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(72) Inventors:
• **SHIN, Ji-Cheol**
10845 Gyeonggi-do (KR)
• **JOO, Sung-Hoon**
10845 Gyeonggi-do (KR)
• **YOO, Seon-Keun**
10845 Gyeonggi-do (KR)
• **YOON, Seung-Hee**
10845 Gyeonggi-do (KR)

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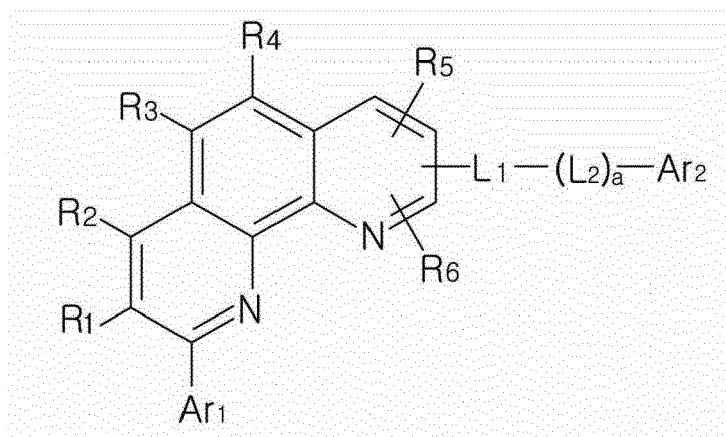
(71) Applicant: **LG Display Co., Ltd.**
Seoul, 07336 (KR)

(74) Representative: **Ter Meer Steinmeister & Partner**
Patentanwälte mbB
Nymphenburger Straße 4
80335 München (DE)

(54) **ORGANIC COMPOUND, LIGHT EMITTING DIODE AND ORGANIC LIGHT EMITTING DIODE DISPLAY**

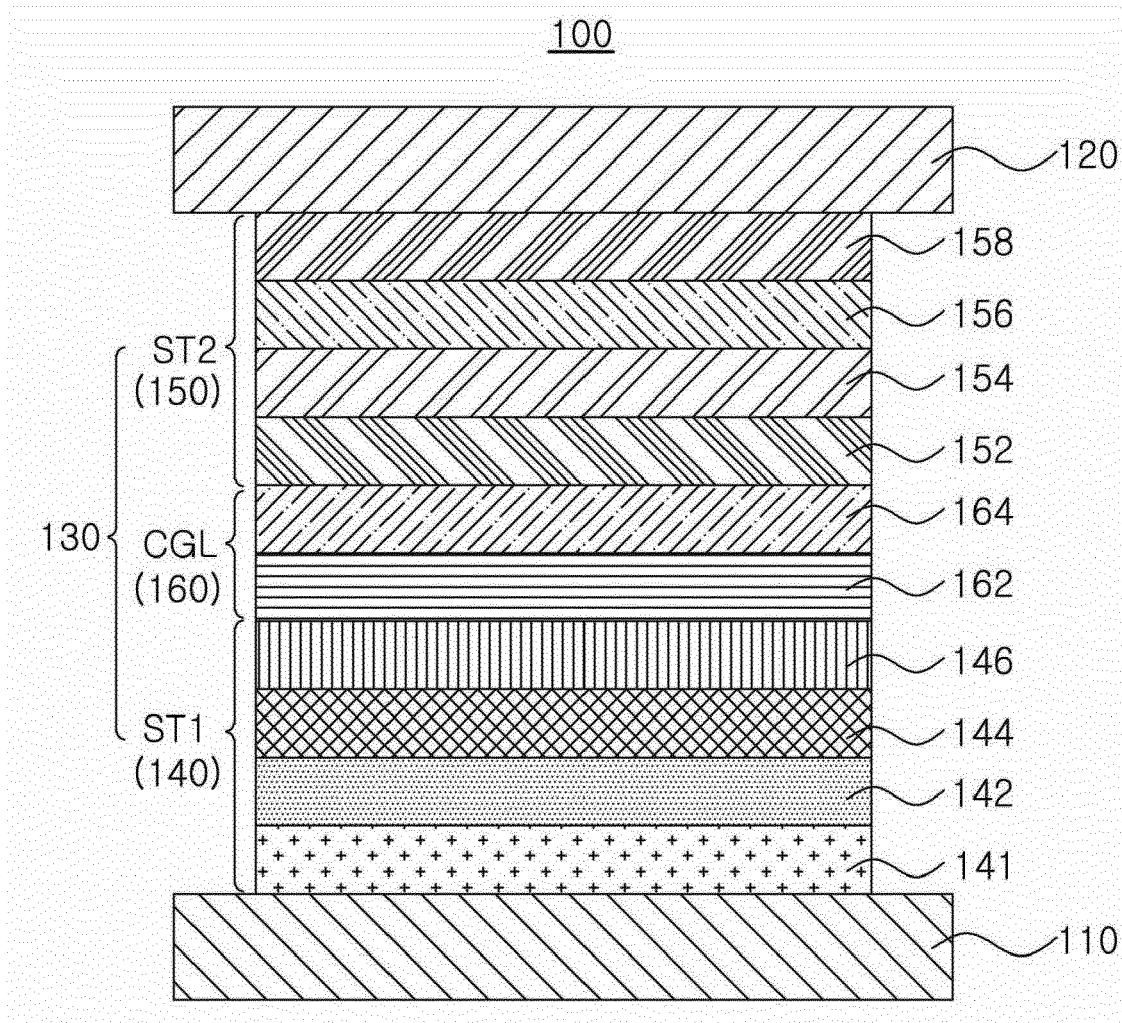
(57) The present disclosure relates to an organic compound, a light emitting diode and an organic light emitting diode display device using the same. The organic compound is represented by a following chemical formula 1.

Chemical Formula 1



This organic compound has the advantages in the electron transmitting property and the thermal stability and forms a stable gap state with an alkali metal and an alkali earth metal. The driving voltage of the light emitting diode is reduced and the emission efficiency and the lifetime of the light emitting diode are improved by applying the organic compound to the charge generation layer and/or the electron transporting layer of the light emitting diode of the tandem structure.

FIG. 1



Description**BACKGROUND****1. Technical Field**

[0001] The present disclosure relates to an organic compound, and more particularly, to an organic compound where a driving voltage and an emission efficiency are improved and a light emitting diode and an organic light emitting diode display device including the organic compound.

2. Discussion of the Related Art

[0002] As a display device is enlarged, a request for a flat panel display of a small space possession increases. Among various flat panel displays, an organic light emitting diode (OLED) display device, which may be referred to as an organic electroluminescent display (OELD) device, including a light emitting diode (LED) has been the subject of recent research.

[0003] The LED is an element where a hole and an electron are injected into an emitting material layer from an anode (a hole injecting electrode) and a cathode (an electron injecting electrode) to constitute an exciton and the emitting material layer emits a light due to transition of the exciton. The LED has an advantage such that an element is formed on a flexible transparent substrate such as a plastic. In addition, the LED has a relatively low driving voltage (equal to or lower than 10V), a relatively low power consumption and an excellent color property.

[0004] Recently, the LED emitting a white colored light has been applied to various fields such as a thin light source, a light source of a backlight unit for a liquid crystal display (LCD) device and a light source for a full color display device having a color filter layer as well as a lighting.

[0005] In the white LED, a color purity, a color stability according to variation of current and voltage and a capability of fabrication as well as a high efficiency and a long lifetime have been the subject. The white LED may be classified into a single stack structure and a multiple stack structure. To obtain the white LED having a relatively long lifetime, the LED having a tandem structure where a plurality of emitting units are laminated has been widely used.

[0006] For example, the white LED may have the tandem structure where a first emitting part including a blue emitting layer and a second emitting part including a yellow-green emitting layer are vertically laminated. The white LED may emit the white colored light by mixing a light emitted from the blue emitting layer and a light emitted from the yellow-green emitting layer.

[0007] In the LED having the tandem structure, a charge generation layer is formed between the first and second emitting parts to increase a current efficiency of each emitting layer and to smoothly distribute charges to each emitting layer. In general, the charge generation layer may have a positive negative (PN) junction structure where an N type charge generation layer and a P type charge generation layer are sequentially formed.

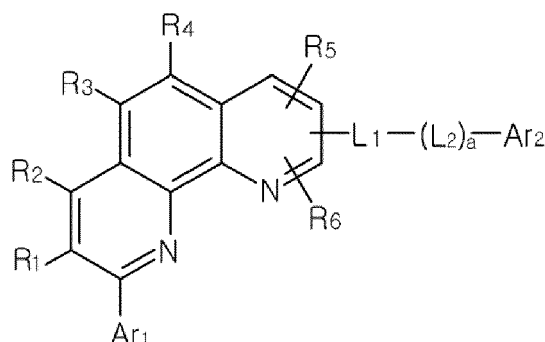
[0008] In the charge generation layer of the tandem structure, a charge is generated at an interface between the P type charge generation layer and a hole injecting layer or a hole transporting layer due to an energy level difference between the N type charge generation layer and the P type charge generation layer, and an electron injection property into the N type charge generation layer is deteriorated.

[0009] Further, when the N type charge generation layer is doped with a metal, the metal diffuses to the P type charge generation layer and a lifetime of the LED is reduced. Specifically, a material for the charge generation layer has a disadvantage in a thermal stability and an electric stability. When the white LED operates for a relatively long time, the material for the charge generation layer is deteriorated or spoiled. Accordingly, an injection efficiency of an electron generated at the interface between the P type charge generation layer and a hole injecting layer or a hole transporting layer into the N type charge generation layer is reduced. Since the electron is not injected from the N type charge generation layer into the adjacent electron transporting layer, a property of the LED is deteriorated and a lifetime of the LED is reduced.

SUMMARY

[0010] Embodiments relate to an organic compound where an aryl group is connected to a phenanthroline moiety having at least one substituted aromatic ring through at least one linker.

[0011] For example, an organic compound of the present disclosure may be represented by a following chemical formula 1.

Chemical Formula 1

[0012] In the chemical formula 1, each of R_1 to R_6 is independently one of hydrogen, deuterium, tritium, a non-substituted or substituted alkyl group of C1 to C20, a non-substituted or substituted alkoxy group of C1 to C20, a non-substituted or substituted aryl group of C5 to C60 and a non-substituted or substituted hetero aryl group of C4 to C60; each of L_1 and L_2 is independently one of a non-substituted or substituted arylene group of C5 to C60 and a non-substituted or substituted hetero arylene group of C5 to C60; a is 0 or 1; and each of Ar_1 and Ar_2 is independently one of a non-substituted or substituted aryl group of C5 to C60 and a non-substituted or substituted hetero aryl group of C4 to C30.

[0013] One or more embodiments relate to a light emitting diode having a tandem structure where the organic compound is applied to a charge generation layer and/or an electron transporting layer and an organic light emitting diode display device.

[0014] Advantages and features of the disclosure will be set forth in part in the description, which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the disclosure. Other advantages and features of the embodiments herein may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

[0015] It is to be understood that both the foregoing general description and the following detailed description are explanatory, and are intended to provide further explanation of the embodiments as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The accompanying drawings, which are included to provide a further understanding of the disclosure, are incorporated in and constitute a part of this specification, illustrate implementations of the disclosure and together with the description serve to explain the principles of embodiments of the disclosure.

FIG. 1 is a cross-sectional view showing a light emitting diode of a tandem structure having two emitting parts according to a first embodiment of the present disclosure.

FIG. 2 is a cross-sectional view showing a light emitting diode of a tandem structure having three emitting parts according to a second embodiment of the present disclosure.

FIG. 3 is a cross-sectional view showing an organic light emitting diode display device according to a third embodiment of the present disclosure.

FIGs. 4A to 4D are graphs showing a voltage-current density property, a brightness-current efficiency property, a brightness-external quantum efficiency (EQE) property and a lifetime property, respectively, of light emitting diodes of the embodiment 1 and the comparative example 1.

FIGs. 5A to 5D are graphs showing a voltage-current density property, a brightness-current efficiency property, a brightness-external quantum efficiency (EQE) property and a lifetime property, respectively, of light emitting diodes of the embodiment 2 and the comparative example 2.

FIGs. 6A to 6D are graphs showing a voltage-current density property, a brightness-current efficiency property, a brightness-external quantum efficiency (EQE) property and a lifetime property, respectively, of light emitting diodes of the embodiment 3 and the comparative example 3.

DETAILED DESCRIPTION

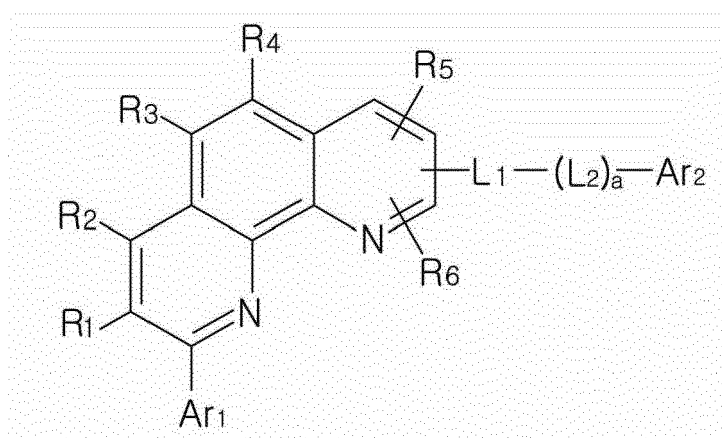
[0017] Reference will now be made in detail to embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. In the following description, when a detailed description of well-known functions or

configurations related to this document is determined to unnecessarily cloud a gist of an embodiment of the disclosure, the detailed description thereof will be omitted. The progression of processing steps and/or operations described is an example; however, the sequence of steps and/or operations is not limited to that set forth herein and may be changed as is known in the art, with the exception of steps and/or operations necessarily occurring in a certain order. Like reference numerals designate like elements throughout. Names of the respective elements used in the following explanations are selected only for convenience of writing the specification and may be thus different from those used in actual products.

[Organic Compound]

[0018] Embodiments relate to an organic compound where an aryl group is connected to a phenanthroline moiety having at least one substituted aromatic ring through at least one linker. An organic compound of the present disclosure is represented by a following chemical formula 1.

Chemical Formula 1



[0019] In the chemical formula 1, each of R_1 to R_6 is independently one of hydrogen, deuterium, tritium, a non-substituted or substituted alkyl group of C1 to C20, a non-substituted or substituted alkoxy group of C1 to C20, a non-substituted or substituted aryl group of C5 to C60 and a non-substituted or substituted hetero aryl group of C4 to C60; each of L_1 and L_2 is independently one of a non-substituted or substituted arylene group of C5 to C60 and a non-substituted or substituted hetero arylene group of C5 to C60; a is 0 or 1; and each of Ar_1 and Ar_2 is independently one of a non-substituted or substituted aryl group of C5 to C60 and a non-substituted or substituted hetero aryl group of C4 to C30.

[0020] The term of 'non-substituted' preferably means that a hydrogen atom is bonded, and in this case, the hydrogen atom includes protium, deuterium and tritium.

[0021] A substituent for the word of 'substituted' includes one of a non-substituted or substituted with halogen alkyl group of C1 to C20, a non-substituted or substituted with halogen alkoxy group of C1 to C20, halogen, a cyano group, a carboxyl group, a carbonyl group, an amine group, an alkylamine group of C1 to C20, a nitro group, a hydrazyl group, a sulfonyl group, an alkyl silyl group of C1 to C20, an alkoxy silyl group of C1 to C20, a cycloalkyl silyl group of C3 to C30, an aryl silyl group of C5 to C30, a non-substituted or substituted aryl group of C5 to C30 and a hetero aryl group of C4 to C30.

[0022] The word of 'hetero' in 'a hetero aromatic ring,' 'a hetero cycloalkylene group,' 'a hetero arylene group,' 'a hetero arylalkylene group,' 'a hetero oxyarylene group,' 'a hetero cycloalkyl group,' 'a hetero aryl group,' 'a hetero arylalkyl group,' 'a hetero oxyaryl group' and 'a hetero aryl amine group' means that at least one, for example, one to five, of carbon atoms constituting an aromatic ring or an alicyclic ring is substituted with at least one hetero atom selected from the group including N, O, P, Si, S and a combination thereof.

[0023] In the chemical formula 1, the organic compound of the present disclosure includes a phenanthroline moiety. Due to the phenanthroline moiety, transporting property of an electron is improved and diffusion of an alkali metal or an alkali earth metal from an N type charge generation layer to a P type charge generation layer is prevented. Further, the phenanthroline moiety is substituted with an aromatic ring such as at least one aryl group or a hetero aryl group Ar_1 . Accordingly, a thermal stability as well as transporting property of an electron are improved in the organic compound according to the present disclosure.

[0024] In an exemplary embodiment, each of R_1 to R_6 may be independently one of hydrogen, deuterium, tritium, a

non-substituted or substituted alkyl group of C1 to C20, a non-substituted or substituted alkoxy group of C1 to C20.

[0025] In the chemical formula 1, each of Ar₁ and Ar₂ may be independently one of a non-substituted or substituted aryl group and a non-substituted or substituted hetero aryl group. In an exemplary embodiment, each of R₁ and R₂ may include a non-substituted or substituted aromatic ring. For example, each of Ar₁ and Ar₂ may be independently one of a non-substituted or substituted phenyl, biphenyl, terphenyl, naphthalene, anthracene, indene, indenoidene, heptalenyl, biphenylenyl, indacenyl, phenalenyl, phenanthrenyl, benzophenanthrenyl, dibenzophenanthrenyl, azulenyl, pyrenyl, fluoranthrenyl, triphenylenyl, chrysenyl, tetraphenyl, fluoroanthrenyl, tetracenyl, pleiadenyl, picenyl, pentaphenyl, pentacenyl, fluorenyl, indenofluorenyl, diazafluorenyl, or a non-fused or fused homo aryl such as spirofluorenyl and/or pyrolyl, pyridinyl, terpyridinyl, phenylpyridinyl, pyrimidinyl, pyridazinyl, triazinyl, tetrazinyl, imidazolyl, pyrazolyl, indolyl, isoindolyl, indazolyl, indoliziny, pyroliziny, carbazolyl, benzocarbazolyl, dibenzocarbazolyl, indolocarbazolyl, indenocarbazolyl, benzofurocarbazolyl, benzothiocabazolyl, quinolinyl, isoquinolinyl, phthalazinyl, quinoxalinyl, cynolinyl, quinazolinyl, quinoxolinyl, quinoliziny, furyl, benzoquinolinyl, benzoisoquinolinyl, benzoquinazolinyl, benzoquinoxalinyl, acridinyl, phenanthrolinyl, phenanthrenyl, pyrimidinyl, phenanthridinyl, pteridinyl, naphthylridinyl, naphtharidinyl, furanyl, pyranyl, oxazinyl, oxazolyl, oxadiazolyl, triazolyl, dioxinyl, benzofuranyl, dibenzofuranyl, arylthiazolyl, thiopyranyl, xanthenyl, chromenyl, isochromenyl, thioazinyl, thiophenyl, benzothiophenyl, dibenzothiophenyl, carbolinyl, difuopyrazinyl, benzofurodibenzofuranyl, benzothiodibenzofuranyl, or a non-fused or fused hetero aryl such as N-substituted spiro fluorenyl.

[0026] For example, each of Ar₁ and Ar₂ may be independently selected from a group including phenyl, alkylphenyl, biphenyl, alkylbiphenyl, halophenyl, alkoxyphenyl, haloalkoxyphenyl, cyanophenyl, silylphenyl, naphthyl, alkyl naphthyl, halonaphthyl, cyanonaphthyl, silylnaphthyl, phenyl naphthyl, pyridyl, alkylpyridyl, halopyridyl, cyanopyridyl, alkoxy pyridyl, silylpyridyl, phenylpyridyl, pyrimidyl, halopyrimidyl, cyanopyrimidyl, alkoxy pyrimidyl, phenylpyrimidyl, quinolinyl, isoquinolinyl, phenylquinolinyl, quinoxalinyl, pyrazinyl, quinazolinyl, naphthylridinyl, benzothiophenyl, benzofuranyl, dibenzothiophenyl, arylthiazolyl, dibenzofuranyl, fluorenyl, carbazolyl, imidazolyl, carbolinyl, phenanthrenyl, terphenyl, terpyridinyl, phenylterpyridinyl, triphenylenyl, fluoranthrenyl and diazafluorenyl.

[0027] In an exemplary embodiment, Ar₁ is a homo aryl group such as a substituted or non-substituted phenyl, biphenyl and naphthyl, and Ar₂ is a homo aryl group such as a substituted or non-substituted phenyl, naphthyl, anthracenyl, phenalenyl, phenanthrenyl, pyrenyl, triphenylenyl, chrysenyl, fluoranthrenyl, fluorenyl, diphenylfluorenyl and spirofluorenyl, or a hetero aryl group such as a substituted or non-substituted pyridyl, pyrazinyl, pyrimidyl, pyridazinyl, triazinyl, quinolinyl, isoquinolinyl, phthalazinyl, quinoxalinyl, cynolinyl, quinazolinyl, quinoxolinyl, quinoliziny and carbazolyl. Although Ar₂ of a hetero aryl group may include one or two of an aromatic ring in an exemplary embodiment, the present disclosure is not limited to that set forth herein.

[0028] In the chemical formula 1, each of L1 and L2 may be independently selected from a group including a non-substituted or substituted phenylene, biphenylene, terphenylene, tetraphenylene, indenylene, naphthylene, azulenylene, indacenylene, acenaphthylene, fluorenylene, spirofluorenylene, phenalenylene, phenanthrenylene, anthracenylene, fluoranthrenylene, triphenylenylene, pyrenylene, chrysenylene, naphthacenylene, picenylene, perylenylene, pentaphenylene, hexacenylene, pyrrolylene, imidazolylene, pyrazolylene, pyridinylene, pyrazinylene, pyrimidinylene, pyridazinylene, isoindolylene, indolylene, indazolylene, purinylene, quinolinylene, isoquinolinylene, benzoquinolinylene, phthalazinylene, naphthylridinylene, quinoxalinylene, quinazolinylene, benzoisoquinolinylene, benzoquinazolinylene, benzoquinoxalinylene, cinnolinylene, phenanthridinylene, acridinylene, phenanthrolinylene, phenazinylene, benzoxazolylene, benzimidazolylene, furanylene, benzofuranylene, thiophenylene, benzothiophenylene, thiazolylene, isothiazolylene, benzothiazolylene, isoxazolylene, oxazolylene, triazolylene, tetrazolylene, oxadiazolylene, arylthiazolylene, triazinylene, dibenzofuranylene, dibenzothiophenylene, carbazolylene, benzocarbazolylene, dibenzocarbazolylene, indolocarbazolylene, indenocarbazolylene, imidazopyrimidinylene and imidazopyridinylene.

[0029] For example, each of L1 and L2 may be independently selected from a group including phenylene, alkylphenylene, cyanophenylene, naphthylene, alkyl naphthylene, biphenylene, alkylbiphenylene, anthracenylene, triphenylene, pyrenylene, benzothiophenylene, benzofuranylene, dibenzothiophenylene, arylthiazolylene, dibenzofuranylene, fluorenylene and triphenylenylene.

[0030] Each of L1 and L2 may be one of non-substituted or substituted with alkyl, cyano and halogen phenylene, biphenylene and naphthalene.

[0031] The organic compound represented by the chemical formula 1 may include a phenanthroline moiety substituted with at least one aromatic ring. Since the organic compound has a relatively high decomposition temperature or a relatively high glass transition temperature due to the phenanthroline moiety, the organic compound has an excellent thermal stability. As a result, the organic compound may not be deteriorated or spoiled even by a Joule's heat generated from driving of an element. Accordingly, a lifetime of an LED including the organic compound is extended and a driving voltage of the LED including the organic compound is reduced.

[0032] Further, since the organic compound represented by the chemical formula 1 includes a phenanthroline moiety having a nitrogen atom of a hybrid orbital of sp² of sufficient electrons, the organic compound has an excellent electron transporting property. As a result, the organic compound may be used for an electron transporting layer to efficiently supply an electron to an emitting material layer. Specifically, a nitrogen atom of a phenanthroline moiety is combined

with an alkali metal or an alkali earth metal of a dopant of an N type charge generation layer to form a gap state. As a result, an energy level difference between an N type charge generation layer and a P type charge generation layer is alleviated. Since the injection of an electron into the N type charge generation layer is improved, the electron transporting property from the N type charge generation layer to an adjacent electron transporting layer may be maximized.

[0033] In addition, the compound having a nitrogen atom is combined with an alkali metal or an alkali earth metal in an N type charge generation layer to prevent the alkali metal or the alkali earth metal from diffused into a P type charge generation layer. As a result, reduction of a lifetime of an LED is prevented.

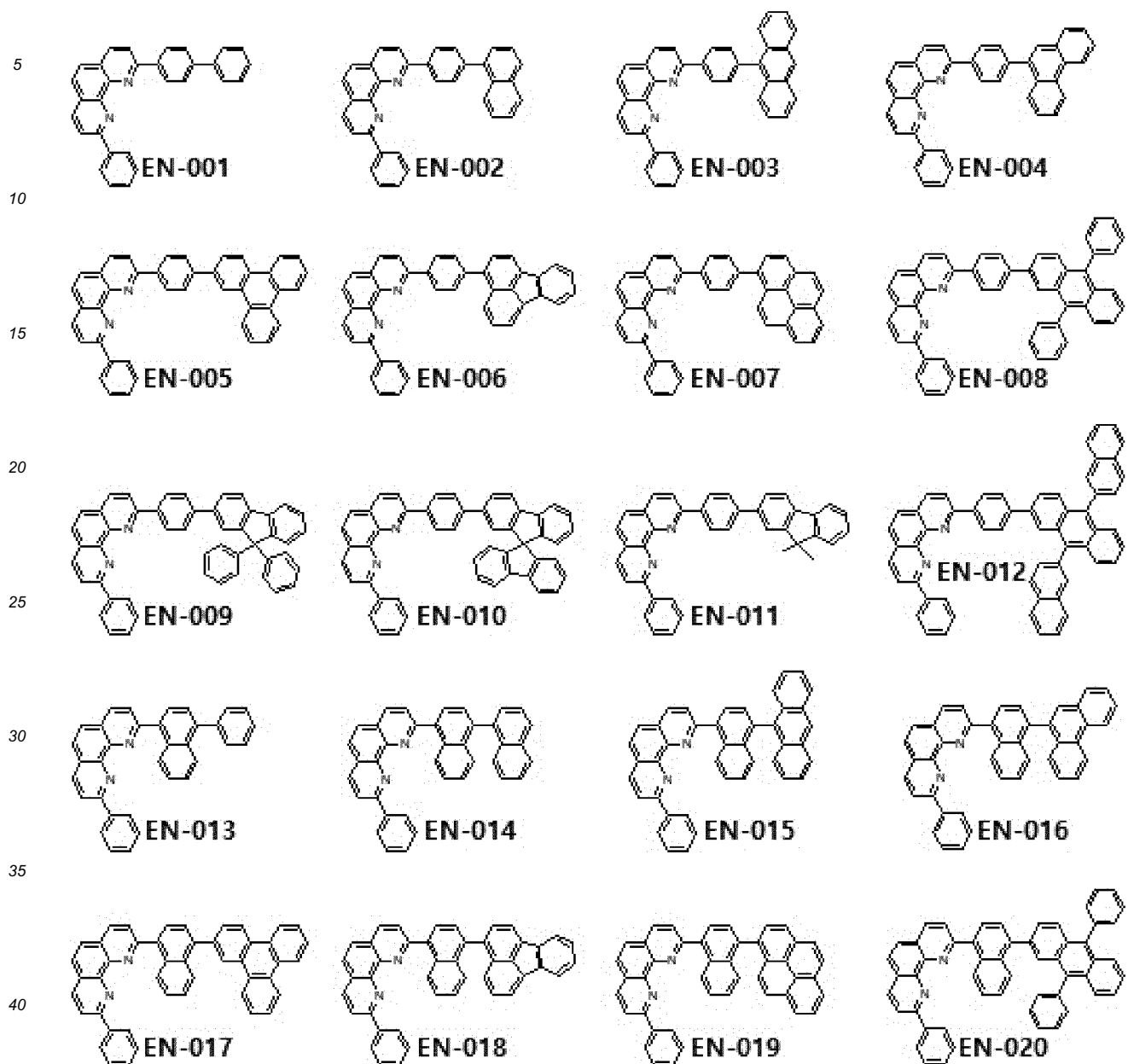
[0034] Preferably, each of L1 and L2 is independently selected from a group including phenylene, alkylphenylene, cyanophenylene, naphthylene, alkylnaphthylene, biphenylene, alkylbiphenylene, anthracenylene, triphenylene, pyrenylene, benzothiophenylene, benzofuranylene, dibenzothiophenylene, arylthiazolyene, dibenzofuranylene, fluorenylene and triphenylenylene. More preferably, each of L1 and L2 is independently selected from non-substituted phenylene, biphenylene, naphthylene, and anthracenylene,

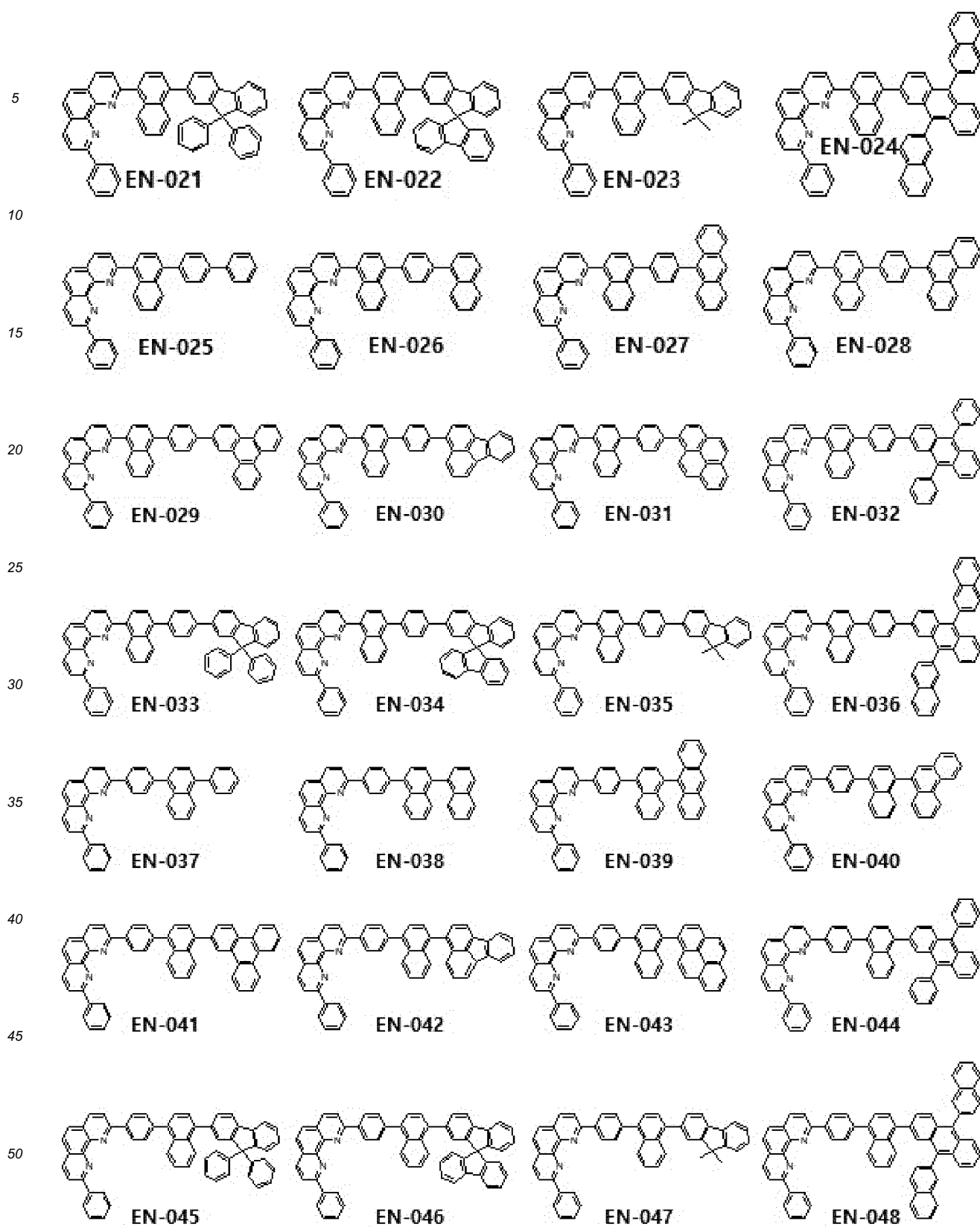
[0035] Preferably, each of Ar1 and Ar2 is independently selected from a group including phenyl, alkylphenyl, biphenyl, alkylbiphenyl, halophenyl, alkoxyphenyl, haloalkoxyphenyl, cyanophenyl, silylphenyl, naphthyl, alkylnaphthyl, halonaphthyl, cyanonaphthyl, silylnaphthyl, phenylnaphthyl, pyridyl, alkylpyridyl, halopyridyl, cyanopyridyl, alkoxyppyridyl, silylpyridyl, phenylpyridyl, pyrimidyl, halopyrimidyl, cyanopyrimidyl, alkoxyppyrimidyl, phenylpyrimidyl, quinolinyl, isoquinolinyl, phenylquinolinyl, quinoxalinyl, pyrazinyl, quinazolinyl, naphthyridinyl, benzothiophenyl, benzofuranyl, dibenzothiophenyl, arylthiazolyl, dibenzofuranyl, fluorenyl, carbazoyl, imidazolyl, carbolinyl, phenanthrenyl, terphenyl, terpyridinyl, phenylterpyridinyl, triphenylenyl, fluoranthenyl and diazafluorenyl. Preferably, Ar1 is selected from a group including phenyl, alkylphenyl, biphenyl, alkylbiphenyl. More preferably, Ar1 is phenyl. Preferably, Ar2 is a homo aryl group selected from a substituted or non-substituted phenyl, naphthyl, anthracenyl, phenanthrenyl, triphenylenyl, fluoranthenyl, fluorenyl, diphenylfluorenyl and spirofluorenyl, or a hetero aryl group selected from a substituted or non-substituted pyridyl, pyrazinyl, pyrimidyl, pyridazinyl, triazinyl, quinolinyl, isoquinolinyl, phthalazinyl, quinoxalinyl, cynolinyl, quinazolinyl, quinoxolinyl, quinoliziny and carbazolyl. More preferably, Ar2 is a homo aryl group selected from non-substituted phenyl, naphthyl, anthracenyl, phenanthrenyl, or a hetero aryl group selected from a substituted or non-substituted pyridyl, pyrazinyl, pyrimidyl, pyridazinyl, triazinyl, quinolinyl, isoquinolinyl, wherein the substitution is preferably a phenyl, bisphenyl or naphthyl.

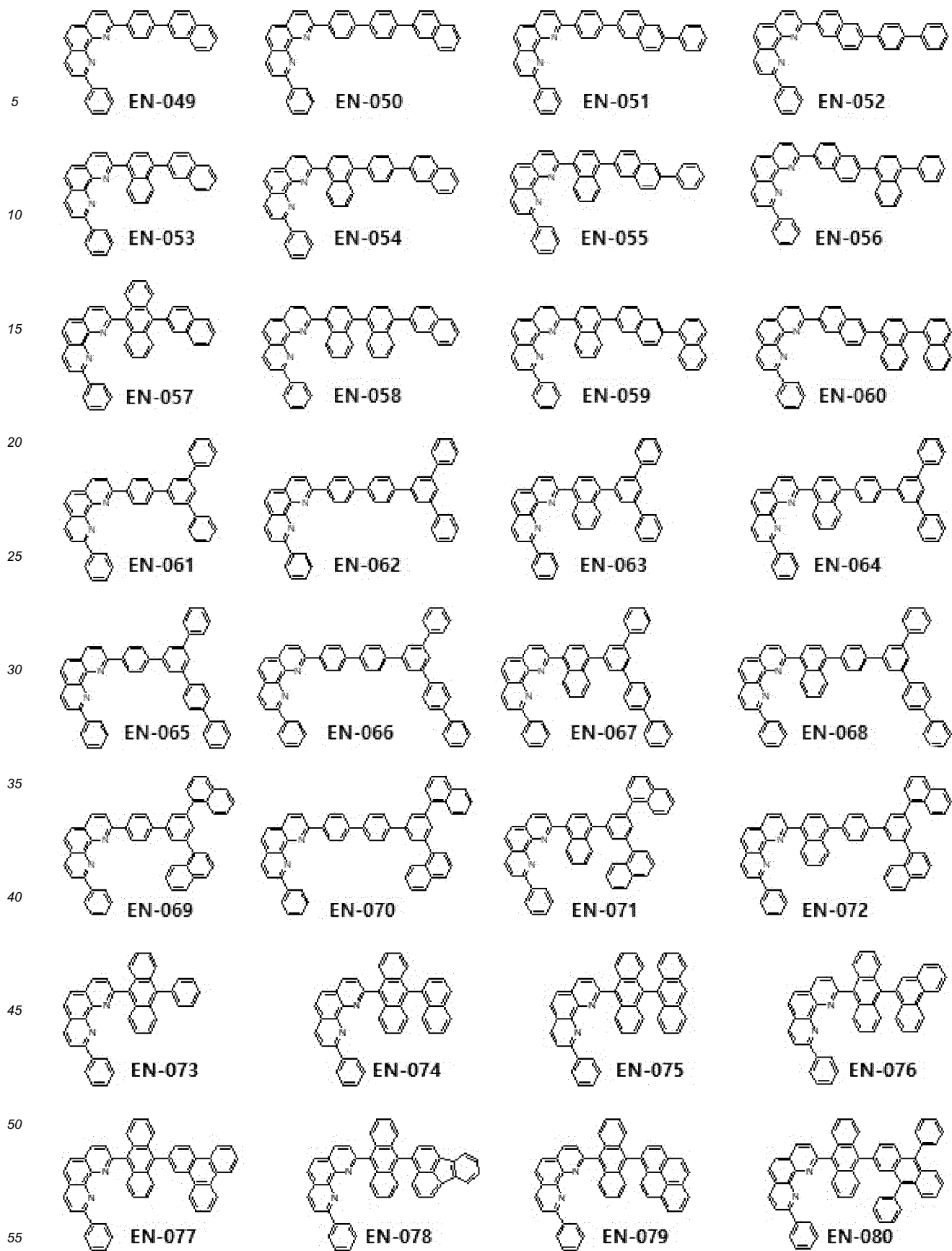
[0036] Preferably, each of R₁ to R₆ is hydrogen.

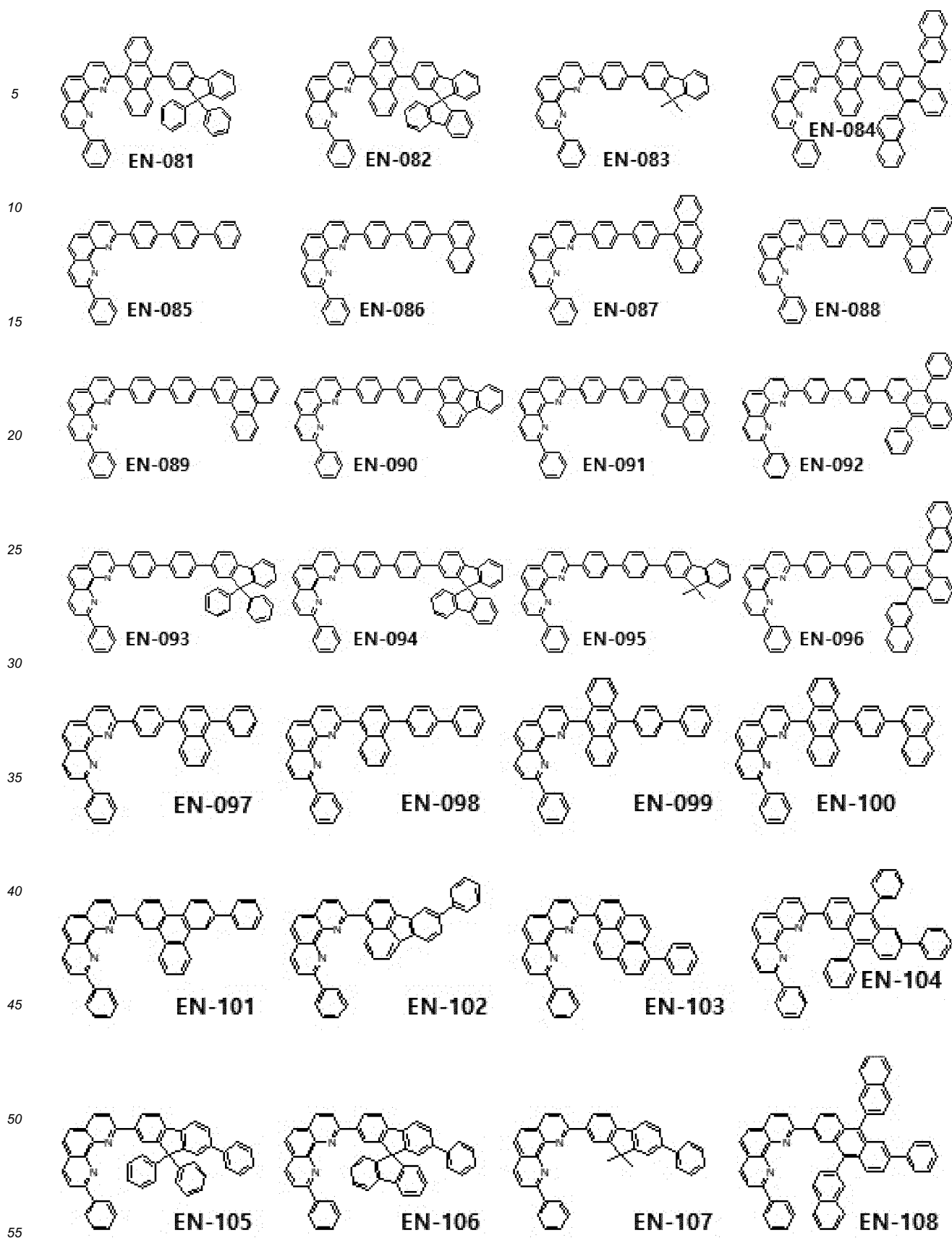
[0037] More preferably, each of R₁ to R₆ is hydrogen and Ar₁ is phenyl.

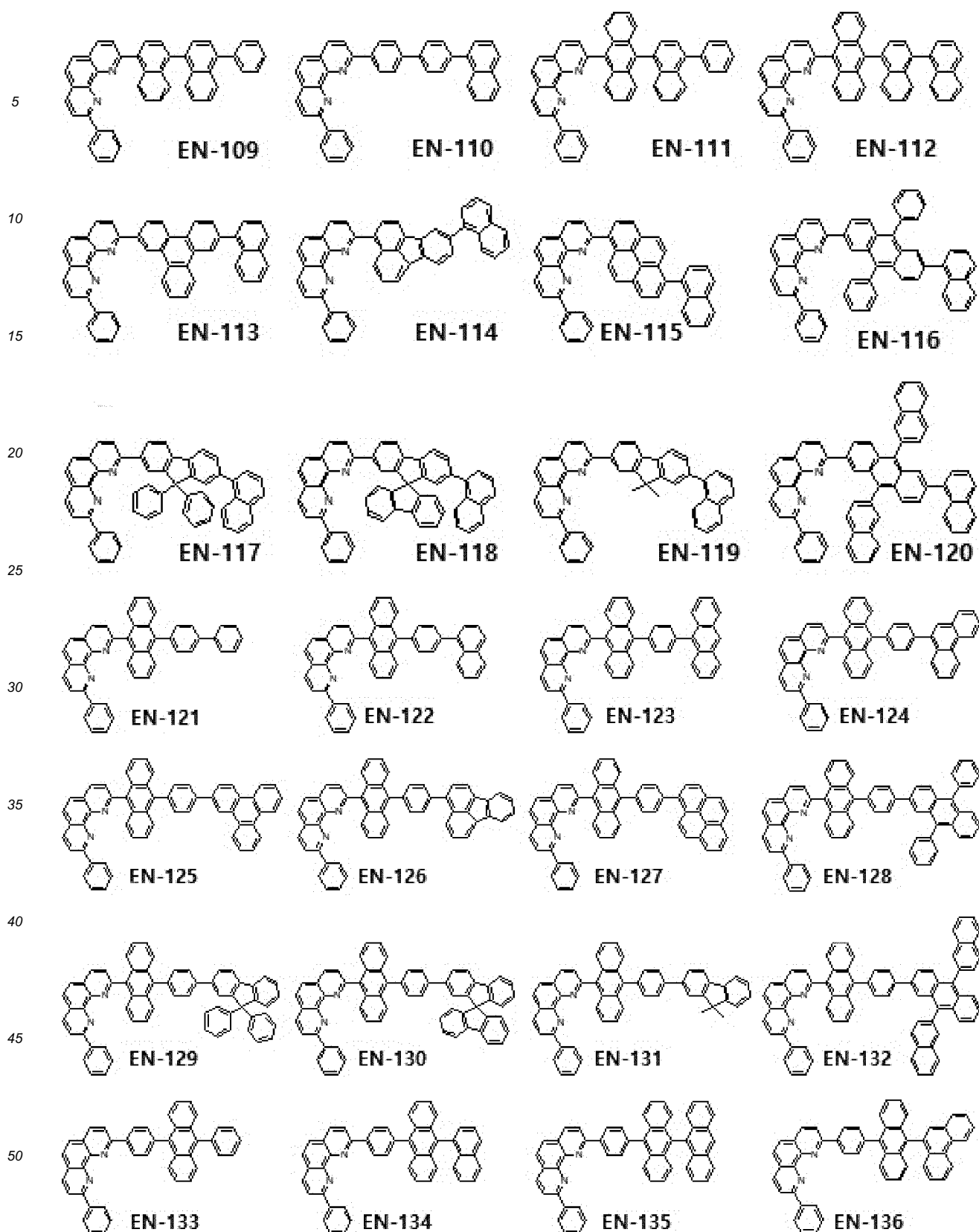
[0038] In an exemplary embodiment, an organic compound represented by the chemical formula 1 may be one of compounds represented by a following chemical formula 2.

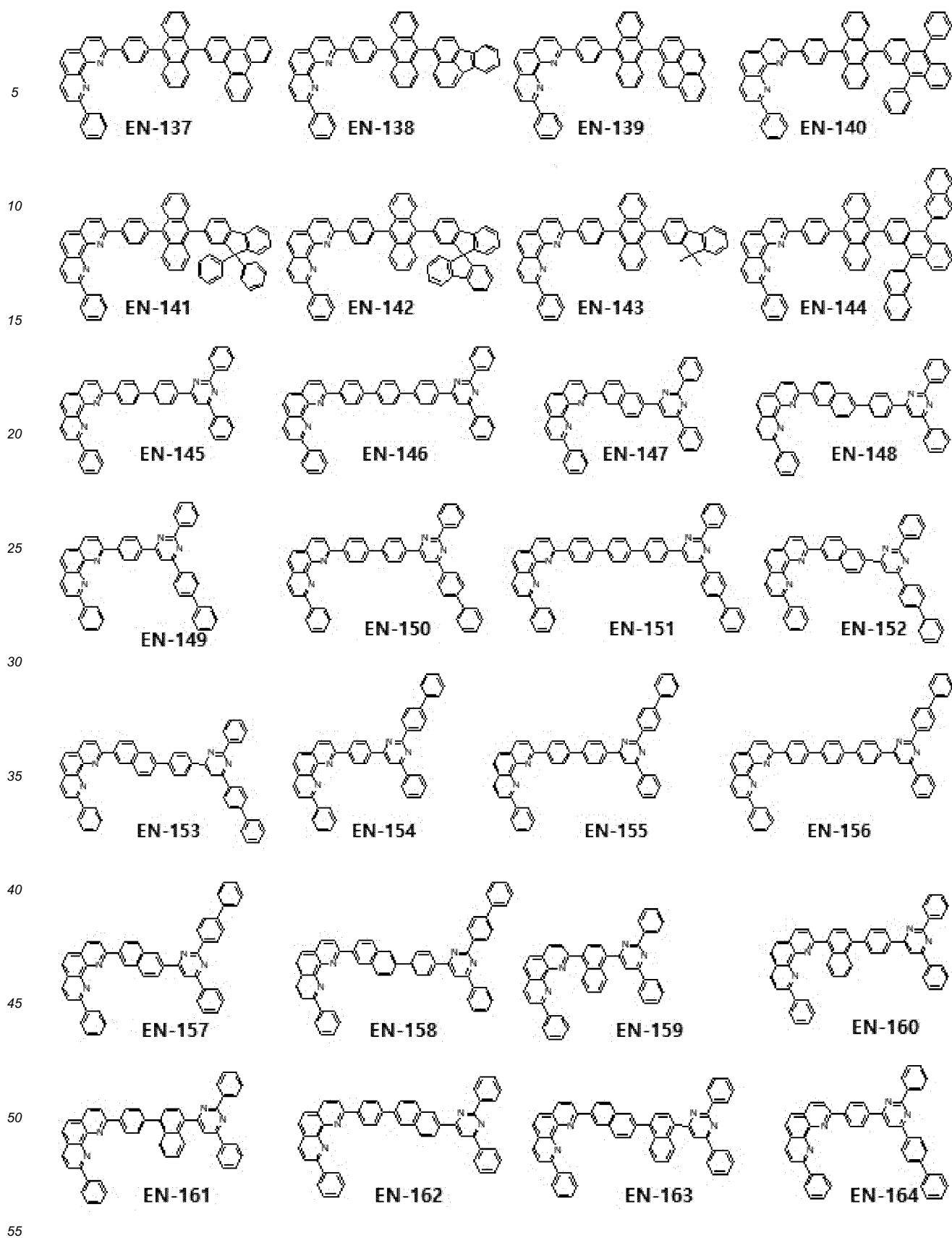
Chemical Formula 2

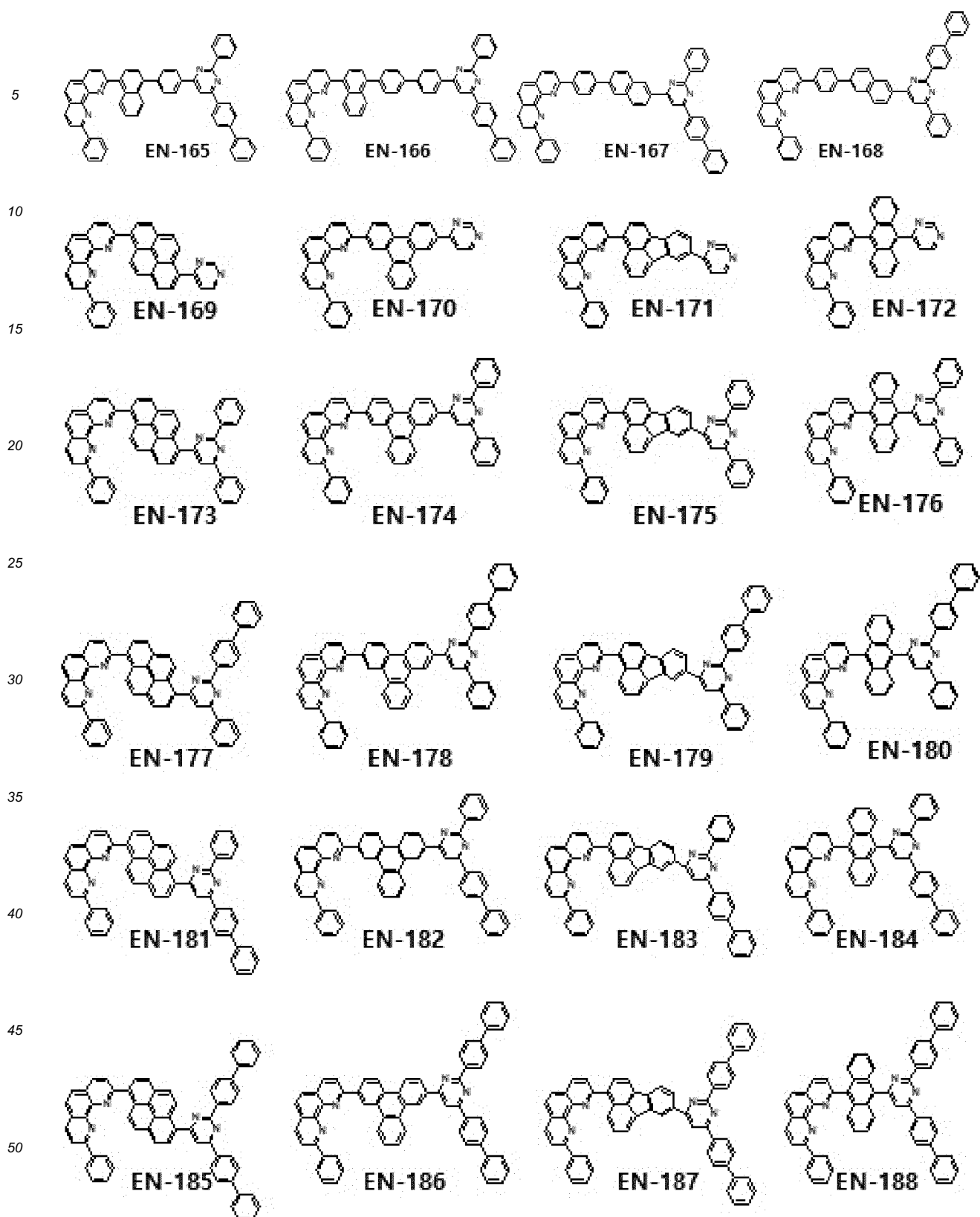


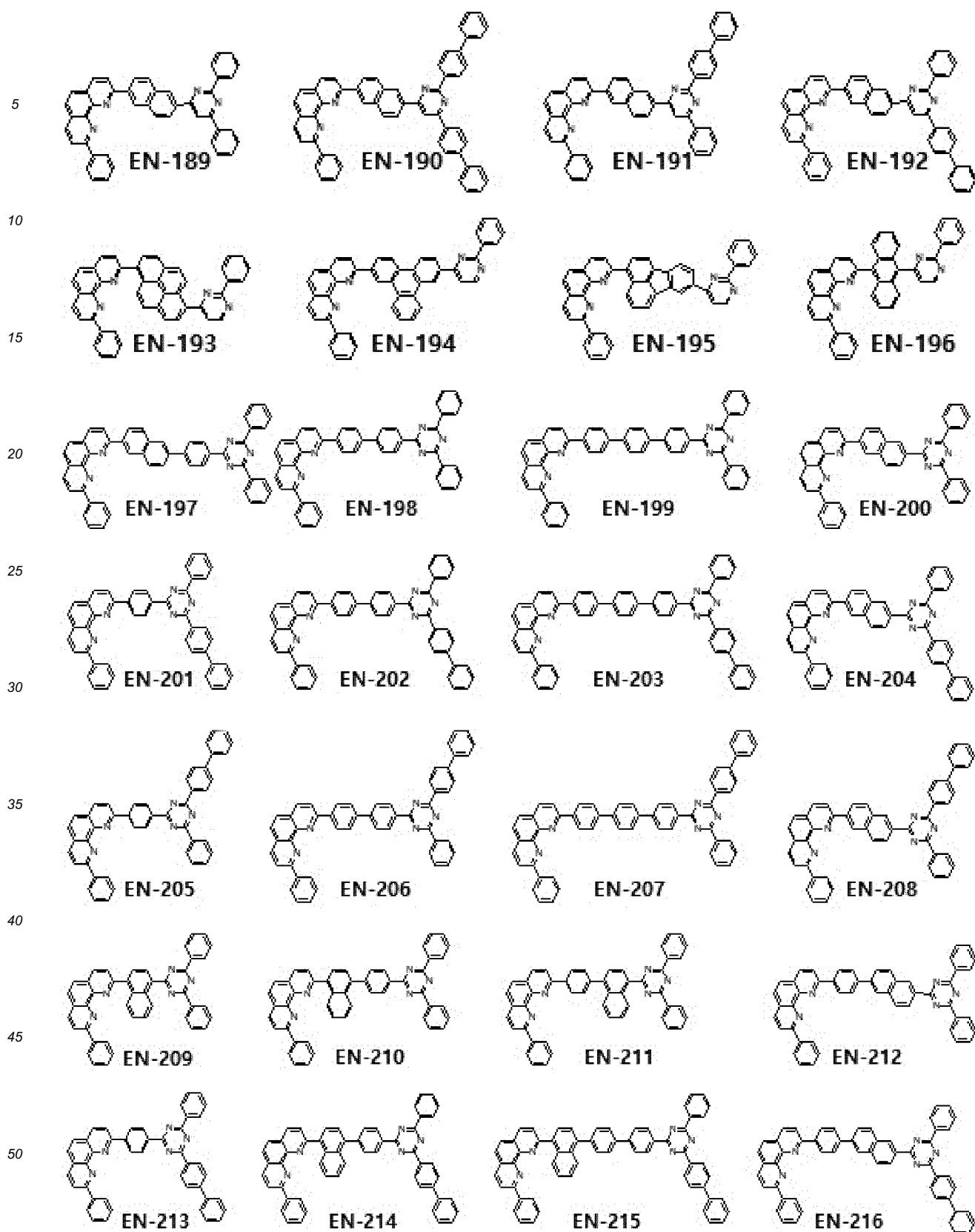


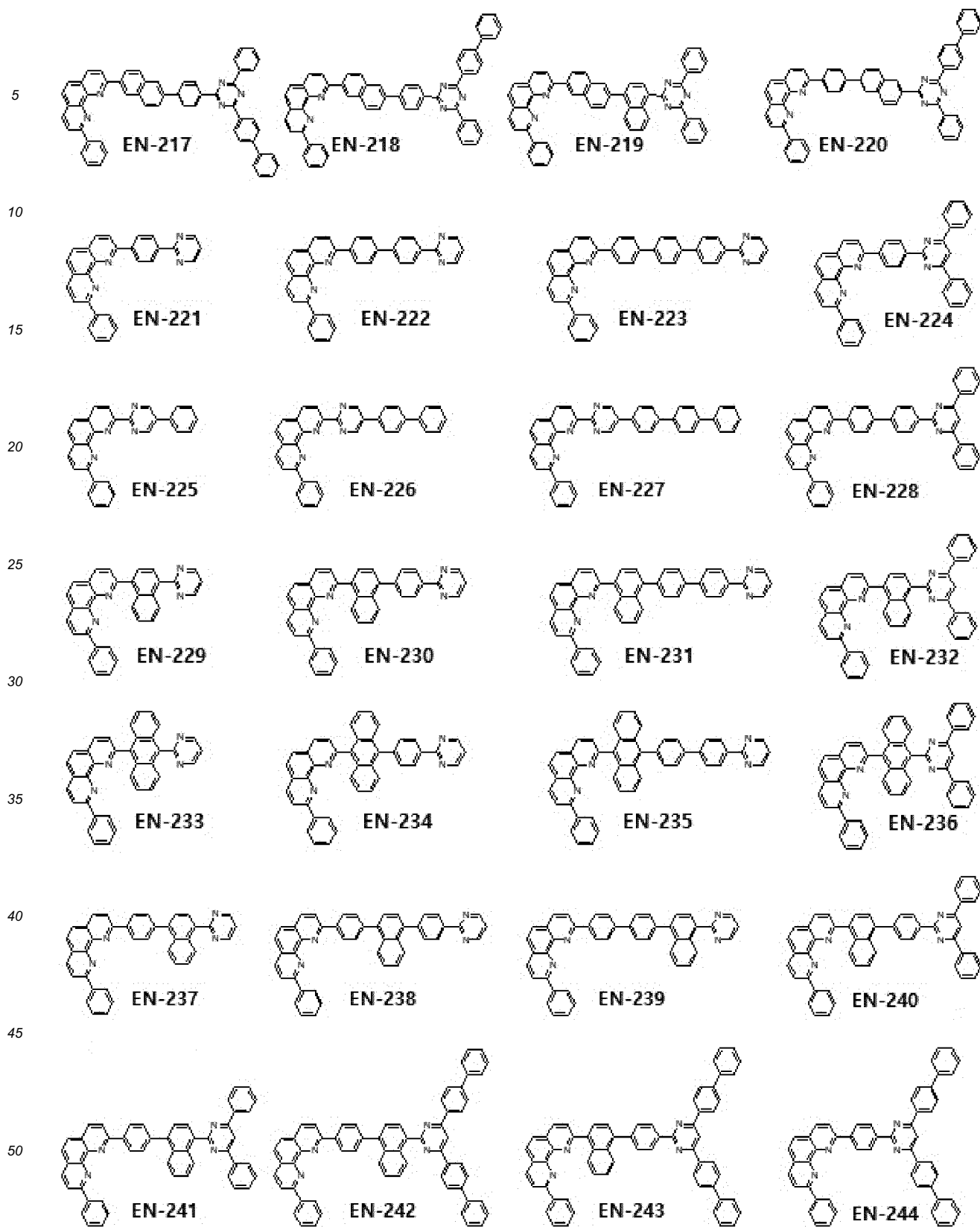


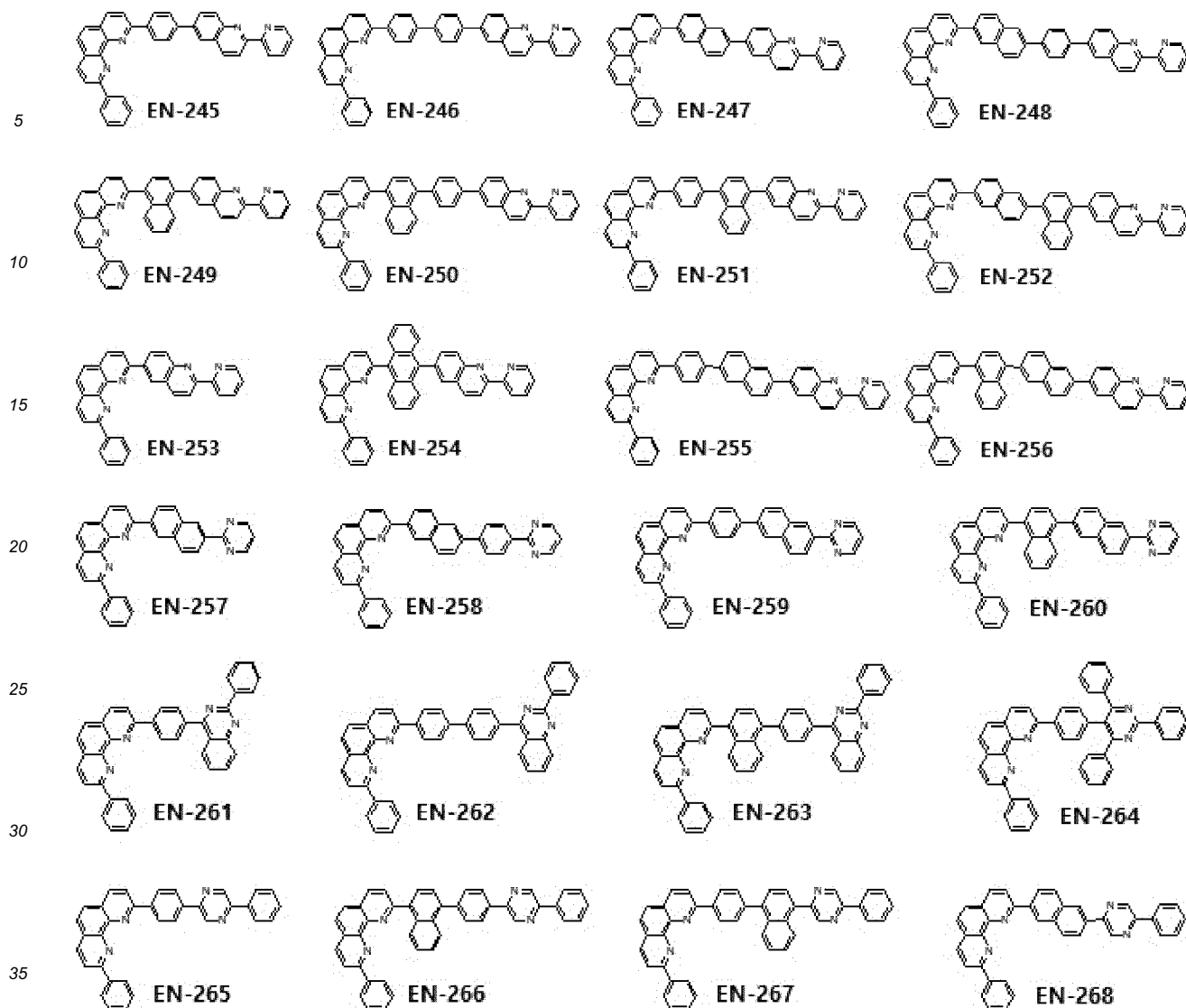












[0039] Since the organic compound represented by the chemical formula 2 includes a phenanthroline substituted with an aromatic ring, a thermal stability, an electron transporting property and an electron moving property are improved as compared with a compound which is not substituted with an aromatic ring. Since the organic compound represented by the chemical formula 2 is applied to an N type charge generation layer of an LED having a tandem structure, the LED has an extended lifetime, a reduced driving voltage and an improved emission efficiency.

[Light Emitting Diode And Display Device]

[0040] Since the organic compound represented by the chemical formulas 1 and 2 includes a phenanthroline moiety substituted with an aromatic ring, the organic compound has an excellent electron transporting property and an excellent thermal stability. As a result, an LED may have a reduced driving voltage, an improved emission efficiency and an extended lifetime by applying the organic compound represented by the chemical formulas 1 and 2 to an electron transporting layer and/or a charge generation layer of the LED having a tandem structure.

[0041] FIG. 1 is a cross-sectional view showing a light emitting diode of a tandem structure having two emitting parts according to a first embodiment of the present disclosure.

[0042] In FIG. 1, a light emitting diode (LED) 100 according to a first embodiment of the present disclosure includes first and second electrodes 110 and 120 spaced apart from each other and an organic emitting layer 130 between the first and second electrodes 110 and 120. The organic emitting layer 130 includes a first emitting part (ST1) 140 between the first and second electrodes 110 and 120, a second emitting part (ST2) 150 between the first emitting part 140 and the second electrode 120 and a charge generation layer (CGL) 160 between the first and second emitting parts 140 and 150. The first emitting part 140 includes a first emitting material layer (lower emitting material layer) 144, and the second

emitting part 150 includes a second emitting material layer (upper emitting material layer) 154.

[0043] The first electrode 110 may be an anode where a hole is injected and may include a material having a relatively high work function. For example, the first electrode 110 may include a transparent conductive material such as indium tin oxide (ITO), indium zinc oxide (IZO) and zinc oxide (ZO). The second electrode 120 may be a cathode where an electron is injected and may include a material having a relatively low work function. For example, the second electrode 120 may include a metallic material such as aluminum (Al), magnesium (Mg) and aluminum magnesium (AlMg) alloy.

[0044] The first emitting part 140 may include a hole injecting layer 141 between the first electrode 110 and the first emitting material layer 144, a first hole transporting layer 142 between the hole injecting layer 141 and the first emitting material layer 144 and a first electron transporting layer (lower electron transporting layer) 146 between the first emitting material layer 144 and the charge generation layer 160.

[0045] The hole injecting layer 141 may improve an interface property between the first electrode 120 of an inorganic material and the first hole transporting layer 142 of an organic material. For example, the hole injecting layer 141 may include one of 4,4',4"-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), copper phthalocyanine (CuPc), tris(4-carbazoyl-9-ylphenyl)amine (TCTA), N,N'-di(naphthalen-1-yl)-N,N'-diphenylbenzidine(NPB), N,N'-diphenyl-N,N'-bis(1-naphthyl)-1,1'-biphenyl-4,4"-diamine (NPD), 1,4,5,8,9,11-hexaazatriphenylenehexacarbonitrile (HATCN), poly(3,4-ethylenedioxythiophene)polystyrene sulfonate(PEDOT/PSS) 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ) and/or N-(biphenyl-4-yl)-9,9-dimethyl-N-(4-(9-phenyl-9H-carbazol-3-yl)phenyl)-9H-fluorene-2-amine.

[0046] For example, the hole injecting layer 141 may have a thickness of about 1nm to about 150nm. A hole injecting property is improved when the thickness of the hole injecting layer 141 is equal to or greater than about 1nm, and an increase of a driving voltage due to an increase of the thickness is prevented when the thickness of the hole injecting layer 141 is equal to or smaller than about 150nm. The hole injecting layer 141 may be omitted in another embodiment.

[0047] The first hole transporting layer 142 is disposed between the hole injecting layer 141 and the first emitting material layer 144, the first emitting material layer 144 is disposed between the first hole transporting layer 142 and the first electron transporting layer 146, and the first electron transporting layer 146 is disposed between the first emitting material layer 144 and the charge generation layer 160.

[0048] The second emitting part 150 may include a second hole transporting layer (upper hole transporting layer) 152, a second emitting material layer (upper emitting material layer) 154, a second electron transporting layer (upper electron transporting layer) 156 and an electron injecting layer 158. The second hole transporting layer 152 is disposed between the charge generation layer 160 and the second emitting material layer 154, and the second emitting material layer 154 is disposed between the second hole transporting layer 152 and the second electrode 120. Further, the second electron transporting layer 156 is disposed between the second emitting material layer 154 and the second electrode 120, and the electron injecting layer 158 is disposed between the second electron transporting layer 156 and the second electrode 120.

[0049] Each of the first and second hole transporting layers 142 and 152 may include one of N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), NPD, MTDATA, 1,3-bis(N-carbazolyl)benzene (mCP), CuPC, TCTA, tris(trifluorovinyl ether)-tris(4-carbazoyl-9-yl-phenyl)amine (TFV-TCTA), tris[4-(diethylamino)phenyl]amine, N-(biphenyl-4-yl)-9,9-dimethyl-N-(4-(9-phenyl-9H-carbazol-3-yl)phenyl)-9H-fluorene-2-amine, tri-p-tolylamine, N-[1,1'-biphenyl]-4-yl-9,9-dimethyl-N-[4-(9-phenyl-9H-carbazol-3-yl)phenyl]-amine, 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP) and/or 1,1-bis(4-(N,N'-di(ptolyl)amino)phenyl)cyclohexane (TAPC).

[0050] For example, each of the first and second hole transporting layers 142 and 152 may have a thickness of about 1nm to about 150nm. A hole transporting property is improved when the thickness of each of the first and second hole transporting layers 142 and 152 is equal to or greater than about 1nm, and an increase of a driving voltage due to an increase of the thickness is prevented when the thickness of the first and second hole transporting layers 142 and 152 is equal to or smaller than about 150nm. The first and second hole transporting layers 142 and 152 may include the same material or may include different materials.

[0051] In an exemplary embodiment, the first and second emitting material layers 144 and 154 may include a host doped with a dopant and may emit different colors. The dopant may be added to the host with a ratio of about 1wt% to about 30wt%.

[0052] For example, the first emitting material layer 144 may emit a blue (B), red (R), green (G) or yellow (Y) light. When the first emitting material layer 144 is a blue emitting layer, the first emitting material layer 144 may include one of a blue emitting material layer, a dark blue emitting material layer and a sky blue emitting material layer. Alternatively, the first emitting material layer 144 may include one of a blue emitting material layer and a red emitting material layer, a blue emitting material layer and a yellow-green emitting material layer, and a red emitting material layer and a green emitting material layer.

[0053] The second emitting material layer may include one of a red emitting material layer, a green emitting material layer, a blue emitting material layer and a yellow-green emitting material layer. In an exemplary embodiment, the first emitting material layer 144 may emit a blue light, and the second emitting material layer 154 may emit a green light, a yellow-green light or an orange light having a wavelength longer than a blue light.

[0054] For example, when the first emitting material layer 144 emits a blue light, the first emitting material layer 144 may include at least one fluorescent host material selected from a group including anthracene and derivatives thereof, pyrene and derivatives thereof, and perylene and derivatives thereof doped with a fluorescent dopant.

[0055] A blue fluorescent host material for the first emitting material layer 144 may include one of 4,4'-bis(2,2'-diphenylvinyl)-1,1'-biphenyl (DPVBi), 9,10-di-(2-naphthyl)anthracene (ADN), 2,5,8,11-tetra-*t*-butylperylene (TBADN), 2-*tert*-butyl-9,10-di(2-naphthyl)anthracene, 2-methyl-9,10-di(2-naphthyl)anthracene (MADN) and/or 2,2',2''-(1,3,5-benzinetriyl)-tris(1-phenyl-1-*H*-benzimidazole (TBPI)).

[0056] A blue fluorescent dopant material for the first emitting material layer 144 may include one of 4,4'-bis(9-ethyl-3-carbazovinylene)-1,1'-biphenyl (BCzVBi) and/or diphenyl-[4-(2-[1,1;4,1]terphenyl-4-yl-vinyl)-phenyl]-amine (BD-1) and may include one selected from a group including spiro-DPVBi, spiro-CBP, distyrylbenzene (DSB) and derivatives thereof, distyryl arylene (DSA) and derivatives thereof, polyfluorene (PF) polymer and polyphenylene vinylene (PPV) polymer. Alternatively, a blue dopant may include an iridium dopant as a phosphorescent dopant. Here, the first emitting material layer 144 may include a sky blue emitting material layer or a deep blue emitting material layer as well as a blue emitting material layer. The light emitted from the first emitting material layer 144 may have a wavelength of about 440nm to about 480nm.

[0057] When the first emitting material layer 144 emits a green light, the first emitting material layer 144 may be a phosphorescent emitting material layer including a host such as CBP and a dopant of an iridium group (e.g., $\text{dp}_2\text{Ir}(\text{acac})$, $\text{op}_2\text{Ir}(\text{acac})$). However, the first emitting material layer 144 is not limited to that set forth herein. Alternatively, the first emitting material layer 144 may be a fluorescent emitting material layer including tris(8-hydroxyquinolato)aluminum (Alq). Here, the light emitted from the first emitting material layer 144 may have a wavelength of about 510nm to about 570nm.

[0058] When the first emitting material layer 144 emits a red light, the first emitting material layer 144 may be a phosphorescent emitting material layer including a host such as CBP and a dopant of one selected from a group including bis(1-phenylisoquinoline)acetylacetonate iridium ($\text{PIQIr}(\text{acac})$), bis(1-phenylquinoline)acetylacetonate iridium ($\text{PQIr}(\text{acac})$) and octaethylporphyrin platinum (PtOEP). However, the first emitting material layer 144 is not limited to that set forth herein.

[0059] Alternatively, the first emitting material layer 144 may be a fluorescent emitting material layer including 1,3,4-oxadiazole:tris(dibenzoylmethane)mono(1,10-phenanthroline)europium(III) (PBD:Eu(DBM)3(Phen)), perylene and derivatives thereof. The light emitted from the first emitting material layer 144 may have a wavelength of about 600nm to about 650nm.

[0060] When the first emitting material layer 144 emits a yellow light, the first emitting material layer 144 may have a single layered structure of a yellow-green emitting material layer or a double layered structure of a yellow-green emitting material layer and a green emitting material layer. For example, a yellow emitting material layer for the first emitting material layer 144 may have at least one host selected from CBP and bis(2-methyl-8-quinolinate)-4-(phenylphenolato)aluminum (BALq) and a yellow-green phosphorescent dopant. Here, the light emitted from the first emitting material layer 144 may have a wavelength of about 510nm to about 590nm.

[0061] In an exemplary embodiment, to increase a red efficiency of the LED 100 having a tandem structure, the first emitting material layer 144 may include two emitting material layers, for example, a pair of a yellow-green emitting material layer and a red emitting material layer or a pair of a blue emitting material layer and a red emitting material layer.

[0062] When the second emitting material layer 154 is a yellow-green emitting material layer, the second emitting material layer 154 may have a single layered structure of a yellow-green emitting material layer or a double layered structure of a yellow-green emitting material layer and a green emitting material layer. When the second emitting material layer 154 has a single layered structure of a yellow-green emitting material layer, the second emitting material layer 154 may include at least one host selected from CBP and BALq and a yellow-green phosphorescent dopant. However, the second emitting material layer 154 is not limited to that set forth herein.

[0063] When the second emitting material layer 154 is a yellow emitting material layer, the second emitting material layer 154 may include at least one host selected from CBP and BALq and a yellow phosphorescent dopant.

[0064] Each of the first and second electron transporting layers 146 and 156 may improve an electron transporting in the first and second emitting parts 140 and 150. Each of the first and second electron transporting layers 146 and 156 may include oxadiazole, triazole, phenanthroline, benzoxazole, benzothiazole, benzoimidazole, triazine and derivatives thereof.

[0065] For example, each of the first and second electron transporting layers 146 and 156 may include an electron transporting material such as Alq3, 2-biphenyl-4-yl-5-(4-*t*-butylphenyl)-1,3,4-oxadiazole (PBD), spiro-PBD, lithium quinolate (LiQ), 2-[4-(9,10-Di-2-naphthalenyl-2-anthracenyl)phenyl]-1-phenyl-1H-benzimidazol, 3-(biphenyl-4-yl)-5-(4-*tert*-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), 4,7-diphenyl-1,10-phenanthroline (Bphen), tris(phenylquinoxaline (TPQ), 1,3,5-Tri[(3-pyridyl)-phen-3-yl]benzene (TmPyPB) and/or 1,3,5-tris(N-phenylbenzimidazole-2-yl)benzene (TPBI). In addition, each of the first and second electron transporting layers 146 and 156 may include an organic compound represented by the chemical formulas 1 and 2.

[0066] Alternatively, each of the first and second electron transporting layers 146 and 156 may be doped with an alkali metal or an alkali earth metal. The dopant for each of each of the first and second electron transporting layers 146 and 156 may include an alkali metal such as lithium (Li), sodium (Na), potassium (K) and cesium (Cs) and/or an alkali earth metal such as magnesium (Mg), strontium (Sr), barium (Ba) and radium (Ra). However, the dopant for each of the first and second electron transporting layers 146 and 156 is not limited to that set forth herein. The alkali metal or the alkali earth metal may be added with a ratio of about 1wt% to about 20wt%. However, the ratio is not limited to that set forth herein.

[0067] Each of the first and second electron transporting layers 146 and 156 may have a thickness of about 1nm to about 150nm. Decrease of an electron transporting property is prevented when the thickness of each of the first and second electron transporting layers 146 and 156 is equal to or greater than about 1nm, and an increase of a driving voltage due to an increase of the thickness is prevented when the thickness of the first and second electron transporting layers 146 and 156 is equal to or smaller than about 150nm.

[0068] The electron injecting layer 158 may improve an electron injecting property. The electron injecting layer 158 may include an alkali halide material such as lithium fluoride (LiF), sodium fluoride (NaF), potassium fluoride (KF), rubidium fluoride (RbF), cesium fluoride (CsF), francium fluoride (FrF), beryllium fluoride (BeF₂), magnesium fluoride (MgF₂), calcium (CaF₂), barium fluoride (BaF₂) and radium fluoride (RaF₂) and/or an organic material such as lithium quinolate (LiQ), lithium benzoate, sodium stearate, Alq₃, BAlq, PBD, spiro-PBD and TAZ.

[0069] The electron injecting layer 158 may have a thickness of about 0.5nm to about 50nm. Decrease of an electron injecting property is prevented when the thickness of the electron injecting layer 158 is equal to or greater than about 0.5nm, and an increase of a driving voltage due to an increase of the thickness is prevented when the thickness of the electron injecting layer 158 is equal to or smaller than about 50nm.

[0070] In an exemplary embodiment of the present disclosure, to improve a current efficiency in each of the first and second emitting parts 140 and 150 and to improve distribution of charges, the charge generation layer (CGL) 160 is disposed between the first and second emitting parts 140 and 150, and the first and second emitting parts 140 and 150 are connected to each other through the charge generation layer 160. The charge generation layer 160 may include a PN junction charge generation layer where an N type charge generation layer 162 and a P type charge generation layer 164 are adjacently disposed and combined to each other.

[0071] The N type charge generation layer 162 is disposed between the first electron transporting layer 146 and the second hole transporting layer 152, and the P type charge generation layer 164 is disposed between the N type charge generation layer 162 and the second hole transporting layer 152. The charge generation layer 160 may supply an electron and a hole to the first and second emitting parts 140 and 150 by generating a charge such as an electron and a hole.

[0072] The N type charge generation layer 162 supplies an electron to the first electron transporting layer 146 of the first emitting part 140, and the first electron transporting layer 146 supplies an electron to the first emitting material layer 144 adjacent to the first electrode 110. The P type charge generation layer 164 supplies a hole to the second hole transporting layer 152 of the second emitting part 150, and the second hole transporting layer 152 supplies a hole to the second emitting material layer 154 adjacent to the second electrode 120.

[0073] The P type charge generation layer 164 may include an organic material doped with a metal or a P type dopant. For example, the metal may include an alloy of one or two selected from a group including aluminum (Al), copper (Cu), iron (Fe), lead (Pb), zinc (Zn), gold (Au), platinum (Pt), tungsten (W), indium (In), molybdenum (Mo), nickel (Ni) and titanium (Ti). The P type dopant may include F4-TCNQ, iodine (I), iron chloride (FeCl₃), iron fluoride (FeF₃) and antimony chloride (SbCl₅), and the host may include at least one selected from a group including NPB, TPD, N,N,N',N'-tetraphthalenyl-benzidine (TNB) and HAT-CN.

[0074] When an electron moves from the N type charge generation layer 162 to the first electron transporting layer 146, a driving voltage of the LED 100 may increase due to difference in a lowest unoccupied molecular orbital (LUMO) energy level between the first electron transporting layer 146 and the N type charge generation layer 162. To solve the above problem, the organic compound represented by the chemical formulas 1 and 2 may be used for the N type charge generation layer 162 and/or the first electron transporting layer 146. Alternatively, the N type charge generation layer 162 may include a metallic compound such as an alkali metal compound or an alkali earth metal compound as a dopant. The alkali metal or the alkali earth metal may be added with a ratio of about 1wt% to about 30wt%. However, the ratio is not limited to that set forth herein.

[0075] An electron injecting property to the N type charge generation layer 162 may be improved by doping the N type charge generation layer 162 with the alkali metal or the alkali earth metal. For example, when the alkali metal or the alkali earth metal is used as a dopant of the N type charge generation layer 162, the alkali metal or the alkali earth metal may combine with the organic compound of the present disclosure to form a gap state. Accordingly, the energy level difference between the N type charge generation layer 162 and the P type charge generation layer 164 is alleviated, and the electron injecting property from the N type charge generation layer 162 to the first electron transporting layer 146 may be improved.

[0076] The organic compound of the present disclosure includes a phenanthroline moiety substituted with at least one aromatic ring. Since the organic compound has a relatively high decomposition temperature or a relatively high glass

transition temperature due to the phenanthroline moiety, the organic compound has an excellent thermal stability. As a result, the organic compound may not be deteriorated or spoiled even by a Joule's heat generated from driving of an element. Accordingly, a lifetime of the LED 100 including the organic compound is extended and a driving voltage of the LED 100 including the organic compound is reduced.

[0077] Further, since the organic compound of the present disclosure includes a phenanthroline moiety having a nitrogen atom of a hybrid orbital of sp^2 of sufficient electrons, the organic compound has an excellent electron transporting property. As a result, the organic compound may be used for the electron transporting layers 146 and 156 and/or the charge generation layer 160.

[0078] Specifically, a nitrogen atom of a phenanthroline moiety is combined with the alkali metal or the alkali earth metal of the dopant of the N type charge generation layer to form a gap state. As a result, the energy level difference between the N type charge generation layer and the P type charge generation layer is alleviated. Since the injection of an electron into the N type charge generation layer is improved, the electron transporting property to the electron transporting layer adjacent to the N type charge generation layer may be maximized.

[0079] An electron may be efficiently transmitted from the N type charge generation layer 162 to the first electron transporting layer 146 by applying the organic compound represented by the chemical formulas 1 and 2 to the N type charge generation layer 162.

[0080] Further, since the compound including a nitrogen atom is combined with the alkali metal compound or the alkali earth metal compound of the N type charge generation layer, diffusion of the alkali metal compound or the alkali earth metal compound to the P type charge generation layer is prevented. Accordingly, reduction of a lifetime of the LED is prevented.

[0081] FIG. 2 is a cross-sectional view showing a light emitting diode of a tandem structure having three emitting parts according to a second embodiment of the present disclosure.

[0082] In FIG. 2, a light emitting diode (LED) 200 according to a second embodiment of the present disclosure includes first and second electrodes 210 and 220 facing and spaced apart from each other and an organic emitting layer 230 between the first and second electrodes 210 and 220. The organic emitting layer 230 includes a first emitting part (ST1) 240, a second emitting part (ST2) 250, a third emitting part (ST3) 270, a first charge generation layer (CGL1) 260 and a second charge generation layer (CGL2) 280. At least four emitting parts and at least three charge generation layers may be disposed between the first and second electrodes 210 and 220 in another embodiment.

[0083] The first electrode 210 may be an anode where a hole is injected and may include a material having a relatively high work function. For example, the first electrode 210 may include a transparent conductive material such as indium tin oxide (ITO), indium zinc oxide (IZO) and zinc oxide (ZO). The second electrode 220 may be a cathode where an electron is injected and may include a material having a relatively low work function. For example, the second electrode 220 may include a metallic material such as aluminum (Al), magnesium (Mg) and aluminum magnesium (AlMg) alloy.

[0084] The first charge generation layer 260 is disposed between the first and second emitting parts 240 and 250, and the second charge generation layer 280 is disposed between the second and third emitting parts 250 and 270. The first emitting part 240, the first charge generation layer 260, the second emitting part 250, the second charge generation layer 280 and the third emitting part 270 are sequentially formed on the first electrode 210. The first emitting part 240 is disposed between the first electrode 210 and the first charge generation layer 260, the second emitting part 250 is disposed between the first charge generation layer 260 and the second charge generation layer 280, and the third emitting part 270 is disposed between the second electrode 220 and the second charge generation layer 280.

[0085] The first emitting part 240 may include a hole injecting layer 241, a first hole transporting layer 242, a first emitting material layer 244 and a first electron transporting layer 246 on the first electrode 210. The hole injecting layer 241 and the first hole transporting layer 242 are disposed between the first electrode 210 and the first emitting material layer 244. The hole injecting layer 241 is disposed between the first electrode 210 and the first hole transporting layer 242. The first electron transporting layer 246 is disposed between the first emitting material layer 244 and the first charge generation layer 260.

[0086] The hole injecting layer 241, the first hole transporting layer 242, the first emitting material layer 244 and the first electron transporting layer 246 may have the same property as the hole transporting layer 141, the first hole transporting layer 142, the first emitting material layer 144 and the first electron transporting layer 146, respectively, of FIG. 1 and the illustrations thereof is omitted. For example, the first emitting material layer 244 may be a blue (B) emitting material layer, and the light emitted from the first emitting material layer 244 may have a wavelength of about 440nm to about 480nm.

[0087] The second emitting part 250 may include a second hole transporting layer 252, a second emitting material layer 254 and a second electron transporting layer 256. The second hole transporting layer 252 is disposed between the first charge generation layer 260 and the second emitting material layer 254, and the second electron transporting layer 256 is disposed between the second emitting material layer 254 and the second charge generation layer 280.

[0088] The second hole transporting layer 252, the second emitting material layer 254 and the second electron transporting layer 256 may have the same property as the second hole transporting layer 152, the second emitting material

layer 154 and the second electron transporting layer 156, respectively, of FIG. 1 and illustrations thereof is omitted. For example, the second emitting material layer 254 may be a yellow-green (YG) emitting material layer or a yellow emitting material layer, and the light emitted from the second emitting material layer 254 may have a wavelength of about 510nm to about 590nm or of about 460nm to about 510nm.

[0089] The third emitting part 270 may include a third hole transporting layer 272, a third emitting material layer 274, a third electron transporting layer 276 and an electron injecting layer 278. The third hole transporting layer 272 is disposed between the second charge generation layer 280 and the third emitting material layer 274, the third electron transporting layer 276 is disposed between the third emitting material layer 274 and the second electrode 220, and the electron injecting layer 278 is disposed between the third electron transporting layer 276 and the second electrode 220.

[0090] The third hole transporting layer 272, the third electron transporting layer 276 and the electron injecting layer 278 may have the same property as the second hole transporting layer 152, the second electron transporting layer 156 and the electron injecting layer 158, respectively, of FIG. 1 and illustrations thereof is omitted. The third emitting material layer 274 may have the same property as the first emitting material layer 144 or the second emitting material layer 154. For example, the third emitting material layer 274 may be a blue (B) emitting material layer, and the light emitted from the third emitting part 270 may have a wavelength of about 440nm to about 480nm. In another embodiment, the third emitting material layer 274 may be a yellow-green (YG) emitting material layer or a yellow emitting material layer, and the light emitted from the third emitting part 270 may have a wavelength of about 460nm to about 590nm.

[0091] For example, at least one of the first electron transporting layer 246, the second electron transporting layer 256 and the third electron transporting layer 276 may include an organic compound represented by the chemical formulas 1 and 2.

[0092] The first charge generation layer 260 is disposed between the first emitting part 240 and the second emitting part 250, and the second charge generation layer 280 is disposed between the second emitting part 250 and the third emitting part 270. Each of the first and second charge generation layers 260 and 280 may include a PN junction charge generation layer where an N type charge generation layer 262 and 282 and a P type charge generation layer 264 and 284 are combined to each other.

[0093] In the first charge generation layer 260, the N type charge generation layer 262 is disposed between the first electron transporting layer 246 and the second hole transporting layer 252, and the P type charge generation layer 264 is disposed between the N type charge generation layer 262 and the second hole transporting layer 252.

[0094] In the second charge generation layer 280, the N type charge generation layer 282 is disposed between the second electron transporting layer 256 and the third hole transporting layer 272, and the P type charge generation layer 284 is disposed between the N type charge generation layer 282 and the third hole transporting layer 272.

[0095] The first and second charge generation layers 260 and 280 may supply an electron and a hole to the first, second and third emitting parts 240, 250 and 270 by generating a charge such as an electron and a hole.

[0096] In the first charge generation layer 260, the N type charge generation layer 262 may supply an electron to the first electron transporting layer 246 of the first emitting part 240, and the P type charge generation layer 264 may supply a hole to the second hole transporting layer 252 of the second emitting part 250.

[0097] In the second charge generation layer 280, the N type charge generation layer 282 may supply an electron to the second electron transporting layer 256 of the second emitting part 250, and the P type charge generation layer 284 may supply a hole to the third hole transporting layer 272 of the third emitting part 270.

[0098] The P type charge generation layers 264 and 284 may include an organic material doped with a metal or a P type dopant. For example, the metal may include an alloy of one or two selected from a group including aluminum (Al), copper (Cu), iron (Fe), lead (Pb), zinc (Zn), gold (Au), platinum (Pt), tungsten (W), indium (In), molybdenum (Mo), nickel (Ni) and titanium (Ti). The P type dopant may include F4-TCNQ, iodine (I), iron chloride (FeCl_3), iron fluoride (FeF_3) and antimony chloride (SbCl_5), and the host may include at least one selected from a group including NPB, TPD, TNB and HAT-CN.

[0099] When an electron moves from the N type charge generation layers 262 and 282 to the first and second electron transporting layers 246 and 256, a driving voltage of the LED 200 may increase due to difference in a LUMO energy level between the first and second electron transporting layers 246 and 256 and the N type charge generation layers 262 and 282.

[0100] To solve the above problem, the organic compound of the present disclosure may be used for at least one of the N type charge generation layers 262 and 282 and/or at least one of the first and second electron transporting layers 246 and 256. Alternatively, the N type charge generation layers 262 and 282 may include a metallic compound such as an alkali metal or an alkali earth metal as a dopant.

[0101] For example, the N type charge generation layers 262 and 282 may further include at least one selected from a group including lithium quinolate (LiQ), lithium fluoride (LiF), sodium fluoride (NaF), potassium fluoride (KF), rubidium fluoride (RbF), cesium fluoride (CsF), francium fluoride (FrF), beryllium fluoride (BeF_2), magnesium fluoride (MgF_2), calcium fluoride (CaF_2), strontium fluoride (SrF_2), barium fluoride (BaF_2) and radium fluoride (RaF_2). However, the material for the N type charge generation layers 262 and 282 is not limited to that set forth herein.

[0102] An electron injecting property to the N type charge generation layers 262 and 282 may be improved by doping the N type charge generation layers 262 and 282 with the alkali metal or the alkali earth metal.

[0103] The organic compound of the present disclosure includes a phenanthroline moiety substituted with at least one aromatic ring. Since the organic compound has a relatively high decomposition temperature or a relatively high glass transition temperature due to the phenanthroline moiety, the organic compound has an excellent thermal stability. As a result, the organic compound may not be deteriorated or spoiled even by a Joule's heat generated from driving of an element. Accordingly, a lifetime of the LED 200 including the organic compound is extended and a driving voltage of the LED 200 including the organic compound is reduced.

[0104] Further, since the organic compound of the present disclosure includes a phenanthroline moiety having a nitrogen atom of a hybrid orbital of sp^2 of sufficient electrons, the organic compound has an excellent electron transporting property. As a result, the organic compound may be used for the electron transporting layers 246, 256 and 276 and/or the charge generation layers 260 and 280.

[0105] Specifically, a nitrogen atom of a phenanthroline moiety is combined with the alkali metal or the alkali earth metal of the dopant of the N type charge generation layer to form a gap state. As a result, the energy level difference between the N type charge generation layer and the P type charge generation layer is alleviated. Since the injection of an electron into the N type charge generation layer is improved, the electron transporting property to the electron transporting layer adjacent to the N type charge generation layer may be maximized.

[0106] Further, since the compound including a nitrogen atom is combined with the alkali metal compound or the alkali earth metal compound of the N type charge generation layer, diffusion of the alkali metal compound or the alkali earth metal compound to the P type charge generation layer is prevented. Accordingly, reduction of a lifetime of the LED is prevented.

[0107] The LED of the present disclosure may be applied to an OLED display device and a lighting apparatus. FIG. 3 is a cross-sectional view showing an organic light emitting diode display device according to a third embodiment of the present disclosure.

[0108] In FIG. 3, an organic light emitting diode (OLED) display device 300 includes a substrate 301, a light emitting diode (LED) 400 and an encapsulation film 390 covering the LED 400. A driving thin film transistor (TFT) Td and the LED 400 connected to the driving TFT Td are formed on the substrate 301.

[0109] Although not shown, a gate line, a data line, a power line, a switching TFT and a storage capacitor are formed on the substrate 301. The gate line and the data line cross each other to define a pixel region, and the power line is disposed to be parallel to one of the gate line and the data line. The switching TFT is connected to the gate line and the data line, and the storage capacitor is connected to the power line and the switching TFT.

[0110] The driving TFT Td is connected to the switching TFT and includes a semiconductor layer 310, a gate electrode 330, a source electrode 352 and a drain electrode 354.

[0111] The semiconductor layer 310 is formed on the substrate 301 and may include an oxide semiconductor material or polycrystalline silicon. When the semiconductor layer 310 includes an oxide semiconductor material, a light shielding pattern (not shown) may be formed under the semiconductor layer 310. Since a light incident to the semiconductor layer 310 is blocked by the light shielding pattern, deterioration of the semiconductor layer 310 due to a light may be prevented. When the semiconductor layer 310 includes polycrystalline silicon, both side portions of the semiconductor layer 310 may be doped with impurities.

[0112] A gate insulating layer 320 of an insulating material is formed on an entire surface of the substrate 301 having the semiconductor layer 310. The gate insulating layer 320 may include an inorganic insulating material such as silicon oxide and silicon nitride.

[0113] A gate electrode 330 of a conductive material such as a metal is formed on the gate insulating layer 320 corresponding to a central portion of the semiconductor layer 310. The gate electrode 330 is connected to the switching TFT.

[0114] An interlayer insulating layer 340 of an insulating material is formed on an entire surface of the substrate 301 having the gate electrode 330. The interlayer insulating layer 340 may include an inorganic insulating material such as silicon oxide and silicon nitride or an organic insulating material such as benzocyclobutene and photoacryl.

[0115] The interlayer insulating layer 340 has first and second semiconductor contact holes 342 and 344 exposing both side portions of the semiconductor layer 310. The first and second semiconductor contact holes 342 and 344 are disposed at sides of the gate electrode 330 and spaced apart from the gate electrode 330.

[0116] A source electrode 352 and a drain electrode 354 of a conductive material such as a metal are formed on the interlayer insulating layer 340. The source electrode 352 and the drain electrode 354 are spaced apart from each other with respect to the gate electrode 330 as a center and are connected to the both side portions of the semiconductor layer 310 through the first and second semiconductor contact holes 342 and 344, respectively. The source electrode 352 is connected to the power line (not shown).

[0117] The semiconductor layer 310, the gate electrode 330, the source electrode 352 and the drain electrode 354 constitute the driving TFT Td having a coplanar structure where the gate electrode 330, the source electrode 352 and

the drain electrode 354 are disposed over the semiconductor layer 310.

[0118] In another embodiment, the driving TFT Td may have an inverted staggered structure where the gate electrode is formed under the semiconductor layer and the source and drain electrodes are formed over the semiconductor layer. When the driving TFT Td has an inverted staggered structure, the semiconductor layer may include amorphous silicon. The switching TFT may have substantially the same structure as the driving TFT Td.

[0119] The OLED display device 300 may include a color filter layer 360 filtering a light emitted from the LED 400. For example, the color filter layer 360 may selectively absorb one of red (R), green (G), blue (B) and white (W) colored lights. Red, green and blue color filters may be formed in pixel regions, respectively, and may be disposed to overlap an organic emitting layer 430 of the LED 400. The OLED display device 300 may display a full color image by using the color filter layer 360.

[0120] For example, when the OLED display device 300 has a bottom emission type, the color filter layer 360 may be formed on the interlayer insulating layer 340 corresponding to the LED 400. When the OLED display device 300 has a top emission type, the color filter layer 360 may be formed over a second electrode 420 of the LED 400. The color filter layer 360 may have a thickness of about 2 μ m to about 5 μ m. The LED 400 may include a white LED having a tandem structure of FIGs. 1 and 2.

[0121] A passivation layer 370 is formed on the driving TFT Td and has a drain contact hole exposing the drain electrode 354 of the driving TFT Td.

[0122] A first electrode 410 is formed on the passivation layer 370 in each pixel region and is connected to the drain electrode 354 of the driving TFT Td through the drain contact hole 372.

[0123] The first electrode 410 may be an anode of a conductive material having a relatively high work function. For example, the first electrode 410 may include a transparent conductive material such as indium tin oxide (ITO), indium zinc oxide (IZO) and zinc oxide (ZO).

[0124] When the OLED display device 300 has a top emission type, a reflecting electrode or a reflecting layer may be further formed under the first electrode 410. For example, the reflecting electrode or the reflecting layer may include one of aluminum (Al), silver (Ag), nickel (Ni) and aluminum palladium copper (APC) alloy.

[0125] A bank layer 380 is formed on the passivation layer 370 to cover an edge portion of the first electrode 410. The bank layer 380 exposes a central portion of the first electrode 410 corresponding to the pixel region.

[0126] An organic emitting layer 430 is formed on the first electrode 410. For example, the organic emitting layer 430 may include at least two emitting parts as shown in FIGs. 1 and 2 such that the LED 400 has a tandem structure.

[0127] A second electrode 420 is formed on an entire surface of the substrate 301 having the organic emitting layer 430. The second electrode 420 may be a cathode of a conductive material having a relatively low work function. For example, the second electrode 420 may include a metallic material such as aluminum (Al), magnesium (Mg) and aluminum magnesium (AlMg) alloy.

[0128] The first electrode 410, the organic emitting layer 430 and the second electrode 420 constitute the LED 400.

[0129] An encapsulation film 390 is formed on the second electrode 420 to prevent penetration of external moisture into the LED 400. Although not shown, the encapsulation film 390 may have a triple layered structure including a first inorganic layer, an organic layer and a second inorganic layer. However, the encapsulation film 390 is not limited to that set forth herein.

[0130] The organic compound of the present disclosure includes a phenanthroline moiety substituted with at least one aromatic ring. Since the organic compound has a relatively high decomposition temperature or a relatively high glass transition temperature due to the phenanthroline moiety, the organic compound has an excellent thermal stability. Accordingly, a lifetime of the LED 400 including the organic compound is extended and a driving voltage of the LED 400 including the organic compound is reduced.

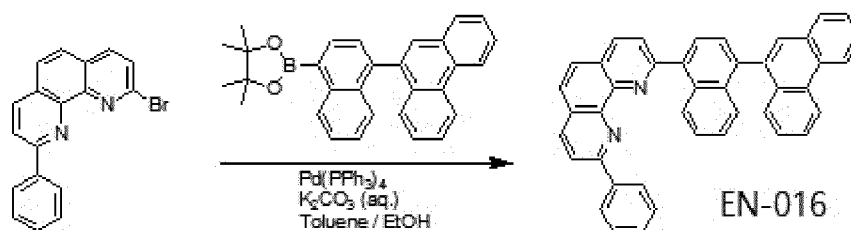
[0131] Further, since the organic compound of the present disclosure includes a phenanthroline moiety having a nitrogen atom of a hybrid orbital of sp² of sufficient electrons, the organic compound has an excellent electron transporting property. A nitrogen atom of a phenanthroline moiety is combined with the alkali metal or the alkali earth metal of the dopant of the N type charge generation layer to form a gap state. As a result, the energy level difference between the N type charge generation layer and the P type charge generation layer is alleviated. Since the injection of an electron into the N type charge generation layer is improved, the electron transporting property to the electron transporting layer adjacent to the N type charge generation layer may be maximized.

[0132] Further, since the compound including a nitrogen atom is combined with the alkali metal compound or the alkali earth metal compound of the N type charge generation layer, diffusion of the alkali metal compound or the alkali earth metal compound to the P type charge generation layer is prevented. Accordingly, reduction of a lifetime of the LED is prevented.

Synthesis Example 1: Synthesis of Compound EN-016

[0133]

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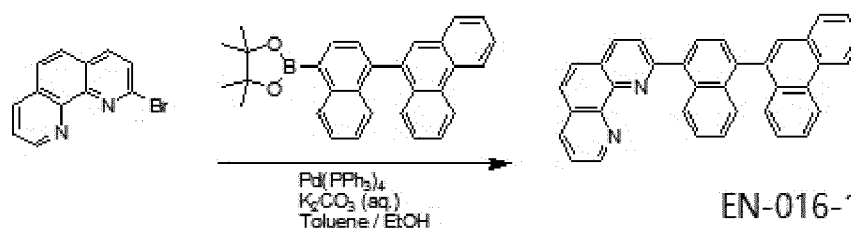


10 **[0134]** After a mixture was formed by dissolving 4,4,5,5-tetramethyl-2-(1-(phenanthren-10-yl)naphthalen-4-yl)-1,3,2-dioxaborolane (6.0g, 13.94mmol), 2-bromo-9-phenyl-1,10-phenanthroline (4.20g, 12.57mmol), tetrakis-triphenylphosphine palladium(0) ($\text{Pd}(\text{PPh}_3)_4$) (0.50g, 0.70mmol), 4M potassium carbonate aqueous solution (10mL), toluene 30mL, ethanol (EtOH) 10mL under a nitrogen atmosphere, the mixture was refluxed and stirred for 12 hours. After a reaction was finished, H_2O 50mL was added to the mixture, the mixture was stirred for 3 hours and a vacuum filtration was performed. After the mixture was divided through a column chromatography using methylene chloride (MC) and hexane as an eluent, the mixture was re-crystallized by using MC to obtain a compound EN-016 (6.25g, transference number of 80.3%).

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Comparative Synthesis Example 1: Synthesis of Compound EN-016-1

25 **[0135]**



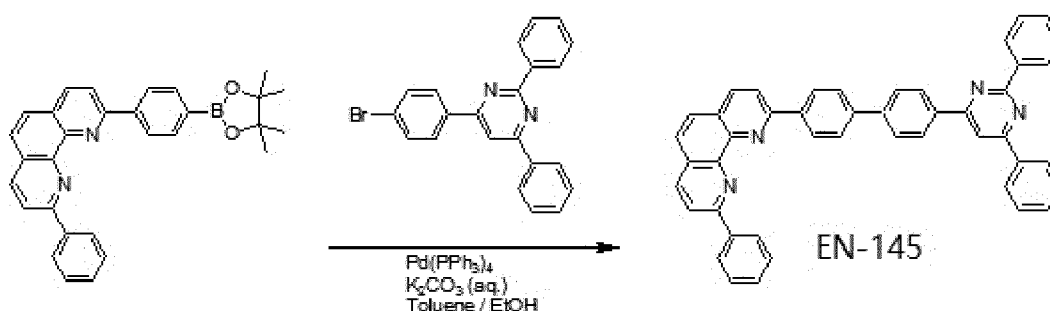
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35 **[0136]** After a mixture was formed by dissolving 4,4,5,5-tetramethyl-2-(1-(phenanthren-10-yl)naphthalen-4-yl)-1,3,2-dioxaborolane (50g, 19.38mmol), 2-bromo-1,10-phenanthroline (8.50g, 19.76mmol), tetrakis-triphenylphosphine palladium(0) ($\text{Pd}(\text{PPh}_3)_4$) (1.14g, 0.99mmol), 4M potassium carbonate aqueous solution (10mL), toluene 30mL, ethanol (EtOH) 10mL under a nitrogen atmosphere, the mixture was refluxed and stirred for 12 hours. After a reaction was finished, H_2O 50mL was added to the mixture, the mixture was stirred for 3 hours and a vacuum filtration was performed. After the mixture was divided through a column chromatography using methylene chloride (MC) and hexane as an eluent, the mixture was re-crystallized by using MC to obtain a compound EN-016-1 (7.94g, transference number of 85.1%).

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Synthesis Example 2: Synthesis of Compound EN-145

45 **[0137]**



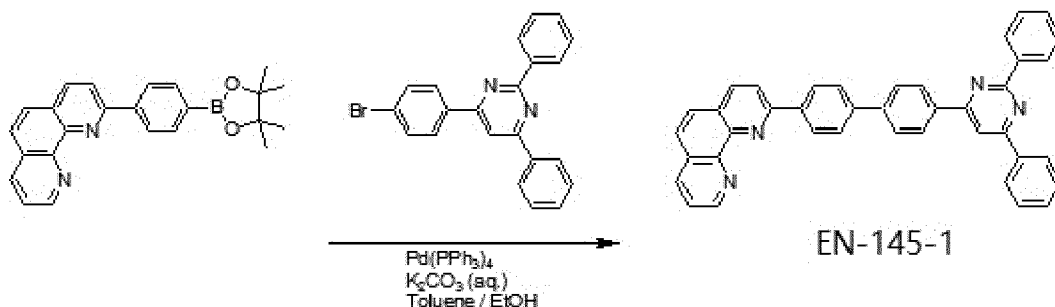
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[0138] After a mixture was formed by dissolving 2-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)-9-phenyl-1,10-phenanthroline (5.0g, 10.91mmol), 4-(4-bromophenyl)-2,6-diphenylpyrimidine (4.80g, 12.40mmol), tetrakis-triphenylphosphine palladium(0) ($\text{Pd}(\text{PPh}_3)_4$) (0.63g, 0.55mmol), 4M potassium carbonate aqueous solution (10mL), toluene

30mL, ethanol (EtOH) 10mL under a nitrogen atmosphere, the mixture was refluxed and stirred for 12 hours. After a reaction was finished, H₂O 50mL was added to the mixture, the mixture was stirred for 3 hours and a vacuum filtration was performed. After the mixture was divided through a column chromatography using methylene chloride (MC) and hexane as an eluent, the mixture was re-crystallized by using MC to obtain a compound EN-145 (5.01g, transference number of 72.3%).

Comparative Synthesis Example 2: Synthesis of Compound EN-145-1

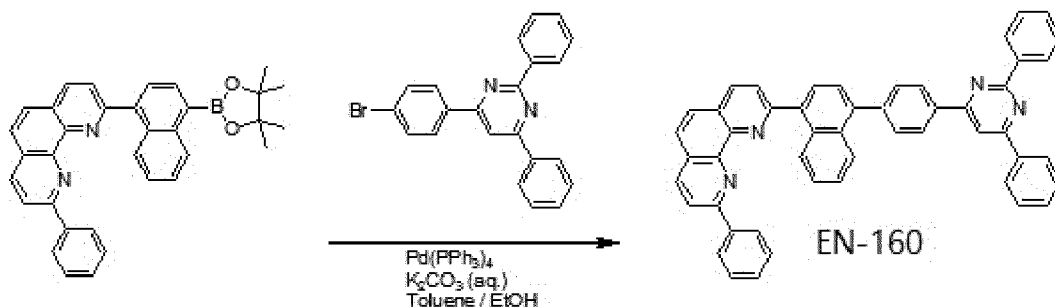
[0139]



[0140] After a mixture was formed by dissolving 2-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)-1,10-phenanthroline (5.0g, 13.08mmol), 4-(4-bromophenyl)-2,6-diphenylpyrimidine (6.10g, 15.96mmol), tetrakis-triphenylphosphine palladium(0) (Pd(PPh₃)₄) (0.75g, 0.65mmol), 4M potassium carbonate aqueous solution (10mL), toluene 30mL, ethanol (EtOH) 10mL under a nitrogen atmosphere, the mixture was refluxed and stirred for 12 hours. After a reaction was finished, H₂O 50mL was added to the mixture, the mixture was stirred for 3 hours and a vacuum filtration was performed. After the mixture was divided through a column chromatography using methylene chloride (MC) and hexane as an eluent, the mixture was re-crystallized by using MC to obtain a compound EN-145-1 (5.56g, transference number of 75.6%).

Synthesis Example 3: Synthesis of Compound EN-160

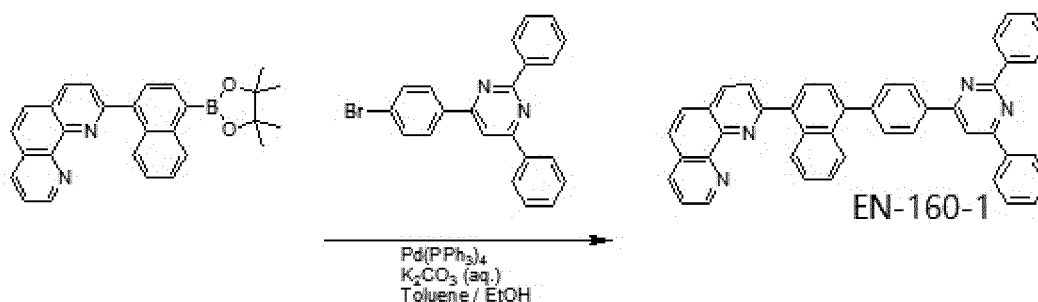
[0141]



[0142] After a mixture was formed by dissolving 2-(1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)naphthalen-4-yl)-9-phenyl-1,10-phenanthroline (5.5g, 10.82mmol), 4-(4-bromophenyl)-2,6-diphenylpyrimidine (4.50g, 11.63mmol), tetrakis-triphenylphosphine palladium(0) (Pd(PPh₃)₄) (0.63g, 0.54mmol), 4M potassium carbonate aqueous solution (10mL), toluene 30mL, ethanol (EtOH) 10mL under a nitrogen atmosphere, the mixture was refluxed and stirred for 12 hours. After a reaction was finished, H₂O 50mL was added to the mixture, the mixture was stirred for 3 hours and a vacuum filtration was performed. After the mixture was divided through a column chromatography using methylene chloride (MC) and hexane as an eluent, the mixture was re-crystallized by using MC to obtain a compound EN-160 (5.03g, transference number of 72.8%).

Comparative Synthesis Example 3: Synthesis of Compound EN-160-1

[0143]



[0144] After a mixture was formed by dissolving 2-(1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)naphthalen-4-yl)-1,10-phenanthroline (6.0g, 13.88mmol), 4-(4-bromophenyl)-2,6-diphenylpyrimidine (6.0g, 15.50mmol), tetrakis-triphenylphosphine palladium(0) ($\text{Pd(PPh}_3)_4$) (0.80g, 0.69mmol), 4M potassium carbonate aqueous solution (10mL), toluene 30mL, ethanol (EtOH) 10mL under a nitrogen atmosphere, the mixture was refluxed and stirred for 12 hours. After a reaction was finished, H_2O 50mL was added to the mixture, the mixture was stirred for 3 hours and a vacuum filtration was performed. After the mixture was divided through a column chromatography using methylene chloride (MC) and hexane as an eluent, the mixture was re-crystallized by using MC to obtain a compound EN-160-1 (6.11g, transference number of 71.8%).

Experimental Example 1: Estimation of Thermal Stability and Electron Moving Property

[0145] A thermal stability and an electron moving property of the compounds of the synthesis examples 1 to 3 and the comparative synthesis examples 1 to 3 were estimated. A thermal stability was obtained by measuring a decomposition temperature (1%, 5%) and a glass transition temperature (T_g) through a thermogravimetric analysis (TGA) and a differential scanning calorimeter (DSC). An electron moving property was obtained by calculating an electron affinity (EA), a reorganization energy ($\lambda_{\text{electron}}$) and a ratio of rate constants of an electron and a hole ($k_{\text{et}}(\text{e})/k_{\text{et}}(\text{h})$) using a density functional theory (B3LYP/6-31G*). Results of measurement and estimation are illustrated in a following table.

[TABLE 1]

	Thermal Analysis(°C)			Simulation Analysis		
	Td(1%)	Td(5%)	T_g	Electron Affinity	$\lambda_{\text{electron}}$	$k_{\text{et}}(\text{e})/k_{\text{et}}(\text{h})$
EN-016	415	456	157	0.57	0.29	1.18
EN-016-1	401	442	151	0.44	0.38	1.11
EN-145	465	506	138	0.96	0.27	0.30
EN-145-1	436	477	131	0.89	0.29	0.27
EN-160	471	510	147	0.92	0.31	0.43
EN-160-1	445	588	141	0.72	0.35	0.31

[0146] In TABLE 1, the compound according to the present disclosure including a phenanthroline moiety where a phenyl group corresponding to an aryl group is substituted has a higher decomposition temperature and a higher glass transition temperature as compared with the compound where a phenyl group is not substituted. As a result, the thermal stability is improved. Further, the compound including a phenanthroline moiety where a phenyl group is substituted has a greater electron affinity (EA) as compared with the compound where a phenyl group is not substituted. As a result, the compound including a phenanthroline moiety where a phenyl group is substituted may receive an electron more easily as compared with the compound where a phenyl group is not substituted. Specifically, a material for the N type charge generation layer (n-CGL) is required to have an excellent property of receiving an electron from the P type charge generation layer (p-CGL) and transmitting an electron to the electron transporting layer (ETL). Since the compound including a phenanthroline moiety where a phenyl group is substituted has a reduced reorganization energy ($\lambda_{\text{electron}}$) and a increased ratio of rate constants of an electron and a hole ($k_{\text{et}}(\text{e})/k_{\text{et}}(\text{h})$), the compound including a phenanthroline moiety where a phenyl group has a superior negative ion stability and a superior electron moving property as compared with the compound where a phenyl group is not substituted.

Embodiment 1: Fabrication of Light Emitting Diode of Tandem Structure

[0147] A light emitting diode (LED) of a tandem structure including three emitting parts by using the compound EN-016 of the synthesis example 1 for the N type charge generation layer was fabricated. After an indium tin oxide (ITO) substrate was patterned to have an emission area of 2mm*2mm, the ITO substrate was cleaned using an ultraviolet (UV) and ozone. In a vacuum deposition chamber having a pressure of 5×10^{-8} to 7×10^{-8} torr, the following layers were sequentially formed on the ITO substrate.

[0148] Hole Injecting Layer (NPD doped with 10% of F4-TCNQ) 100Å, First Hole Transporting Layer (NPD) 1200Å, First Emitting Material Layer (Blue Emitting Material Layer, anthracene host doped with 4% of pyrene dopant) 200Å, First Electron Transporting Layer (1,3,5-tri[(3-pyridyl)-phen-3-yl]benzene (TmPyPB) 100Å, First N Type Charge Generation Layer (EN-016 doped with 2% of Li) 100Å, First P Type Charge Generation Layer (NPD doped with 10% of F4-TCNQ) 200Å, Second Hole Transporting Layer (NPD) 200Å, Second Emitting Material Layer (Yellow Emitting Material Layer, CBP host doped with 10% of Ir complex) 200Å, Second Electron Transporting Layer (Alq3), Second N Type Charge Generation Layer (EN-016 doped with 2% of Li) 100Å, Second P Type Charge Generation Layer (NPD doped with 10% of F4-TCNQ) 200Å, Third Hole Transporting Layer (NPD) 200Å, Third Emitting Material Layer (Yellow Emitting Material Layer, CBP host doped with 10% of Ir complex) 200Å, Third Electron Transporting Layer (TmPyPB) 100Å, Electron Injecting Layer (LiF) 10Å, Cathode (aluminum) 200Å.

Comparative Example 1: Fabrication of Light Emitting Diode of Tandem Structure

[0149] Through a process the same as that of the embodiment 1 except that the compound EN-016-1 of the comparative synthesis example 1 was used for the host of the first and second N type charge generation layers instead of the compound EN-016, the LED was fabricated.

Experimental Example 2: Estimation of Property of Light Emitting Diode

[0150] Driving properties of the LED of a tandem structure of the embodiment 1 and the comparative example 1 were estimated. FIGs. 4A to 4D are graphs showing a voltage-current density property, a brightness-current efficiency property, a brightness-external quantum efficiency (EQE) property and a lifetime property, respectively, of light emitting diodes of the embodiment 1 and the comparative example 1. The driving voltage of the LED of the embodiment 1 is reduced by about 0.2V as compared with the driving voltage of the LED of the comparative example 1. The current efficiency of the LED of the embodiment 1 is increased by about 2% as compared with the current efficiency of the LED of the comparative example 1. The external quantum efficiency of the LED of the embodiment 1 is similar to the external quantum efficiency of the LED of the comparative example 1. The lifetime of the LED of the embodiment 1 is extended by about 10% as compared with the lifetime of the LED of the comparative example 1.

Embodiment 2: Fabrication of Light Emitting Diode of Tandem Structure

[0151] Through a process the same as that of the embodiment 1 except that the compound EN-145 of the synthesis example 2 was used for the host of the first and second N type charge generation layers instead of the compound EN-016, the LED was fabricated.

Comparative Example 2: Fabrication of Light Emitting Diode of Tandem Structure

[0152] Through a process the same as that of the embodiment 1 except that the compound EN-145-1 of the comparative synthesis example 2 was used for the host of the first and second N type charge generation layers instead of the compound EN-016, the LED was fabricated.

Experimental Example 3: Estimation of Property of Light Emitting Diode

[0153] Driving properties of the LED of a tandem structure of the embodiment 2 and the comparative example 2 were estimated. FIGs. 5A to 5D are graphs showing a voltage-current density property, a brightness-current efficiency property, a brightness-external quantum efficiency (EQE) property and a lifetime property, respectively, of light emitting diodes of the embodiment 2 and the comparative example 2. The driving voltage of the LED of the embodiment 2 is similar to the driving voltage of the LED of the comparative example 2. The current efficiency of the LED of the embodiment 2 is increased by about 1% as compared with the current efficiency of the LED of the comparative example 2. The external quantum efficiency of the LED of the embodiment 2 is increased by about 1% as compared with the external quantum efficiency of the LED of the comparative example 2. The lifetime of the LED of the embodiment 2 is extended by about

29% as compared with the lifetime of the LED of the comparative example 2.

Embodiment 3: Fabrication of Light Emitting Diode of Tandem Structure

[0154] Through a process the same as that of the embodiment 1 except that the compound EN-160 of the synthesis example 3 was used for the host of the first and second N type charge generation layers instead of the compound EN-016, the LED was fabricated.

Comparative Example 3: Fabrication of Light Emitting Diode of Tandem Structure

[0155] Through a process the same as that of the embodiment 1 except that the compound EN-160-1 of the comparative synthesis example 3 was used for the host of the first and second N type charge generation layers instead of the compound EN-016, the LED was fabricated.

Experimental Example 4: Estimation of Property of Light Emitting Diode

[0156] Driving properties of the LED of a tandem structure of the embodiment 3 and the comparative example 3 were estimated. FIGs. 6A to 6D are graphs showing a voltage-current density property, a brightness-current efficiency property, a brightness-external quantum efficiency (EQE) property and a lifetime property, respectively, of light emitting diodes of the embodiment 3 and the comparative example 3. The driving voltage of the LED of the embodiment 3 is reduced by about 0.2V as compared with the driving voltage of the LED of the comparative example 3. The current efficiency of the LED of the embodiment 3 is increased by about 5% as compared with the current efficiency of the LED of the comparative example 3. The external quantum efficiency of the LED of the embodiment 3 is increased by about 1% as compared with the external quantum efficiency of the LED of the comparative example 3. The lifetime of the LED of the embodiment 3 is extended by about 15% as compared with the lifetime of the LED of the comparative example 3.

[0157] As shown in the results of the experimental examples 2 to 4, the organic compound including a phenanthroline moiety where a phenyl group is substituted has the similar or reduced driving voltage as compared with the organic compound where a phenyl group is not substituted. The organic compound including a phenanthroline moiety where a phenyl group is substituted has the similar or improved current efficiency and the similar or improved external quantum efficiency as compared with the organic compound where a phenyl group is not substituted. Specifically, since the thermal stability and the electron moving property are improved due to a phenyl group, the lifetime of the LED is greatly extended.

[0158] Consequently, the organic compound of the present disclosure includes a phenanthroline moiety substituted with at least one aromatic ring. Since the organic compound has a relatively high decomposition temperature or a relatively high glass transition temperature due to the phenanthroline moiety, the organic compound has an excellent thermal stability. As a result, the organic compound may not be deteriorated or spoiled even by a Joule's heat generated from driving of an element. Accordingly, a lifetime of the LED including the organic compound is extended and a driving voltage of the LED including the organic compound is reduced.

[0159] Further, since the organic compound of the present disclosure includes a phenanthroline moiety having a nitrogen atom of a hybrid orbital of sp^2 of sufficient electrons, the organic compound has an excellent electron transporting property. Accordingly, the organic compound of the present disclosure may be used for the electron transporting layer. A nitrogen atom of a phenanthroline moiety is combined with the alkali metal or the alkali earth metal of the dopant of the N type charge generation layer to form a gap state. As a result, the energy level difference between the N type charge generation layer and the P type charge generation layer is alleviated. Since the injection of an electron into the N type charge generation layer is improved, the electron transporting property to the electron transporting layer adjacent to the N type charge generation layer may be maximized.

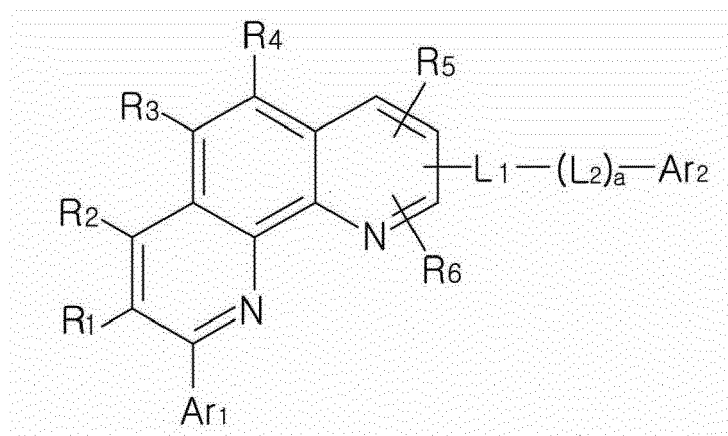
[0160] An electron may be efficiently transmitted from the N type charge generation layer to the electron transporting layer by applying the organic compound of the present disclosure to the N type charge generation layer.

[0161] Further, since the compound including a nitrogen atom is combined with the alkali metal compound or the alkali earth metal compound of the N type charge generation layer, diffusion of the alkali metal compound or the alkali earth metal compound from to the P type charge generation layer is prevented. Accordingly, reduction of a lifetime of the LED is prevented.

Claims

1. An organic compound represented by a following chemical formula 1,

Chemical Formula 1



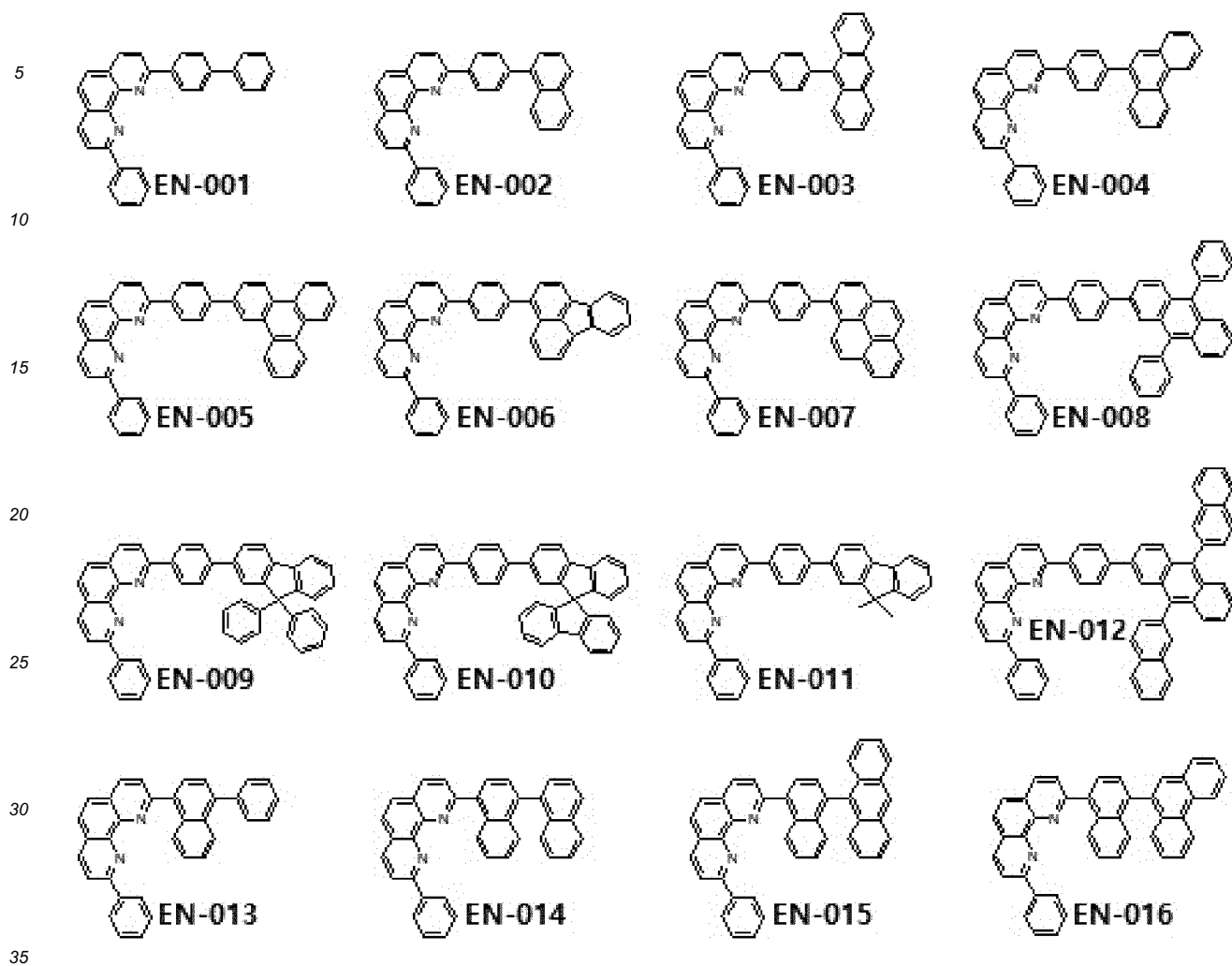
wherein, each of R_1 to R_6 is independently one of hydrogen, deuterium, tritium, a non-substituted or substituted alkyl group of C1 to C20, a non-substituted or substituted alkoxy group of C1 to C20, a non-substituted or substituted aryl group of C5 to C60 and a non-substituted or substituted hetero aryl group of C4 to C60;

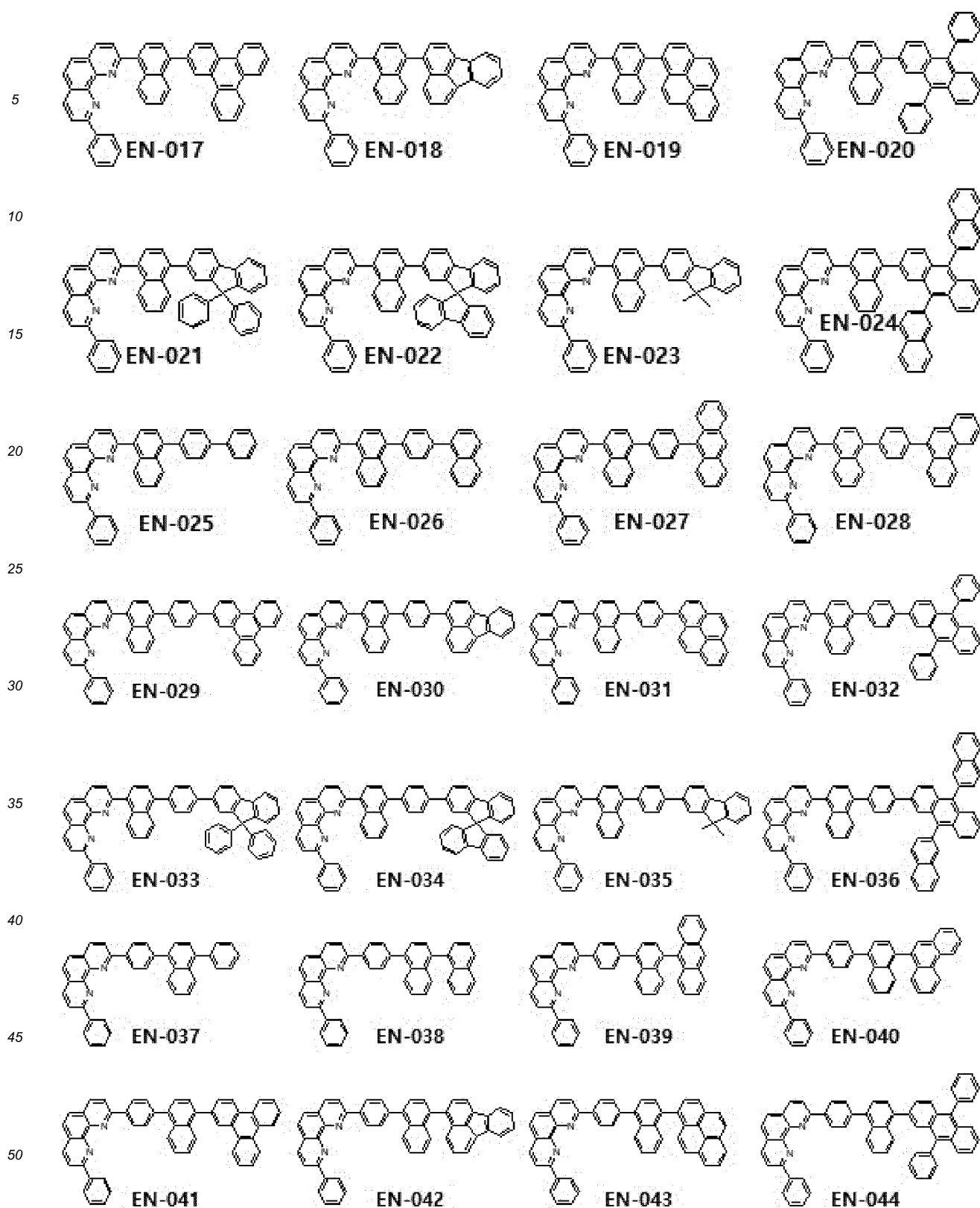
each of L_1 and L_2 is independently one of a non-substituted or substituted arylene group of C5 to C60 and a non-substituted or substituted hetero arylene group of C5 to C60;

a is 0 or 1; and

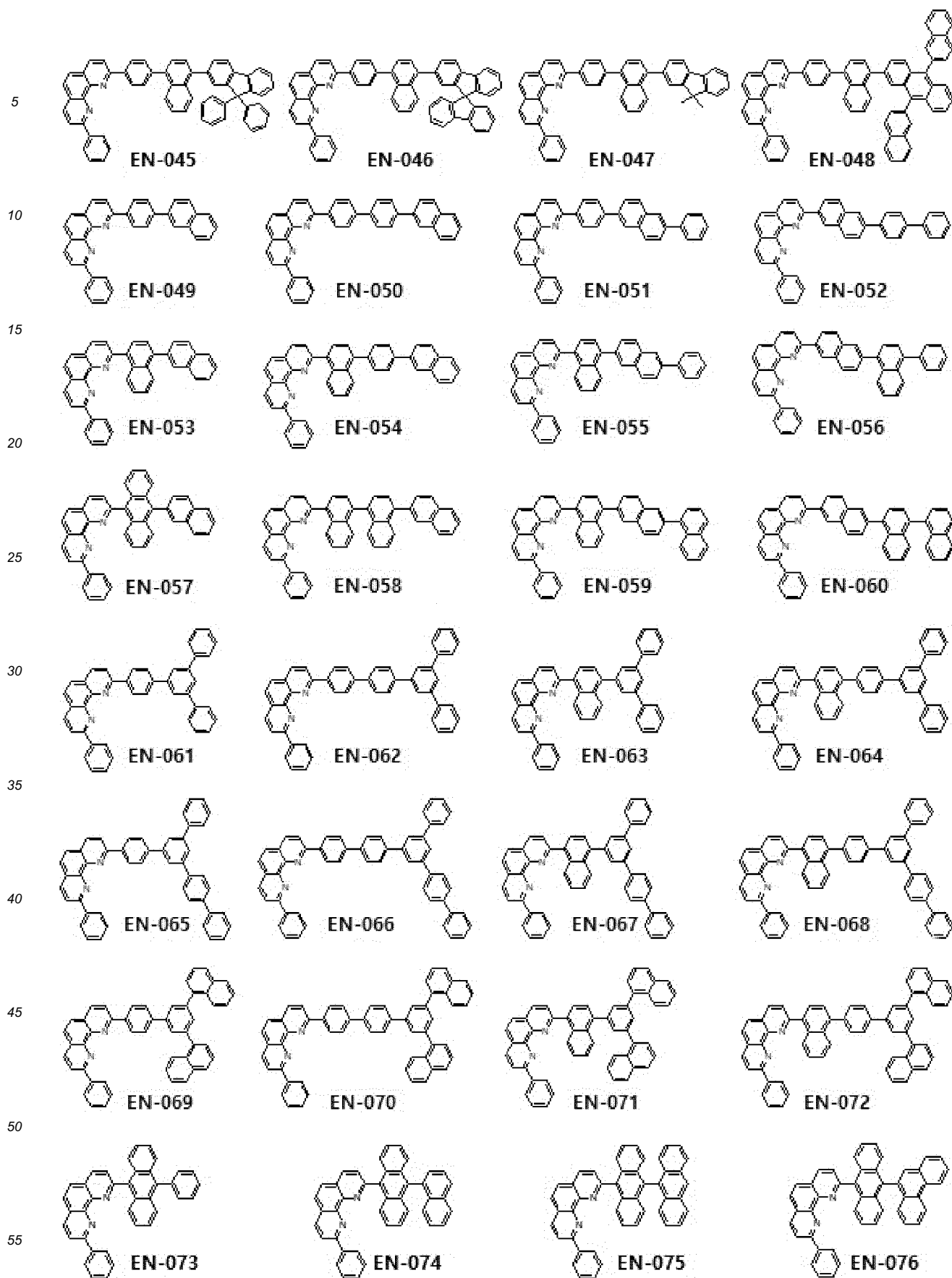
each of Ar_1 and Ar_2 is independently one of a non-substituted or substituted aryl group of C5 to C60 and a non-substituted or substituted hetero aryl group of C4 to C30.

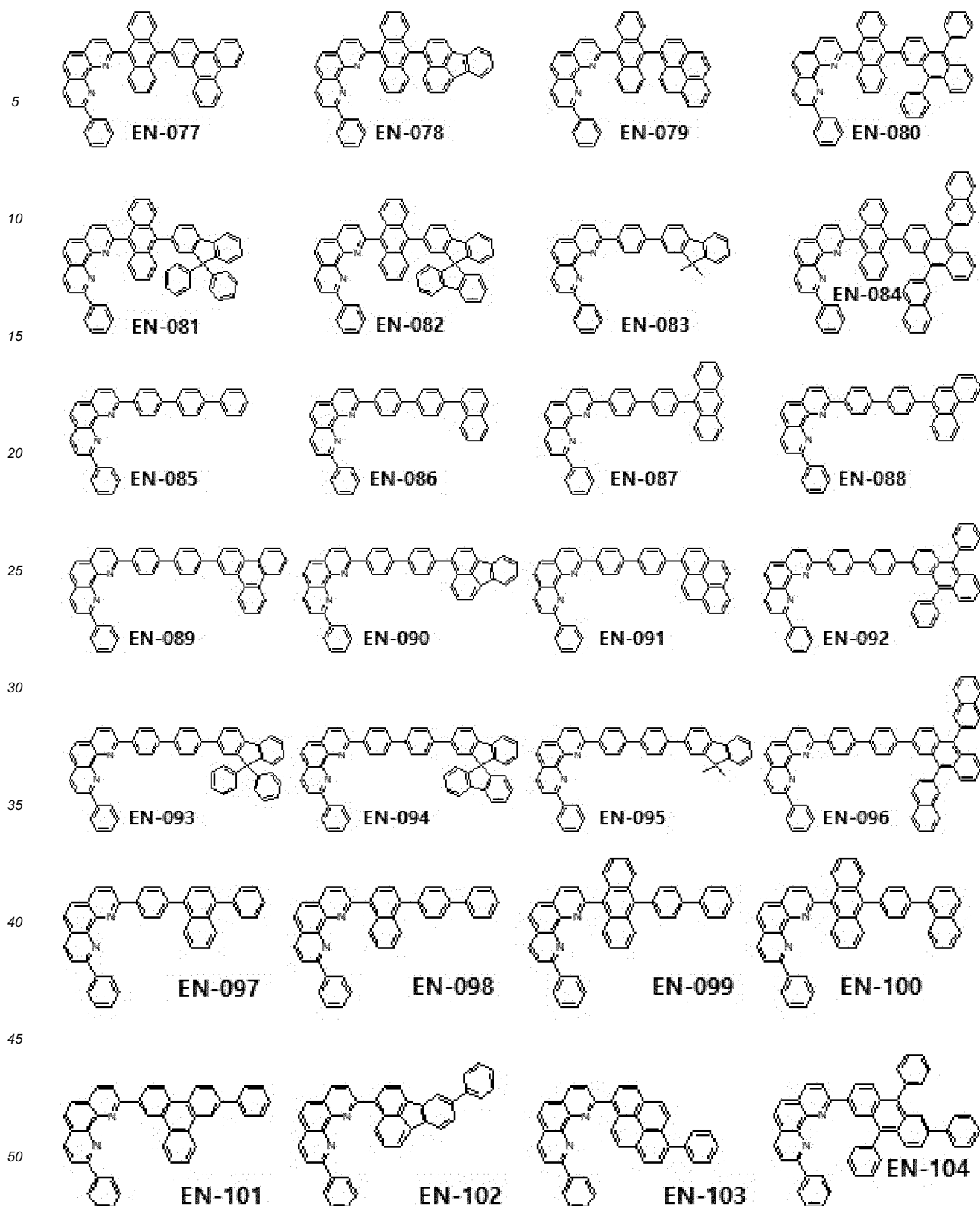
2. The organic compound of claim 1, wherein each of Ar_1 and Ar_2 is independently selected from a group including phenyl, alkylphenyl, biphenyl, alkylbiphenyl, halophenyl, alkoxyphenyl, haloalkoxyphenyl, cyanophenyl, silylphenyl, naphthyl, alkyl naphthyl, halonaphthyl, cyanonaphthyl, silylnaphthyl, phenyl naphthyl, pyridyl, alkylpyridyl, halopyridyl, cyanopyridyl, alkoxy pyridyl, silylpyridyl, phenylpyridyl, pyrimidyl, halopyrimidyl, cyanopyrimidyl, alkoxy pyrimidyl, phenylpyrimidyl, quinoliny, isoquinoliny, phenylquinoliny, quinoxaliny, pyraziny, quinazoliny, naphthyridiny, benzothiophenyl, benzofuranyl, dibenzothiophenyl, arylthiazolyl, dibenzofuranyl, fluorenyl, carbazoyl, imidazolyl, carbolinyl, phenanthrenyl, terphenyl, terpyridiny, phenylterpyridiny, triphenylenyl, fluoranthenyl and diazafluorenyl.
3. The organic compound of claim 1 or claim 2, wherein each of L_1 and L_2 is independently selected from a group including phenylene, alkylphenylene, cyanophenylene, naphthylene, alkyl naphthylene, biphenylene, alkylbiphenylene, anthracenylene, triphenylene, pyrenylene, benzothiophenylene, benzofuranylene, dibenzothiophenylene, arylthiazolylene, dibenzofuranylene, fluorenylene and triphenylenylene.
4. The organic compound of anyone of claims 1 to 3, wherein each of R_1 to R_6 is hydrogen and Ar_1 is phenyl.
5. The organic compound of anyone of claims 1 to 4, wherein the organic compound is one of compounds represented by a following chemical formula 2,

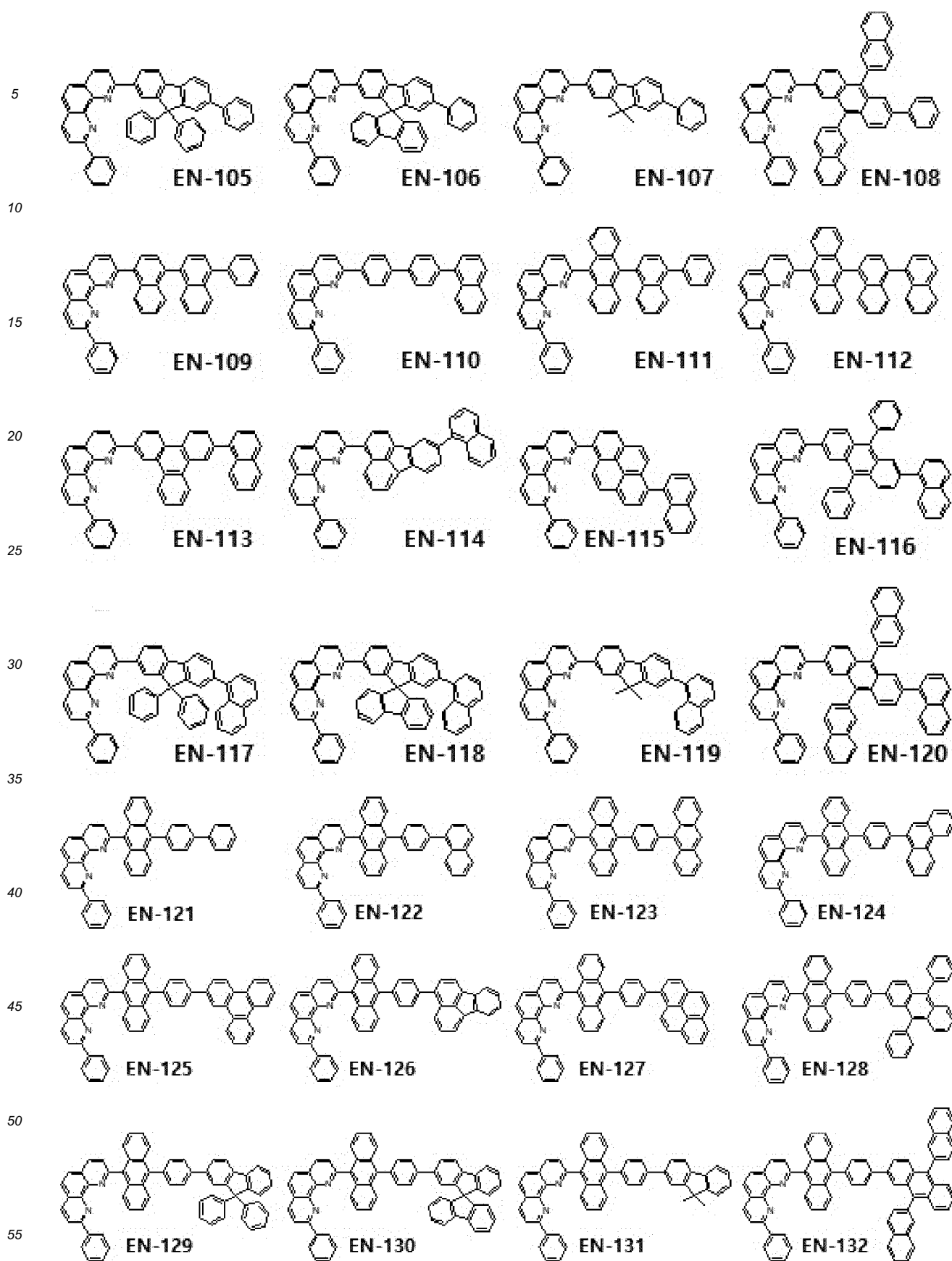
Chemical Formula 2

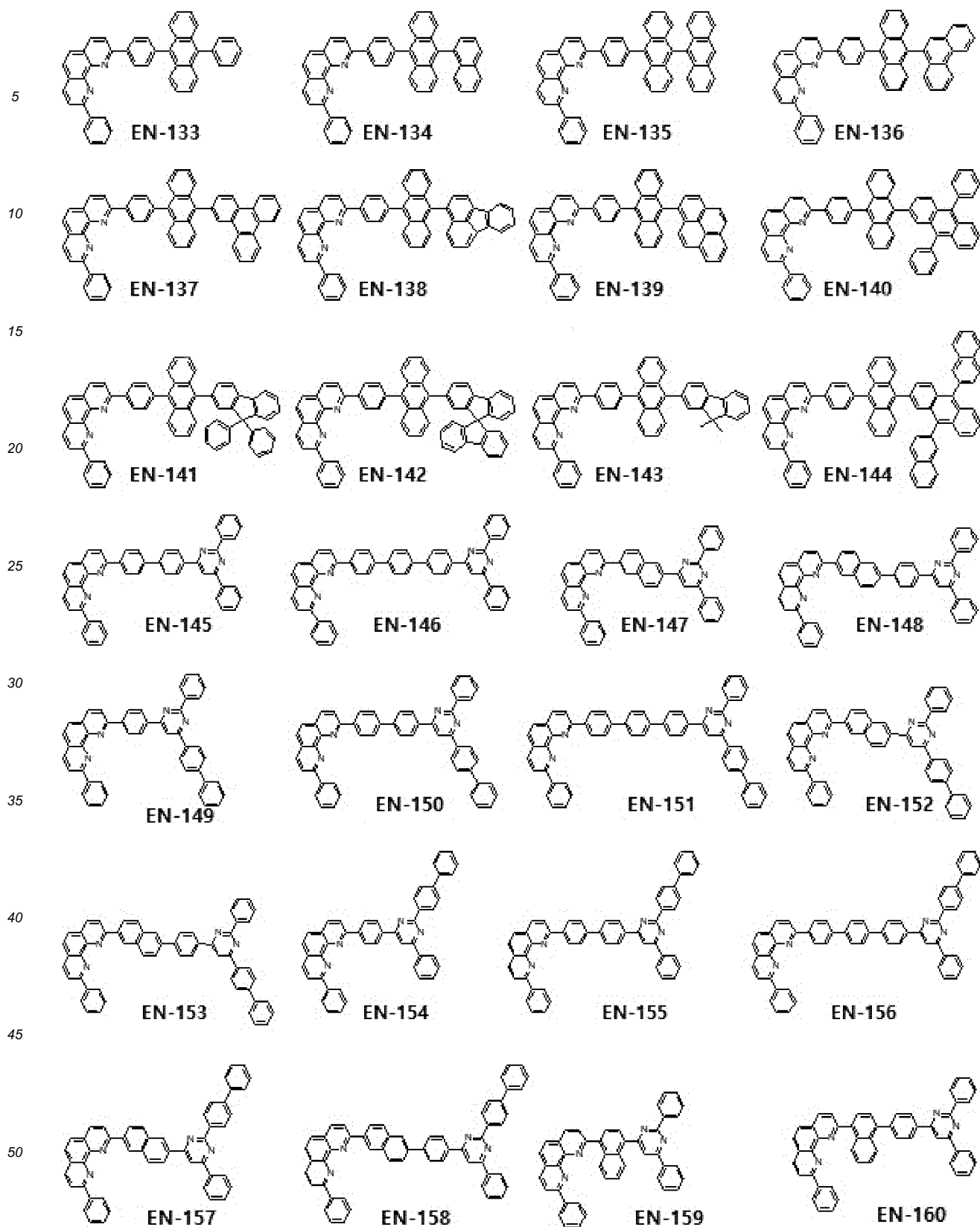


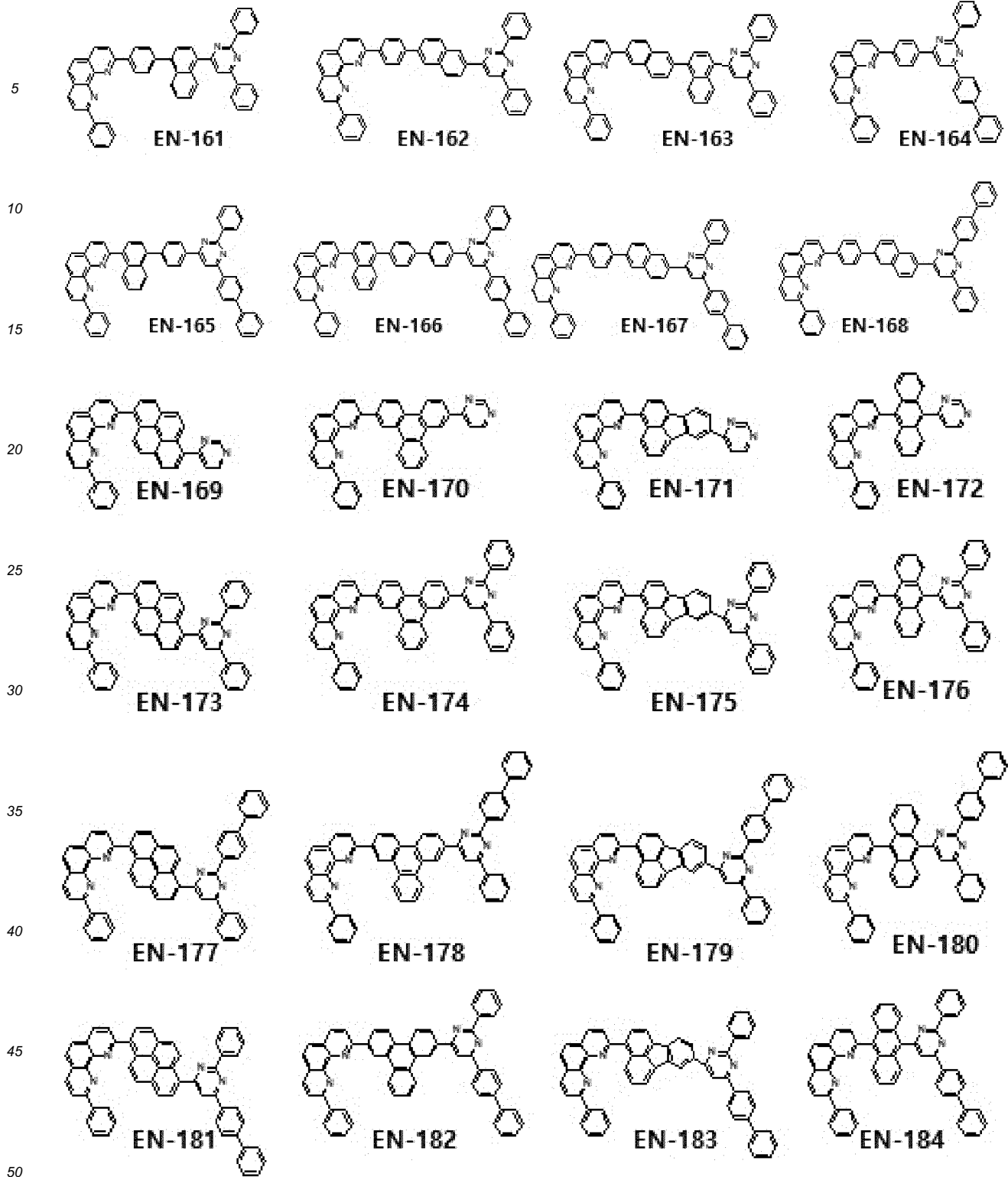
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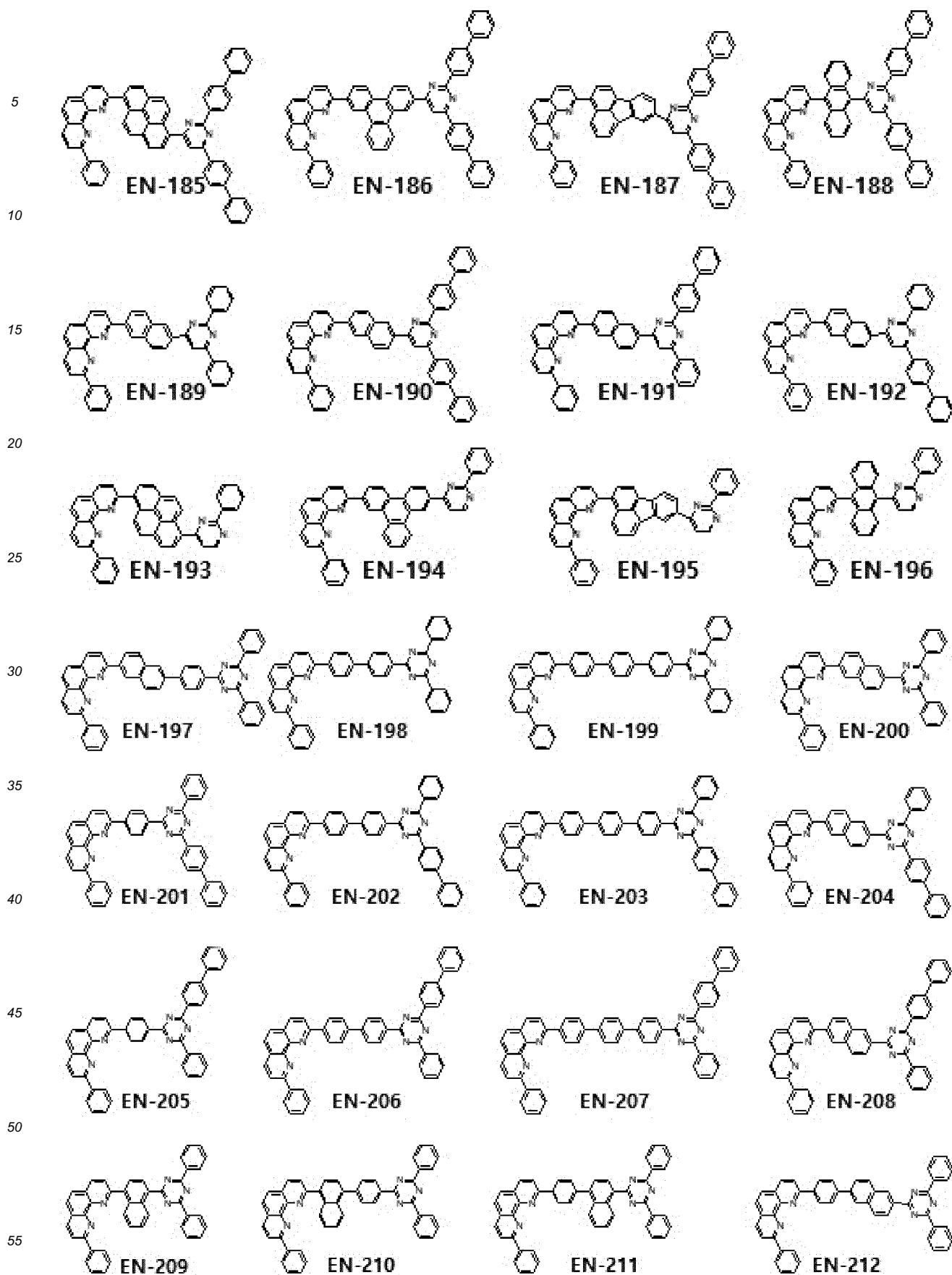


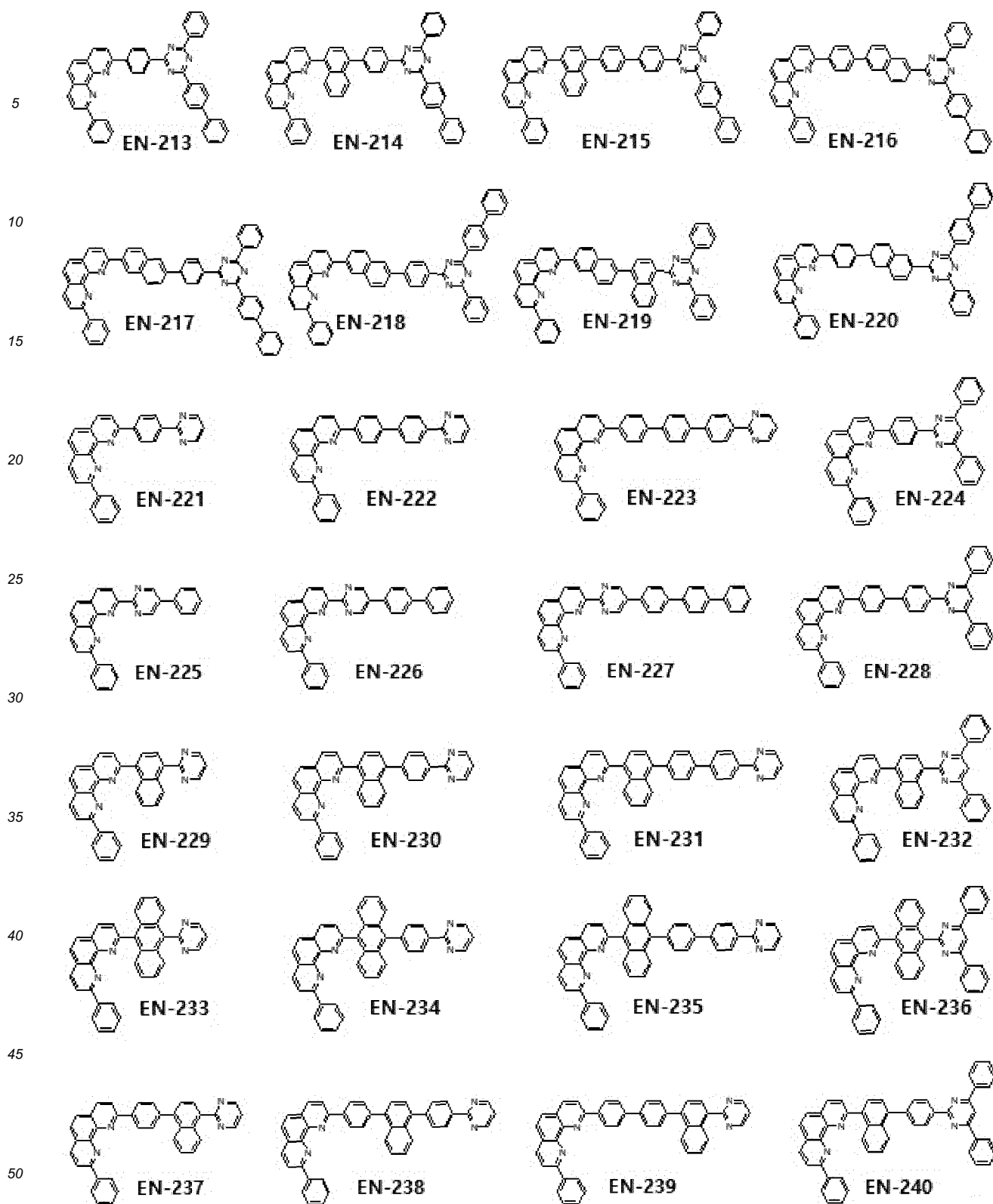


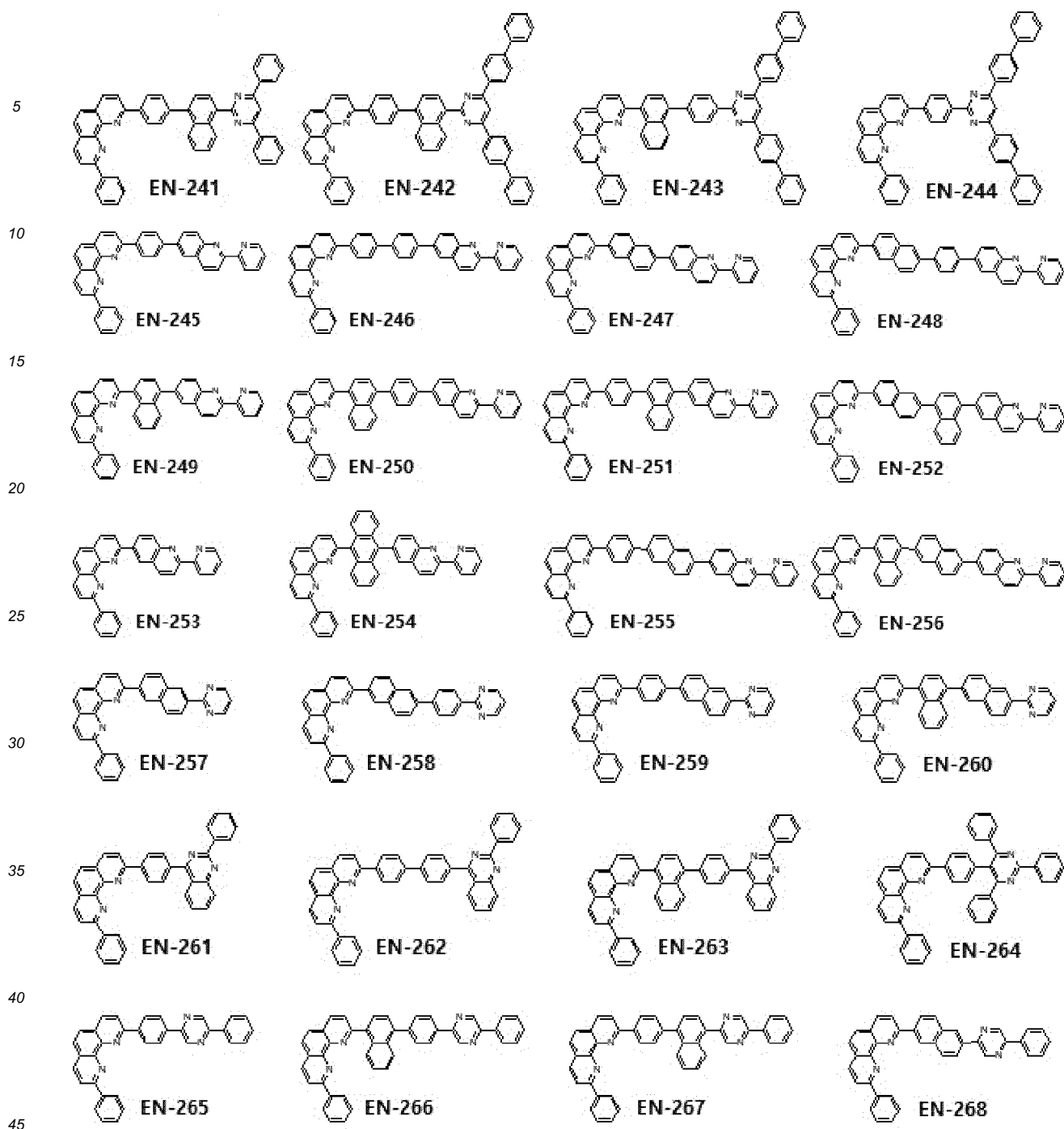












6. A light emitting diode, comprising:

- first and second electrodes facing each other;
 a first emitting part between the first and second electrodes and including a first emitting material layer and an electron transporting layer;
 a second emitting part between the first emitting part and the second electrode and including a second emitting material layer; and
 a first charge generation layer between the first and second emitting parts,
 wherein at least one of the electron transporting layer and the first charge generation layer includes an organic compound according to anyone of claims 1 to 5.

7. The light emitting diode of claim 6, wherein the first charge generation layer includes an N type charge generation layer and a P type charge generation layer, and the N type charge generation layer includes the organic compound.

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8. The light emitting diode of claim 7, wherein the N type charge generation layer includes one of an alkali metal and an alkali earth metal.

9. The light emitting diode of claim 6, further comprising:

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a third emitting part between the second emitting part and the second electrode; and
a second charge generation layer between the second emitting part and the third emitting part,
wherein the second charge generation layer includes the organic compound.

10. An organic light emitting diode display device, comprising:

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a substrate;
a light emitting diode according to anyone of claims 6 to 9 on the substrate; and
a driving element between the substrate and the light emitting diode.

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11. The device of claim 10, further comprising a color filter layer between the substrate and the first electrode.

12. The device of claim 10, further comprising a color filter layer on the light emitting diode.

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FIG. 1

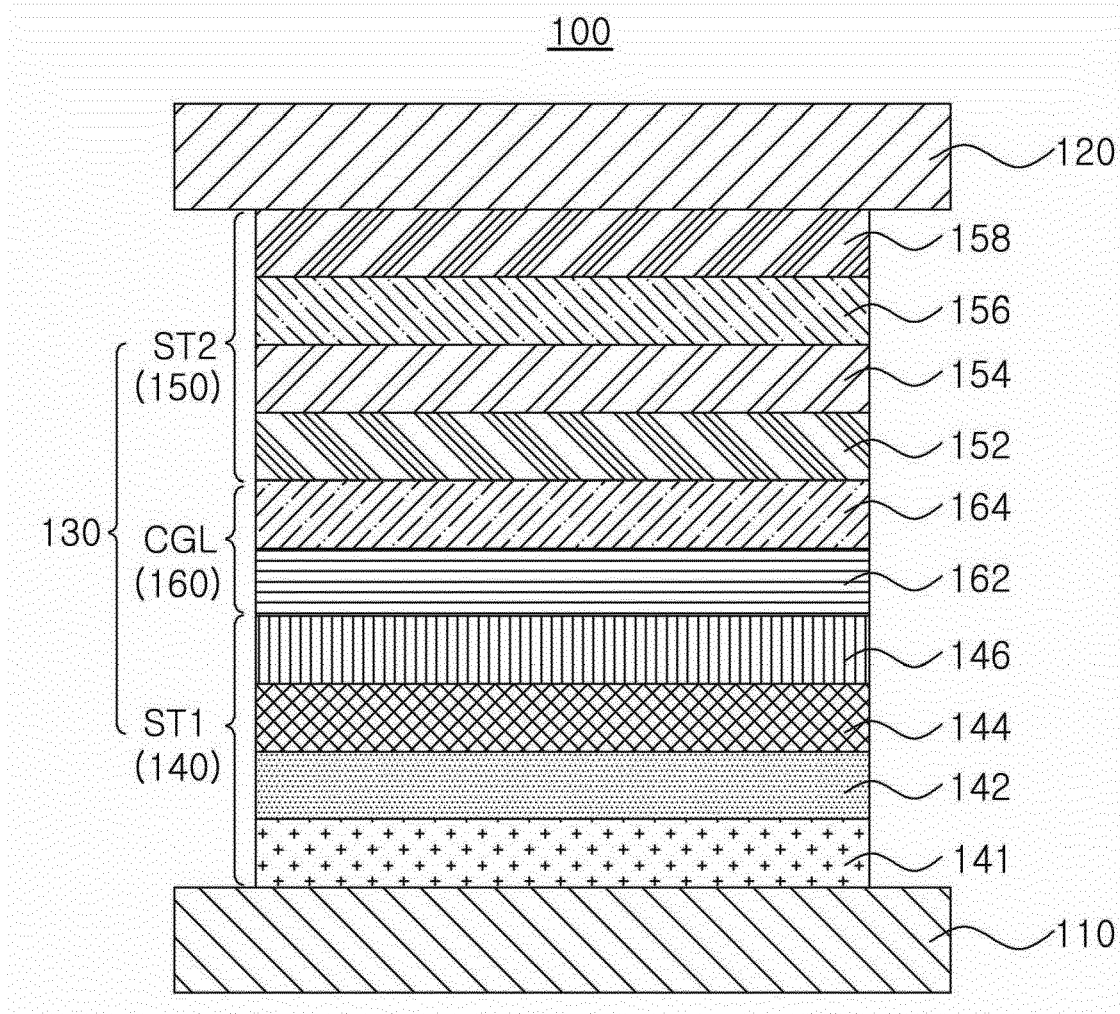


FIG. 2

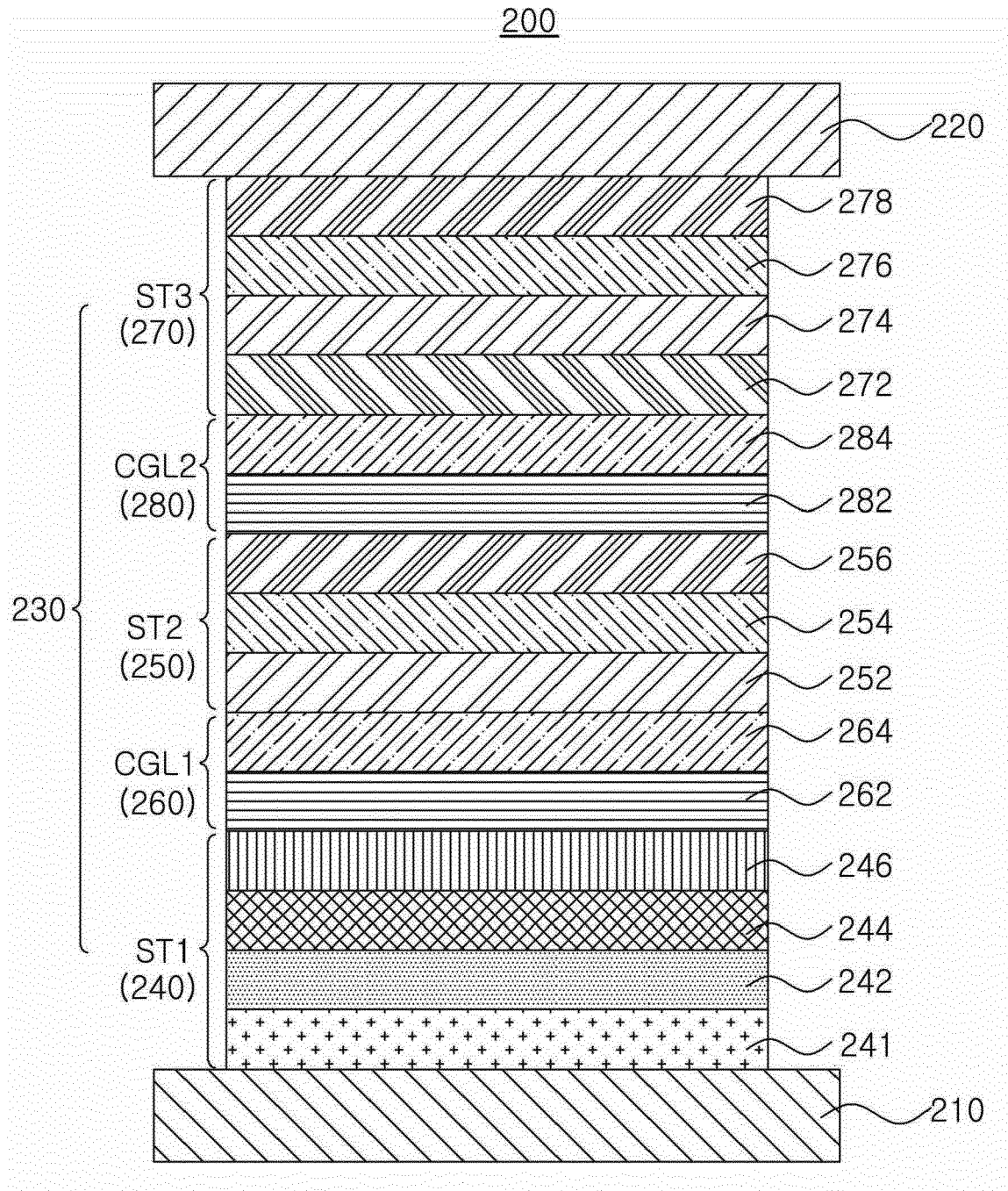


FIG. 3

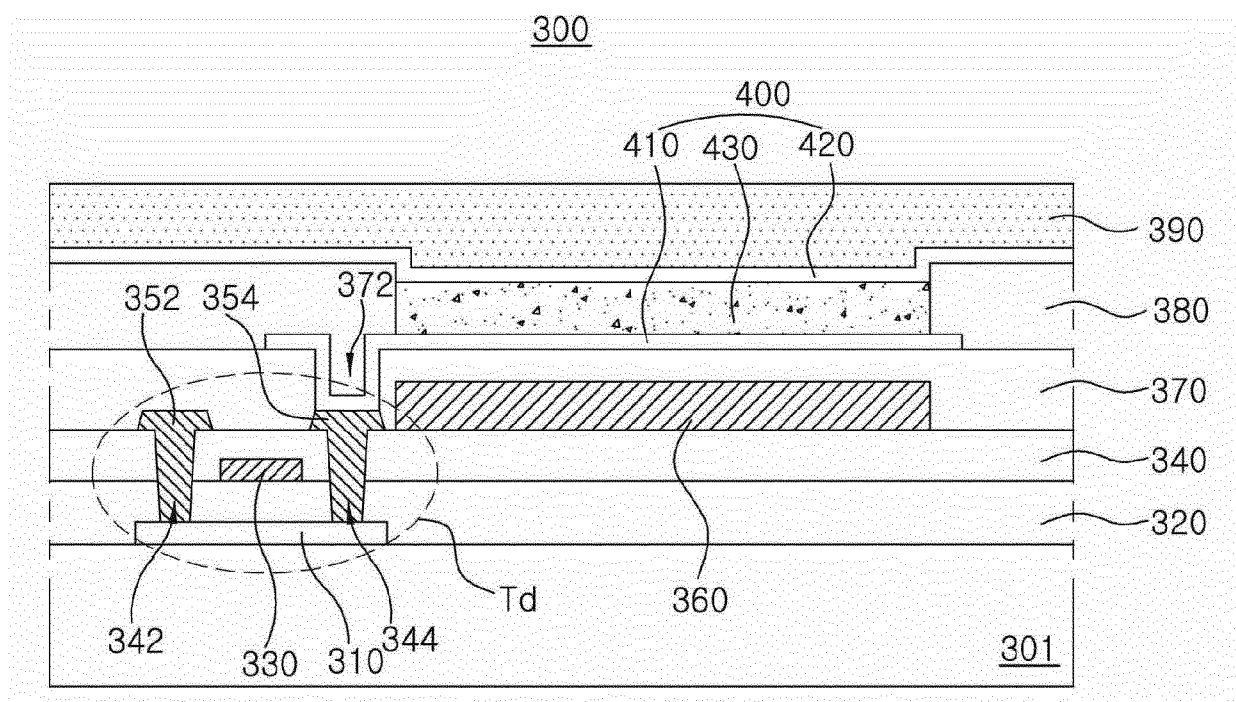


FIG. 4A

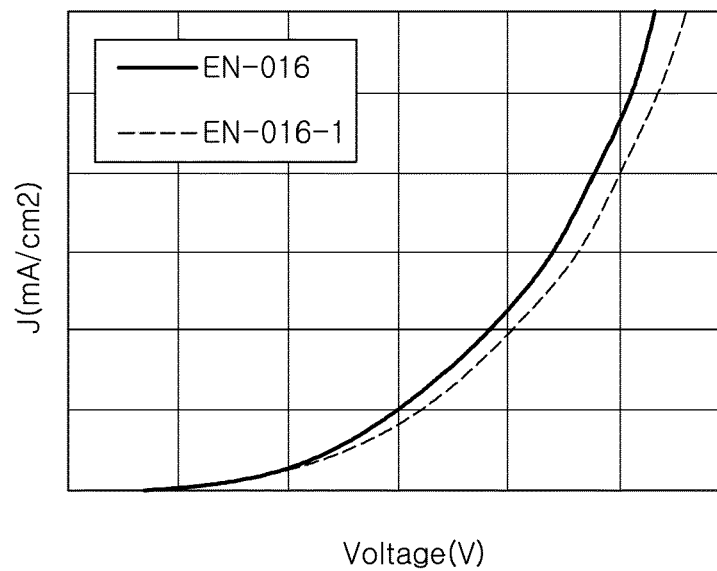


FIG. 4B

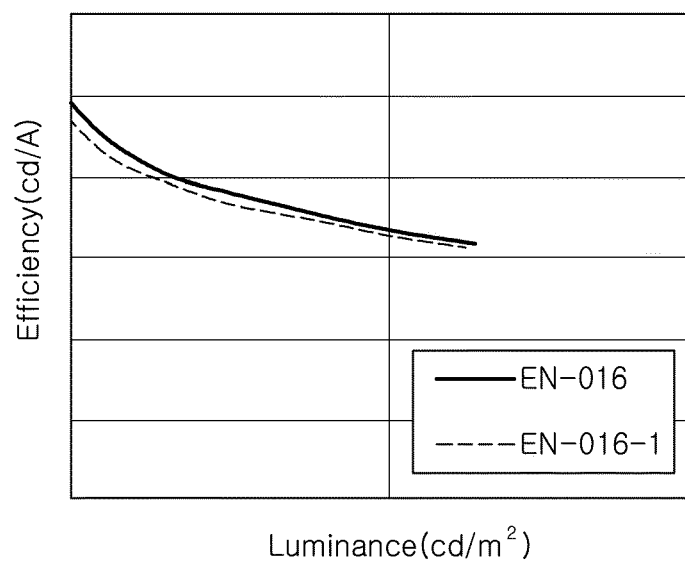


FIG. 4C

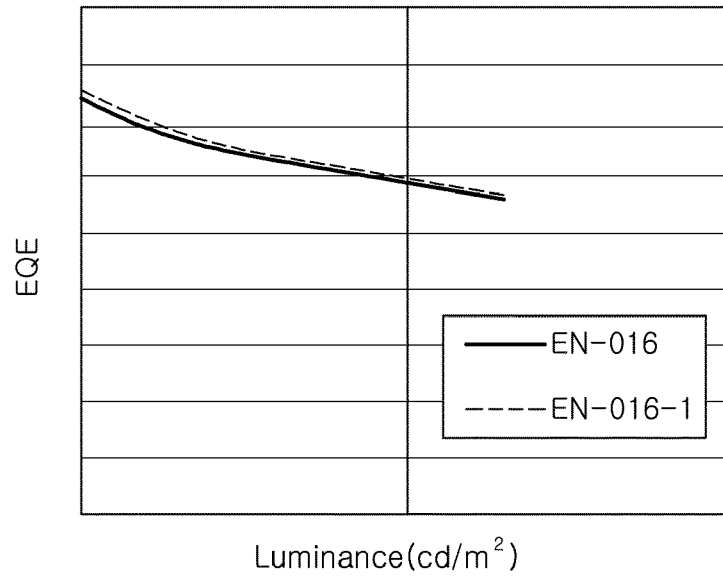


FIG. 4D

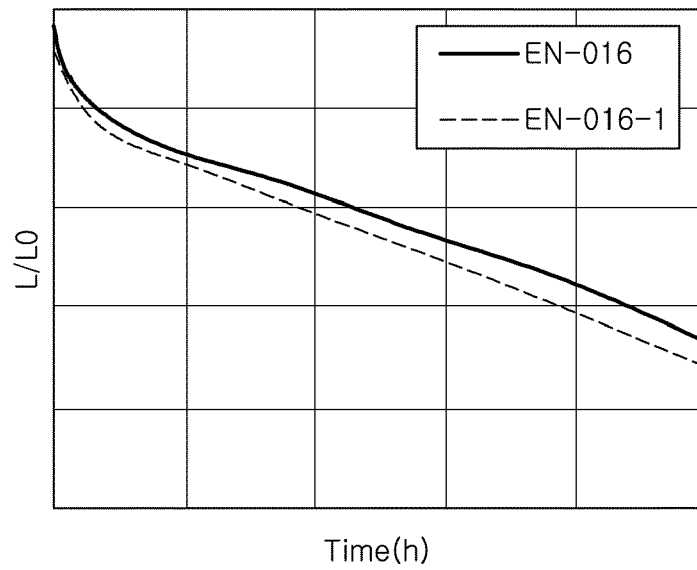


FIG. 5A

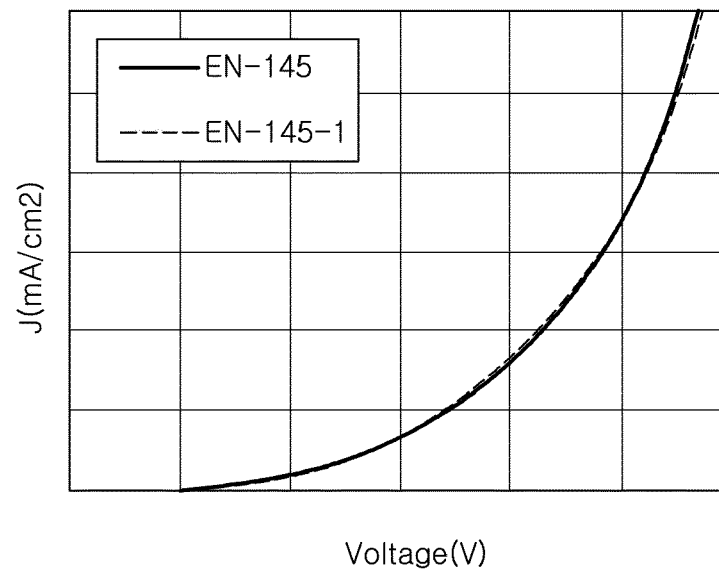


FIG. 5B

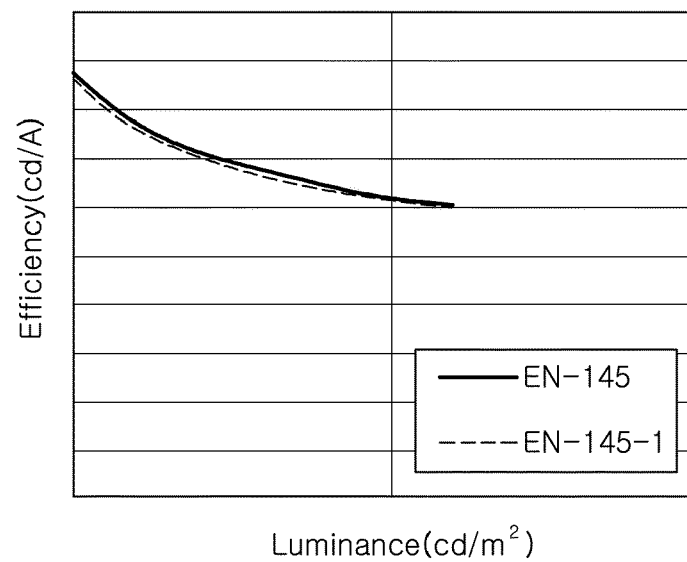


FIG. 5C

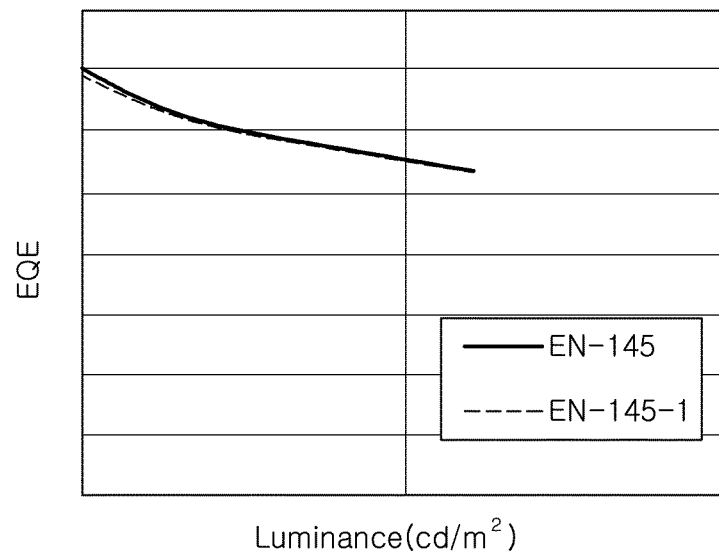


FIG. 5D

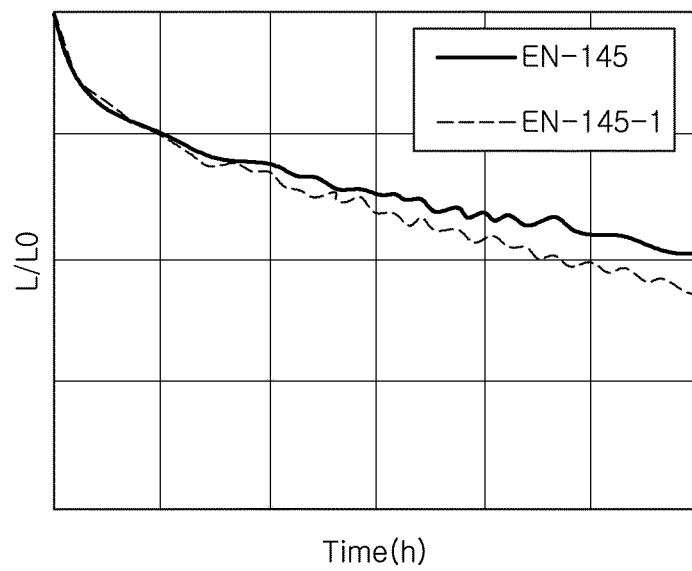


FIG. 6A

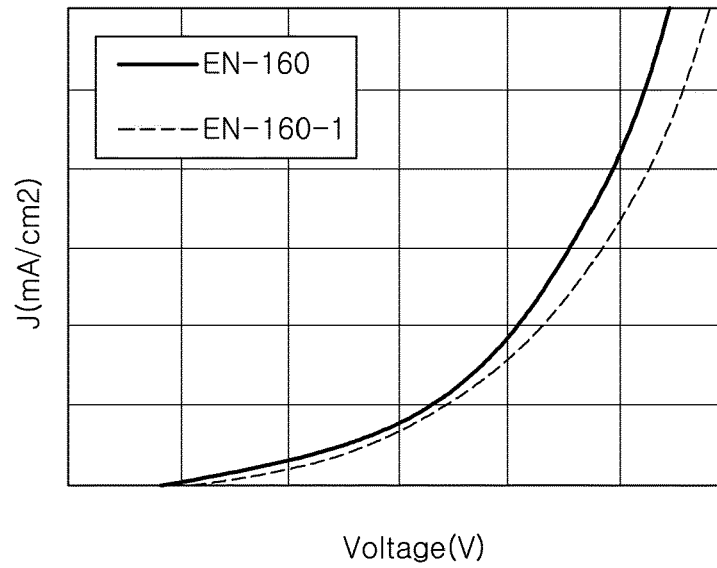


FIG. 6B

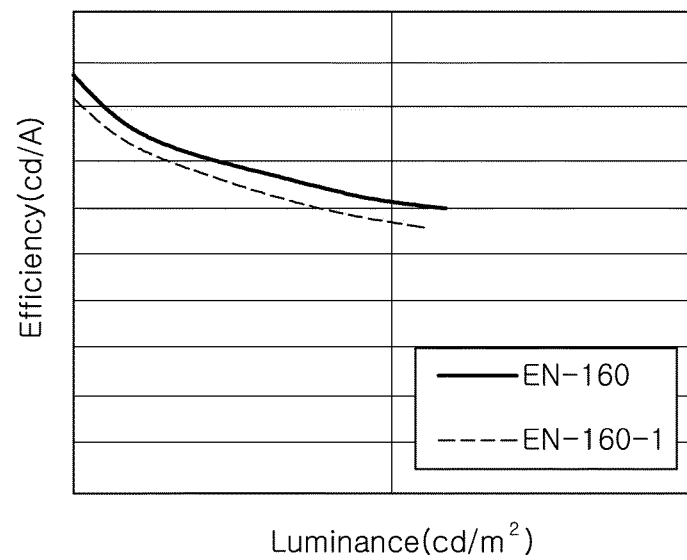


FIG. 6C

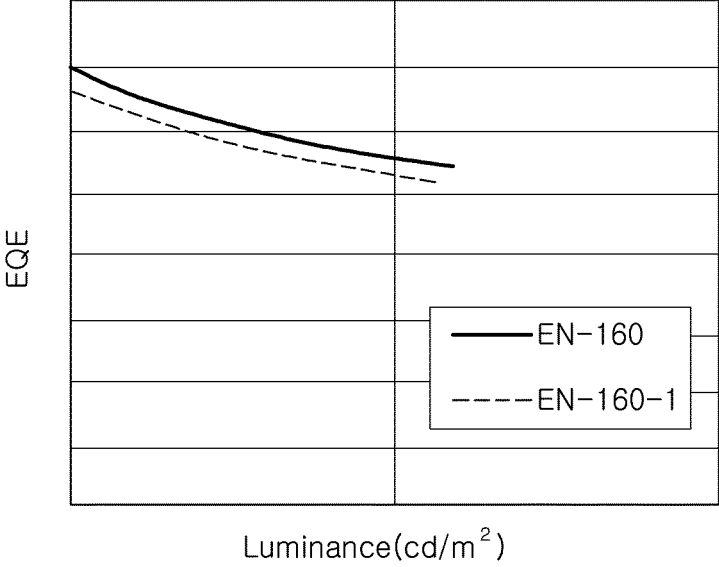
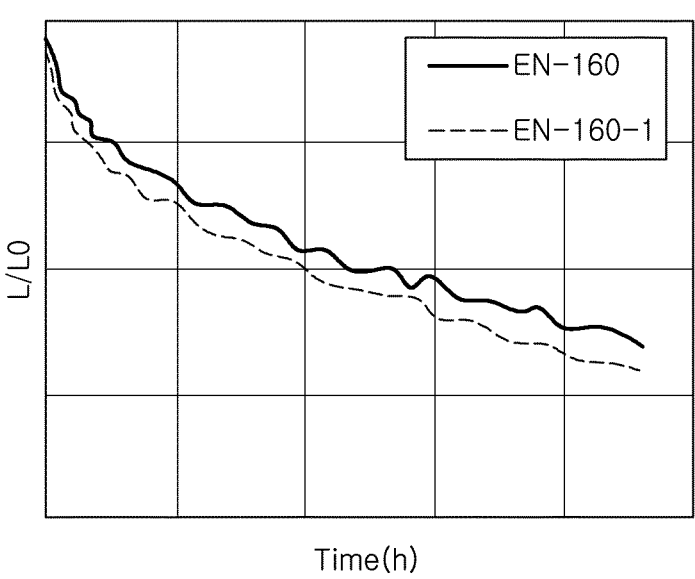


FIG. 6D





EUROPEAN SEARCH REPORT

Application Number
EP 17 20 3371

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	EP 2 896 621 A1 (IDEMITSU KOSAN CO [JP]) 22 July 2015 (2015-07-22) * page 22 - page 55; claims 1-38; compounds ET1-ET12, ET105-ET128 * -----	1,3,4,6, 7,10-12 2,5,8,9	INV. H01L51/50 H01L51/54 ADD. C07D471/04
			TECHNICAL FIELDS SEARCHED (IPC)
			H01L C07D C09K
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 17 April 2018	Examiner Königstein, C
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 20 3371

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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17-04-2018

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2896621 A1	22-07-2015	CN 104603137 A	06-05-2015
		EP 2896621 A1	22-07-2015
		JP 6167105 B2	19-07-2017
		JP W02014042163 A1	18-08-2016
		KR 20150054797 A	20-05-2015
		TW 201420585 A	01-06-2014
		US 2014077191 A1	20-03-2014
		US 2018102484 A1	12-04-2018
		WO 2014042163 A1	20-03-2014

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

专利名称(译)	有机化合物，发光二极管和有机发光二极管显示器		
公开(公告)号	EP3333921A1	公开(公告)日	2018-06-13
申请号	EP2017203371	申请日	2017-11-23
[标]申请(专利权)人(译)	乐金显示有限公司		
申请(专利权)人(译)	LG DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	LG DISPLAY CO. , LTD.		
[标]发明人	SHIN JI CHEOL JOO SUNG HOON YOO SEON KEUN YOON SEUNG HEE		
发明人	SHIN, JI-CHEOL JOO, SUNG-HOON YOO, SEON-KEUN YOON, SEUNG-HEE		
IPC分类号	H01L51/50 H01L51/54 C07D471/04		
CPC分类号	C07D471/04 C09K11/06 C09K2211/1007 C09K2211/1011 C09K2211/1044 C09K2211/1059 H01L51/0052 H01L51/0054 H01L51/0056 H01L51/0058 H01L51/0072 H01L51/5072 H01L51/5278 C07D401/14 H01L51/0067 H01L27/3209 H01L51/0035 H01L51/5036 H01L51/5092 H05B45/60		
优先权	1020160168918 2016-12-12 KR		
外部链接	Espacenet		

摘要(译)

本公开涉及有机化合物，发光二极管和使用其的有机发光二极管显示装置。该有机化合物由以下化学式1表示。该有机化合物具有电子传输性和热稳定性的优点，并与碱金属和碱土金属形成稳定的间隙状态。通过将有机化合物施加到串联结构的发光二极管的电荷产生层和/或电子传输层，降低了发光二极管的驱动电压并且提高了发光效率和发光二极管的寿命。

FIG. 1

