



(51) International Patent Classification:

C09K 11/06 (2006.01) H01L 51/50 (2006.01)

(21) International Application Number:

PCT/GB2020/050230

(22) International Filing Date:

31 January 2020 (31.01.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1901356.4 31 January 2019 (31.01.2019) GB

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(81) Designated States (unless otherwise indicated, for every

kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: LIGHT-EMITTING COMPOSITION

(57) Abstract: A composition comprising a first semiconducting host compound having a glass transition temperature (T_g) of less than 80°C; a first light-emitting material; and a polymer. The polymer may be an inert polymer, e.g. polystyrene. The composition may be used in the light-emitting layer of an organic light-emitting device.



WO 2020/157516 A1

LIGHT-EMITTING COMPOSITION

BACKGROUND

Embodiments of the present disclosure relate to light-emitting compositions, in particular for organic light-emitting diodes.

Electronic devices containing active organic materials are known for use in devices such as organic light emitting diodes (OLEDs), organic photoresponsive devices (in particular organic photovoltaic devices and organic photosensors), organic transistors and memory array devices. Devices containing active organic materials offer benefits such as low weight, low power consumption and flexibility. Moreover, use of soluble organic materials allows use of solution processing in device manufacture, for example inkjet printing or spin-coating.

An OLED may comprise a substrate carrying an anode, a cathode and one or more organic light-emitting layers between the anode and cathode.

Holes are injected into the device through the anode and electrons are injected through the cathode during operation of the device. Holes in the highest occupied molecular orbital (HOMO) and electrons in the lowest unoccupied molecular orbital (LUMO) of a light-emitting material combine to form an exciton that releases its energy as light.

Light-emitting materials include small molecule, polymeric and dendrimeric materials. Light-emitting polymers include poly(arylene vinylenes) such as poly(p-phenylene vinylenes) and polymers containing arylene repeat units, such as fluorene repeat units.

A light emitting layer may comprise a host material and a light-emitting dopant wherein energy is transferred from the host material to the light-emitting dopant. For example, J. Appl. Phys. 65, 3610, 1989 discloses a host material doped with a fluorescent light-emitting dopant (that is, a light-emitting material in which light is emitted via decay of a singlet exciton).

Phosphorescent dopants are also known (that is, a light-emitting dopant in which light is emitted via decay of a triplet exciton).

US 2016/197275 discloses a mixed host used in an emission layer of an OLED.

SUMMARY

A summary of aspects of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects and/or a combination of aspects that may not be set forth.

When a light-emitting layer of an OLED is formed by depositing the components of the layer using a solution deposition method, it is desirable to heat the layer to remove the solvent. The present inventors have found that heating a light-emitting layer containing a host material having a low glass transition temperature (T_g), e.g. a T_g of less than about 80°C, can result in rapid decay of luminance from the resultant OLED.

The present inventors have found that the presence of a polymer in the light-emitting layer of an OLED can retard the rate at which luminance of the OLED decays.

Accordingly, in some embodiments there is provided a composition comprising a semiconducting host material having a T_g of less than 80°C; a light-emitting material; and a polymer.

In some embodiments there is provided a formulation comprising a composition as described herein dissolved or dispersed in one or more solvents.

In some embodiments there is provided an organic light-emitting device comprising an anode, a cathode and a light-emitting layer between the anode and the cathode wherein the light-emitting layer comprises a composition as described herein.

In some embodiments there is provided a method of forming the organic light-emitting device comprising forming the light-emitting layer over one of the anode and the cathode and forming the other of the anode and the cathode over the light-emitting layer, wherein formation of the light-emitting layer comprises deposition of a formulation as described herein and evaporation of the one or more solvents.

BRIEF DESCRIPTION OF DRAWINGS

The present disclosure is described in conjunction with the appended figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

In the appended figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

Figure 1 illustrates an OLED according to some embodiments of the present disclosure;

Figure 2 is a graph of luminance vs time for an OLED according to some embodiments of the present disclosure and a comparative OLED in which the light emitting layer does not contain a polymer;

Figure 3 is a graph of luminance vs time for an OLED according to some embodiments of the present disclosure and a comparative OLED in which the light emitting layer does not contain a polymer; and

Figure 4 is a graph of luminance vs time for comparative OLEDs in which the light emitting layer does not contain a semiconducting host material.

DETAILED DESCRIPTION

Figure 1 illustrates an OLED 100 according to an embodiment of the invention comprising an anode 101, a cathode 105 and a light-emitting layer 103 between the anode and cathode. The device 100 is supported on a substrate 107, for example a glass or plastic substrate.

One or more further layers may be provided between the anode 101 and cathode 105, for example hole-transporting layers, electron transporting layers, hole blocking layers and electron blocking layers. The device may contain more than one light-emitting layer.

Exemplary device structures include, without limitation:

Anode / Hole-injection layer / Light-emitting layer / Cathode

Anode / Hole transporting layer / Light-emitting layer / Cathode

Anode / Hole-injection layer / Hole-transporting layer / Light-emitting layer / Cathode

Anode / Hole-injection layer / Hole-transporting layer / Light-emitting layer / Electron-transporting layer / Cathode.

Preferably, at least one of a hole-transporting layer and hole injection layer is present.

Preferably, both a hole injection layer and hole-transporting layer are present.

Light-emitting materials include red, green and blue light-emitting materials.

A blue emitting material may have a photoluminescent spectrum with a peak in the range of 400-490 nm, optionally 420-490 nm.

A green emitting material may have a photoluminescent spectrum with a peak in the range of more than 490nm up to 580 nm, optionally more than 490 nm up to 540 nm.

A red emitting material may optionally have a peak in its photoluminescent spectrum of more than 580 nm up to 630 nm, optionally 585-625 nm.

The photoluminescence spectrum of a compound of formula (I) may be measured by casting 5 wt % of the material in a polystyrene film onto a quartz substrate and measuring in a nitrogen environment using apparatus C9920-02 supplied by Hamamatsu.

Light-emitting layer 103 contains a composition comprising a first semiconducting host compound having a T_g of less than 80°C doped with a first light-emitting material. The light-emitting layer further contains a polymer.

The light-emitting layer 103 may consist essentially of these materials or may contain

one or more further materials, for example one or more further semiconducting host materials and / or one or more further light-emitting materials.

In some embodiments, the semiconducting host compound makes up 40-95 weight % of the mass of the composition, optionally 40-75 weight %, optionally 40-60 wt %.

In some embodiments, the first light-emitting material makes up 0.5-45 weight % of the mass of the composition, optionally 5-45 wt %, optionally 10-30 wt %.

In some embodiments, the polymer makes up 10-40 weight % of the mass of the composition, optionally 15-30 wt %, optionally 20-25 wt %.

The first light-emitting material, and any further light-emitting materials, may be selected from fluorescent and phosphorescent light-emitting materials.

In the case of a fluorescent material, the lowest excited stated singlet (S^1) of the, or each, host material is preferably no more than 0.1 eV below that of the fluorescent light-emitting material, and is more preferably about the same as or higher than that of the fluorescent light-emitting material.

In the case of a phosphorescent material, the lowest excited state triplet (T_1) energy level of the, or each, host material is preferably no more than 0.1 eV below that of the phosphorescent light-emitting material, and is more preferably about the same as or higher than that of the phosphorescent light-emitting material.

In the case where the light-emitting layer comprises a phosphorescent dopant the, or each, host compound preferably has a T_1 of greater than 2.8 eV, preferably greater than 3.0 eV.

Triplet energy levels of host compounds and phosphorescent compounds may be measured from the energy onset of the phosphorescence spectrum measured by low temperature phosphorescence spectroscopy (Y.V. Romaovskii et al, Physical Review Letters, 2000, 85 (5), p1027, A. van Dijken et al, Journal of the American Chemical Society, 2004, 126, p7718).

The first host compound preferably has a HOMO level of at least 5.8 eV from vacuum level, preferably at least 5.9 eV from vacuum level.

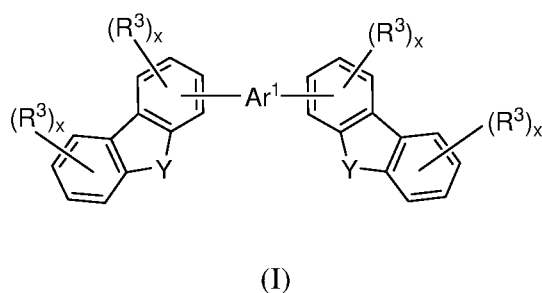
The first host compound preferably has a LUMO level of no more than 2.5 eV from vacuum level, optionally no more than 2.0 eV from vacuum level.

HOMO and LUMO levels as given herein are as measured by square wave voltammetry.

First host compound

The first host compound has a Tg of less than 80°C, optionally no more than 75°C, 70°C or 65°C.

The first host compound may have formula (I):



wherein:

Ar¹ is an arylene or heteroarylene group which is unsubstituted or substituted with one or more substituents;

each Y is independently O or S;

R³ independently in each occurrence is a substituent; and

each x is independently 0, 1, 2 or 3.

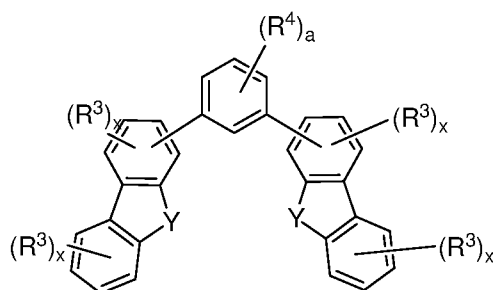
Ar¹ may be a monocyclic or fused arylene or heteroarylene group. Ar¹ is optionally selected from C₆₋₂₀ arylenes and 5-20 membered heteroarylenes. Preferably, Ar¹ is phenylene.

Ar¹ may be unsubstituted or substituted with one or more groups R⁴ wherein R⁴ in each occurrence is independently a substituent. If present, substituents R⁴ are optionally selected from branched, linear or cyclic C₁₋₂₀ alkyl wherein one or more non-adjacent C atoms may be replaced with O, S, CO or COO.

Optionally, one or both of the dibenzofuran or dibenzofuran groups of formula (I) are bound to Ar¹ through their 2-positions.

Preferably, each x is 0 or 1, more preferably 0.

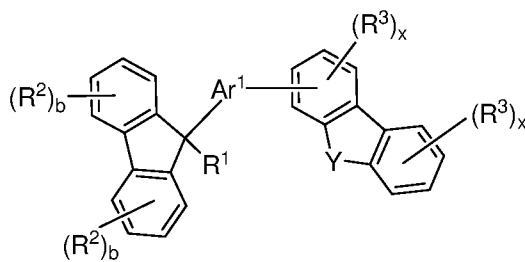
Optionally, the compound of formula (I) has formula (Ia):



(Ia)

wherein a is 0, 1, 2 or 3, preferably 0 or 1.

Optionally, the first host compound has formula (II):



(II)

wherein Ar¹, Y, R³ and x are as described with reference to Formula (I); R¹ is a substituent; R² is a substituent; and each b is independently 0, 1, 2 or 3.

Optionally, R^1 is selected from the group consisting of:

alkyl, optionally C_{1-20} alkyl, wherein one or more non-adjacent, non-terminal C atoms may be replaced with a group selected from O, S, C=O or -COO; and

a group of formula $-(Ar^2)_n$ wherein Ar^2 in each occurrence is independently a C_{6-20} aryl or 5-20 membered heteroaryl group that is unsubstituted or substituted with one or more substituents and n is at least 1, optionally 1, 2 or 3.

By “non-terminal C atom” of an alkyl group as used herein is meant an atom of an alkyl chain other than the methyl group at the end of a n-alkyl chain or the methyl groups at the ends of a branched alkyl chain.

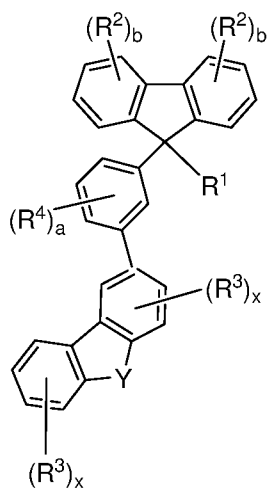
Optionally, Ar^2 is phenyl.

Substituents of Ar^2 , where present, may be selected from C_{1-12} alkyl, wherein one or more non-adjacent, non-terminal C atoms may be replaced with a group selected from O, S, C=O or -COO and one or more H atoms of the alkyl may be replaced with F.

Where present, R^2 may in each occurrence independently be selected from the group consisting of C_{1-20} alkyl wherein one or more non-adjacent, non-terminal carbon atoms of the alkyl may be replaced with O, S, C=O or COO and one or more H atoms of the alkyl may be replaced with F.

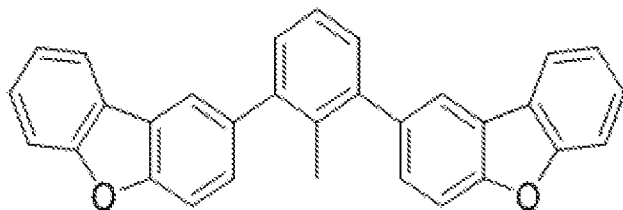
Preferably, b is 0 or 1, more preferably 0.

The compound of formula (II) may have formula (IIa):

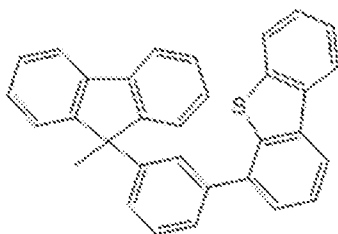


(IIa)

Exemplary compounds of formula (I) are:



Exemplary compounds of formula (II) are:



Polymer

The polymer may be an inert polymer, i.e. a polymer which does not contribute to hole or electron transport in the light-emitting layer of an OLED.

The inert polymer preferably has a non-conjugated backbone, e.g. a linear or branched backbone of sp^3 -hybridised carbon atoms which may be unsubstituted or substituted with

one or more substituents. Monocyclic aromatic rings may be pendant from the polymer backbone, e.g. as in polystyrene.

The inert polymer may have a HOMO which is at least 1 eV deeper (further from vacuum level) than the first light-emitting material. The inert polymer may have a LUMO which is shallower (closer to vacuum) than any other material of the composition.

The lowest triplet excited state (T₁) of the inert polymer is suitably higher than that of any other material in the light-emitting layer. Optionally, T₁ of the polymer is at least 3.0 eV, optionally at least 3.5 eV.

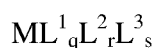
Optionally, the weight average molecular weight of the polymer is at least 10,000, optionally at least 100,000, optionally at least 250,000. Optionally, the Mw of the polymer may be up to about 2,000,000.

Light-emitting compounds

Light-emitting materials for a light-emitting layer, including first and further light-emitting materials as described herein, include polymeric and non-polymeric light-emitting materials, each of which may be fluorescent or phosphorescent.

Preferably, the first light-emitting material is a non-polymeric light-emitting material.

Exemplary phosphorescent compounds have formula (IX):



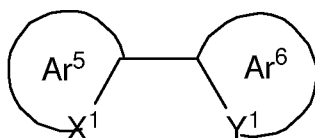
(III)

wherein M is a metal; each of L¹, L² and L³ is a coordinating group that independently may be unsubstituted or substituted with one or more substituents; q is a positive integer; r and s are each independently 0 or a positive integer; and the sum of (a. q) + (b. r) + (c. s) is equal to the number of coordination sites available on M, wherein a is the number of coordination sites on L¹, b is the number of coordination sites on L² and c is the number of coordination sites on L³.

a, b and c are preferably each independently 1, 2 or 3. Preferably, L^1 , L^2 and L^3 are each a bidentate ligand (a, b and c are each 2). In an embodiment, q is 3 and r and s are 0. In another embodiment, q is 1 or 2; r is 1; and s is 0 or 1, preferably 0.

Heavy elements M induce strong spin-orbit coupling to allow rapid intersystem crossing and emission from triplet or higher states. Suitable heavy metals M include d-block metals, in particular those in rows 2 and 3 i.e. elements 39 to 48 and 72 to 80, in particular ruthenium, rhodium, palladium, rhenium, osmium, iridium, platinum and gold. Iridium is particularly preferred.

Exemplary ligands L^1 , L^2 and L^3 include carbon or nitrogen donors such as porphyrin or bidentate ligands of formula (IV):



(IV)

wherein Ar^5 and Ar^6 may be the same or different and are independently selected from substituted or unsubstituted aryl or heteroaryl; X^1 and Y^1 may be the same or different and are independently selected from carbon or nitrogen; and Ar^5 and Ar^6 may be fused together. Ligands wherein X^1 is carbon and Y^1 is nitrogen are preferred, in particular ligands in which Ar^5 is a single ring or fused heteroaromatic of N and C atoms only, for example pyridyl or isoquinoline, and Ar^6 is a single ring or fused aromatic, for example phenyl or naphthyl.

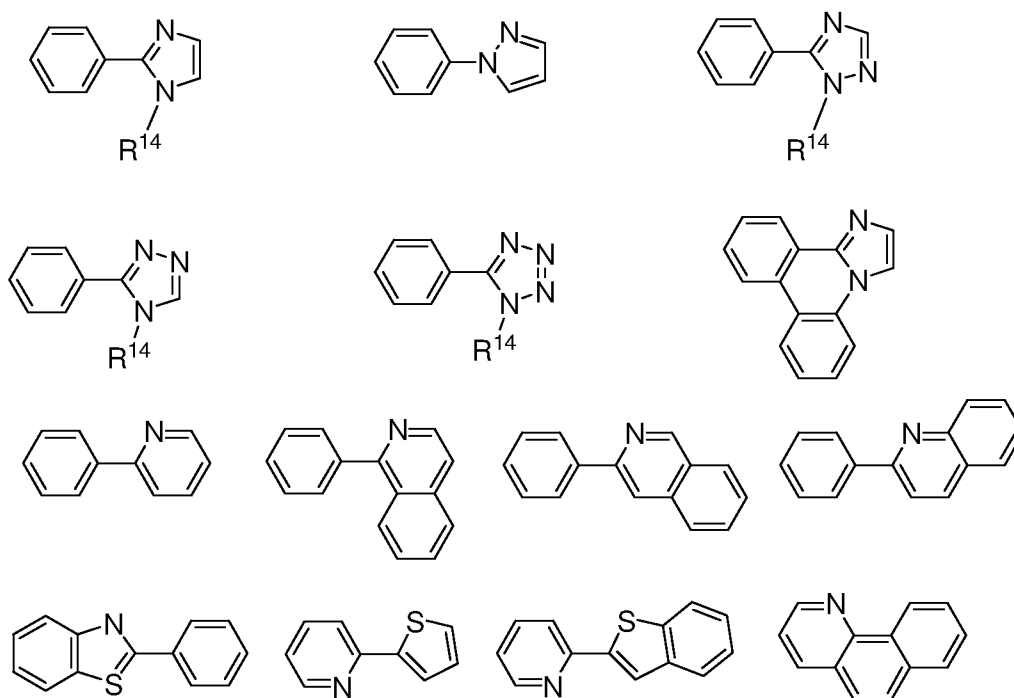
Each of Ar^5 and Ar^6 may carry one or more substituents. Two or more of these substituents may be linked to form a ring, for example an aromatic ring. Preferred substituents are selected from D, F, C_{1-20} alkyl groups wherein one or more non-adjacent C atoms may be replaced with O, S, CO or COO and one or more H atoms may be replaced with F; phenyl or biphenyl that may be unsubstituted or substituted with one or more substituents, optionally one or more C_{1-10} alkyl or C_{1-12} alkoxy groups; and dendrons.

To achieve red emission, Ar⁵ may be selected from phenyl, fluorene, naphthyl and Ar⁶ are selected from quinoline, isoquinoline, thiophene and benzothiophene.

To achieve green emission, Ar⁵ may be selected from phenyl or fluorene and Ar⁶ may be pyridine.

To achieve blue emission, Ar⁵ may be selected from phenyl and Ar⁶ may be selected from imidazole, pyrazole, triazole and tetrazole.

Examples of bidentate ligands of formula (X) wherein X¹ is carbon and Y¹ is nitrogen are:



wherein R¹⁴ is a substituent and wherein each C atom may independently be unsubstituted or substituted with a substituent R¹⁵.

Substituents R¹⁴ and R¹⁵ are preferably selected from C₁₋₄₀ hydrocarbyl groups, preferably linear, branched or cyclic C₁₋₂₀ alkyl groups; phenyl or biphenyl which may be unsubstituted or substituted with one or more C₁₋₁₂ alkyl groups; and dendrons.

Other ligands suitable for use with d-block elements include O,O-bidentate ligands, optionally diketones, O,N-bidentate ligands and N,N bidentate ligands, in particular

acetylacetonate (acac), tetrakis-(pyrazol-1-yl)borate, 2-carboxypyridyl, triarylphosphines and pyridine, each of which may be substituted.

One or more of L^1 , L^2 and L^3 may comprise a carbene group.

In some embodiments, compositions described herein comprise a blue phosphorescent material of formula (III) wherein:

q is 2 or 3 and each L^1 is a C,N-bidentate ligand of formula (IV);

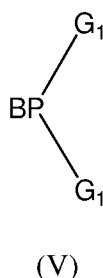
r is 0 or 1 and L^2 , if present, is a C,N-bidentate ligand of formula (IV) or an O,O-, N,N- or O,N-bidentate ligand;

s is 0;

and M is iridium.

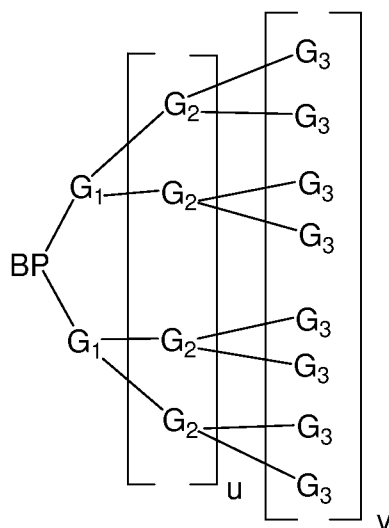
Dendrons as described herein comprise a branching point attached to a ligand of the metal complex and two or more dendritic branches. Preferably, the dendron is at least partially conjugated, and at least one of the branching points and dendritic branches comprises an aryl or heteroaryl group, for example a phenyl group. In one arrangement, the branching point group and the branching groups are all phenyl, and each phenyl may independently be substituted with one or more substituents, for example C_{1-20} alkyl or alkoxy.

A dendron may have optionally substituted formula (V)



wherein BP represents a branching point for attachment to a core and G_1 represents first generation branching groups.

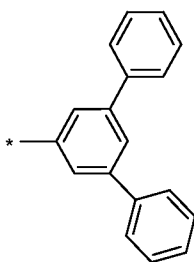
The dendron may be a first, second, third or higher generation dendron. G_1 may be substituted with two or more second generation branching groups G_2 , and so on, as in optionally substituted formula (Va):



(Va)

wherein u is 0 or 1; v is 0 if u is 0 or may be 0 or 1 if u is 1; BP represents a branching point for attachment to a core and G_1 , G_2 and G_3 represent first, second and third generation dendron branching groups. In one preferred embodiment, each of BP and G_1 , $G_2 \dots G_n$ is phenyl, and each phenyl BP, G_1 , $G_2 \dots G_{n-1}$ is a 3,5-linked phenyl.

A preferred dendron is a substituted or unsubstituted dendron of formula (Vb):



(Vb)

wherein * represents an attachment point of the dendron to a ligand.

BP and / or any group G may be substituted with one or more substituents, for example one or more C₁₋₂₀ alkyl or alkoxy groups.

A light-emitting layer may contain the first light-emitting material and one or more further light-emitting materials, for example a mixture of light-emitting materials that together provide white light emission.

A white-emitting OLED may contain a single, white-emitting layer containing a light-emitting composition as described herein, or may contain two or more layers that emit different colours which, in combination, produce white light and wherein at least one of the light emitting layers comprises a composition as described herein.

The light emitted from a white-emitting OLED may have CIE x coordinate equivalent to that emitted by a black body at a temperature in the range of 2500-9000K and a CIE y coordinate within 0.05 or 0.025 of the CIE y co-ordinate of said light emitted by a black body, optionally a CIE x coordinate equivalent to that emitted by a black body at a temperature in the range of 2700-6000K.

Charge transporting and charge blocking layers

An OLED as described herein may have one or more layers selected from charge-transporting and charge blocking layers.

A hole transporting layer may be provided between the anode and the light-emitting layer or layers of an OLED. An electron transporting layer may be provided between the cathode and the light-emitting layer or layers.

An electron blocking layer may be provided between the anode and the light-emitting layer(s) and a hole blocking layer may be provided between the cathode and the light-emitting layer(s). Charge-transporting and charge-blocking layers may be used in combination. Depending on the HOMO and LUMO levels of the material or materials in a layer, a single layer may both transport one of holes and electrons and block the other of holes and electrons.

If present, a hole transporting layer located between the anode and the light-emitting layer(s) preferably has a material having a HOMO level of less than or equal to 5.5 eV, more preferably around 4.8-5.5 eV or 4.9-5.3 eV as measured by square wave

voltammetry. The HOMO level of the material in the hole transport layer may be selected so as to be within 0.2 eV, optionally within 0.1 eV of the light-emitting material of the light-emitting layer. An inert polymer of the light-emitting layer may have a HOMO level that is at least 1 eV deeper than any material of the hole-transporting layer.

A hole-transporting layer may contain polymeric or non-polymeric charge-transporting materials. A hole-transporting polymer may be as described in WO 99/54385, WO 2004/060970, WO 2005/049546 or WO 2013/108023, the contents of which are incorporated herein by reference.

A charge-transporting layer or charge-blocking layer may be crosslinked, particularly if a layer overlying that charge-transporting or charge-blocking layer is deposited from a solution. The crosslinkable group used for this crosslinking may be a crosslinkable group comprising a reactive double bond such as a vinyl or acrylate group, or a benzocyclobutane group. The crosslinkable group may be provided as a substituent of, or may be mixed with, a charge-transporting or charge-blocking material used to form the charge-transporting or charge-blocking layer. Crosslinkable groups may be provided as substituents of repeat units of a hole-transporting polymer, for example as described in WO2016/005749, the contents of which are incorporated herein by reference.

A charge-transporting layer adjacent to a light-emitting layer containing a phosphorescent light-emitting material preferably contains a charge-transporting material having a lowest triplet excited state (T_1) excited state that is no more than 0.1 eV lower than, preferably the same as or higher than, the T_1 excited state energy level of the phosphorescent light-emitting material(s) in order to avoid quenching of triplet excitons.

A charge-transporting layer as described herein may be non-emissive, or may contain a light-emitting material such that the layer is a charge transporting light-emitting layer. If the charge-transporting layer is a polymer then a light-emitting dopant may be provided as a side-group of the polymer, a repeat unit in a backbone of the polymer, or an end group of the polymer. Optionally, a hole-transporting polymer as described herein comprises a phosphorescent polymer in a side-group of the polymer, in a repeat unit in a backbone of the polymer, or as an end group of the polymer.

Hole injection layers

A conductive hole injection layer, which may be formed from a conductive organic or inorganic material, may be provided between the anode 101 and the light-emitting layer 103 of an OLED as illustrated in Figure 1 to assist hole injection from the anode into the layer or layers of semiconducting polymer. Examples of doped organic hole injection materials include optionally substituted, doped poly(ethylene dioxythiophene) (PEDOT), in particular PEDOT doped with a charge-balancing polyacid such as polystyrene sulfonate (PSS) as disclosed in EP 0901176 and EP 0947123, polyacrylic acid or a fluorinated sulfonic acid, for example Nafion ®; polyaniline as disclosed in US 5723873 and US 5798170; and optionally substituted polythiophene or poly(thienothiophene). Examples of conductive inorganic materials include transition metal oxides such as VOx, MoOx and RuOx as disclosed in Journal of Physics D: Applied Physics (1996), 29(11), 2750-2753.

Cathode

The cathode 105 is selected from materials that have a work function allowing injection of electrons into the light-emitting layer of the OLED. Other factors influence the selection of the cathode such as the possibility of adverse interactions between the cathode and the light-emitting material. The cathode may consist of a single material such as a layer of aluminium. Alternatively, it may comprise a plurality of conductive materials such as metals, for example a bilayer of a low work function material and a high work function material such as calcium and aluminium, for example as disclosed in WO 98/10621. The cathode may comprise elemental barium, for example as disclosed in WO 98/57381, Appl. Phys. Lett. 2002, 81(4), 634 and WO 02/84759. The cathode may comprise a thin (e.g. 1-5 nm) layer of metal compound, in particular an oxide or fluoride of an alkali or alkali earth metal, between the organic layers of the device and one or more conductive cathode layers to assist electron injection, for example lithium fluoride as disclosed in WO 00/48258; barium fluoride as disclosed in Appl. Phys. Lett. 2001, 79(5), 2001; and barium oxide. In order to provide efficient injection of electrons into the device, the cathode preferably has a work function of less than 3.5 eV, more

preferably less than 3.2 eV, most preferably less than 3 eV. Work functions of metals can be found in, for example, Michaelson, J. Appl. Phys. 48(11), 4729, 1977.

The cathode may be opaque or transparent. Transparent cathodes are particularly advantageous for active matrix devices because emission through a transparent anode in such devices is at least partially blocked by drive circuitry located underneath the emissive pixels. A transparent cathode comprises a layer of an electron injecting material that is sufficiently thin to be transparent. Typically, the lateral conductivity of this layer will be low as a result of its thinness. In this case, the layer of electron injecting material is used in combination with a thicker layer of transparent conducting material such as indium tin oxide.

It will be appreciated that a transparent cathode device need not have a transparent anode (unless, of course, a fully transparent device is desired), and so the transparent anode used for bottom-emitting devices may be replaced or supplemented with a layer of reflective material such as a layer of aluminium. Examples of transparent cathode devices are disclosed in, for example, GB 2348316.

Encapsulation

Organic optoelectronic devices tend to be sensitive to moisture and oxygen.

Accordingly, the substrate preferably has good barrier properties for prevention of ingress of moisture and oxygen into the device. The substrate is commonly glass, however alternative substrates may be used, in particular where flexibility of the device is desirable. For example, the substrate may comprise one or more plastic layers, for example a substrate of alternating plastic and dielectric barrier layers or a laminate of thin glass and plastic.

The device may be encapsulated with an encapsulant to prevent ingress of moisture and oxygen. Suitable encapsulants include a sheet of glass, films having suitable barrier properties such as silicon dioxide, silicon monoxide, silicon nitride or alternating stacks of polymer and dielectric or an airtight container. In the case of a transparent cathode device, a transparent encapsulating layer such as silicon monoxide or silicon dioxide may be deposited to micron levels of thickness, although in one preferred embodiment the thickness of such a layer is in the range of 20-300 nm. A getter material for absorption of

any atmospheric moisture and / or oxygen that may permeate through the substrate or encapsulant may be disposed between the substrate and the encapsulant.

Formulation processing

A formulation suitable for forming a light-emitting layer of an OLED may be formed by dissolving or dispersing the components of a composition as described herein in one or more solvents.

The formulation may be a solution of the composition, or may be a dispersion in which one or more components of the composition are not dissolved. Preferably, the formulation is a solution.

Exemplary solvents include, without limitation, benzenes substituted with one or more C₁₋₁₀ alkyl or C₁₋₁₀ alkoxy groups, for example toluene, xylenes and methylanisoles.

The formulation may contain at least one solvent having a boiling point of at least 100°C, optionally 110°C or 120°C.

Particularly preferred solution deposition techniques including printing and coating techniques such spin-coating, inkjet printing and slot-die coating.

Spin-coating is particularly suitable for devices wherein patterning of the light-emitting layer is unnecessary – for example for lighting applications or simple monochrome segmented displays.

Inkjet printing is particularly suitable for high information content displays, in particular full colour displays. A device may be inkjet printed by providing a patterned layer over the first electrode and defining wells for printing of one colour (in the case of a monochrome device) or multiple colours (in the case of a multicolour, in particular full colour device). The patterned layer is typically a layer of photoresist that is patterned to define wells as described in, for example, EP 0880303.

As an alternative to wells, the ink may be printed into channels defined within a patterned layer. In particular, the photoresist may be patterned to form channels which, unlike

walls, extend over a plurality of pixels and which may be closed or open at the channel ends.

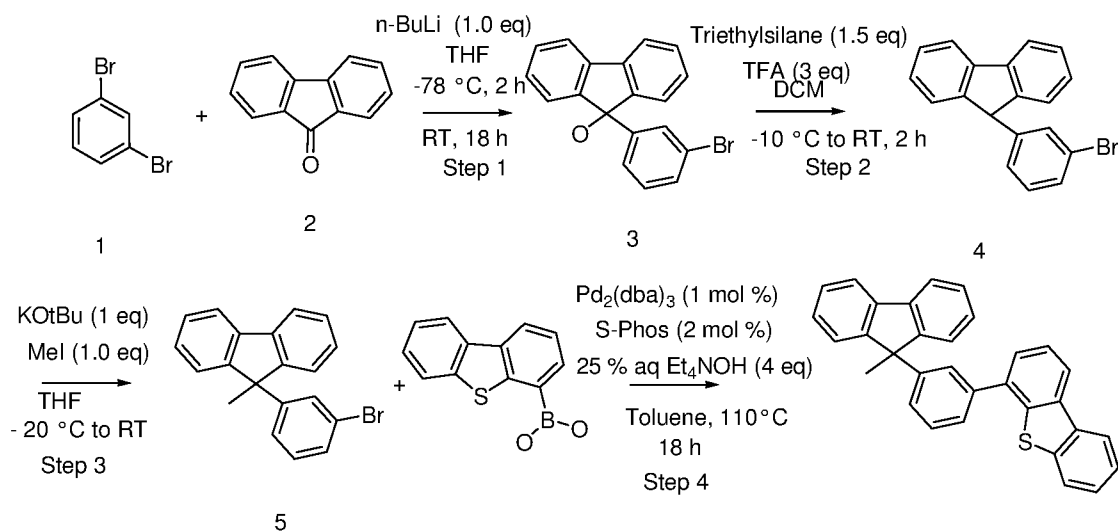
Other solution deposition techniques include dip-coating, roll printing and screen printing.

Following deposition of the formulation, the formulation may be heated, at atmospheric pressure or vacuum, to evaporate the solvent or solvents. Optionally, the formulation is heated to a temperature above the T_g of the first host. Optionally, the formulation is heated to a temperature in the range of 80-180°C, optionally 100-150°C.

EXAMPLES

Materials

Host 2 was prepared according to the following reaction scheme:



Step 1 - Synthesis of Intermediate 3

In a 10 L 3-necked round-bottomed flask, equipped with a mechanical overhead stirrer, nitrogen inlet and exhaust, 1,3-dibromobenzene (288 g, 1.220 mol) was taken in tetrahydrofuran (2 L) and cooled to -78 °C.

2.5M n-butyl lithium in hexane (443 mL, 1.109 mol) was slowly added and stirred at the same temperature for 2 h. 9-Fluorenone (200 g, 1.109 mol) in THF (500 mL) was slowly added at the same temperature. The reaction mixture was allowed to room temperature, stirred for 18 h and then quenched with saturated NH_4Cl solution (200 mL) and extracted with EtOAc (3 x 1 L).

The combined organic phase was washed with water (1000 mL), brine (500 mL), dried over sodium sulphate and concentrated.

The residue showed ~ 60 % Intermediate 3 which was used without further purification.

Step 2 - Synthesis of Intermediate 4

Intermediate 3 (~60 % pure, 420 g, 0.771 mol) and Triethyl silane (186 mL, 1.156 mol) were taken in dry dichloromethane (3 L) in a 10 L 3-necked round-bottomed flask, equipped with a mechanical overhead stirrer, nitrogen inlet and exhaust.

The reaction mixture was cooled to $-10\text{ }^{\circ}\text{C}$ and stirred for 0.5 h. Trifluoroacetic acid (175 mL, 2.313 mol) was slowly added and the reaction mixture was stirred at room temperature for 2 h. Crude GCMS analysis showed complete conversion of starting material. The reaction mixture was quenched with water (300 mL) and the organic phase was washed with water (500 mL), brine (500 mL), dried over sodium sulphate and concentrated to give 326 g of crude product.

The crude product was purified by silica column chromatography using 3 to 4 % ethyl acetate in hexane as an eluent and the product was triturated with methanol to give 216 g of intermediate 4 with 92.9 % HPLC purity. The compound was crystallized using hot acetonitrile to give 195 g of intermediate 4 with 97.02 % purity.

Step 3 - Synthesis of Intermediate 5

Intermediate 4 (195 g, 0.607 mol) was dissolved in dry tetrahydrofuran (1800 mL) and degassed with N_2 for an hour in a 10 L 3-necked round-bottomed flask, equipped with a mechanical overhead stirrer, nitrogen inlet and exhaust and then cooled to $-20\text{ }^{\circ}\text{C}$.

To degassed THF (1200 mL) was added potassium tert-butoxide (68.1 g, 0.607 mol) and nitrogen purged for an hour. Methyl iodide (37.9 mL, 0.607 mol) and the degassed potassium tert-butoxide solution were added dropwise to Intermediate 4.

The reaction mixture was slowly allowed to warm to room temperature and stirred for 18 h. The reaction mixture was then quenched with NH_4Cl solution (500 mL) and extracted with ethyl acetate (3 x 1 L). The combined organic phases were washed with water (1 L), brine (500 mL), dried over sodium sulphate and concentrated (210 g). The crude product (210 g) was purified by silica column chromatography using 5 to 6 % ethyl acetate in hexane as an eluent. The pure fractions obtained purified twice by hot methanol crystallization to give 155 g of Intermediate 5 with 99.19 % HPLC purity.

Step 4 - Synthesis of Host 2

To a mixture of Intermediate 5 (18 g, 0.053 mol) and dibenzothiophene- 4 boronic acid (18.3 g, 0.053 mol) in toluene (360 mL), N_2 gas was purged for an hour. In another container, aqueous 25 % Tetraethyl ammonium hydroxide (124 mL, 0.212 mol) solution was degassed with N_2 for 1 h.

The reaction mixture was heated to 60 °C. S-phos (0.43 g, 0.0011 mol) and $\text{Pd}_2(\text{dba})_3$ (0.41 g, 0.00053 mol) were added at 60 °C. The degassed tetraethyl ammonium hydroxide were added and refluxed at 110 °C for 18 h. The reaction mixture was filtered and washed with toluene. The organic phase was washed with water (400 mL), brine (300 mL), dried over sodium sulphate and concentrated (28 g). The crude product was purified by silica column chromatography using 5 % ethyl acetate in hexane as an eluent to give 24 g of Host 2 with 91.6 % HPLC purity.

The product was recrystallized twice with hot toluene/ acetonitrile to get 16 g with 99.70 % purity and then dissolved in toluene, washed with concentrated sulfuric acid, and concentrated to get 15.5 g of M849 with 99.91 % HPLC purity.

HOMO and LUMO measurement

Equipment:

CHI660D Electrochemical workstation with software (IJ Cambria Scientific Ltd))

CHI 104 3mm Glassy Carbon Disk Working Electrode (IJ Cambria Scientific Ltd))

Platinum wire auxiliary electrode

Reference Electrode (Ag/AgCl) (Havard Apparatus Ltd)

Chemicals

Acetonitrile (Hi-dry anhydrous grade-ROMIL) (Cell solution solvent)

Toluene (Hi-dry anhydrous grade) (Sample preparation solvent)

Ferrocene - FLUKA (Reference standard)

Tetrabutylammoniumhexafluorophosphate - FLUKA (Cell solution salt)

Sample preparation

The HOMO and LUMO values of the semiconducting host compounds were measured from a dilute solution (0.3w%) in toluene.

Electrochemical cell

The measurement cell contains the electrolyte, a glassy carbon working electrode, a platinum counter electrode, and a Ag/AgCl reference glass electrode. Ferrocene is added into the cell at the end of the experiment as reference material (LUMO (ferrocene) = - 4.8eV).

Tg measurement

Tg values given herein are as measured by differential scanning calorimetry using a PerkinElmer DSC8500 according to the following method:

The apparatus is purged with nitrogen gas at 20ml/min.

5-10mg of sample is weighed into a sample pan, and lid crimped to sample pan to close it.

A reference pan (empty sample pan and lid) is placed in the reference furnace, and the sample is loaded into the sample furnace.

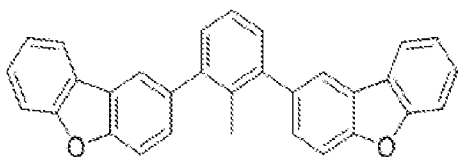
Heating and cooling is conducted according to the following temperature program:

- 1) Hold for 1.0 min at -50.00°C. Switch the Gas to Helium at 20.0 ml/min at start of step.
- 2) Heat from -50.00°C to 300.00°C at 300.00°C/min.
- 3) Hold for 1.0 min at 300.00°C.
- 4) Cool from 300.00°C to -50.00°C at 300.00°C/min.
- 5) Hold for 1.0 min at -50.00°C.
- 6) Heat from -50.00°C to 300.00°C at 20.00°C/min.
- 7) Hold for 1.0 min at 300.00°C.
- 8) Cool from 300.00°C to -50.00°C at 20.00°C/min.
- 9) Hold for 1.0 min at -50.00°C.
- 10) Heat from -50.00°C to 300.00°C at 100.00°C/min.
- 11) Hold for 1.0 min at 300.00°C.
- 12) Cool from 300.00°C to -50.00°C at 100.00°C/min.
- 13) Hold for 1.0 min at -50.00°C Switch the Gas to Nitrogen at 20.0 ml/min at end of step.

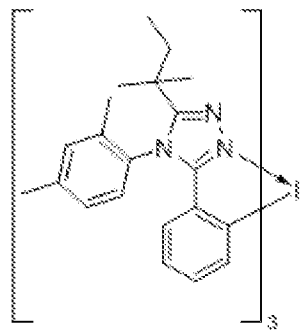
Following analysis the sample T_g is determined from the rising temperature ramp of 20°C/min (i.e. step 6 above). The falling temperature ramp of 100°C/min is used to confirm the T_g event.

Formulation Example 1

A formulation of Host 1 (50 wt %), Blue Phosphorescent Emitter 1 (25 wt %) and polystyrene (25 wt %) was dissolved in mixed xylenes.



Host 1



Blue Phosphorescent Emitter 1

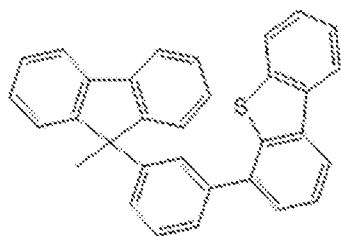
Host 1 has a Tg of 54°C and a LUMO of 1.78 eV.

Comparative Formulation 1

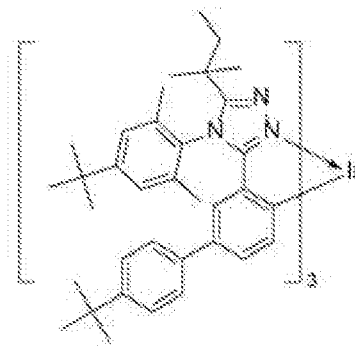
For the purpose of comparison, a formulation was prepared as described for Formulation Example 1 except that polystyrene was omitted and the Host 1 : Blue Phosphorescent Emitter 1 weight ratio was 75 : 25.

Formulation Example 2

A formulation of Host 2 (55 wt %), Blue Phosphorescent Emitter 2 (25 wt %) and polystyrene (20 wt %) was dissolved in mixed xylenes.



Host 2



Blue Phosphorescent Emitter 2

Host 2 has a Tg of 62°C and a LUMO of 1.93 eV.

Comparative Formulation 2

For the purpose of comparison, a formulation was prepared as described for Formulation Example 2 except that polystyrene was omitted and the Host 2 : Blue Phosphorescent Emitter 2 weight ratio was 75 : 25.

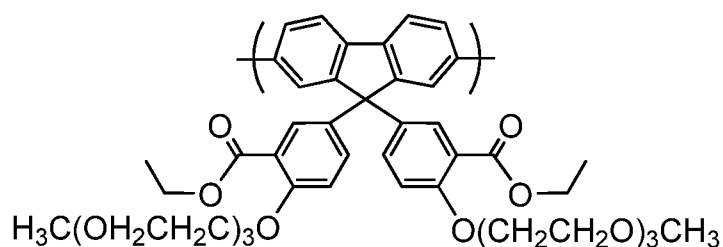
Device Example 1

An organic light-emitting device having the following structure was made:

ITO / HIL / HTL / LEL / ETL / Cathode

wherein ITO is an indium-tin oxide anode; HIL is a hole-injecting layer comprising a hole-injecting material, HTL is a hole-transporting layer, LEL is a light-emitting layer,; and ETL is an electron-transporting layer.

A substrate carrying ITO (45 nm) was cleaned using UV / Ozone. A hole injection layer was formed to a thickness of about 35 nm by spin-coating a formulation of a hole-injection material available from Nissan Chemical Industries. A hole-transporting layer was formed to a thickness of about 20 nm by spin-coating a crosslinkable hole-transporting polymer containing crosslinkable fluorene repeat units, an amine repeat unit and a red phosphorescent repeat unit and crosslinking the polymer by heating at 180°C. The light-emitting layer was formed to a thickness of about 90 nm by spin-coating Formulation Example 1 followed by heating at 130°C for 10 minutes. An electron-transporting layer was formed by spin-coating a polymer comprising the cesium salt of Electron-Transporting Unit 1 as described in WO 2012/133229 to a thickness of 10 nm. A cathode was formed on the electron-transporting layer of a first layer of sodium fluoride of about 10 nm thickness, a layer of aluminium of about 100 nm thickness and a layer of silver of about 100 nm thickness.



Electron-Transporting Unit 1

Device Example 2

Device Example 2 was made as described for Device Example 1 except that Formulation Example 2 was used in place of Formulation Example 1.

Comparative Devices 1 and 2

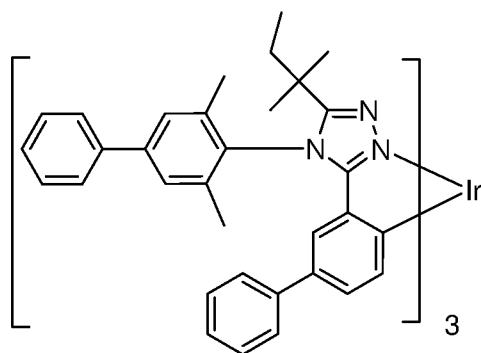
Comparative Devices 1 and 2 were made as described for Device Examples 1 and 2, respectively, except that Comparative Formulations 1 and 2 were used in place of Formulation Examples 1 and 2, respectively.

With reference to Figure 2, T_{70} (time taken for luminance to fall to 70% of an initial value at constant current) is much longer for Device Example 1 compared to Comparative Device 1.

With reference to Figure 3, T_{70} is much longer for Device Example 2 compared to Comparative Device 2.

Comparative Device 3

Comparative Device 3 was made as described for Device Example 1 except that the light-emitting layer was formed from a formulation containing polystyrene (50 wt%) and Phosphorescent Blue Emitter 3 (50 wt %)



Phosphorescent Blue Emitter 3

Comparative Device 4

Comparative Device 4 was made as described for Comparative Device 3 except that the polystyrene : Phosphorescent Blue Emitter 3 weight ratio was 40 : 60.

With reference to Figure 4, very rapid decay of luminance was observed, demonstrating that the improvement in lifetime observed in Device Examples 1 and 2 cannot be attributed to the presence of polystyrene alone.

The description above provides preferred exemplary embodiment(s) only, and is not intended to limit the scope, applicability or configuration of the invention. Rather, the ensuing description of the preferred exemplary embodiment(s) will provide those skilled in the art with an enabling description for implementing a preferred exemplary embodiment of the invention, it being understood that various changes may be made in the function and arrangement of elements, including combinations of features from different embodiments, without departing from the scope of the invention.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." As used herein, the terms "connected," "coupled," or any variant thereof means any connection or coupling, either direct or indirect, between two or more elements; the coupling or connection between the elements can be physical, logical, electromagnetic, or a combination thereof. Additionally, the words "herein," "above," "below," and words of similar import, when used in this application, refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the Detailed Description using the singular or plural number may also include the plural or singular number respectively. The word "or," in reference to a list of two or more items, covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list.

The teachings of the technology provided herein can be applied to other systems, not necessarily the system described below. The elements and acts of the various examples described below can be combined to provide further implementations of the technology. Some alternative implementations of the technology may include not only additional elements to those implementations noted below, but also may include fewer elements.

These and other changes can be made to the technology in light of the following detailed description. While the description describes certain examples of the technology, and describes the best mode contemplated, no matter how detailed the description appears, the technology can be practiced in many ways. Details of the system may vary considerably in its specific implementation, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the technology to the specific examples disclosed in the specification, unless the Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the technology encompasses not only the disclosed examples, but also all equivalent ways of practicing or implementing the technology under the claims.

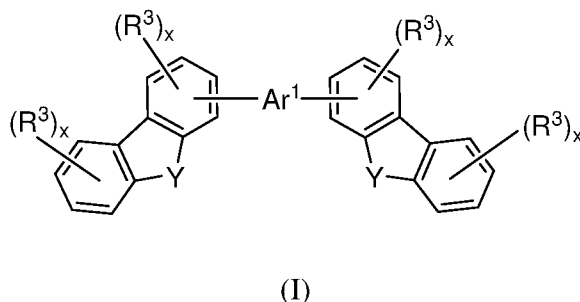
To reduce the number of claims, certain aspects of the technology are presented below in certain claim forms, but the applicant contemplates the various aspects of the technology in any number of claim forms. For example, while some aspect of the technology may be recited as a computer-readable medium claim, other aspects may likewise be embodied as a computer-readable medium claim, or in other forms, such as being embodied in a means-plus-function claim.

In the description above, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of implementations of the disclosed technology. It will be apparent, however, to one skilled in the art that

embodiments of the disclosed technology may be practiced without some of these specific details.

Claims

1. A composition comprising a first semiconducting host compound having a glass transition temperature (T_g) of less than 80°C; a first light-emitting material; and a polymer.
2. The composition according to claim 1 wherein the T_g of the first semiconducting host compound is less than 70°C
3. The composition according to claim 2 wherein the T_g of the first semiconducting host compound is less than 65°C.
4. The composition according to any one of the preceding claims wherein the first semiconducting host compound has formula (I):



wherein:

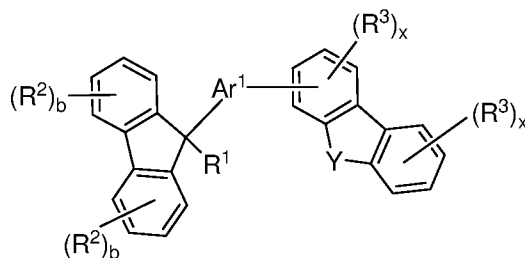
Ar¹ is an arylene or heteroarylene group which is unsubstituted or substituted with one or more substituents;

each Y is independently O or S;

R³ independently in each occurrence is a substituent; and

each x is independently 0, 1, 2 or 3.

5. The composition according to any one of claims 1-3 wherein the first semiconducting host compound has formula (II):



(II)

wherein:

Ar¹ is an arylene or heteroarylene group which is unsubstituted or substituted with one or more substituents;

Y is O or S;

R¹, R² and R³ independently in each occurrence is a substituent;

each x is independently 0, 1, 2 or 3; and

each b is independently 0, 1, 2 or 3.

6. The composition according to any one of the preceding claims wherein the polymer is an inert polymer.
7. The composition according to claim 6 wherein the polymer has a non-conjugated backbone.
8. The composition according to any one of the preceding claims wherein the polymer is polystyrene.
9. The composition according to any one of the preceding claims wherein the first semiconducting host compound makes up 40-95 weight % of the mass of the composition.
10. The composition according to any one of the preceding claims wherein the first light-emitting material makes up 0.5-45 weight % of the mass of the composition.

11. The composition according to any one of the preceding claims wherein the polymer makes up 10-40 weight % of the mass of the composition.
12. The composition according to any one of the preceding claims wherein the first light-emitting material is a phosphorescent light-emitting material.
13. The composition according to any one of the preceding claims wherein the first light-emitting material is a blue light-emitting material.
14. The composition according to any one of the preceding claims wherein the first semiconducting host compound has a LUMO of no more than 2.5 eV from vacuum level.
15. A formulation comprising a composition according to any one of the preceding claims and one or more solvents.
16. An organic light-emitting device comprising an anode, a cathode and a light-emitting layer between the anode and the cathode wherein the light-emitting layer comprises a composition according to any of claims 1-14.
17. The method of forming an organic light-emitting device according to claim 16 comprising forming the light-emitting layer over one of the anode and the cathode and forming the other of the anode and the cathode over the light-emitting layer, wherein formation of the light-emitting layer comprises deposition of a formulation according to claim 15 and evaporation of the one or more solvents.
18. The method according to claim 17 wherein evaporation of the one or more solvents comprises heating the deposited formulation at a temperature above the glass transition temperature of the first semiconducting host material.
19. The method according to claim 18 wherein the heating temperature is in the range of 80-180°C.

FIGURE 1

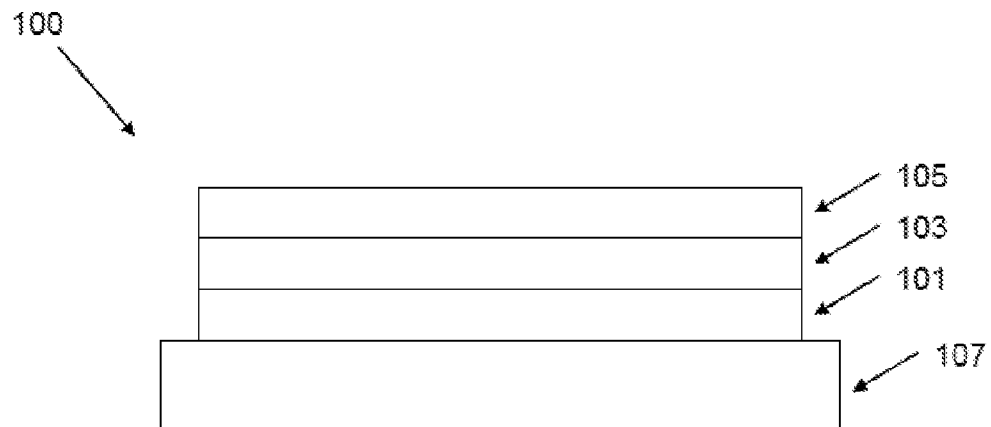


FIGURE 2

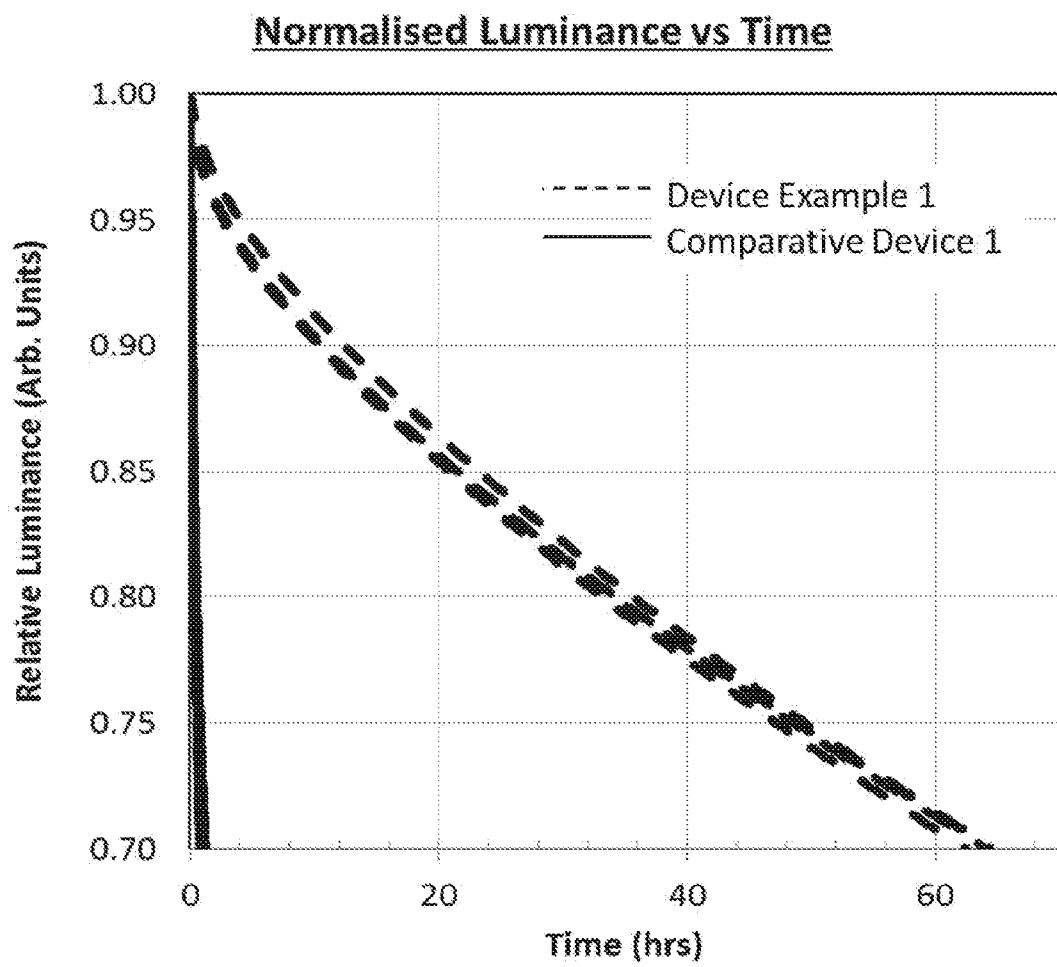


FIGURE 3

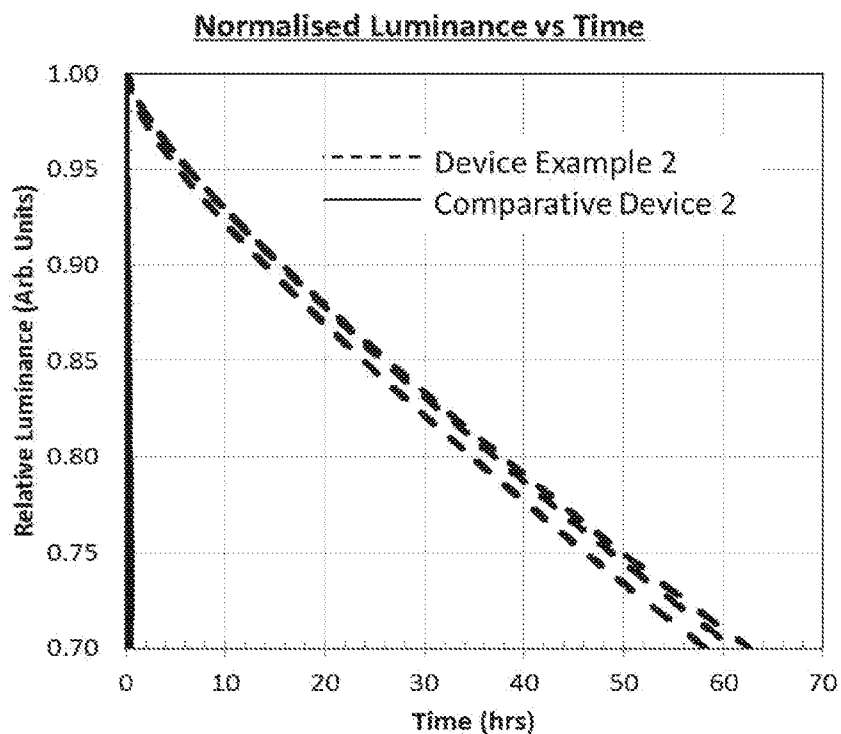
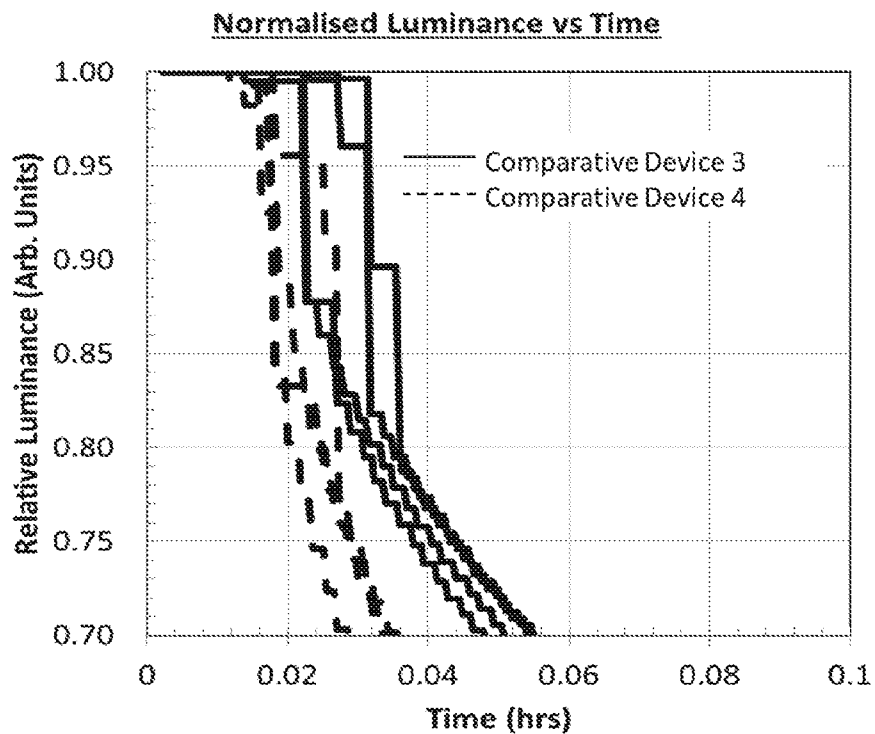


FIGURE 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2020/050230

A. CLASSIFICATION OF SUBJECT MATTER
INV. C09K11/06 H01L51/50
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C09K H01L C08J

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	EP 2 894 686 A1 (KONICA MINOLTA INC [JP]) 15 July 2015 (2015-07-15) OLED 1-9; table 1 page 71; compound 42 page 20; compound DP85 the whole document	4 1-3,5-19
Y A	----- JP 2018 083941 A (SUMITOMO CHEMICAL CO; CAMBRIDGE DISPLAY TECH LTD) 31 May 2018 (2018-05-31) OLED D11; table 2 page 70; compound B8 compounds H-118 the whole document ----- -/-	5 1-4,6-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search

12 March 2020

Date of mailing of the international search report

27/03/2020

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Ziegler, Jan

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2020/050230

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SHIGERU IKAWA ET AL: "White polymer light-emitting diodes co-doped with phosphorescent iridium complexes bearing the same cyclometalated ligand", PHYSICA STATUS SOLIDI. C: CURRENT TOPICS IN SOLID STATE PHYSICS, vol. 9, no. 12, 9 November 2012 (2012-11-09), pages 2553-2556, XP055229162, DE ISSN: 1862-6351, DOI: 10.1002/pssc.201200422	1-3,6-19
Y	composition comprising an iridium complex; compounds Ir-1a, Ir-1b, Ir-2 figure 1 point 2.2 the whole document	4,5
A	----- EP 3 243 820 A1 (HEESUNG MAT LTD [KR]) 15 November 2017 (2017-11-15) page 46; compound host 72 paragraph [0088] -----	1-19
A	US 2017/346020 A1 (LEE SEUNGJAE [KR] ET AL) 30 November 2017 (2017-11-30) page 62; compounds 3-4 page 68; compound 3.38 page 54; compounds 3-16 page 56; compounds 5-10 the whole document -----	1-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/050230

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2894686	A1	15-07-2015	EP 2894686 A1 15-07-2015
			JP 6119754 B2 26-04-2017
			JP W02014038456 A1 08-08-2016
			US 2015207085 A1 23-07-2015
			WO 2014038456 A1 13-03-2014

JP 2018083941	A	31-05-2018	NONE

EP 3243820	A1	15-11-2017	CN 107365306 A 21-11-2017
			EP 3243820 A1 15-11-2017
			JP 6560292 B2 14-08-2019
			JP 2017222636 A 21-12-2017
			KR 101693744 B1 06-02-2017
			TW 201802084 A 16-01-2018
			US 2017331052 A1 16-11-2017

US 2017346020	A1	30-11-2017	CN 107428739 A 01-12-2017
			KR 20160137265 A 30-11-2016
			US 2017346020 A1 30-11-2017
			WO 2016190501 A1 01-12-2016
