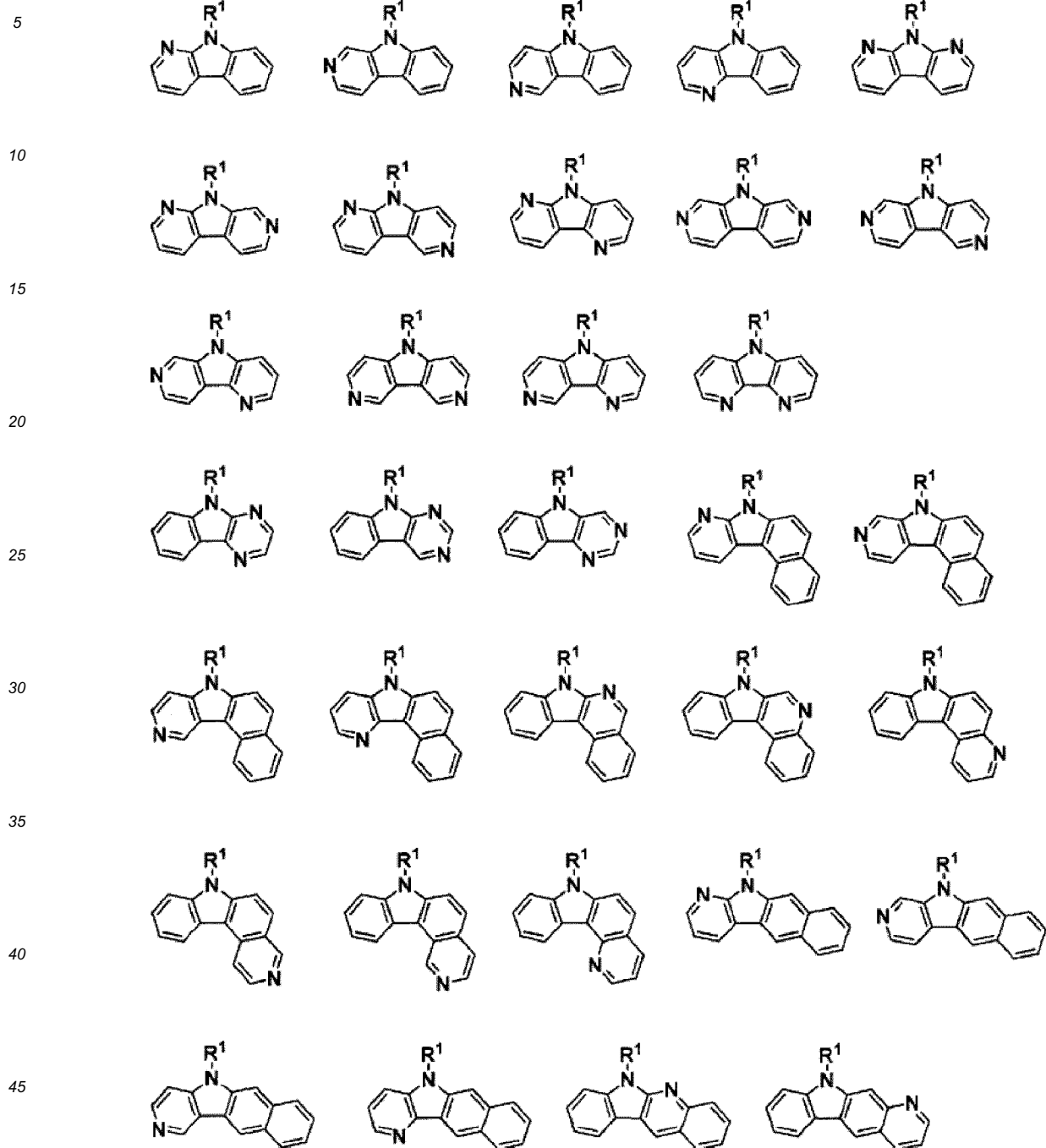


wherein B¹ to B²² represent C-R³² or N, with the proviso that when Z is a group represented by the general formula (5), at least one of B^ks (K = 1 to 22) contained in ring B is electron-accepting nitrogen; a substituent that B¹ to B²² optionally have is the same as in the general formula (2); and R³² is selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³.

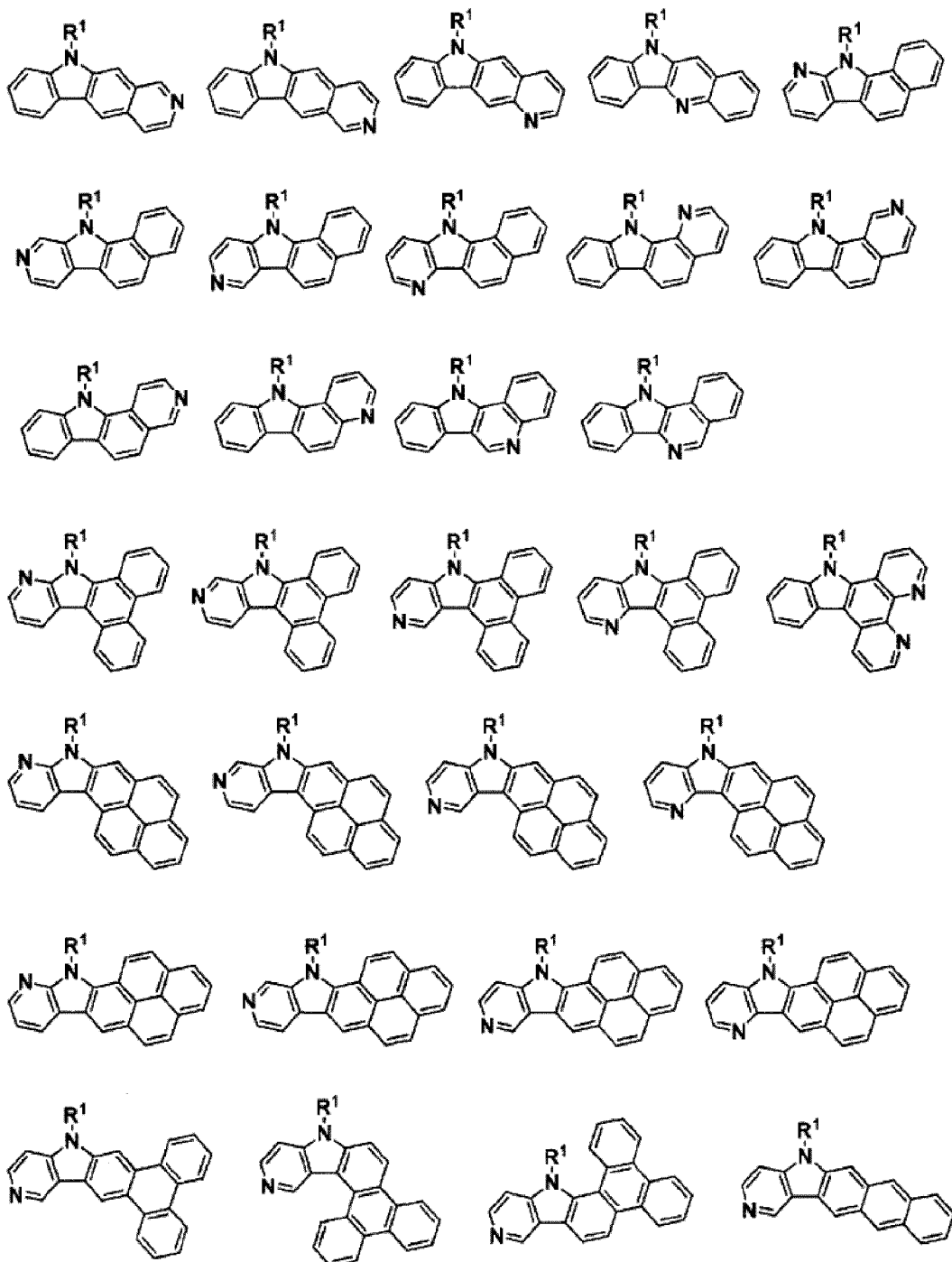
[0050] Ring B is not particularly limited, but is more preferably a structure represented by any of the general formulae (11) to (13). When ring B is a structure represented by any of the general formulae (11) to (13), conjugation is further expanded, so that high carrier mobility and high electron-accepting property are achieved. As a result, further low-voltage driving of the light-emitting device becomes possible, so that luminous efficiency can be further improved.

[0051] The group represented by Z is not particularly limited, and specific examples include groups of the following general formulae. Here, R¹ is the same as in the general formula (2).

[Chemical Formula 9]

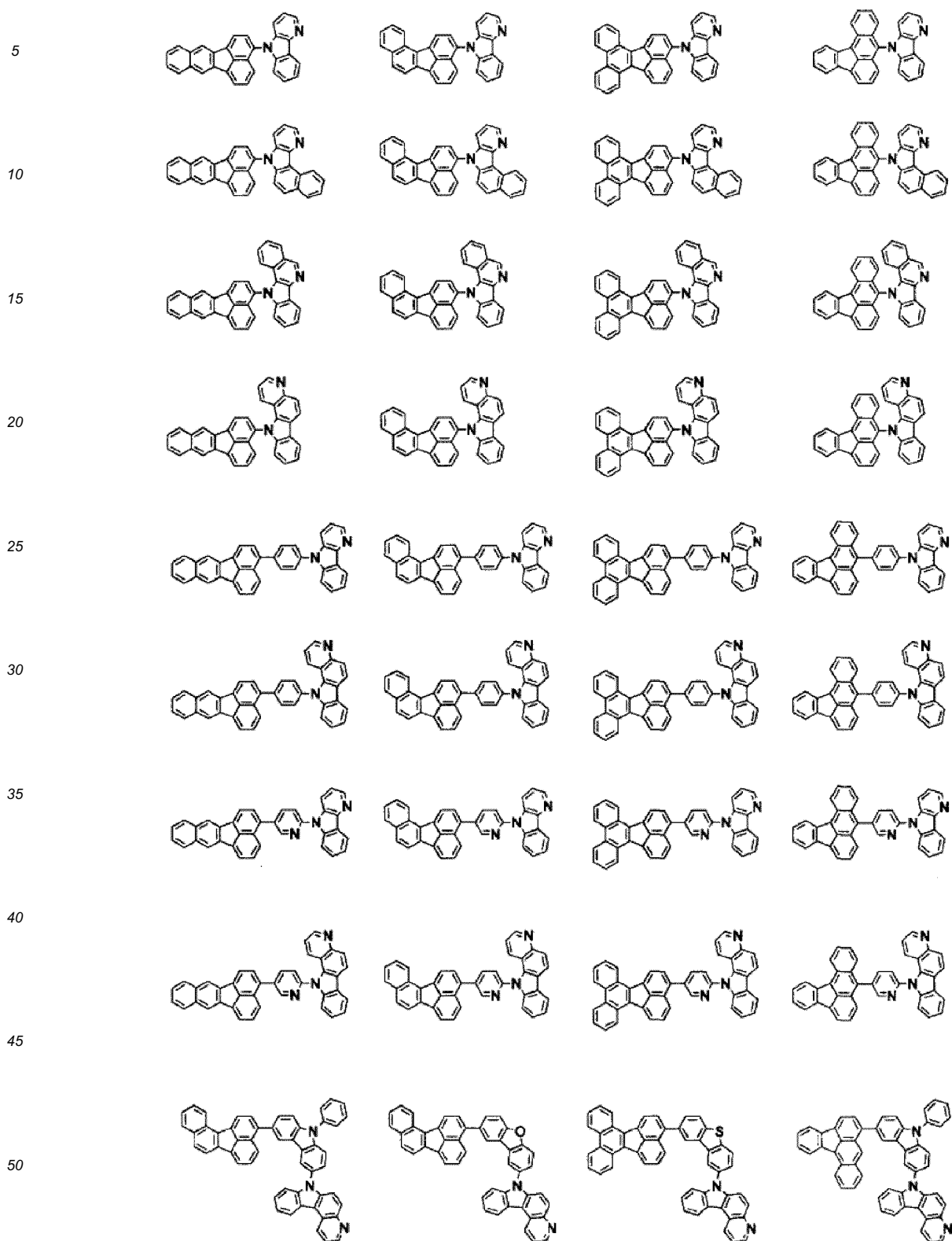


[Chemical Formula 10]



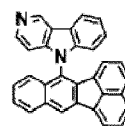
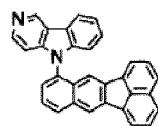
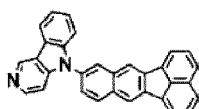
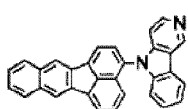
[0052] The light-emitting device material of the present invention is not particularly limited, and specific examples thereof include the following.

[Chemical Formula 11]

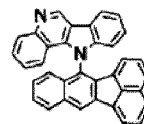
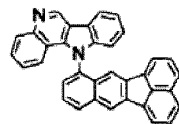
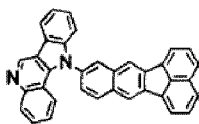
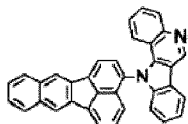


[Chemical Formula 12]

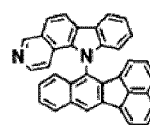
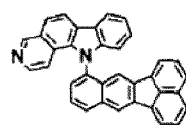
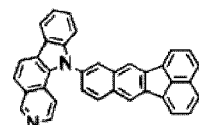
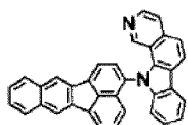
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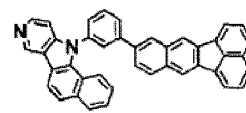
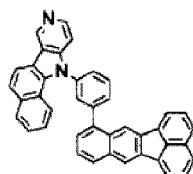
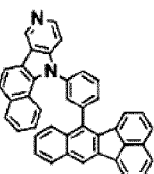
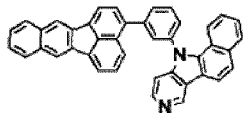
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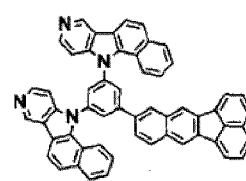
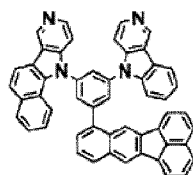
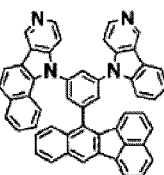
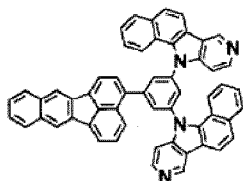
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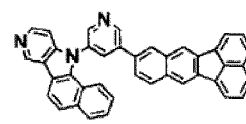
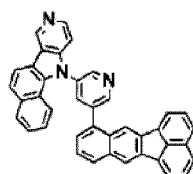
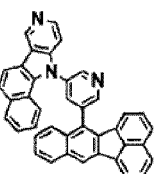
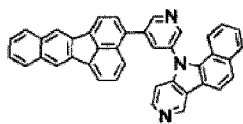


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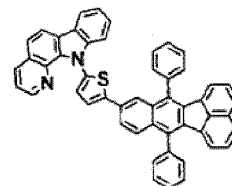
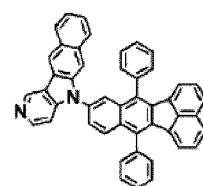
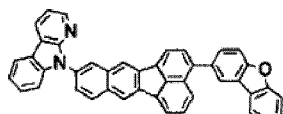
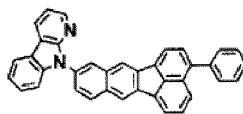


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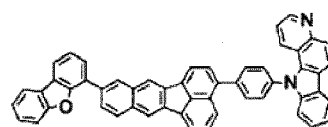
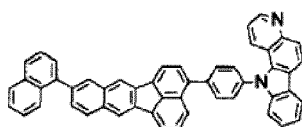
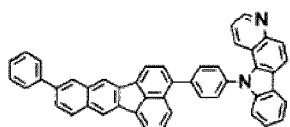


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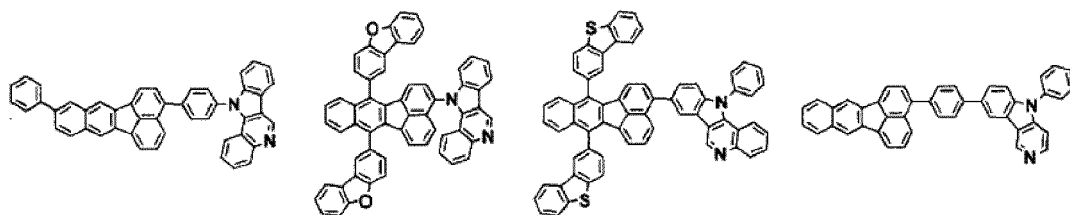
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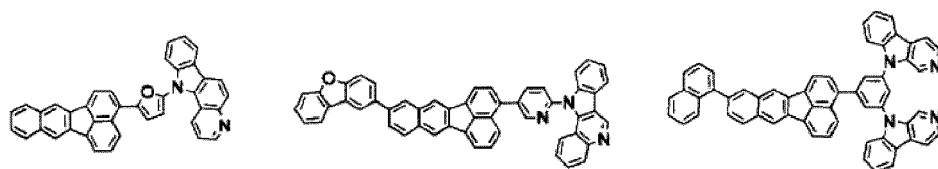
[Chemical Formula 13]

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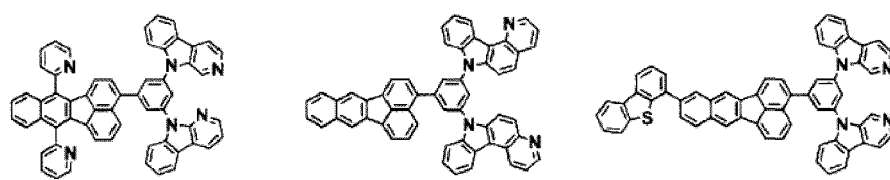
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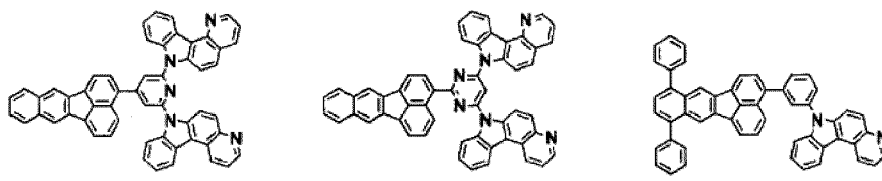


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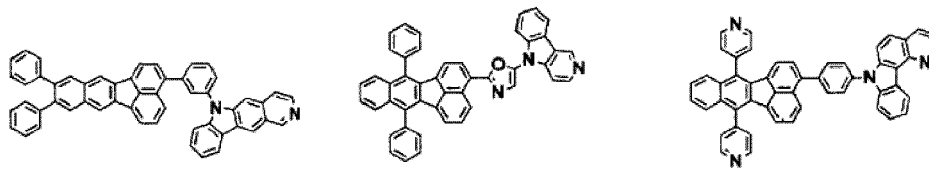
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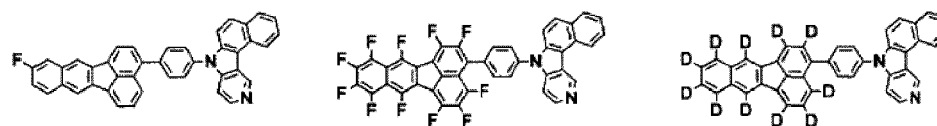
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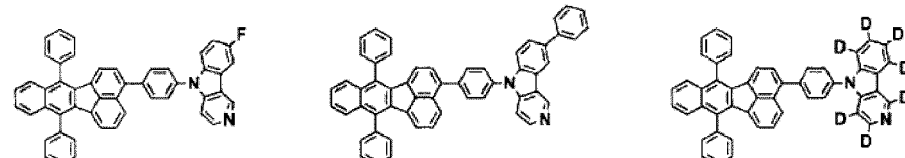
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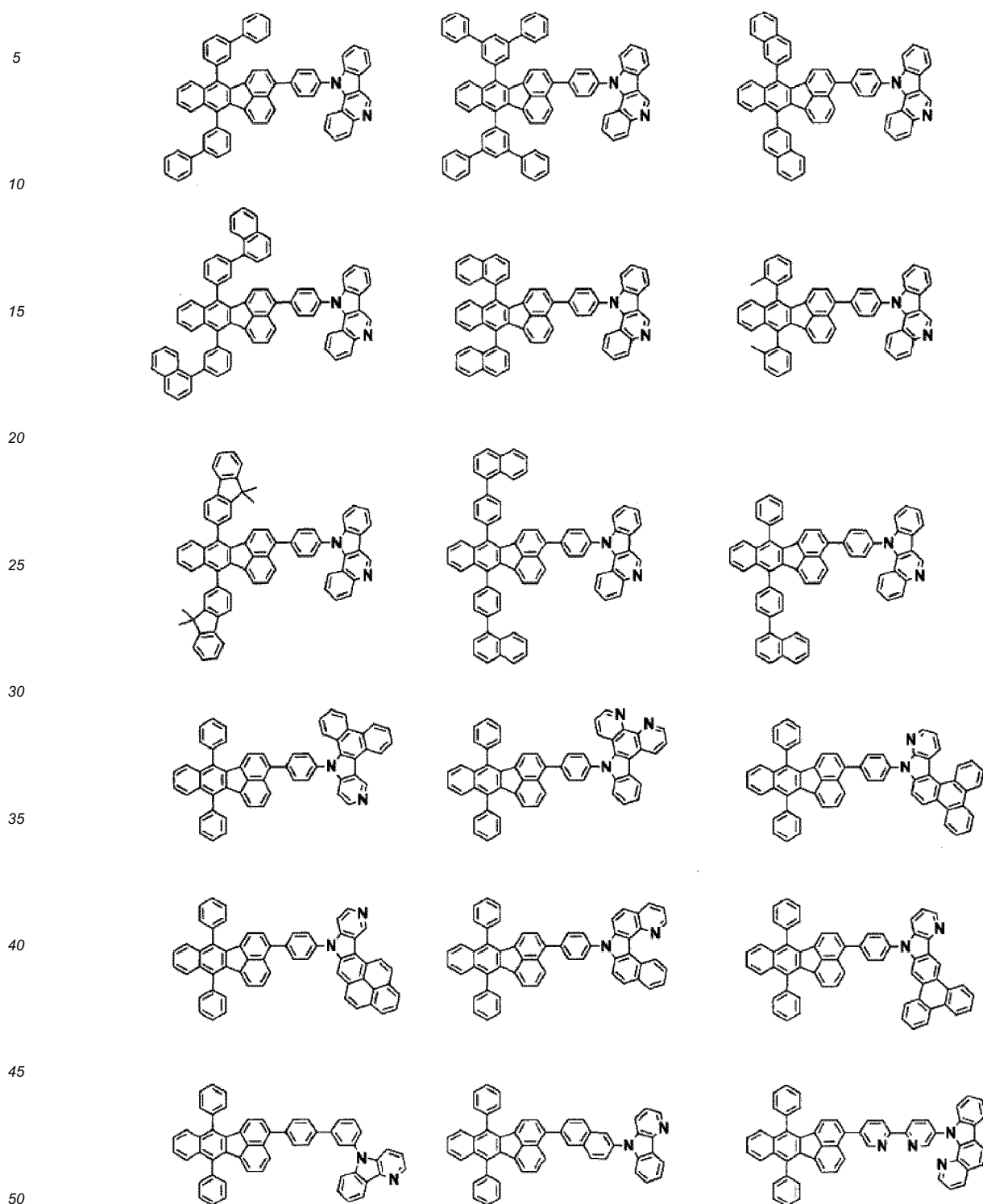
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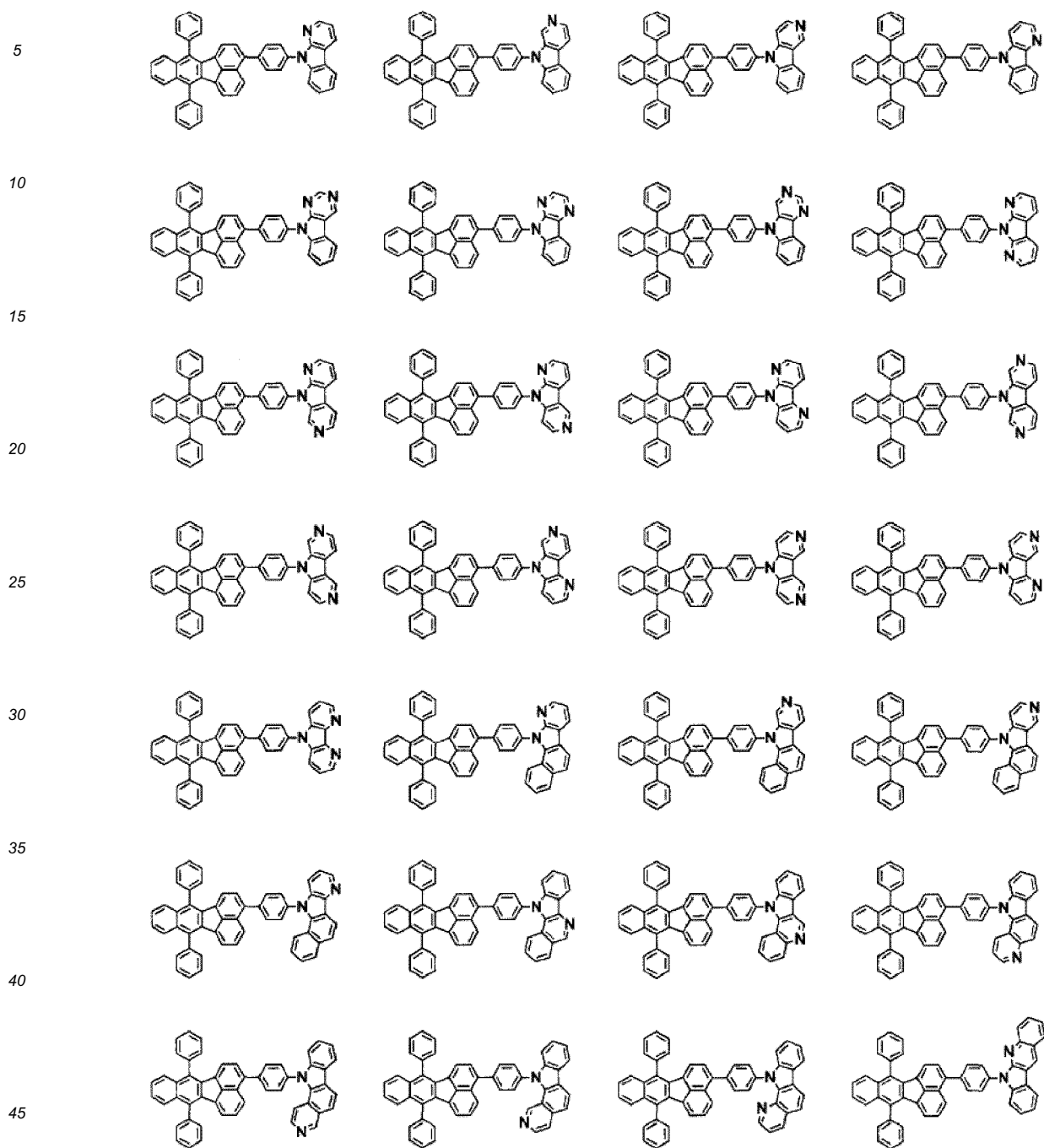
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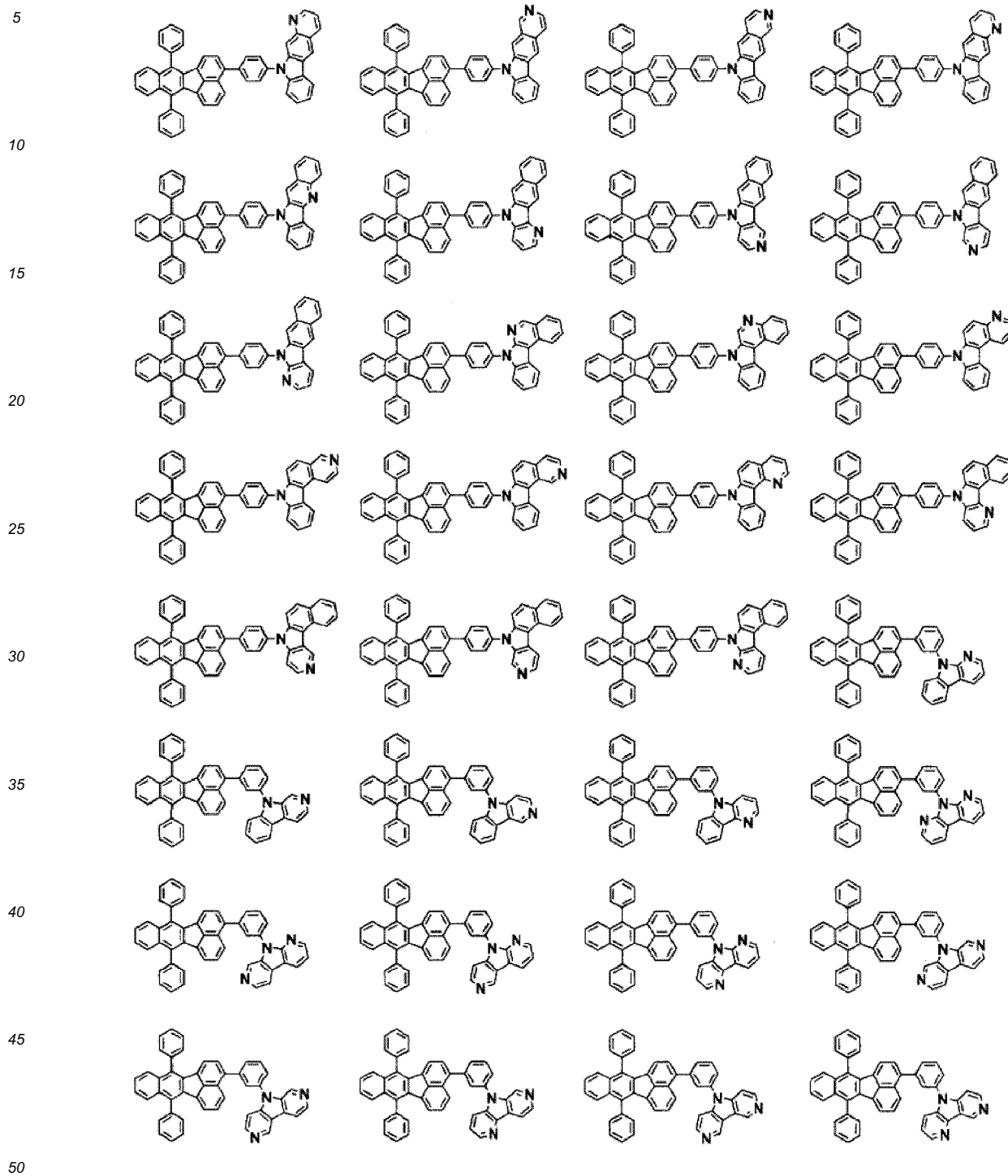
[Chemical Formula 14]



[Chemical Formula 15]

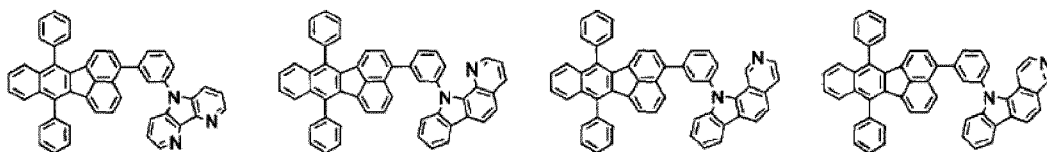


[Chemical Formula 16]

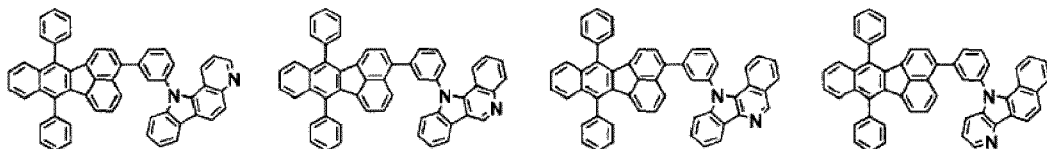


[Chemical Formula 17]

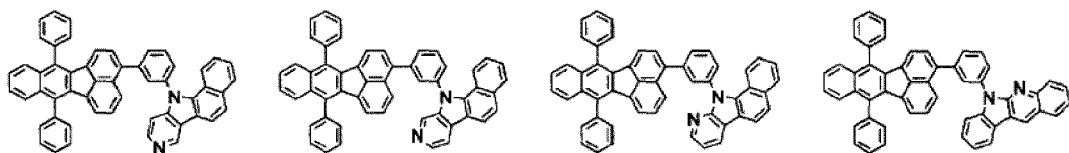
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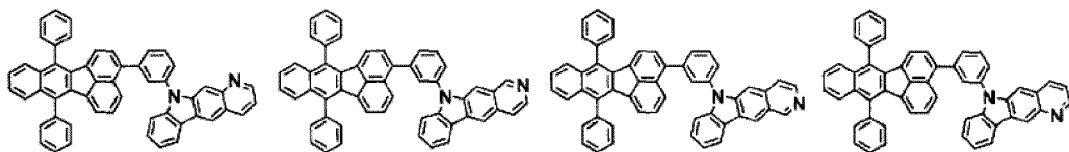
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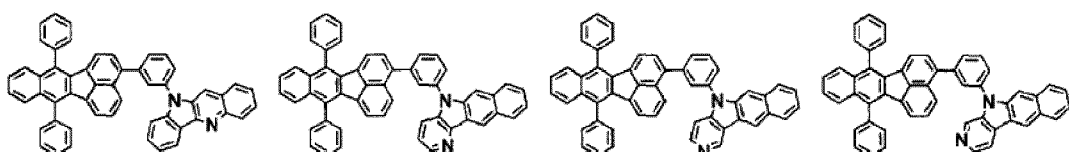
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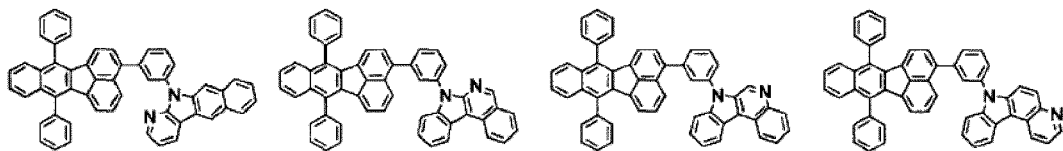
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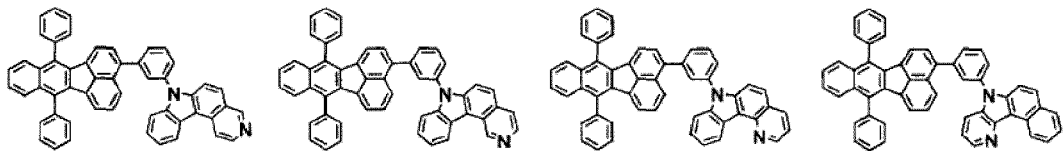
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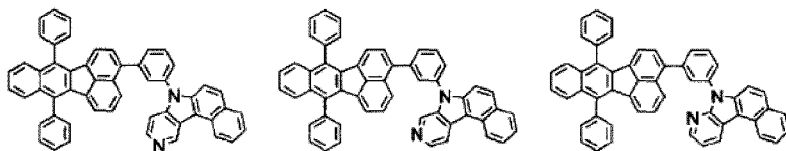
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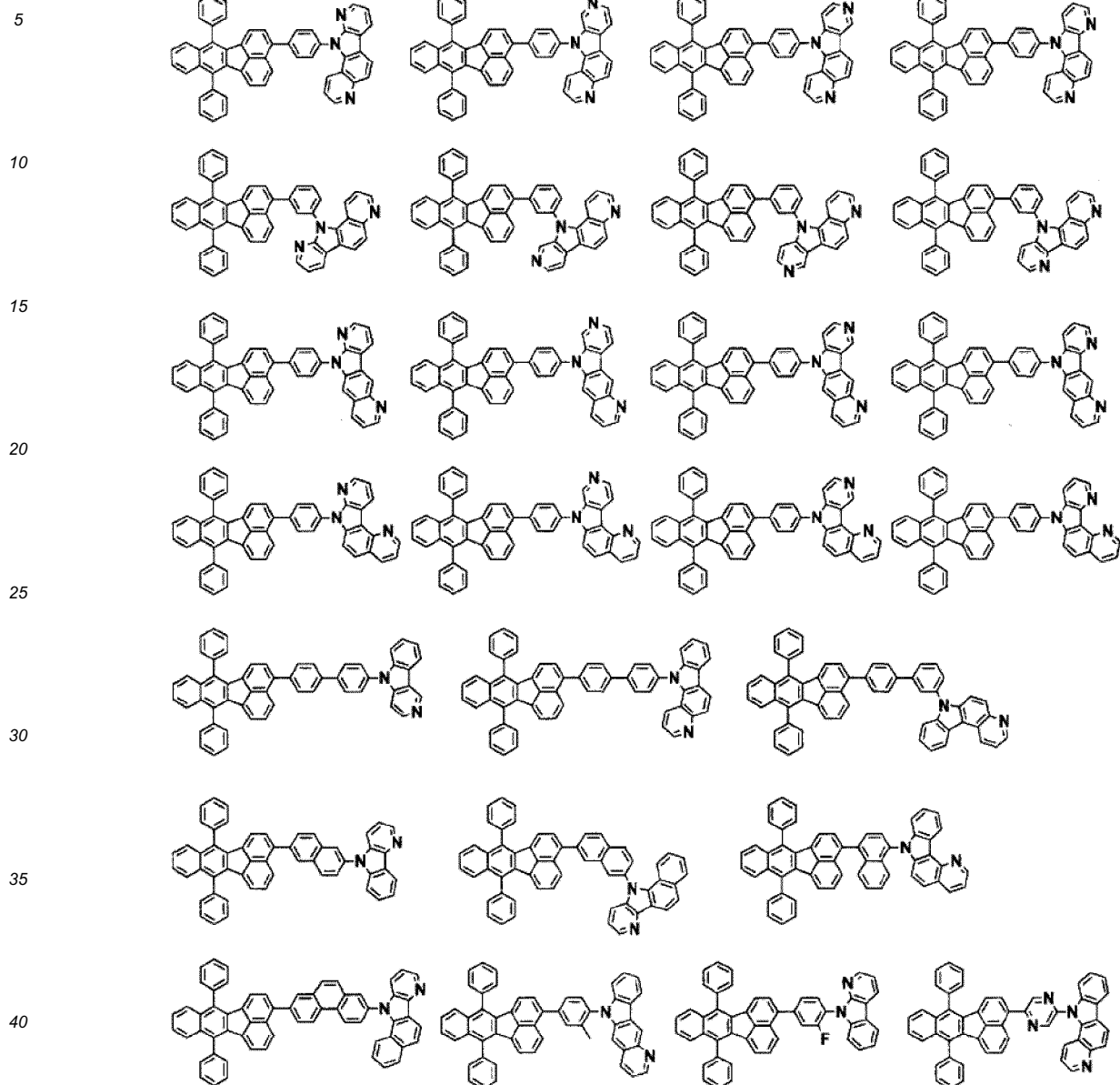


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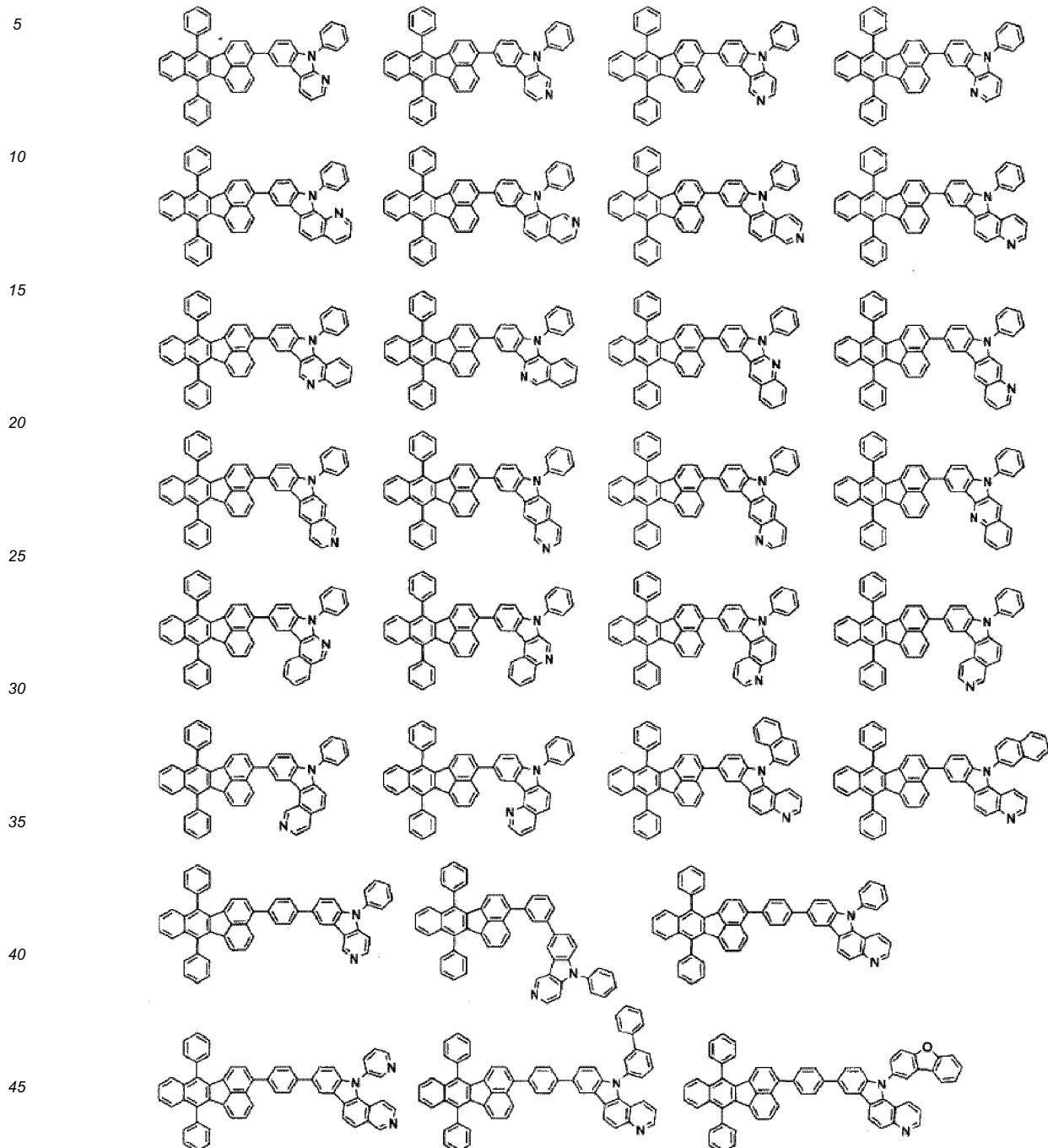
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[Chemical Formula 18]



[Chemical Formula 19]



[0053] A known method can be used for synthesis of the light-emitting device material of the present invention. Examples of the method for introducing Z into the benzofluoranthene skeleton include, but are not limited to, a method using a coupling reaction of a substituted or unsubstituted halogenated benzofluoranthene derivative and substituted or unsubstituted Z under a palladium catalyst or a nickel catalyst. When Z is introduced into the benzofluoranthene skeleton via an arylene group or a heteroarylene group, an arylboronic acid or heteroarylboronic acid substituted with Z may be used. A boronic acid ester may be used in place of the above-mentioned boronic acid.

[0054] The light-emitting device material of the present invention denotes a material to be used in any layer of a light-emitting device and also includes a material to be used in a protective film of a cathode, in addition to materials to be used in a hole transporting layer, an emissive layer and an electron transporting layer as described later. Use of the light-emitting device material of the present invention in any layer of a light-emitting device can afford high luminous

efficiency and also can afford a light-emitting device having a low driving voltage and high durability.

[0055] Next, embodiments of the light-emitting device of the present invention will be described in detail. The light-emitting device of the present invention has an anode and a cathode, and an organic layer interposed between the anode and the cathode, the organic layer includes at least an emissive layer and an electron transporting layer, and the emissive layer emits light by electric energy.

[0056] Examples of the laminated configuration of the organic layer include, besides a configuration made up of only emissive layer/electron transporting layer, laminated configurations such as 1) hole transporting layer/emissive layer/electron transporting layer, 2) hole transporting layer/emissive layer/electron transporting layer/electron injection layer, and 3) hole injection layer/hole transporting layer/emissive layer/electron transporting layer/electron injection layer. Each of the layers may be in the form of a single layer or a plurality of layers.

[0057] The light-emitting device material of the present invention may be used for any layer in the above-mentioned device configuration, but is preferably used for the emissive layer or electron transporting layer of the light-emitting device because it has high electron injection/transporting abilities, a high fluorescence quantum yield and high thin-film stability. Particularly, the light-emitting device material has excellent electron injection/transporting abilities, and is therefore preferably used for the electron transporting layer.

[0058] In the light-emitting device of the present invention, the anode and the cathode have a role for supplying a sufficient current for light emission of the device, and it is preferred that at least one of them is transparent or translucent in order to take out light. Usually, the anode formed on a substrate is made to be a transparent electrode.

[0059] While the material to be used for an anode is not particularly limited and may be electroconductive metal oxides, such as tin oxide, indium oxide, tin oxide indium (ITO), and zinc-oxide indium (IZO), metals, such as gold, silver, and chromium, inorganic electroconductive substances, such as copper iodide and copper sulfide, or electroconductive polymers, such as polythiophene, polypyrrole, and polyaniline as long as being a material that is capable of injecting holes into an organic layer efficiently and that is transparent or translucent in order to take out light, use of ITO glass or NESA glass is particularly preferable. These electrode materials may be used alone, or a plurality of materials may be used in lamination or in admixture. Since it is favorable that a sufficient current for light emission of the device can be supplied, the resistance of a transparent electrode is not limited, but from the viewpoint of the power consumption of the device, a low resistance is desirable. For example, an ITO substrate having a resistance of $300 \Omega/\square$ or lower functions as a device electrode, but since currently, it is possible to supply a substrate having a resistance of about $10 \Omega/\square$, it is particularly preferable to use a substrate having a low resistance of $20 \Omega/\square$ or lower. The thickness of ITO can be arbitrarily selected according to a resistance value, but ITO is usually used at a thickness of between 100 to 300 nm in many cases.

[0060] In addition, in order to retain the mechanical strength of the light-emitting device, it is preferred to form the light-emitting device on a substrate. As the substrate, a glass substrate such as soda glass or alkali-free glass is suitably used. Since it is favorable that the thickness of a glass substrate has a sufficient thickness for retaining the mechanical strength, a thickness of 0.5 mm or more is sufficient. Regarding the material of glass, since it is preferred that the amount of ions eluted from glass is small, alkali-free glass is more preferable. Alternatively, since soda lime glass provided with a barrier coating such as SiO_2 is commercially available, it can also be used. Further, as far as the first electrode stably functions, it is not necessary that the substrate is glass and, for example, the anode may be formed on a plastic substrate. Examples of a method of forming an ITO film include, but are not particularly limited to, an electron beam method, a sputtering method, and a chemical reaction method.

[0061] A material to be used in the cathode is not particularly limited, as far as it is a substance which can efficiently inject electrons into the emissive layer. Generally, metals such as platinum, gold, silver, copper, iron, tin, aluminum, and indium, or alloys or multilayer lamination of these metals with metals having a low work function such as lithium, sodium, potassium, calcium and magnesium are preferred. Among them, as a main component, aluminum, silver, and magnesium are preferred from the viewpoints of electric resistance value, easiness of making a film, stability of a film, and luminous efficiency. In particular, it is preferred that the material is constituted by magnesium and silver because electron injection into the electron transporting layer and the electron injection layer in the present invention becomes easier, and further low voltage driving becomes possible.

[0062] Further, preferable examples include lamination of metals such as platinum, gold, silver, copper, iron, tin, aluminum, and indium, or alloys using these metals, inorganic substances such as silica, titania, and silicon nitride, and organic polymer compounds such as polyvinyl alcohol, polyvinyl chloride, and a hydrocarbon-based polymer compound as a protective film layer on the cathode for protecting the cathode. The light-emitting device material of the present invention can also be used as the protective film layer. However, in the case of a device structure for taking out light from the cathode side (top emission structure), the protective film layer is selected from materials having light permeability in a visible light region. Examples of a method for preparation of these electrodes include, but are not particularly limited to, resistance heating, electron beam, sputtering, ion plating and coating.

[0063] The hole transporting layer is formed by a method in which one or more hole transporting materials are laminated or mixed, or a method using a mixture of a hole transporting material and a polymer binder. The hole transporting material

is required to efficiently transport holes from a positive electrode between electrodes given an electric field, and preferably has high hole injection efficiency and efficiently transports injected holes. For this purpose, the hole transporting material is required to be a substance having an appropriate ionization potential and, moreover, great hole mobility and, further, excellent stability, and generating impurities that become a trap with difficulty at the time of production and at the time of use. The substance satisfying the above-mentioned requirements is not particularly limited, and, for example, benzidine derivatives such as 4,4'-bis(N-(3-methylphenyl)-N-phenylamino)biphenyl (TPD), 4,4'-bis(N-(1-naphthyl)-N-phenylamino)biphenyl (NPD), 4,4'-bis(N,N-bis(4-biphenyl)amino)biphenyl (TBDB) and bis(N,N'-diphenyl-4-aminophenyl)-N,N'-diphenyl-4,4'-diamino-1,1'-biphenyl (TPD232); materials called starburst arylamines, such as 4,4',4''-tris(3-methylphenyl(phenyl)amino)triphenylamine (m-MTDATA) and 4,4',4''-tris(1-naphthyl(phenyl)amino)triphenylamine (1-TNATA); materials having a carbazole skeleton, particularly carbazole polymers, specifically derivatives of a carbazole dimer such as bis(N-arylcarbazole) or bis(N-alkylcarbazole), derivatives of a carbazole trimer and derivatives of a carbazole tetramer; triphenylene compounds; pyrazoline derivatives; stilbene-based compounds; hydrazone-based compounds; benzofuran derivatives; heterocyclic compounds such as thiophene derivatives, oxadiazole derivatives, phthalocyanine derivatives and porphyrin derivatives; fullerene derivatives; and such polymers as polycarbonates and styrene derivatives having the aforementioned monomers on their side chains, polythiophene, polyaniline, polyfluorene, polyvinylcarbazole and polysilane are preferred. Further, inorganic compounds such as p-type Si and p-type SiC can also be used.

[0064] The light-emitting device material of the present invention can also be used as a hole transporting material because it has great hole mobility and, further, excellent electrochemical stability. The light-emitting device material of the present invention may be used as a hole injection material, but is suitably used as a hole transporting material because it has high hole mobility.

[0065] The light-emitting device material of the present invention has excellent electron injection/transporting properties, and therefore when the light-emitting device material is used for the electron transporting layer, there is the possibility that electrons are not recombined in the emissive layer, and are partially leaked to the hole transporting layer. Therefore, it is preferred that a compound excellent in electron blocking property is used for the hole transporting layer. Particularly, a compound containing a carbazole skeleton is preferred because it is excellent in electron blocking property, and can contribute to an increase in efficiency of the light-emitting device. Further, it is preferred that the compound containing a carbazole skeleton contains a carbazole dimer, carbazole trimer or carbazole tetramer skeleton. This is because they have both a proper electron blocking property and proper hole injection/transporting properties.

[0066] Further, when the compound containing a carbazole skeleton is used for the hole transporting layer, it is more preferable that an emissive layer to be combined contains the later-described phosphorescence emitting material. This is because the compound having a carbazole skeleton has a high triplet exciton blocking function, so that luminous efficiency can be increased when the compound is combined with a phosphorescence emitting material. Use of a triphenylene skeleton-containing compound excellent in that it has high hole mobility is preferred because a carrier balance is improved, so that the effects of improving luminous efficiency and improving durable life can be obtained. It is further preferable that the compound containing a triphenylene skeleton has two or more diarylamino groups. The compound containing a carbazole skeleton and the compound containing a triphenylene skeleton may be each used alone as a hole transporting layer, or may be mixed and used. Other materials may be mixed as long as the effects of the present invention are not impaired. When the hole transporting layer includes a plurality of layers, any one layer should contain the compound containing a carbazole skeleton or the compound containing a triphenylene skeleton.

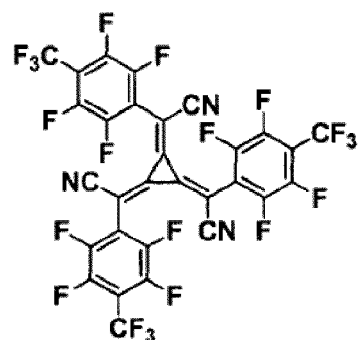
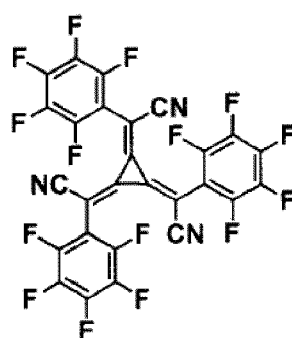
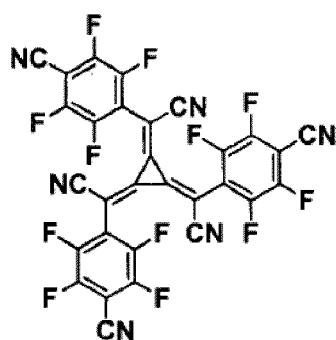
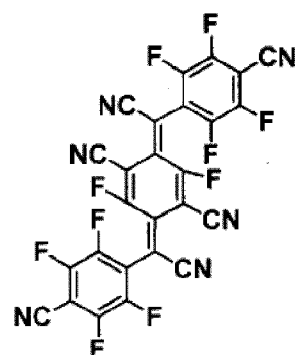
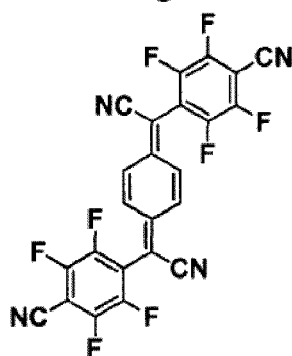
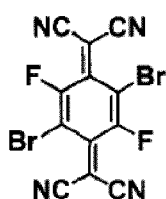
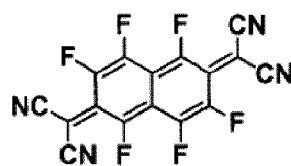
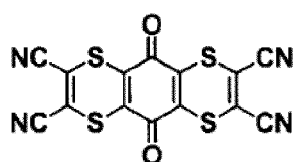
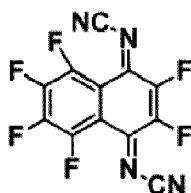
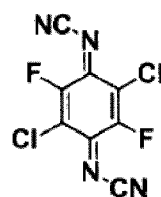
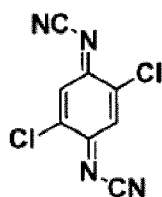
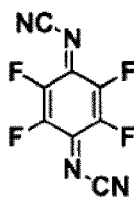
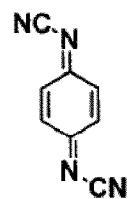
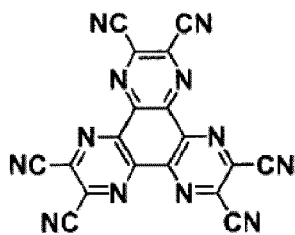
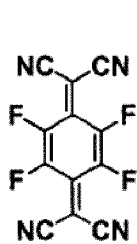
[0067] A hole injection layer may be provided between an anode and a hole transporting layer. When a hole injection layer is provided, the light-emitting device has a further reduced driving voltage, and durable life is further improved. A material having an ionization potential smaller than that of a material which is usually used for the hole transporting layer is used for the hole injection layer. Specific examples include benzidine derivatives such as TPD232, and starburst arylamine materials, and besides, phthalocyanine derivatives can also be used. It is preferred that the hole injection layer is formed of an acceptor compound alone, or used with another hole transporting material doped with an acceptor compound. Examples of the acceptor compound include metal chlorides such as iron(III) chloride, aluminum chloride, gallium chloride, indium chloride, and antimony chloride, metal oxides such as molybdenum oxide, vanadium oxide, tungsten oxide, and ruthenium oxide, and charge transfer complexes such as tris(4-bromophenyl)aminium hexachloroantimonate (TBPAAH). Moreover, organic compounds having a nitro group, a cyano group, halogen, or a trifluoromethyl group in the molecule, quinone-based compounds, acid anhydride-based compounds, and fullerene can also be used suitably.

[0068] Specific examples of such compounds include hexacyanobutadiene, hexacyanobenzene, tetracyanoethylene, tetracyanoquinodimethane (TCNQ), tetrafluorotetracyanoquinodimethane (F4-TCNQ), 2,3,6,7,10,11-hexacyano-1,4,5,8,9,12-hexaazatriphenylene (HAT-CN6), p-fluoranil, p-chloranil, p-bromanil, p-benzoquinone, 2,6-dichlorobenzoquinone, 2,5-dichlorobenzoquinone, tetramethylbenzoquinone, 1,2,4,5-tetracyanobenzene, o-dicyanobenzene, p-dicyanobenzene, 1,4-dicyanotetrafluorobenzene, 2,3-dichloro-5,6-dicyanobenzoquinone, p-dinitrobenzene, m-dinitrobenzene, o-dinitrobenzene, p-cyanonitrobenzene, m-cyanonitrobenzene, o-cyanonitrobenzene, 1,4-naphthoquinone, 2,3-dichloronaphthoquinone, 1-nitronaphthalene, 2-nitronaphthalene, 1,3-dinitronaphthalene, 1,5-dinitronaphthalene, 9-cy-

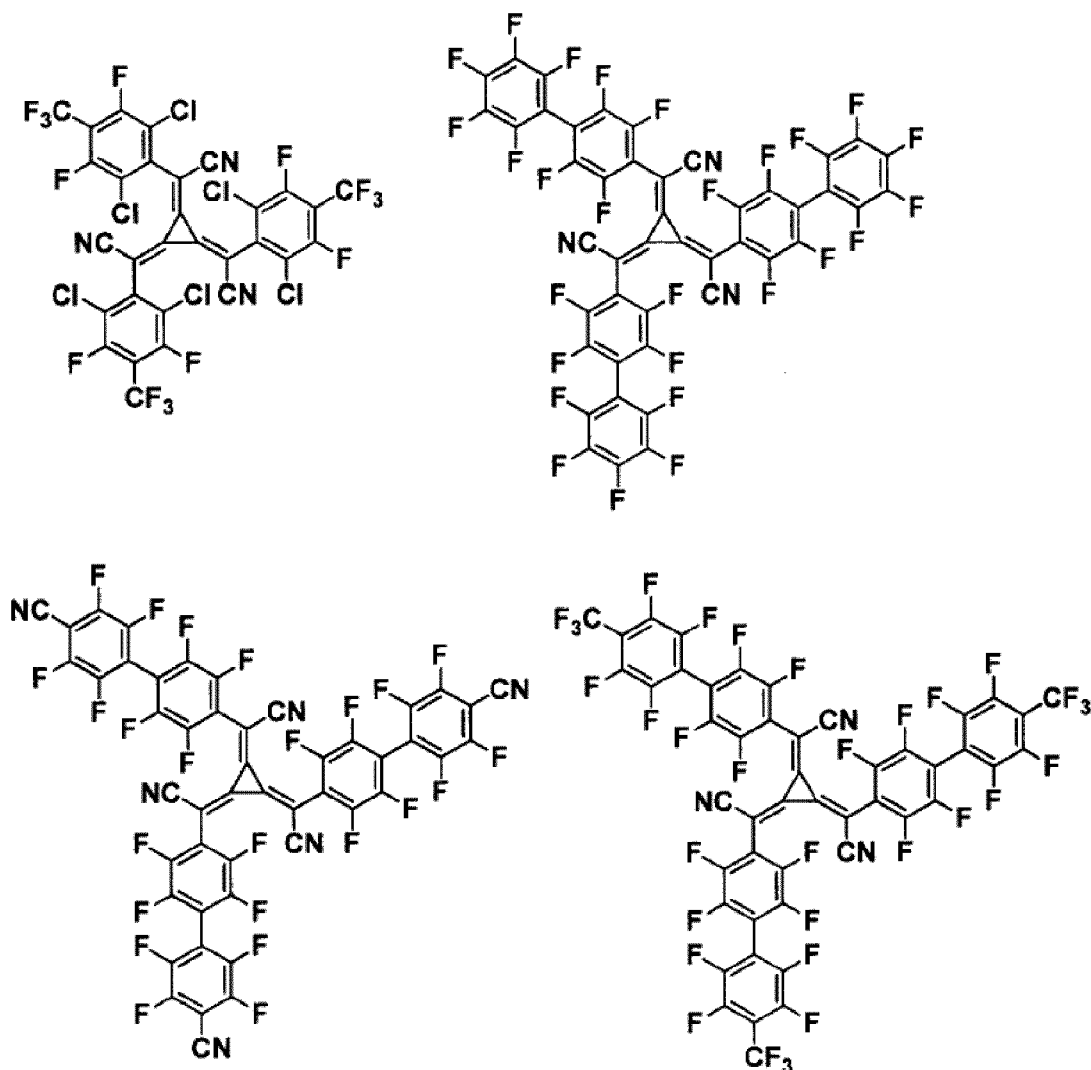
anoanthracene, 9-nitroanthracene, 9,10-anthraquinone, 1,3,6,8-tetranitrocarbazole, 2,4,7-trinitro-9-fluorenone, 2,3,5,6-tetracyanopyridine, maleic anhydride, phthalic anhydride, C60, and C70.

[0069] Of these, metal oxides and cyano group-containing compounds are preferred because they can be easily handled and deposited, and therefore the above-described effects can be obtained easily. Examples of the preferred metal oxide include molybdenum oxide, vanadium oxide and ruthenium oxide. Among cyano group-containing compounds, (a) a compound having in the molecule at least one electron-accepting nitrogen atom in addition to the nitrogen atom of the cyano group, (b) a compound having both halogen and a cyano group in the molecule, (c) a compound having both a carbonyl group and a cyano group in the molecule, or (d) a compound having in the molecule both halogen and a cyano group and further, at least one electron-accepting nitrogen atom in addition to the nitrogen atom of the cyano group is more preferable because it serves as a strong electron acceptor. Specific examples of the above-mentioned compound include the following compounds.

[Chemical Formula 20]



[Chemical Formula 21]



[0070] In either of the case where a hole injection layer is formed of an acceptor compound alone or the case where a hole injection layer is doped with an acceptor compound, the hole injection layer may be a single layer or may be a laminate of a plurality of layers. The hole injection material to be used in combination when the hole injection layer is doped with an acceptor compound is preferably the same compound as the compound to be used for the hole transporting layer because a barrier to injection of holes into the hole transporting layer can be mitigated.

[0071] The emissive layers may be in the form of a single layer or a plurality of layers, each of which is formed of an emissive material (host material, dopant material), and this may be a mixture of the host material and the dopant material, or the host material alone. That is, in the light-emitting device of the present invention, only the host material or the dopant material may emit light, or both of the host material and the dopant material emit light, in each emissive layer. From the viewpoints that electric energy is efficiently utilized and light emission at high color purity is obtained, it is preferred that the emissive layer includes a mixture of the host material and the dopant material. In addition, the host material and the dopant material may be one kind or a combination of a plurality of kinds, respectively. The dopant material may be contained in a whole host material, or may be partially contained therein. The dopant material may be laminated, or may be dispersed. The dopant material can control an emitted color. When the amount of the dopant material is too large, concentration quenching occurs, and therefore the dopant material is preferably used in an amount of 20% by weight or less, further preferably 10% by weight or less based on the host material. As a doping method, the dopant material can be co-deposited with the host material, or the dopant material may be mixed with the host material in advance to be deposited simultaneously.

[0072] Specific examples of the emissive material that can be used include, but are not particularly limited to, fused

ring derivatives such as anthracene and pyrene, metal chelated oxinoid compounds including tris(8-quinolinolato)aluminum, bisstyryl derivatives such as bisstyrylanthracene derivatives and distyrylbenzene derivatives, tetraphenylbutadiene derivatives, indene derivatives, coumarin derivatives, oxadiazole derivatives, pyrrolopyridine derivatives, perinone derivatives, cyclopentadiene derivatives, oxadiazole derivatives, thiadiazolopyridine derivatives, dibenzofuran derivatives, carbazole derivatives, and indolocarbazole derivatives and, as a polymer series, polyphenylenevinylene derivatives, polyparaphenylene derivatives, and polythiophene derivatives, which have hitherto been known as a light emitting body.

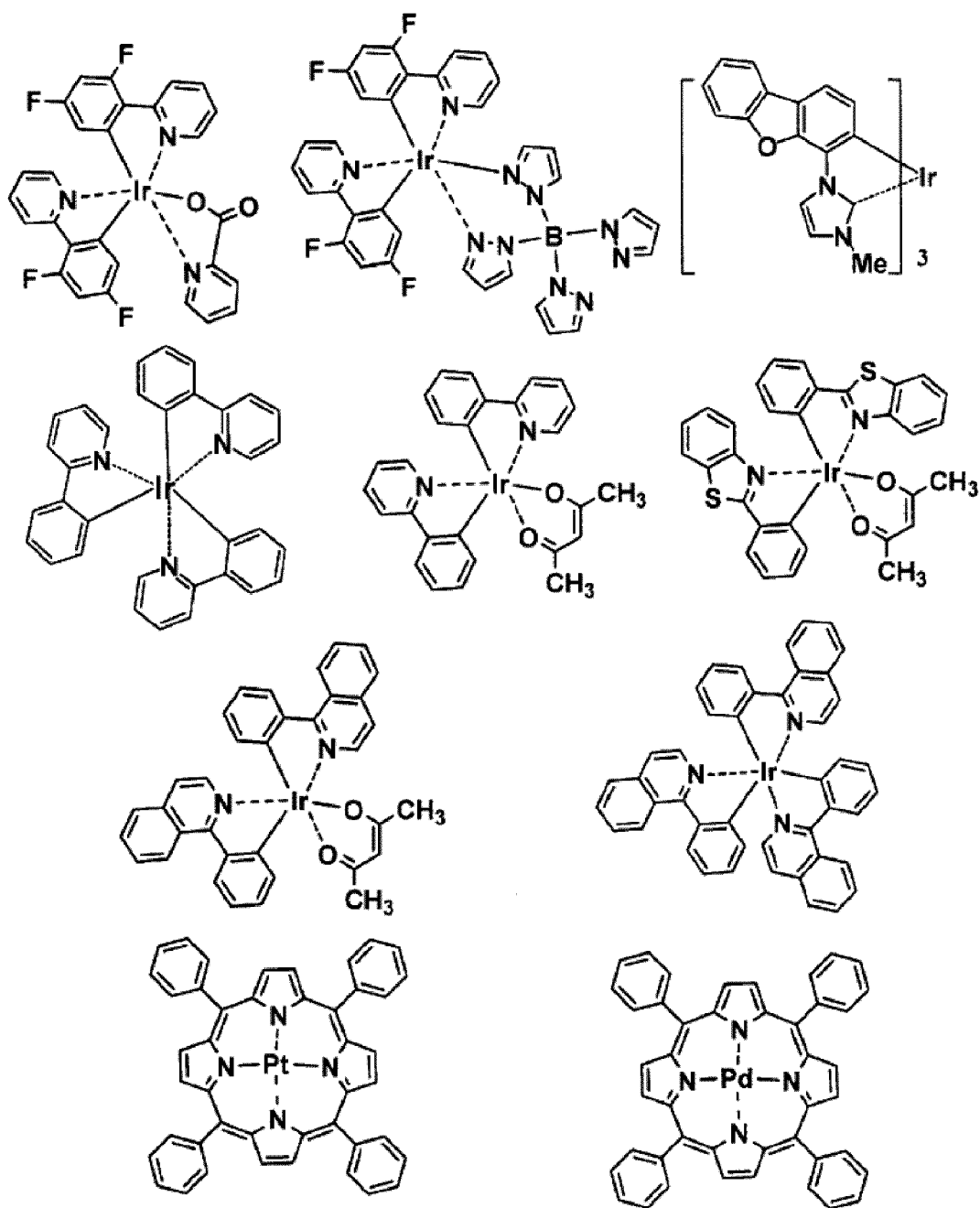
[0073] The host material contained in the emissive material is not particularly limited, and examples of the host material which can be used include, but are not particularly limited to, compounds having a fused aryl ring such as naphthalene, anthracene, phenanthrene, pyrene, chrysene, naphthacene, triphenylene, perylene, fluoranthene, fluorene and indene, and derivatives thereof, aromatic amine derivatives such as N,N'-dinaphthyl-N,N'-diphenyl-4,4'-diphenyl-1,1'-diamine, metal chelated oxinoid compounds including tris(8-quinolinato) aluminum (III), bisstyryl derivatives such as distyrylbenzene derivatives, tetraphenylbutadiene derivatives, indene derivatives, coumarin derivatives, oxadiazole derivatives, pyrrolopyridine derivatives, perinone derivatives, cyclopentadiene derivatives, pyrrolopyrrole derivatives, thiadiazolopyridine derivatives, dibenzofuran derivatives, carbazole derivatives, indolocarbazole derivatives and triazine derivatives and, as a polymer series, polyphenylenevinylene derivatives, polyparaphenylene derivatives, polyfluorene derivatives, polyvinylcarbazole derivatives, and polythiophene derivatives.

[0074] The dopant material is not particularly limited, and examples of the dopant material that can be used include compounds having a fused aryl ring, such as naphthalene, anthracene, phenanthrene, pyrene, chrysene, triphenylene, perylene, fluoranthene, fluorene and indene, and derivatives thereof (e.g., 2-(benzothiazol-2-yl)-9,10-diphenylanthracene and 5,6,11,12-tetraphenylnaphthacene); compounds having a heteroaryl ring, such as furan, pyrrole, thiophene, silole, 9-silafluorene, 9,9'-spirobisilafluorene, benzothiophene, benzofuran, indole, dibenzothiophene, dibenzofuran, imidazopyridine, phenanthroline, pyridine, pyrazine, naphthyridine, quinoxaline, pyrrolopyridine and thioxanthene, and derivatives thereof; borane derivatives; distyrylbenzene derivatives; aminostyryl derivatives such as 4,4'-bis(2-(4-diphenylaminophenyl)ethenyl)biphenyl and 4,4'-bis(N-(stilben-4-yl)-N-phenylamino)stilbene; aromatic acetylene derivatives; tetraphenylbutadiene derivatives; stilbene derivatives; aldazine derivatives; pyrromethene derivatives; diketopyrrolo[3,4-c]pyrrole derivatives; coumarin derivatives such as 2,3,5,6-1H,4H-tetrahydro-9-(2'-benzothiazolyl)quinolizino[9,9a,1-g]coumarin; azole derivatives such as imidazole, thiazole, thiadiazole, carbazole, oxazole, oxadiazole and triazole, and metal complexes thereof; and aromatic amine derivatives typified by N,N'-diphenyl-N,N'-di(3-methylphenyl)-4,4'-diphenyl-1,1'-diamine.

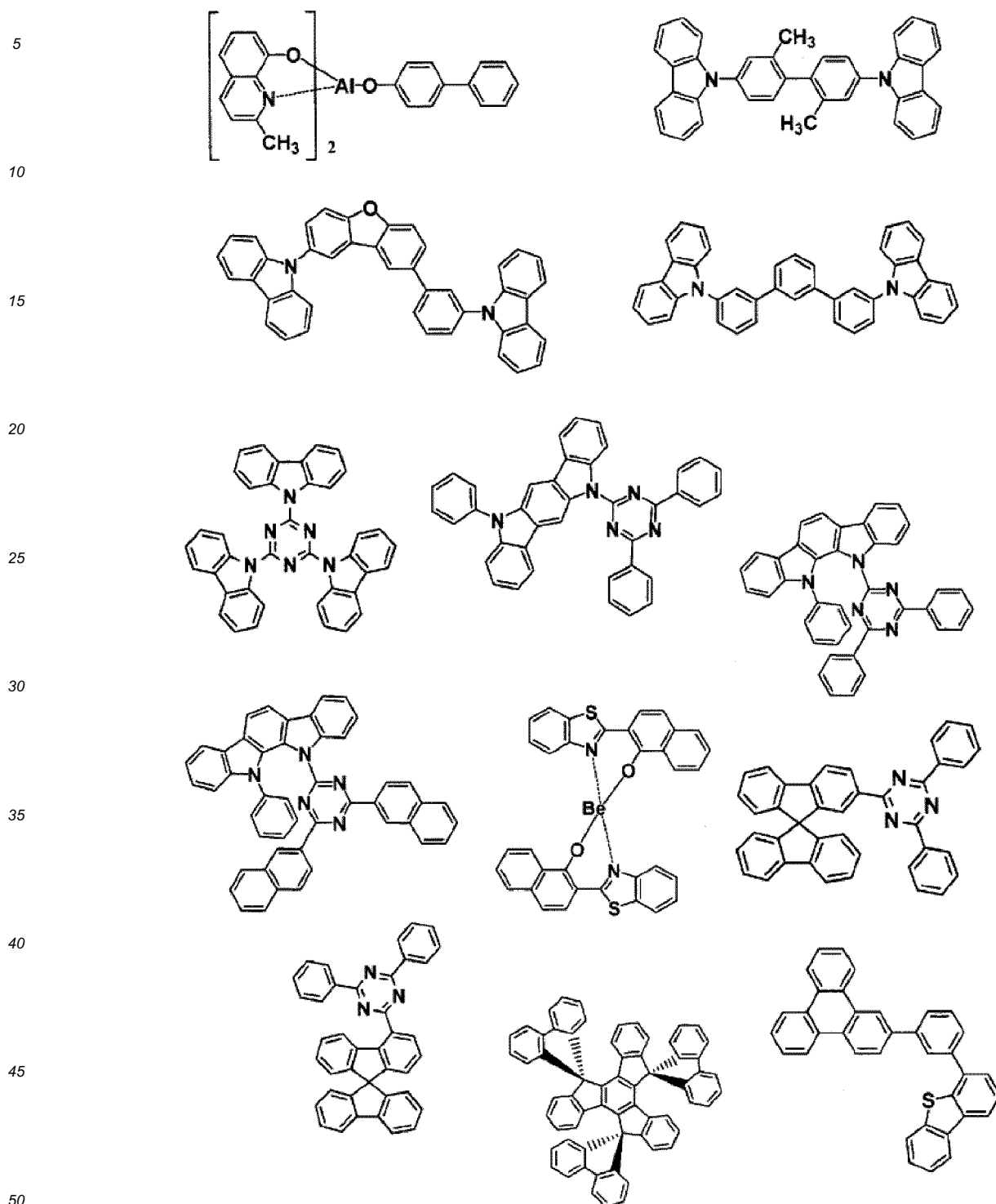
[0075] The emissive layer may contain a phosphorescence emitting material. The phosphorescence emitting material is a material that emits phosphorescence at room temperature. When a phosphorescence emitting material is used as a dopant, basically it is required to obtain phosphorescence emission at room temperature, and the phosphorescence emitting material is not particularly limited, and is preferably an organic metal complex compound containing at least one metal selected from the group consisting of iridium (Ir), ruthenium (Ru), rhodium (Rh), palladium (Pd), platinum (Pt), osmium (Os), and rhenium (Re). Among them, an organic metal complex having iridium or platinum is preferred because it has a high phosphorescence emission yield. As the host to be used in combination with a phosphorescence emitting dopant, aromatic hydrocarbon compound derivatives such as indole derivatives, carbazole derivatives, indolocarbazole derivatives, nitrogen-containing aromatic compound derivatives having a pyridine, pyrimidine or triazine skeleton, polystyrylbenzene derivatives, spirofluorene derivatives, truxene derivatives and triphenylene derivatives; compounds containing a chalcogen element, such as dibenzofuran derivatives and dibenzothiophene derivatives; organic metal complexes such as beryllium quinolinol complexes; and the like are suitably used, but the host is not limited thereto as long as basically it has higher triplet energy than a dopant used, and electrons and holes are smoothly injected and transported from the respective transporting layers. Two or more triplet emissive dopants may be contained, and two or more host materials may be contained. Further, one or more triplet emissive dopants and one or more fluorescence emitting dopants may be contained.

[0076] The preferable phosphorescence emitting host or dopant is not particularly limited, and specific examples thereof include the following.

[Chemical Formula 22]



[Chemical Formula 23]



[0077] The light-emitting device material of the present invention can also be used as an emissive material because it has high light emitting performance. The light-emitting device material of the present invention can be suitably used as a blue light emitting material because it shows intensive luminescence in an ultraviolet to blue region (300 to 500 nm region). The light-emitting device material of the present invention may be used as a host material, but is suitably used as a dopant material because it has a high fluorescence quantum yield.

[0078] In the present invention, the electron transporting layer is a layer in which electrons are injected from the cathode and, further, which transports the electrons. It is desired that the electron transporting layer has a high electron injection

efficiency, and efficiently transports injected electrons. For this reason, it is preferred that the electron transporting layer is formed of a substance having great electron affinity and, moreover, great electron mobility and, further, excellent stability, and generating impurities that become a trap with difficulty at the time of production and at the time of use. However, when transportation balance between holes and electrons is considered, if the electron transporting layer mainly plays a role of being able to inhibiting holes from the anode from flowing to the cathode side without recombination, even when the layer is constituted by a material having not so high electron transporting ability, the effect of improving luminous efficiency becomes equivalent to that when the layer is constituted by a material having a high electron transporting ability. Therefore, the electron transporting layer in the present invention also includes a hole inhibition layer which can efficiently inhibit the transfer of holes as the same meaning.

[0079] Examples of the electron transporting material to be used for the electron transporting layer include fused polycyclic aromatic derivatives, such as naphthalene and anthracene, styryl-based aromatic derivatives typified by 4,4'-bis(diphenylethenyl)biphenyl, quinone derivatives, such as anthraquinone and diphenylquinone, phosphorus oxide derivatives, and various types of metal complexes, such as quinolinol complexes, e.g., tris(8-quinolinolato)aluminum(III), benzoquinolinol complexes, hydroxyazole complexes, azomethine complexes, tropolone metal complexes, and flavonol metal complexes. It is preferred to use a compound that includes an element selected from carbon, hydrogen, nitrogen, oxygen, silicon and phosphorus, and has a heteroaryl ring structure containing electron-accepting nitrogen because it can reduce a driving voltage and a highly efficient light emission can be obtained.

[0080] An aromatic heterocyclic ring containing electron-accepting nitrogen has high electron affinity. An electron transporting material having electron-accepting nitrogen makes easier acceptance of electrons from a cathode having higher electron affinity, and lower voltage driving becomes possible. In addition, since supply of electrons to an emissive layer is increased and a recombining probability is increased, luminous efficiency is further increased.

[0081] Examples of the heteroaryl ring containing electron-accepting nitrogen include a pyridine ring, a pyrazine ring, a pyrimidine ring, a quinoline ring, a quinoxaline ring, a naphthyridine ring, a pyrimidopyrimidine ring, a benzoquinoline ring, a phenanthroline ring, an imidazole ring, an oxazole ring, an oxadiazole ring, a triazole ring, a thiazole ring, a thiadiazole ring, a benzoxazole ring, a benzothiazole ring, a benzimidazole ring, and a phenanthroimidazole ring.

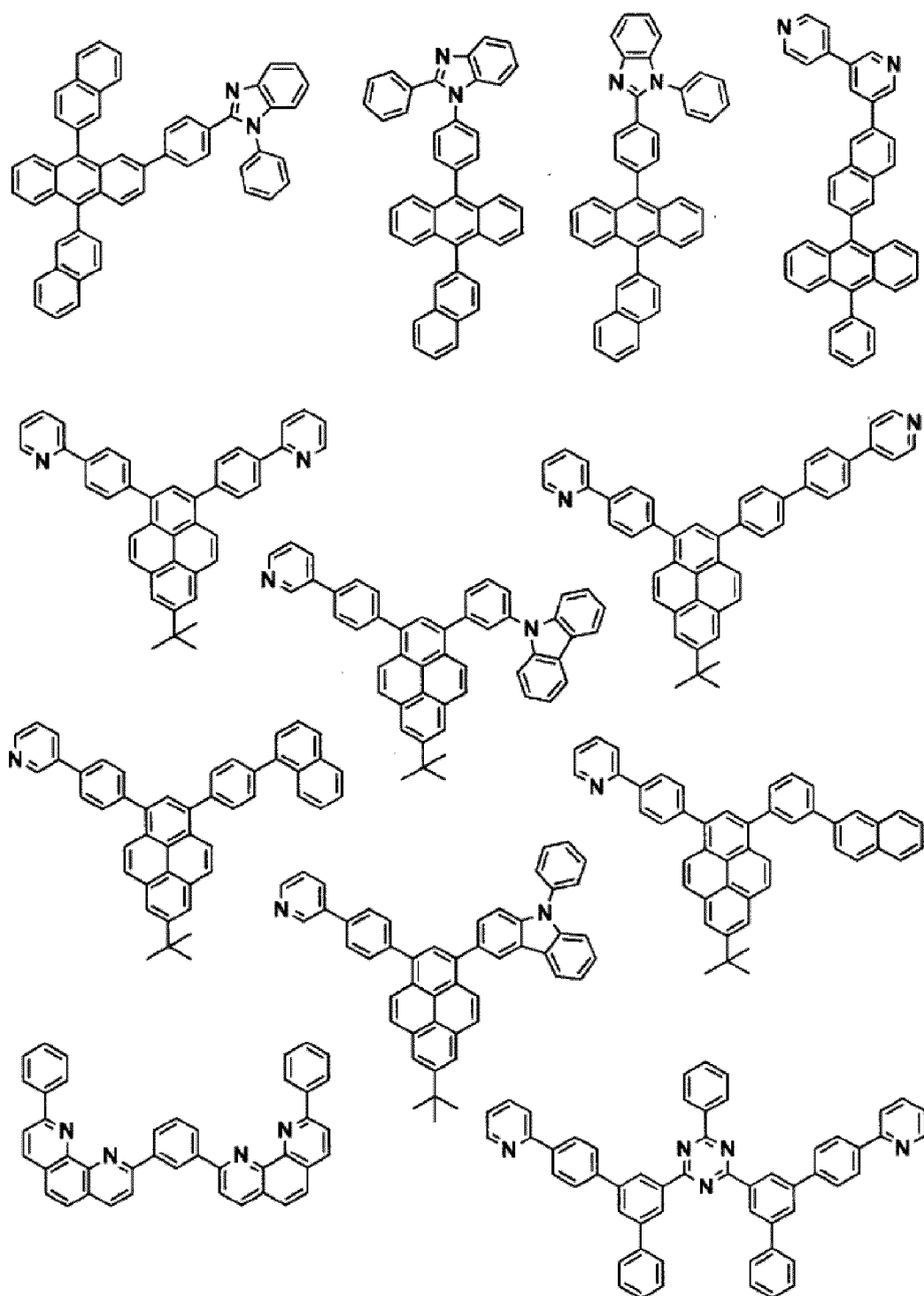
[0082] Examples of preferred compounds having such a heteroaryl ring structure include benzimidazole derivatives, benzoxazole derivatives, benzothiazole derivatives, oxadiazole derivatives, thiadiazole derivatives, triazole derivatives, pyrazine derivatives, phenanthroline derivatives, quinoxaline derivatives, quinoline derivatives, benzoquinoline derivatives, oligopyridine derivatives such as bipyridine and terpyridine, quinoxaline derivatives and naphthyridine derivatives.

[0083] Among them, imidazole derivatives such as tris(N-phenylbenzimidazol-2-yl)benzene; oxadiazole derivatives such as 1,3-bis[(4-tert-butylphenyl)1,3,4-oxadiazolyl]phenylene; triazole derivatives such as N-naphthyl-2,5-diphenyl-1,3,4-triazole; phenanthroline derivatives such as bathocuproine and 1,3-bis(1,10-phenanthrolin-9-yl)benzene; benzoquinoline derivatives such as 2,2'-bis(benzo[h]quinolin-2-yl)-9,9'-spirobifluorene; bipyridine derivatives such as 2,5-bis(6'-(2',2''-bipyridyl))-1,1-dimethyl-3,4-diphenylsilole; terpyridine derivatives such as 1,3-bis(4'-(2,2':6'2''-terpyridinyl))benzene; and naphthyridine derivatives such as bis(1-naphthyl)-4-(1,8-naphthyridin-2-yl)phenylphosphine oxide are suitably used in view of an electron transporting ability.

[0084] It is more preferable that such a derivative has a fused polycyclic aromatic skeleton because if so, then the glass transition temperature will increase and an effect of reducing the voltage of a light-emitting device is great due to increased electron mobility. Moreover, considering the further improvement in durable life of a device, the easiness of synthesis, and easy availability of raw materials, it is particularly preferable that the fused polycyclic aromatic skeleton is an anthracene skeleton, a pyrene skeleton, or a phenanthroline skeleton. While the electron transporting material may be used alone, two or more kinds of the electron transporting materials may be used in combination, or one or more kinds of other electron transporting materials may be used in a combination with the electron transporting material.

[0085] Preferable electron transporting materials are not particularly limited, and specific examples thereof include the following.

[Chemical Formula 24]



[0086] Besides these electron transporting materials, those disclosed in WO 2004/63159, WO 2003/60956, Appl. Phys. Lett. 74, 865 (1999), Org. Electron. 4, 113 (2003), WO 2010/113743 and WO 2010/1817 can be used.

[0087] The light-emitting device material of the present invention can also be used as an electron transporting material because it has high electron injection/transporting abilities.

[0088] When the light-emitting device material of the present invention is used, it need not be restricted to each one type, and a plurality of benzofluoranthene compounds according to the present invention may be used in admixture, or one or more of other electron transporting materials may be used in admixture with the benzofluoranthene compound

according to the present invention as long as the effects of the present invention are not impaired. The electron transporting material that can be mixed is not particularly limited, and examples thereof include compounds having a fused aryl ring, such as naphthalene, anthracene and pyrene, and derivatives thereof, styryl-based aromatic ring derivatives typified by 4,4'-bis(diphenylethenyl)biphenyl, perylene derivatives, perinone derivatives, coumarin derivatives, naphthalimide derivatives, quinone derivatives such as anthraquinone and diphenylquinone, phosphorus oxide derivatives, carbazole derivatives and indole derivatives, quinolinol complexes such as tris(8-quinolinolato)aluminum(III), hydroxyazole complexes such as hydroxyphenyloxazole complexes, azomethine complexes, tropolone metal complexes, and flavonol metal complexes.

[0089] While the electron transporting material may be used alone, two or more kinds of the electron transporting materials may be used in combination, or one or more kinds of other electron transporting materials may be used in combination with the electron transporting material. Moreover, a donor material may be contained. The donor material denotes a compound which makes easier electron injection into the electron transporting layer from the cathode or the electron injection layer and, moreover, further improves the electric conductivity of the electron transporting layer, by improving an electron injection barrier.

[0090] Preferable examples of the donor material in the present invention include an alkali metal, an inorganic salt containing an alkali metal, a complex of an alkali metal and an organic substance, an alkaline earth metal, an inorganic salt containing an alkaline earth metal, or a complex of an alkaline earth metal and an organic substance. Examples of the preferable kind of the alkali metal and the alkaline earth metal include alkali metals such as lithium, sodium and cesium, and alkaline earth metals such as magnesium and calcium which have a low work function and have a great effect of improving electron transporting ability.

[0091] In addition, since deposition in vacuum is easy and handling is excellent, the donor compound is preferably in the state of an inorganic salt or a complex with an organic substance rather than a metal single substance. Moreover, from the viewpoints of improvement in easiness in handling in the atmospheric air and easiness in control of the concentration to be added, the donor compound is more preferably in the state of a complex with an organic substance. Examples of the inorganic salt include oxides such as LiO and Li₂O, nitrides, fluorides such as LiF, NaF and KF, and carbonates such as Li₂CO₃, Na₂CO₃, K₂CO₃, Rb₂CO₃ and Cs₂CO₃. Preferable examples of the alkali metal or alkaline earth metal include lithium from the viewpoints of an inexpensive raw material and ease of synthesis. In addition, preferable examples of the organic substance in complexes with an organic substance include quinolinol, benzoquinolinol, flavonol, hydroxyimidazopyridine, hydroxybenzazole, and hydroxytriazole. Particularly, a complex of an alkali metal and an organic substance is preferred, a complex of lithium and an organic substance is more preferred, and lithium quinolinol is especially preferred. Two or more of these donor materials may be used in admixture.

[0092] The preferred doping concentration varies depending on a material and a film thickness of the doping region, but for example when the donor material is an inorganic material such as an alkali metal or an alkaline earth metal, it is preferred that an electron transporting layer is formed by performing co-deposition so that the deposition rate ratio of an electron transporting material and a donor compound is within the range of 10000 : 1 to 2 : 1. The deposition rate ratio is more preferably 100 : 1 to 5 : 1, further preferably 100 : 1 to 10 : 1. When the donor material is a complex of a metal and an organic substance, it is preferred that an electron transporting layer is formed by performing co-deposition so that the deposition rate ratio of an electron transporting material and the donor material is within the range of 100 : 1 to 1 : 100. The deposition rate ratio is more preferably 10 : 1 to 1 : 10, further preferably 7 : 3 to 3 : 7.

[0093] An electron transporting layer with the light-emitting device material doped with a donor material as described above may be used as a charge generation layer in a tandem structure type device in which a plurality of light-emitting devices are coupled.

[0094] The method in which an electron transporting layer is doped with a donor material to improve an electron transporting ability exhibits an effect particularly when the film thickness of a thin-film layer is large. The method is particularly preferably used when the total film thickness of the electron transporting layer and the emissive layer is 50 nm or more. For example, there is a method in which an interference effect is used for improving luminous efficiency, and the method is intended to improve light extraction efficiency by matching the phases of light emitted directly from an emissive layer and light reflected at a cathode. The optimum conditions thereof vary depending on a light emitting wavelength, and the total film thickness of the electron transporting layer and the emissive layer becomes 50 nm or more, and may become a large film thickness close to 100 nm in the case of emission of light having a long wavelength, such as red light.

[0095] The film thickness of the electron transporting layer, which is doped, may be a part or the whole of the electron transporting layer. When a part of the electron transporting layer is doped, it is desirable to provide a doped-region at least at an electron transporting layer/cathode interface, and the effect of reducing a voltage is obtained by merely doping the vicinity of the cathode interface. On the other hand, when the donor material is in direct contact with the emissive layer, an adverse effect of reducing luminous efficiency may be caused, and in this case, it is preferred to provide a non-doped-region at an emissive layer/electron transporting layer interface.

[0096] In the present invention, an electron injection layer may be provided between a cathode and an electron

transporting layer. Generally, the electron injection layer is inserted for the purpose of injection of electrons from the cathode into the electron transporting layer, and when the electron injection layer is inserted, a compound having a heteroaryl ring structure containing electron-accepting nitrogen may be used, or a layer containing the above-mentioned donor material may be used. The light-emitting device material of the present invention may be contained in the electron injection layer. An inorganic substance such as an insulator or a semiconductor can also be used for the electron injection layer. Use of such a material is preferred because a short-circuit of the light-emitting device can be effectively prevented, and electron injection property can be improved. It is preferred that at least one metal compound selected from the group consisting of an alkali metal chalcogenide, an alkaline earth metal chalcogenide, a halide of an alkali metal and a halide of an alkaline earth metal is used as the insulator. It is preferred that the electron injection layer is formed of the above-mentioned alkali metal chalcogenide and the like because electron injection property can be further improved.

[0097] Specifically, examples of the preferable alkali metal chalcogenide include Li_2O , Na_2S and Na_2Se , and examples of the preferable alkaline earth metal chalcogenide include CaO , BaO , SrO , BeO , BaS and CaSe . Examples of the preferable halide of an alkali metal include LiF , NaF , KF , LiCl , KCl and NaCl . Examples of the preferable halide of an alkaline earth metal include fluorides such as CaF_2 , BaF_2 , SrF_2 , MgF_2 and BeF_2 , and halides other than fluorides. Further, a complex of an organic substance and a metal is suitably used. Use of a complex of an organic substance and a metal for the electron injection layer is preferred because the film thickness is easily adjusted. As examples of the above-mentioned organic metal complex, preferable examples of the organic substance in complexes with an organic substance include quinolinol, benzoquinolinol, pyridylphenol, flavonol, hydroxyimidazopyridine, hydroxybenzazole, and hydroxytriazole. Particularly, a complex of an alkali metal and an organic substance is preferred, a complex of lithium and an organic substance is more preferred, and lithium quinolinol is especially preferred.

[0098] Examples of a method of forming each of the aforementioned layers constituting the light-emitting device include, but are not particularly limited to, resistance heating deposition, electron beam deposition, sputtering, a molecular lamination method, and a coating method, but usually, resistance heating deposition or electron beam deposition is preferable from the viewpoint of device property.

[0099] The thickness of the organic layer depends on the resistance value of an emissive substance and, therefore, it cannot be limited, but it is preferably 1 to 1000 nm. The film thickness of each of the emissive layer, the electron transporting layer and the hole transporting layer is preferably 1 nm or more and 200 nm or less, more preferably 5 nm or more and 100 nm or less.

[0100] The light-emitting device of the present invention has a function of being able to convert electric energy into light. Herein, a direct current is mainly used as the electric energy, but a pulse current or an alternate current can also be used. A current value and a voltage value are not particularly limited, but when the power consumed and life of the device are considered, they should be selected so that the maximum luminance is obtained by energy as low as possible.

[0101] The light-emitting device of the present invention is used suitably as a display that displays in a matrix and/or segment system.

[0102] In the matrix system, pixels for display are arranged two-dimensionally such as lattice-like arrangement or mosaic-like arrangement, and the collection of pixels displays letters and images. The shape and size of the pixel are determined depending on utility. For example, for displaying images and letters on personal computers, monitors and televisions, a square pixel being 300 μm or less at each side is usually used and, in the case of a large display such as a display panel, a pixel being millimeter order at each side is used. In the case of a monochromatic display, pixels having the same color may be arranged, and in the case of a color display, pixels having red, green and blue colors are arranged to perform display. In this case, typically, there are a delta type and a stripe type. A method of driving this matrix may be either a passive matrix driving method or an active matrix. The passive matrix driving has a simple structure, but when operation property is considered, the active matrix is more excellent in some cases, and it is necessary to use them properly depending on utility.

[0103] The segment system in the present invention is a system by which a pattern is formed so as to display predetermined information, and a region determined by arrangement of this pattern is made to emit light. Examples thereof include time and temperature displays in digital watches and thermometers, operating-state displays in audio equipment, IH cookers and so on, and panel displays of automobiles. The above-mentioned matrix display and segment display may exist together in the same panel.

[0104] The light-emitting device of the present invention can also be preferably used as backlight of various instruments. Backlight is used mainly for the purpose of improving the visibility of display apparatuses which do not emit light by themselves, and is used in liquid crystal display equipment, clocks, audio equipment, automobile panels, display panels, signs, and the like. In particular, the light-emitting device of the present invention is preferably used in backlight for liquid crystal display apparatuses, inter alia, for personal computers which are studied to be thinned, and can provide backlight thinner and lighter than conventional products.

EXAMPLES

[0105] The present invention will be described by way of Examples, but the present invention is not limited thereto.

5 Synthesis Example 1

Synthesis of Compound [1]

[0106] Mixed were 14.0 g of acenaphthylene, 25.0 g of diphenylisobenzofuran and 200 ml of o-xylene, and the mixture was heated and refluxed under a nitrogen flow. After 2 hours, the mixture was cooled to room temperature, the solvent was then distilled off, and 300 mL of ether was added. The resultant precipitate was filtered, and vacuum-dried to obtain 27.7 g of an intermediate A (yield: 71%).

[0107] Next, 27.7 g of the intermediate A and 200 mL of acetic acid were mixed, 20 mL of 48% aqueous hydrobromic acid was added, and the mixture was heated and refluxed. After 3 hours, the reaction mixture was cooled to room temperature, then filtered, and washed with water and methanol. The resultant solid was vacuum-dried to obtain 25.8 g of an intermediate B (yield: 96%).

[0108] Next, 25.8 g of the intermediate B, 11.3 g of N-bromosuccinimide and 318 mL of chloroform were mixed, and the mixture was heated and refluxed. After 1 hour, 3.4 g of N-bromosuccinimide was added, and the mixture was further heated and refluxed. After 2 hours, the mixture was cooled to room temperature, and the chloroform solution was then washed with water and an aqueous sodium thiosulfate solution. The organic layer was dried over magnesium sulfate, 3 g of activated carbon was added, the resultant was then filtered, and the solvent was distilled off. The resultant solid was re-crystallized with 800 mL of butyl acetate, filtered, and then vacuum-dried to obtain 26.9 g of an intermediate C (yield: 87%).

[0109] Next, 9.0 g of the intermediate C, 3.2 g of p-chlorophenylboronic acid, 93 mL of dimethoxy ethane and 27 ml of a 1.5 M aqueous sodium carbonate solution were mixed, and purged with nitrogen. To this mixed solution was added 130 mg of bis(triphenylphosphine)palladium dichloride, and the mixture was heated and refluxed. After 3 hours, the mixture was cooled to room temperature, 93 ml of water was then added, and the precipitate was filtered, and dried by a vacuum drier. The product filtered was purified by silica gel column chromatography, and the eluate was evaporated. To the resultant solid was added methanol, and the precipitate was filtered, and then vacuum-dried to obtain 8.4 g of an intermediate D (yield: 87%).

[0110] Next, 10.4 g of 5-aminoquinoline, 21.6 g of 2-bromoiodobenzene, 9.3 g of sodium-t-butoxide and 174 mL of toluene were mixed, and the mixture was purged with nitrogen. To this mixed solution were added 0.80 g of bis(dibenzylideneacetone)palladium (0) and 0.77 g of bis(diphenylphosphine)ferrocene, and the mixture was heated and refluxed. After 3 hours, the mixture was cooled to room temperature, and then filtered with celite, and the solvent of the filtrate was distilled off. The resultant was purified by silica gel column chromatography, the eluate was evaporated, and vacuum-drying was performed to obtain 19.4 g of an intermediate E (yield: 93%).

[0111] Next, 19.4 g of the intermediate E, 9.6 g of potassium acetate and 82 mL of dimethylformamide were mixed, and the mixture was purged with nitrogen. To this mixed solution were added 0.29 g of palladium acetate and 0.85 g of triphenylphosphine, and the mixture was heated and refluxed. After 3 hours, the mixture was cooled to room temperature, and 300 mL of water was then added. An aqueous potassium hydroxide solution was added until the mixture became basic, and the precipitate was filtered, and dried by a vacuum drier. The resultant solid was re-crystallized with butyl acetate, filtered, and then vacuum-dried to obtain 11.0 g of an intermediate F (yield: 77%).

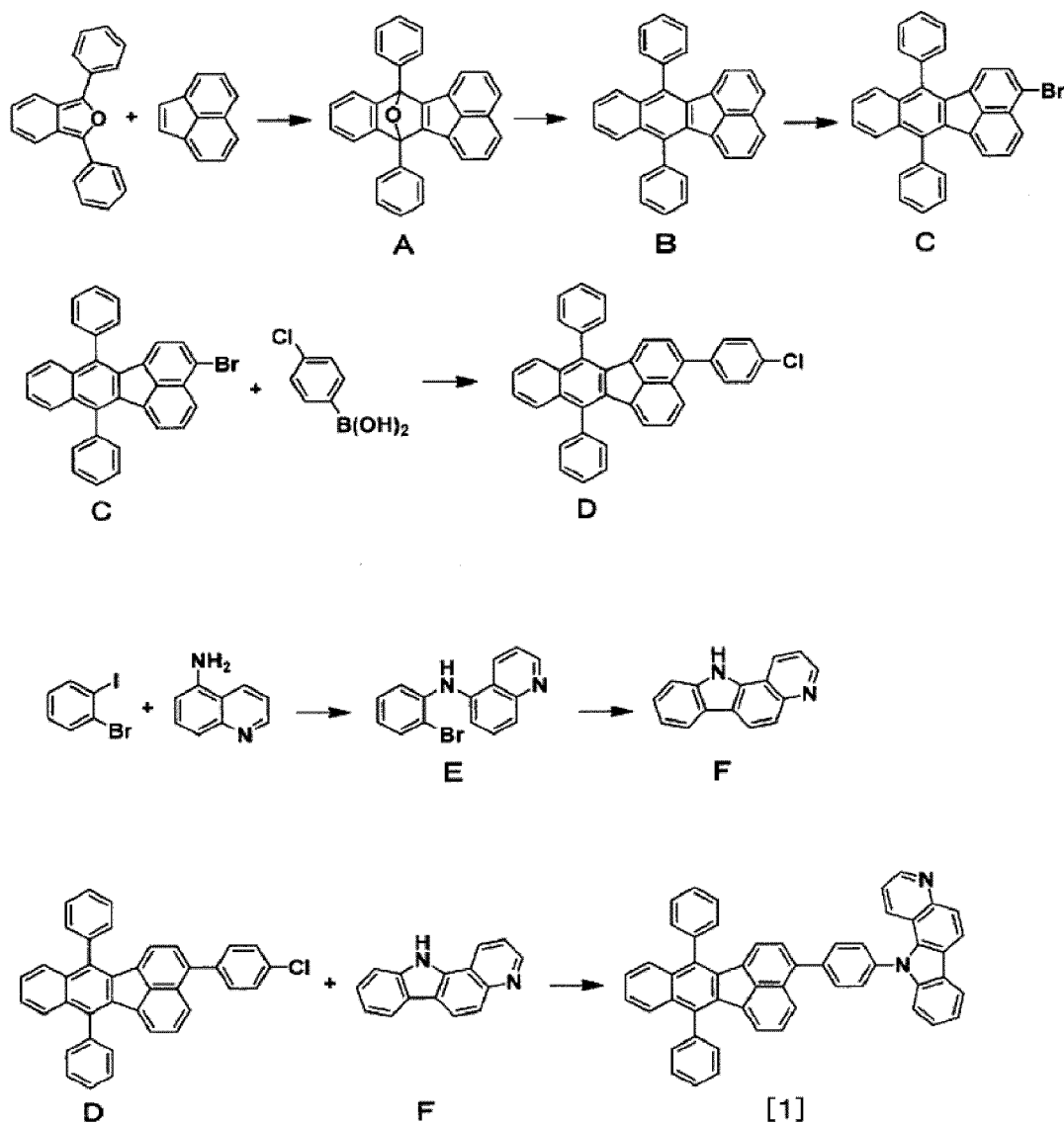
[0112] Next, 5.4 g of the intermediate D, 2.5 g of the intermediate F, 1.4 g of sodium-t-butoxide and 53 mL of o-xylene were mixed, and the mixture was purged with nitrogen. To this mixed solution were added 60 mg of bis(dibenzylideneacetone)palladium (0) and 100 mg of XPhos, and the mixture was heated and refluxed. After 2 hours, the mixture was cooled to room temperature, and then filtered with celite, and the solvent of the filtrate was distilled off. The resultant was dissolved by adding 150 mL of pyridine, activated carbon and QuadraSil (registered trademark) were then added, and the mixture was filtered with a silica pad. The solvent of the filtrate was distilled off, the resultant was then purified by silica gel column chromatography, and the eluate was evaporated. The resultant solid was re-crystallized with 120 mL of o-xylene, filtered, and then vacuum-dried to obtain 4.74 g of a yellow solid of a compound [1] (yield: 64%).

[0113] ¹H-NMR analytical results of the resulting yellow solid are as follows, and it was confirmed that the resulting yellow solid was the compound [1].

Compound [1]: ¹H-NMR (CDCl₃(d=ppm)) δ 6.75(t,2H), 7.22(dd,1H), 7.34-7.54(m,7H), 7.61-7.78(m,15H), 7.83-7.99(m,4H), 8.06(d,1H), 8.27(dd,1H), 8.51(d,1H), 8.89(dd,1H).

[0114] The compound [1] was used as a light-emitting device material after sublimation purification was performed at about 340°C under a pressure of 1×10^{-3} Pa using an oil diffusion pump. The HPLC purity (area % at a measurement wavelength of 254 nm) was 99.9% before sublimation purification, and 99.9% after sublimation purification.

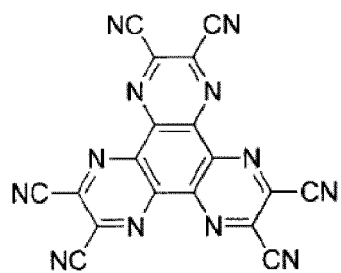
[Chemical Formula 25]



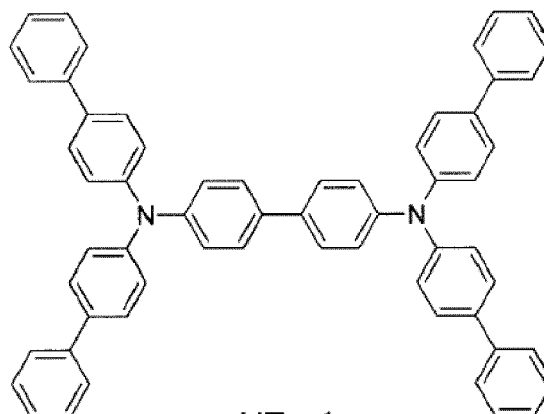
Example 1

[0115] A glass substrate with an ITO transparent electroconductive film deposited thereon in a thickness of 165 nm (manufactured by GEOMATEC Co., Ltd., $11 \Omega/\square$, sputtered product) was cut into 38 x 46 mm, and etched. The resulting substrate was ultrasonically washed with "SEMICOCLEAN 56" (trade name, manufactured by Furuuchi Chemical Corporation) for 15 minutes, and then washed with ultrapure water. This substrate was treated with UV-ozone for 1 hour immediately before preparation of a device, and placed in a vacuum deposition apparatus, and the air was evacuated until the degree of vacuum in the apparatus was 5×10^{-4} Pa or lower. By a resistance heating method, first, HAT-CN6 was deposited as a hole injection layer in a thickness of 5 nm, and HT-1 was deposited as a hole transporting layer in a thickness of 80 nm. Next, as an emissive layer, a host material H-1 and a dopant material D-1 were deposited in a thickness of 40 nm so that the doping concentration was 5% by weight. Next, as an electron transporting layer, the compound [1] was deposited and laminated in a thickness of 30 nm. Next, lithium fluoride was deposited in a thickness of 0.5 nm, and aluminum was then deposited in a thickness of 1000 nm to form a cathode, so that a 5×5 mm square device was prepared. The film thickness referred to herein was an indicated value on a crystal oscillation film thickness monitor. The properties of the light-emitting device at 1000 cd/m² included a driving voltage of 4.6 V and an external quantum efficiency of 4.8%. When the light-emitting device was driven at a constant current with the initial luminance set to 1000 cd/cm², the luminance half-time at which the luminance decreased by 50% was 1100 hours. Compounds HAT-CN6, HT-1, H-1 and D-1 are the compounds shown below.

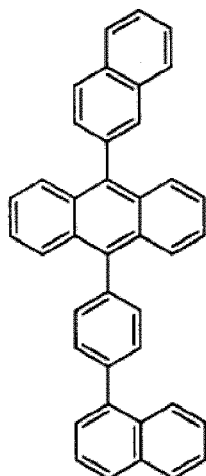
[Chemical Formula 26]



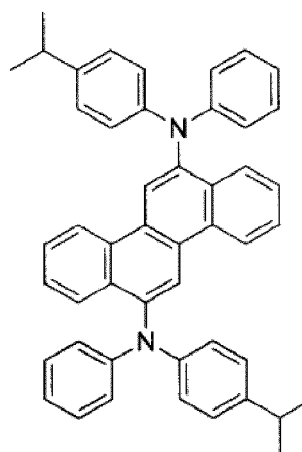
HAT - CN6



HT-1



H-1

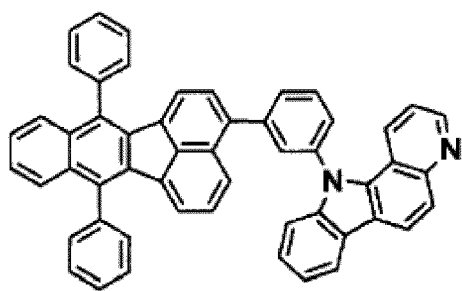


D-1

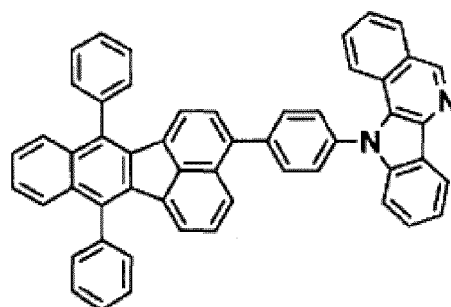
Examples 2 to 17

[0116] In the same manner as in Example 1 except that compounds described in Table 1 were used for the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 1. Compounds [2] to [17] are the compounds shown below.

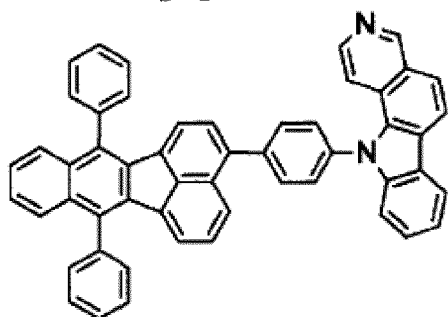
[Chemical Formula 27]



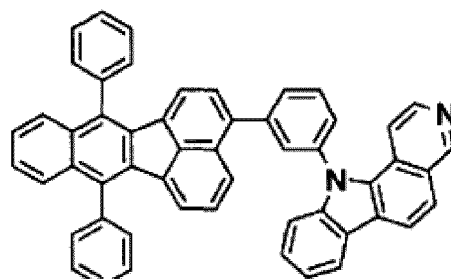
[2]



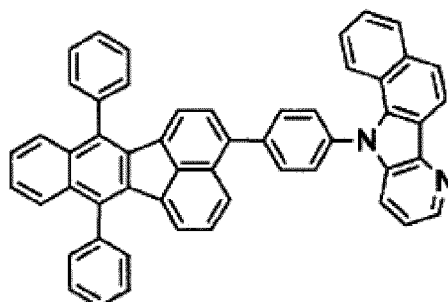
[3]



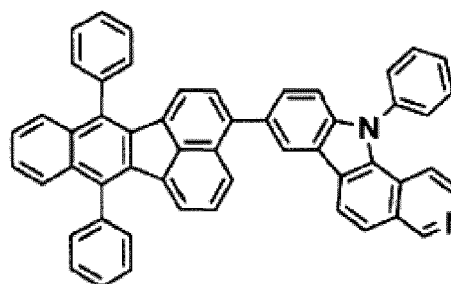
[4]



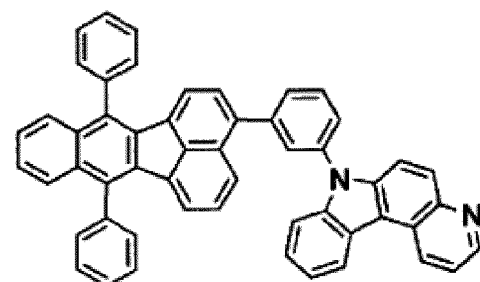
[5]



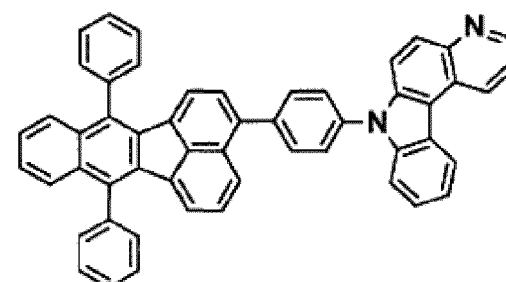
[6]



[7]

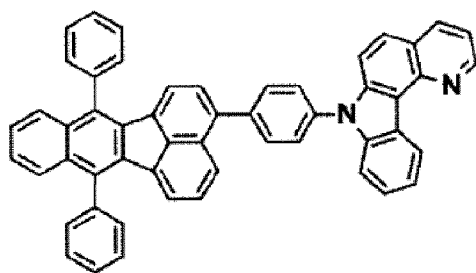


[8]

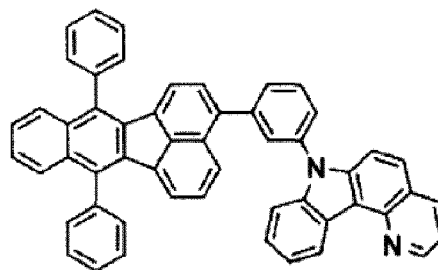


[9]

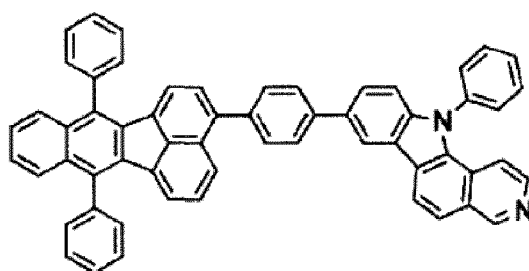
[Chemical Formula 28]



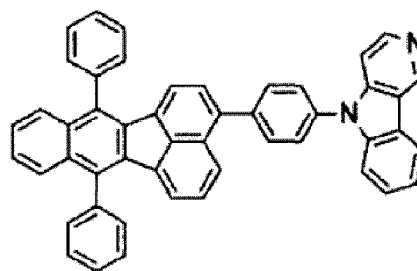
[10]



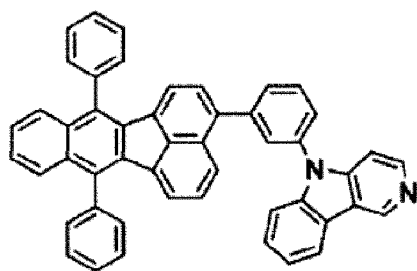
[11]



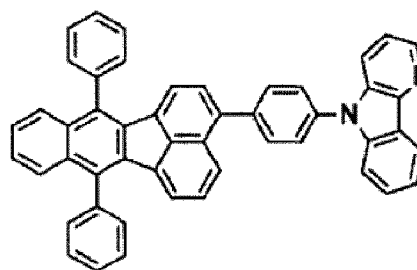
[12]



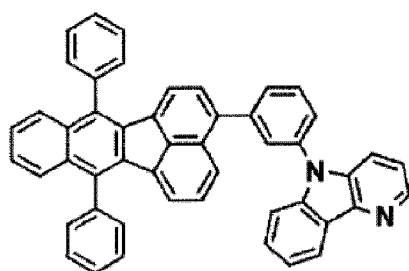
[13]



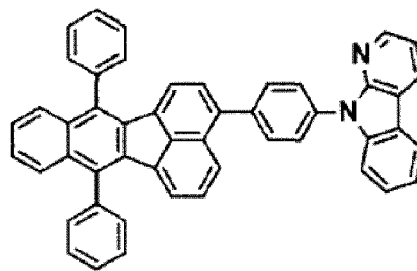
[14]



[15]



[16]

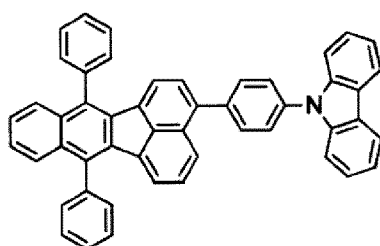


[17]

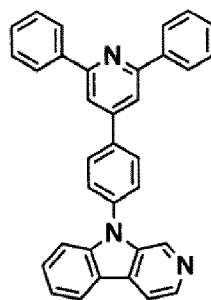
Comparative Examples 1 to 6

[0117] In the same manner as in Example 1 except that compounds described in Table 1 were used for the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 1. E-1 and E-6 are the compounds shown below.

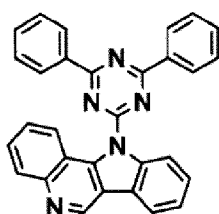
[Chemical Formula 29]



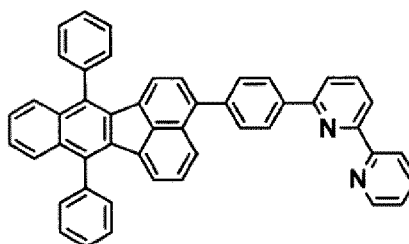
E-1



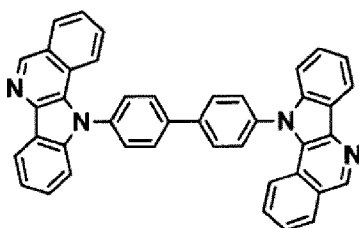
E-2



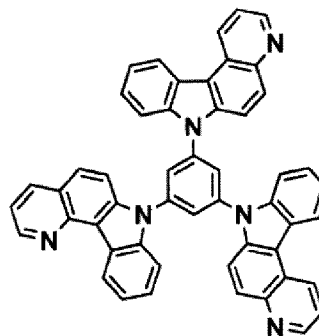
E-3



E-4



E-5



E-6

Example 18

[0118] A glass substrate with an ITO transparent electroconductive film deposited thereon in a thickness of 165 nm (manufactured by GEOMATEC Co., Ltd., $11 \Omega/\square$, sputtered product) was cut into 38×46 mm, and etched. The resulting substrate was ultrasonically washed with "SEMICOCLEAN 56" (trade name, manufactured by Furuuchi Chemical Corporation) for 15 minutes, and then washed with ultrapure water. This substrate was treated with UV-ozone for 1 hour immediately before preparation of a device, and placed in a vacuum deposition apparatus, and the air was evacuated until the degree of vacuum in the apparatus was 5×10^{-4} Pa or lower. By a resistance heating method, first, HAT-CN6 was deposited as a hole injection layer in a thickness of 5 nm, and HT-1 was deposited as a hole transporting layer in a thickness of 80 nm. Next, as an emissive layer, a host material H-1 and a dopant material D-1 were deposited in a thickness of 40 nm so that the doping concentration was 5% by weight. Next, as a first electron transporting layer, the compound [1] was deposited and laminated in a thickness of 10 nm. Further as a second electron transporting layer, the compound [1] used as an electron transporting material and cesium used as a donor material were laminated in a thickness of 20 nm so that the deposition rate ratio of the compound [1] and cesium was 20 : 1. Next, lithium fluoride was deposited in a thickness of 0.5 nm, and aluminum was then deposited in a thickness of 1000 nm to form a cathode, so that a 5×5 mm square device was prepared. The properties of the light-emitting device at 1000 cd/m² included a driving voltage of 4.2 V and an external quantum efficiency of 5.6%. When the light-emitting device was driven at a

constant current with the initial luminance set to 1000 cd/cm², the luminance half-time at which the luminance decreased by 50% was 1500 hours.

Examples 19 to 34

[0119] In the same manner as in Example 2 except that compounds described in Table 18 were used for the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 2.

Comparative Examples 7 to 12

[0120] In the same manner as in Example 2 except that compounds described in Table 18 were used for the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 2.

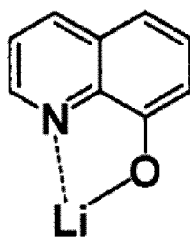
Example 35

[0121] A glass substrate with an ITO transparent electroconductive film deposited thereon in a thickness of 165 nm (manufactured by GEOMATEC Co., Ltd., 11 Ω/□, sputtered product) was cut into 38 × 46 mm, and etched. The resulting substrate was ultrasonically washed with "SEMICOCLEAN 56" (trade name, manufactured by Furuuchi Chemical Corporation) for 15 minutes, and then washed with ultrapure water. This substrate was treated with UV-ozone for 1 hour immediately before preparation of a device, and placed in a vacuum deposition apparatus, and the air was evacuated until the degree of vacuum in the apparatus was 5 × 10⁻⁴ Pa or lower. By a resistance heating method, first, HAT-CN6 was deposited as a hole injection layer in a thickness of 5 nm, and HT-1 was deposited as a hole transporting layer in a thickness of 80 nm. Next, as an emissive layer, a host material H-1 and a dopant material D-1 were deposited in a thickness of 40 nm so that the doping concentration was 5% by weight. Further as an electron transporting layer, the compound [1] used as an electron transporting material and 2E-1 used as a donor material were laminated in a thickness of 30 nm so that the deposition rate ratio of the compound [1] and 2E-1 was 1:1. This electron transporting layer is shown as a second electron transporting layer in Table 2. Next, lithium fluoride was deposited in a thickness of 0.5 nm, and aluminum was then deposited in a thickness of 1000 nm to form a cathode, so that a 5 × 5 mm square device was prepared. The properties of the light-emitting device at 1000 cd/m² included a driving voltage of 3.9 V and an external quantum efficiency of 6.0%. When the light-emitting device was driven at a constant current with the initial luminance set to 1000 cd/cm², the luminance half-time at which the luminance decreased by 50% was 1800 hours.

Examples 36 to 51

[0122] In the same manner as in Example 35 except that compounds described in Table 3 were used for the electron transporting layer and the donor material, light-emitting devices were prepared and evaluated. The results are shown in Table 3. 2E-1 is the compound shown below.

[Chemical Formula 30]



2E-1

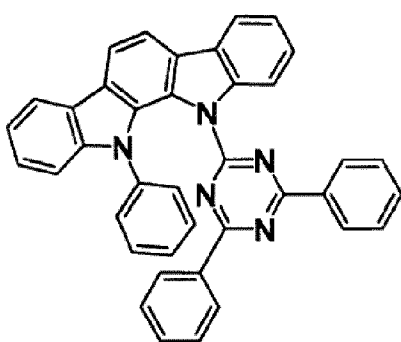
Comparative Examples 13 to 18

[0123] In the same manner as in Example 35 except that compounds described in Table 3 were used for the electron transporting layer and the donor material, light-emitting devices were prepared and evaluated. The results are shown in Table 3.

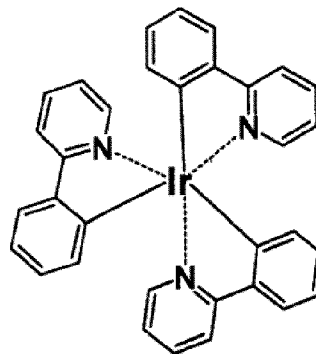
Example 52

[0124] A glass substrate with an ITO transparent electroconductive film deposited thereon in a thickness of 165 nm (manufactured by GEOMATEC Co., Ltd., $11 \Omega/\square$, sputtered product) was cut into 38×46 mm, and etched. The resulting substrate was ultrasonically washed with "SEMICOCLEAN 56" (trade name, manufactured by Furuuchi Chemical Corporation) for 15 minutes, and then washed with ultrapure water. This substrate was treated with UV-ozone for 1 hour immediately before preparation of a device, and placed in a vacuum deposition apparatus, and the air was evacuated until the degree of vacuum in the apparatus was 5×10^{-4} Pa or lower. By a resistance heating method, first, HAT-CN6 was deposited as a hole injection layer in a thickness of 5 nm, and HT-1 was deposited as a hole transporting layer in a thickness of 80 nm. This hole transporting layer is shown as a first hole transporting layer in Table 3. Next, as an emissive layer, a host material H-2 and a dopant material D-2 were deposited in a thickness of 40 nm so that the doping concentration was 10% by weight. Next, as an electron transporting layer, the compound [1] was deposited and laminated in a thickness of 30 nm. Next, lithium fluoride was deposited in a thickness of 0.5 nm, and aluminum was then deposited in a thickness of 1000 nm to form a cathode, so that a 5×5 mm square device was prepared. The film thickness referred to herein was an indicated value on a crystal oscillation film thickness monitor. The properties of the light-emitting device at 4000 cd/m² included a driving voltage of 4.2 V and an external quantum efficiency of 12.1%. When the light-emitting device was driven at a constant current with the initial luminance set to 4000 cd/cm², the luminance half-time was 1200 hours. H-2 and D-2 are the compounds shown below.

[Chemical Formula 31]



H-2

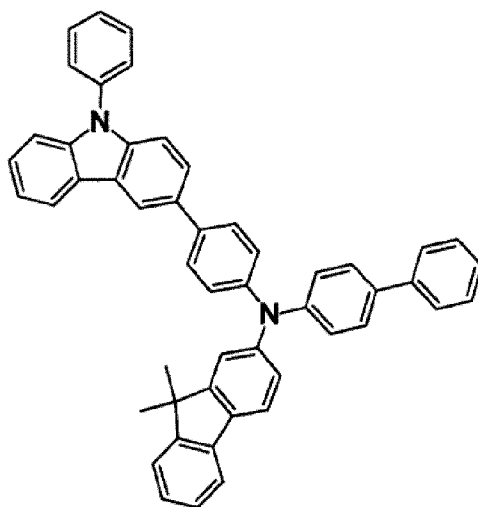


D-2

Example 53

[0125] A glass substrate with an ITO transparent electroconductive film deposited thereon in a thickness of 165 nm (manufactured by GEOMATEC Co., Ltd., $11 \Omega/\square$, sputtered product) was cut into 38×46 mm, and etched. The resulting substrate was ultrasonically washed with "SEMICOCLEAN 56" (trade name, manufactured by Furuuchi Chemical Corporation) for 15 minutes, and then washed with ultrapure water. This substrate was treated with UV-ozone for 1 hour immediately before preparation of a device, and placed in a vacuum deposition apparatus, and the air was evacuated until the degree of vacuum in the apparatus was 5×10^{-4} Pa or lower. By a resistance heating method, first, HAT-CN6 was deposited as a hole injection layer in a thickness of 5 nm, and HT-1 was deposited as a hole transporting layer in a thickness of 70 nm. Further, HT-2 was deposited as a second hole transporting layer in a thickness of 10 nm. Next, as an emissive layer, a host material H-2 and a dopant material D-2 were deposited in a thickness of 40 nm so that the doping concentration was 10% by weight. Next, as an electron transporting layer, the compound [1] was deposited and laminated in a thickness of 30 nm. Next, lithium fluoride was deposited in a thickness of 0.5 nm, and aluminum was then deposited in a thickness of 1000 nm to form a cathode, so that a 5×5 mm square device was prepared. The film thickness referred to herein was an indicated value on a crystal oscillation film thickness monitor. The properties of the light-emitting device at 4000 cd/m² included a driving voltage of 4.3 V and an external quantum efficiency of 14.2%. When the light-emitting device was driven at a constant current with the initial luminance set to 4000 cd/cm², the luminance half-time was 1700 hours. HT-2 is the compound shown below.

[Chemical Formula 32]

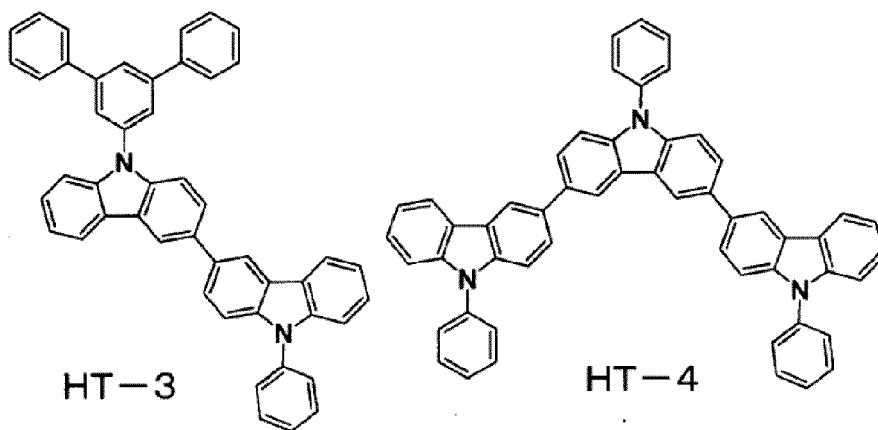


HT-2

Examples 54 and 55

[0126] In the same manner as in Example 53 except that compounds described in Table 4 were used for the second hole transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 4. HT-3 and HT-4 are the compounds shown below.

[Chemical Formula 33]



HT-3

HT-4

Example 56

[0127] In the same manner as in Example 52 except that a compound [2] was used for the electron transporting layer, a light-emitting device was prepared and evaluated. The results are shown in Table 4.

Examples 57 and 59

[0128] In the same manner as in Example 53 except that compounds described in Table 4 were used for the second hole transporting layer, and the compound [2] was used for the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 4.

Comparative Examples 19 and 23

[0129] In the same manner as in Example 52 except that compounds described in Table 4 were used for the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 4.

Comparative Examples 20 to 22 and 24 to 26

[0130] In the same manner as in Example 53 except that compounds described in Table 3 were used for the second hole transporting layer and the electron transporting layer, light-emitting devices were prepared and evaluated. The results are shown in Table 4.

[Table 1]

	Emissive material		Electron transporting layer	Cathode	External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
	Host material	Dopant material					
Example 1	H-1	D-1	Compound [1]	Al	4.8	4.6	1100
Example 2			Compound [2]	Al	4.9	4.5	1000
Example 3			Compound [3]	Al	4.8	4.5	1100
Example 4			Compound [4]	Al	5.0	4.5	1200
Example 5			Compound [5]	Al	4.9	4.6	1300
Example 6			Compound [6]	Al	4.8	4.4	1100
Example 7			Compound [7]	Al	4.8	4.5	1300
Example 8			Compound [8]	Al	4.9	4.4	1300
Example 9			Compound [9]	Al	4.9	4.4	1100
Example 10			Compound [10]	Al	5.0	4.5	1200
Example 11			Compound [11]	Al	5.0	4.4	1300
Example 12			Compound [12]	Al	5.0	4.4	1300
Example 13			Compound [13]	Al	4.4	4.8	1000
Example 14			Compound [14]	Al	4.5	4.8	1100
Example 15			Compound [15]	Al	4.4	4.8	1100
Example 16			Compound [16]	Al	4.5	4.9	1200
Example 17			Compound [17]	Al	4.5	4.8	1100

(continued)

	Emissive material		Electron transporting layer	Cathode	External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
	Host material	Dopant material					
Comparative Example 1	H-1	D-1	E-1	Al	2.7	7.3	300
Comparative Example 2			E-2	Al	2.8	7.8	300
Comparative Example 3			E-3	Al	2.7	7.3	300
Comparative Example 4			E-4	Al	2.9	6.8	200
Comparative Example 5			E-5	Al	2.7	7.8	200
Comparative Example 6			E-6	Al	2.7	7.5	300

[Table 2]

	Emissive material			First electron transporting layer	Second electron transporting layer		Cathode	External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
	Host material	Dopant material	Emitted color		Compound	Donor material				
Example 18	H-1	D-1	Blue	Compound [1]	Compound [1]	Cesium	Al	5.6	4.2	1500
Example 19			Blue	Compound [2]	Compound [2]	Cesium	Al	5.7	4.3	1400
Example 20			Blue	Compound [3]	Compound [3]	Cesium	Al	5.6	4.2	1500
Example 21			Blue	Compound [4]	Compound [4]	Cesium	Al	5.7	4.2	1500
Example 22			Blue	Compound [5]	Compound [5]	Cesium	Al	5.8	4.3	1500
Example 23			Blue	Compound [6]	Compound [6]	Cesium	Al	5.6	4.1	1400
Example 24			Blue	Compound [7]	Compound [7]	Cesium	Al	5.7	4.2	1600
Example 25			Blue	Compound [8]	Compound [8]	Cesium	Al	5.7	4.3	1400
Example 26			Blue	Compound [9]	Compound [9]	Cesium	Al	5.6	4.3	1500
Example 27			Blue	Compound [10]	Compound [10]	Cesium	Al	5.8	4.2	1600
Example 28			Blue	Compound [11]	Compound [11]	Cesium	Al	5.8	4.2	1500
Example 29			Blue	Compound [12]	Compound [12]	Cesium	Al	5.6	4.3	1500
Example 30			Blue	Compound [13]	Compound [13]	Cesium	Al	5.3	4.5	1400

(continued)

	Emissive material			First electron transporting layer	Second electron transporting layer		Cathode		External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
	Host material	Dopant material	Emitted color		Compound	Donor material	Metal				
Example 31			Blue	Compound [14]	Compound [14]	Cesium	Al	5.4	4.4	1400	
Example 32			Blue	Compound [15]	Compound [15]	Cesium	Al	5.3	4.4	1500	
Example 33			Blue	Compound [16]	Compound [16]	Cesium	Al	5.2	4.4	1300	
Example 34			Blue	Compound [17]	Compound [17]	Cesium	Al	5.4	4.4	1400	
Comparative Example 7	H-1	D-1	Blue	E-1	E-1	Cesium	Al	3.2	6.8	500	
Comparative Example 8			Blue	E-2	E-2	Cesium	Al	3.1	6.9	600	
Comparative Example 9			Blue	E-3	E-3	Cesium	Al	3.2	7.0	600	
Comparative Example 10			Blue	E-4	E-4	Cesium	Al	3.2	7.0	600	
Comparative Example 11			Blue	E-5	E-5	Cesium	Al	3.2	7.0	600	
Comparative Example 12			Blue	E-6	E-6	Cesium	Al	3.2	7.0	600	

[Table 3]

	Emissive material			First electron transporting layer	Second electron transporting layer		Cathode	External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
	Host material	Dopant material	Emitted color		Compound	Donor material				
Example 35	H-1	D-1	Blue	None	Compound [1]	2E-1	Al	6.0	3.9	1800
Example 36			Blue	None	Compound [2]	2E-1	Al	6.1	4.0	1900
Example 37			Blue	None	Compound [3]	2E-1	Al	6.0	4.0	1700
Example 38			Blue	None	Compound [4]	2E-1	Al	6.1	4.0	1800
Example 39			Blue	None	Compound [5]	2E-1	Al	6.0	3.9	1900
Example 40			Blue	None	Compound [6]	2E-1	Al	6.2	3.9	1800
Example 41			Blue	None	Compound [7]	2E-1	Al	6.1	4.0	1900
Example 42			Blue	None	Compound [8]	2E-1	Al	6.0	4.0	1800
Example 43			Blue	None	Compound [9]	2E-1	Al	6.2	4.0	1700
Example 44			Blue	None	Compound [10]	2E-1	Al	6.0	3.9	1800
Example 45			Blue	None	Compound [11]	2E-1	Al	6.1	3.9	1900
Example 46			Blue	None	Compound [12]	2E-1	Al	6.2	3.9	1900
Example 47			Blue	None	Compound [13]	2E-1	Al	5.8	4.2	1800

(continued)

	Emissive material			First electron transporting layer	Second electron transporting layer		Cathode	External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
	Host material	Dopant material	Emitted color		Compound	Donor material				
Example 48			Blue	None	Compound [14]	2E-1	Al	5.9	4.2	1800
Example 49			Blue	None	Compound [15]	2E-1	Al	5.7	4.2	1800
Example 50			Blue	None	Compound [16]	2E-1	Al	5.8	4.3	1900
Example 51			Blue	None	Compound [17]	2E-1	Al	5.7	4.2	1700
Comparative Example 13	H-1	D-1	Blue	None	E-1	2E-1	Al	4.1	6.2	800
Comparative Example 14			Blue	None	E-2	2E-1	Al	4.0	6.3	900
Comparative Example 15			Blue	None	E-3	2E-1	Al	4.0	6.3	800
Comparative Example 16			Blue	None	E-4	2E-1	Al	4.2	5.9	600
Comparative Example 17			Blue	None	E-5	2E-1	Al	4.1	6.3	900
Comparative Example 18			Blue	None	E-6	2E-1	Al	4.0	6.2	700

[Table 4]

	Hole injection layer	First hole transporting layer	Second hole transporting layer	Emissive layer		Electron transporting layer	External quantum efficiency (%)	Driving voltage (V)	Luminance half-time (h)
				Host material	Dopant material				
Example 52	HAT-CN6	HT-1	None	H-2	D-2	Compound [1]	12.1	4.2	1200
Example 53			HT-2				14.2	4.3	1700
Example 54			HT-3				17.5	4.4	2100
Example 55			HT-4				18.1	4.3	2200
Example 56			None			Compound [2]	11.9	4.1	1100
Example 57			HT-2				13.9	4.2	1600
Example 58			HT-3				17.5	4.3	2100
Example 59			HT-4				17.6	4.2	2000
Comparative Example 19	HAT-CN6	HT-1	None	H-2	D-2	E-1	7.9	6.8	300
Comparative Example 20			HT-2				8.1	6.7	500
Comparative Example 21			HT-3				8.5	6.8	800
Comparative Example 22			HT-4				8.5	6.7	800
Comparative Example 23			None			E-2	8.1	6.2	250
Comparative Example 24			HT-2				8.4	6.3	450
Comparative Example 25			HT-3				8.8	6.3	700
Comparative Example 26			HT-4				8.7	6.2	700

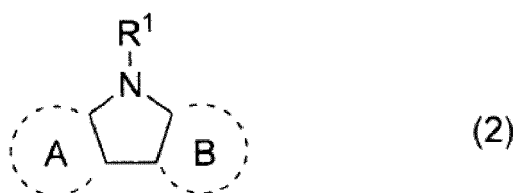
Claims

1. A light-emitting device material comprising a compound represented by the following general formula (1):
[Chemical Formula 1]



wherein Ar represents a group containing a benzo[fluoranthene] skeleton, and Z is represented by the following general formula (2); L is a single bond, a substituted or unsubstituted arylene group, or a substituted or unsubstituted heteroarylene group; n is 1 or 2; and when n is 2, two Zs may be the same or different;

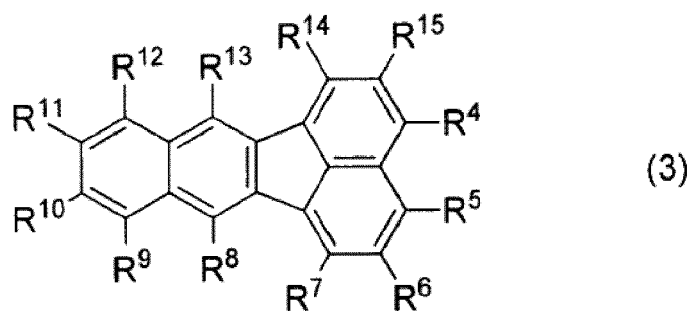
[Chemical Formula 2]



wherein ring A and ring B each represent a substituted or unsubstituted benzene ring, a substituted or unsubstituted fused aromatic hydrocarbon ring, a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsubstituted fused aromatic heterocyclic ring, with the proviso that at least one of atoms that form ring A and ring B is electron-accepting nitrogen; a substituent that ring A and ring B optionally have, and R¹ are each selected from the group consisting of an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³; R¹ may be hydrogen; R² and R³ are each an aryl group or a heteroaryl group; or R² and R³ may be fused to form a ring, with the proviso that the group is coupled to L at the position of any of R¹, ring A and ring B; and when n is 2, positions at which two Zs are coupled to L may be the same or different.

2. The light-emitting device material according to claim 1, wherein Ar is represented by the general formula (3):

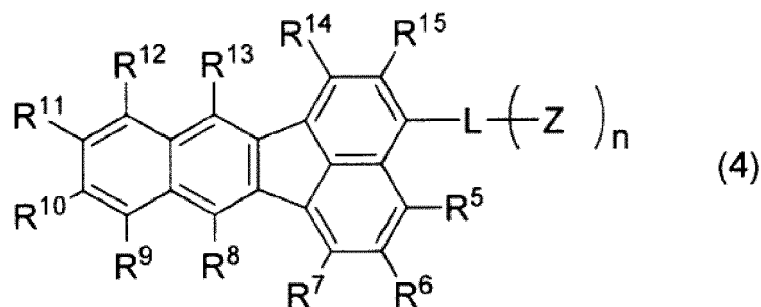
[Chemical Formula 3]



wherein R⁴ to R¹⁵ may be the same or different, and are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group and a carbamoyl group; and R⁴ to R¹⁵ may form a ring by adjacent substituents, with the proviso that the group is coupled to L at the position of any one of R⁴ to R¹⁵.

3. The light-emitting device material according to claim 2, wherein the compound represented by the general formula (1) is a compound represented by the following general formula (4):

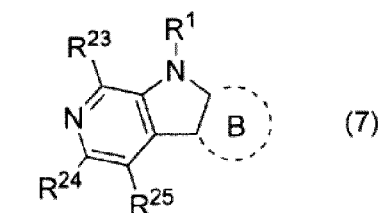
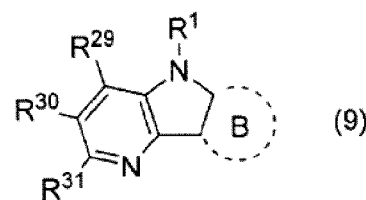
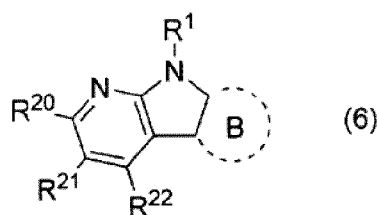
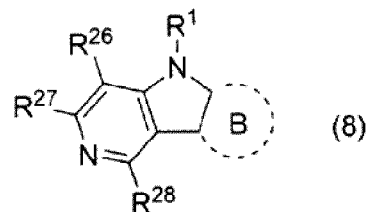
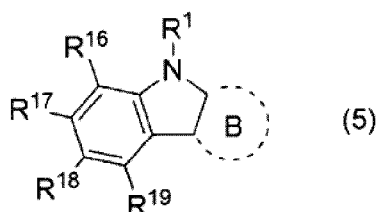
[Chemical Formula 4]



wherein R^5 to R^{15} may be the same or different, and are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group and a carbamoyl group; R^5 to R^{15} may form a ring by adjacent substituents; and L, Z and n are the same as in the general formula (1).

4. The light-emitting device material according to claim 1, wherein n is 1.
5. The light-emitting device material according to claim 2, wherein R^8 and R^{13} are each a substituted or unsubstituted aryl group.
6. The light-emitting device material according to claim 5, wherein R^8 and R^{13} are each a phenyl group.
7. The light-emitting device material according to any one of claims 1 to 6, wherein Z is represented by any of the following general formulae (5) to (9):

[Chemical Formula 5]

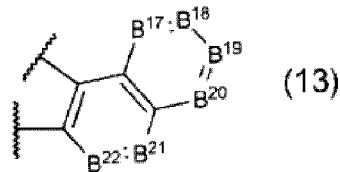
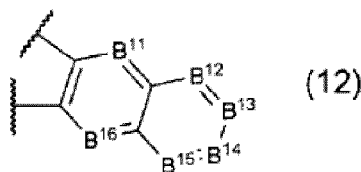
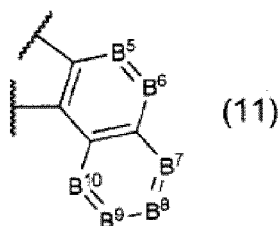
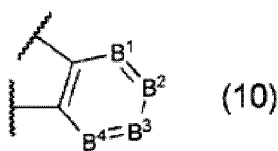


wherein ring B represents a substituted or unsubstituted benzene ring, a substituted or unsubstituted fused aromatic hydrocarbon ring, a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsub-

stituted fused aromatic heterocyclic ring, with the proviso that in the case of the general formula (5), ring B is a substituted or unsubstituted monocyclic aromatic heterocyclic ring, or a substituted or unsubstituted fused aromatic heterocyclic ring, and at least one of atoms that form ring B is electron-accepting nitrogen; a substituent that ring B optionally has, and R¹ are the same as in the general formula (2); and wherein R¹⁶ to R³¹ are each selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³, with the proviso that the group is coupled to L at the position of any of R¹, R¹⁶ to R¹⁹ and ring B in the case of the general formula (5), at the position of any of R¹, R²⁰ to R²² and ring B in the case of the general formula (6), at the position of any of R¹, R²³ to R²⁵ and ring B in the case of the general formula (7), at the position of any of R¹, R²⁶ to R²⁸ and ring B in the case of the general formula (8), and at the position of any of R¹, R²⁹ to R³¹ and ring B in the case of the general formula (9); and when n is 2, two Zs may be the same or different.

8. The light-emitting device material according to claim 7, wherein ring B is a structure represented by any of the following general formulae (10) to (13):

[Chemical Formula 6]



wherein B¹ to B²² represent C-R³² or N, with the proviso that when Z is a group represented by the general formula (5), at least one of B^ks (K = 1 to 22) contained in ring B is electron-accepting nitrogen; a substituent that B¹ to B²² optionally have is the same as in the general formula (2); and R³² is selected from the group consisting of hydrogen, an alkyl group, a cycloalkyl group, a heterocyclic group, an alkenyl group, a cycloalkenyl group, an alkynyl group, an alkoxy group, an alkylthio group, an aryl ether group, an aryl thioether group, an aryl group, a heteroaryl group, halogen, a carbonyl group, a carboxyl group, an oxycarbonyl group, a carbamoyl group and -P(=O)R²R³.

9. A light-emitting device which has an organic layer between an anode and a cathode and emits light by means of electric energy, wherein the light-emitting device contains the light-emitting device material according to any one of claims 1 to 8 in the organic layer.
10. The light-emitting device according to claim 9, wherein the organic layer comprises an electron transporting layer, and the electron transporting layer comprises the light-emitting device material according to any of claims 1 to 8.
11. The light-emitting device according to claim 10, wherein the electron transporting layer further comprises a donor material.
12. The light-emitting device according to claim 11, wherein the donor material is an alkali metal, an inorganic salt containing an alkali metal, a complex of an alkali metal and an organic substance, an alkaline earth metal, an inorganic salt containing an alkaline earth metal, or a complex of an alkaline earth metal and an organic substance.

13. The light-emitting device according to claim 12, wherein the donor material is a complex of an alkali metal and an organic substance or a complex of an alkaline earth metal and an organic substance.
- 5 14. The light-emitting device according to any one of claims 9 to 13, further comprising a hole transporting layer between the anode and the cathode, wherein the hole transporting layer contains a material having a carbazole skeleton.
15. The light-emitting device according to claim 14, wherein the material having a carbazole skeleton is a carbazole polymer.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/065213

A. CLASSIFICATION OF SUBJECT MATTER

H01L51/50(2006.01)i, C07D471/04(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, C07D471/04, 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	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

CAplus/REGISTRY (STN)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2011-249653 A (TDK Corp.), 08 December 2011 (08.12.2011), paragraph [0093] & US 2011/0295017 A1 & CN 102311303 A & KR 10-2011-0131128 A	1-15
A	KR 10-2012-0020816 A (Rohm and Haas Electronic Materials Korea Ltd.), 08 March 2012 (08.03.2012), page 6 (Family: none)	1-15
A	KR 10-2009-0114008 A (LG CHEM, LTD.), 03 November 2009 (03.11.2009), page 10, 1-32; page 11, 1-48; page 32, 2-28 (Family: none)	1-15

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search
31 July, 2013 (31.07.13)Date of mailing of the international search report
13 August, 2013 (13.08.13)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/065213

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Payal Tyagi et al., Solution Processable Indoloquinoline Derivatives Containing Bulky Polyaromatic Hydrocarbons: Synthesis, Optical Spectra, and Electroluminescence, The Journal of Organic Chemistry, 2011, 76, p.4571-4581	1-15
A	JP 2008-156315 A (Canon Inc.), 10 July 2008 (10.07.2008), paragraph [0075] & US 2009/0278118 A1 & WO 2008/078824 A1 & CN 101454288 A & KR 10-2009-0094159 A	1-15
A	WO 2008/059713 A1 (Idemitsu Kosan Co., Ltd.), 22 May 2008 (22.05.2008), paragraph [0028], 5-15, 6-1, 6-2, 6-3 & US 2009/0015144 A1 & EP 2085371 A1 & KR 10-2009-0081390 A & CN 101595080 A & TW 200838976 A	1-15
A	WO 2008/102740 A1 (Idemitsu Kosan Co., Ltd.), 28 August 2008 (28.08.2008), page 35, 1-113; page 42, 3-21, 3-22 & US 2010/0039027 A1 & EP 2113954 A1 & CN 101617417 A & KR 10-2010-0014803 A & TW 200902676 A	1-15
A	US 2012/0112179 A1 (IDEMITSU KOSAN CO., LTD.), 10 May 2012 (10.05.2012), entire text & EP 2495240 A1 & WO 2011/052186 A1 & CN 102574828 A & KR 10-2012-0079022 A	1-15
A	WO 2012/005009 A1 (Idemitsu Kosan Co., Ltd.), 12 January 2012 (12.01.2012), paragraph [0036] & US 2012/0187392 A1 & EP 2597094 A & CN 102471340 A & KR 10-2012-0119981 A & TW 201223953 A	1-15
A	WO 2012/046839 A1 (Idemitsu Kosan Co., Ltd.), 12 April 2012 (12.04.2012), paragraph [0094] & US 2012/0211743 A1 & CN 102574797 A & KR 10-2013-0025858 A & TW 201215659 A	1-15
A	JP 2010-254610 A (Canon Inc.), 11 November 2010 (11.11.2010), paragraph [0032] & US 2010/0270914 A1 & EP 2243761 A1 & CN 101870705 A & KR 10-2010-0117024 A	1-15

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/065213

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	US 2012/0187381 A1 (Universal Display Corp.), 26 July 2012 (26.07.2012), page 14, compound 62 & WO 2012/102967 A1 & TW 201241151 A	1-15

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2012046839 A [0005]
- WO 2010114264 A [0005]
- WO 200463159 A [0086]
- WO 200360956 A [0086]
- WO 2010113743 A [0086]
- WO 20101817 A [0086]

Non-patent literature cited in the description

- *Appl. Phys. Lett.*, 1999, vol. 74, 865 [0086]
- *Org. Electron.*, 2003, vol. 4, 113 [0086]

专利名称(译)	用于发光元件和发光元件的材料		
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摘要(译)

本发明的目的是提供一种具有改进的发光效率，驱动电压和耐久寿命的有机薄膜发光元件。该用于发光元件的材料特征在于包含具有苯并荧蒽骨架的特定化合物。

