

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
15 July 2004 (15.07.2004)

PCT

(10) International Publication Number  
**WO 2004/058912 A2**

- (51) International Patent Classification<sup>7</sup>: **C09K 11/00** [LK/GB]; 19 Southway, Totteridge, London N20 8EB (GB).
- (21) International Application Number: PCT/GB2003/005663 (74) Agent: **COHEN, Alan, Nicol**; 2 Grove Place, Tatsfield, Nr. Westerham, Kent TN16 2BB (GB).
- (22) International Filing Date: 23 December 2003 (23.12.2003) (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (25) Filing Language: English (84) Designated States (*regional*): ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- (26) Publication Language: English
- (30) Priority Data:  
0230074.7 24 December 2002 (24.12.2002) GB  
0230077.0 24 December 2002 (24.12.2002) GB
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- Published:  
— *without international search report and to be republished upon receipt of that report*
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



WO 2004/058912 A2

(54) Title: ELECTROLUMINESCENT MATERIALS AND DEVICES

(57) Abstract: An improved electroluminescent device has a layer of a first electroluminescent metal complex or organo metallic complex and a layer of a second metal complex or organo metallic complex in which the band gap of the metal in the second electroluminescent metal complex or organo metallic complex is larger than the band gap of the metal in the first electroluminescent metal complex or organo metallic complex.

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## Electroluminescent Materials and Devices

The present invention relates to electroluminescent materials and to electroluminescent devices.

5

Materials which emit light when an electric current is passed through them are well known and used in a wide range of display applications. Liquid crystal devices and devices which are based on inorganic semiconductor systems are widely used; however these suffer from the disadvantages of high energy consumption, high cost  
10 of manufacture, low quantum efficiency and the inability to make flat panel displays.

Organic polymers have been proposed as useful in electroluminescent devices, but it is not possible to obtain pure colours; they are expensive to make and have a relatively low efficiency.

15

Another compound which has been proposed is aluminium quinolate, but this requires dopants to be used to obtain a range of colours and has a relatively low efficiency.

20

Patent application WO98/58037 describes a range of transition metal and lanthanide complexes which can be used in electroluminescent devices which have improved properties and give better results. Patent Applications PCT/GB98/01773, PCT/GB99/03619, PCT/GB99/04030, PCT/GB99/04024, PCT/GB99/04028, PCT/GB00/00268 describe electroluminescent complexes, structures and devices  
25 using rare earth chelates.

US Patent 5128587 discloses an electroluminescent device which consists of an organometallic complex of rare earth elements of the lanthanide series sandwiched between a transparent electrode of high work function and a second electrode of low

- 2 -

work function with a hole conducting layer interposed between the electroluminescent layer and the transparent high work function electrode and an electron conducting layer interposed between the electroluminescent layer and the electron injecting low work function anode. The hole conducting layer and the  
5 electron conducting layer are required to improve the working and the efficiency of the device. The hole transporting layer serves to transport holes and to block the electrons, thus preventing electrons from moving into the electrode without recombining with holes. The recombination of carriers therefore mainly takes place in the emitter layer.

10

It is known that electroluminescent europium organometallic complexes emit light in the red part of the spectrum and application WO98/58037 discloses such complexes.

15

We have now devised an electroluminescent structure which gives improved red emission.

20

According to the invention there is provided an electroluminescent device which comprises (i) a first electrode, (ii) a layer of a first electroluminescent metal complex or organo metallic complex, (iii) a layer of a second metal complex or organo  
20 metallic complex and (iv) a second electrode and in which the band gap of the second electroluminescent metal complex or organo metallic complex is larger than the band gap of the first electroluminescent metal complex or organo metallic complex.

25

There can be more than one layer of each of the first and second electroluminescent metal complex or organo metallic complexes arranged alternatively.

30

In an electroluminescent organometallic complex when an electron drops from one level to a lower level, light is emitted and the larger the gap between the levels (the band gap) the higher the energy level difference and the shorter the wave length of the  
30 light emitted. Normally the metal in the second electroluminescent metal complex or organo metallic complex has a higher HOMO (highest occupied molecular orbital)

- 3 -

and a lower LOMO (lowest occupied molecular orbital) than the metal in the second electroluminescent metal complex or organo metallic complex.

5 The band gap of the second organometallic complex can be larger than the band gap of the first electroluminescent metal complex or organo metallic complex by virtue of the metals and/or organic ligands.

10 The metal in the first and second electroluminescent metal complex or organo metallic complex is preferably selected from Sm(III), Eu(II), Eu(III), Tb(III), Dy(III), Yb(III), Lu(III), Gd (III), U(III), U(VI)O<sub>2</sub>, Tm(III), Th(IV), Ce (III), Ce(IV), Pr(III), Nd(III), Pm(III), Dy(III), Ho(III), Er(III).

15 Alternatively the thickness of the layer of the second electroluminescent metal complex or organo metallic complex is too thin to emit light, e.g. of less than 10 nanometres.

20 The metal in the first electroluminescent metal complex or organo metallic complex can be any metal which forms an electroluminescent metal complex or organo metallic complex, provided the band gap is less than the band gap of the organometallic complex in the second metal complex or organo metallic complex.

25 Preferred metals in the first electroluminescent metal complex or organo metallic complex are europium which emits light in the red region of the spectrum, terbium which emits light in the green region of the spectrum or dysprosium which emits light in the yellow region of the spectrum.

30 In the present invention the metal in the second electroluminescent metal complex or organo metallic complex is preferably gadolinium which emits light predominately in the ultra violet region of the spectrum. This has the advantage being that the ultra violet light emitted has no or a limited effect on the colour of the light emitted by the first electroluminescent metal complex or organo metallic complex; another preferred metal is cerium.

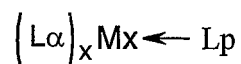
- 4 -

The first electroluminescent metal complex or organo metallic complex preferably has the formula  $(L\alpha)_nM1$  where  $L\alpha$  is an organic complex  $M1$  is the metal and  $n$  is the valence state of  $M1$ .

- 5 The second electroluminescent metal complex or organo metallic complex preferably has the formula  $(L\alpha)_mM2$  where  $L\alpha$  is an organic complex  $M2$  is the metal and  $n$  is the valence state of  $M2$ .

Preferred electroluminescent compounds which can be used in the present invention are of formula

10



(A)

where  $Mx$  is the metal,  $x$  is the valence state of  $Mx$ ;  $L\alpha$  and  $Lp$  are organic ligands and  $Lp$  is a neutral ligand. The ligands  $L\alpha$  can be the same or different and there can be a plurality of ligands  $Lp$  which can be the same or different.

15

For example  $(L_1)(L_2)(L_3)Mx (Lp)$  where  $(L_1)(L_2)(L_3)$  are the same or different organic complexes and  $(Lp)$  is a neutral ligand and the different groups  $(L_1)(L_2)(L_3)$  may be the same or different.

20

$Lp$  can be monodentate, bidentate or multidentate and there can be one or more ligands  $Lp$ .

The metal in the organometallic complex forming the first and second organometallic layers can be the same provided that the organic ligand is such that the band gap of the organometallic complex forming the second layer is larger than the band gap of the organometallic complex forming the first organometallic layer.

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- 5 -

Further electroluminescent compounds which can be used in the present invention are of general formula  $(L\alpha)_nMxM3$  where M3 is a non rare earth metal,  $L\alpha$  is as herein and  $n$  is the combined valence state of Eu and  $M_2$ . The complex can also comprise one or more neutral ligands  $Lp$  so the complex has the general formula

5  $(L\alpha)_nMxM3(Lp)$ , where  $Lp$  is as herein. The metal M3 can be any metal which is not a rare earth, transition metal, lanthanide or an actinide. Examples of metals which can be used include lithium, sodium, potassium, rubidium, caesium, beryllium, magnesium, calcium, strontium, barium, copper (I), copper (II), silver, gold, zinc, cadmium, boron, aluminium, gallium, indium, germanium, tin (II), tin (IV), antimony

10 (II), antimony (IV), lead (II), lead (IV) and metals of the first, second and third groups of transition metals in different valence states, e.g. manganese, iron, ruthenium, osmium, cobalt, nickel, palladium(II), palladium(IV), platinum(II), platinum(IV), cadmium, chromium, titanium, vanadium, zirconium, tantalum, molybdenum, rhodium, iridium, titanium, niobium, scandium, yttrium.

15

Preferred first electroluminescent metal complex or organo metallic complexes are  $Eu(DBM)_3OPNP$  which has a band gap of 3.2eV and  $Eu(TMHD)_3OPNP$  which has a band gap of 3.7 eV and a preferred gadolinium complex is  $Gd(DBM)_3Phen$ , where Phen is phenanthrene, which has a band gap of 3.8 eV.

20

For typical terbium complexes the band gap is of the order of 3.7eV.

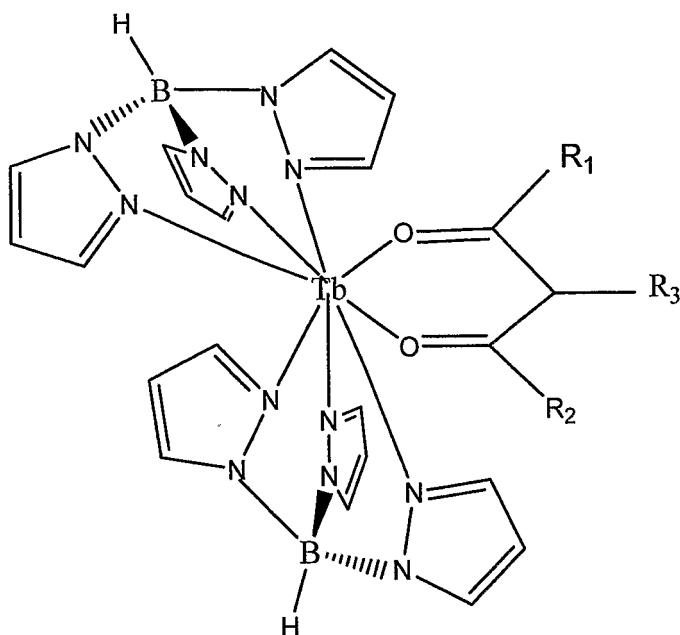
In order to increase the conductivity of the second organometallic complex layer the layer can be doped with a conductivity improving additive such as a powdered metal,

25 conductive polymer.

30

Other complexes which can be used to form the second electroluminescent layer are organometallic complexes in which the organic ligand is a boron complex, e.g. of formula

- 6 -



- where  $R_1$  and  $R_2$  are the same or different and are hydrogen, and substituted and unsubstituted hydrocarbyl groups such as substituted and unsubstituted aliphatic groups, substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups;  $R_1$ ,  $R_2$  and  $R_3$  are the same or different and are hydrogen, and substituted and unsubstituted hydrocarbyl groups such as substituted and unsubstituted aliphatic groups, substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups;  $R_1$ ,  $R_2$  and  $R_3$  can also form substituted and unsubstituted fused aromatic, heterocyclic and polycyclic ring structures, can be copolymerisable with a monomer, e.g. styrene or can be polymer, oligomer or dendrimer substituents.
- 15 In place of the terbium other lanthanide, actinide or rare earth metals can be used.

The invention also provides further red emitters and according to this aspect of the invention there is provided an electroluminescent device which comprises (i) a first electrode, (ii) a layer of an electroluminescent europium metal complex or organo

- 7 -

metallic complex mixed with an iridium metal complex or organo metallic complex and (iii) a second electrode.

5 There is preferably also a layer of an electroluminescent europium metal complex or organo metallic complex and the invention also provides electroluminescent devices of structures:-

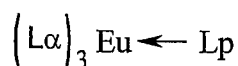
10 A. (i) a first electrode (ii) a layer of an electroluminescent europium metal complex or organo metallic complex (iii) a layer of an electroluminescent europium metal complex or organo metallic complex mixed with an iridium metal complex or organo metallic complex and (iv) a second electrode.

15 B. (i) a first electrode, (ii) a layer of an electroluminescent europium metal complex or organo metallic complex mixed with an iridium metal complex or organo metallic complex, (iii) a layer of an electroluminescent europium metal complex or organo metallic complex and (iv) a second electrode.

20 C. (i) a first electrode, (ii) a layer of an electroluminescent europium metal complex or organo metallic complex, (iii) a layer of an electroluminescent europium metal complex or organo metallic complex mixed with an iridium metal complex or organo metallic complex, (iv) a layer of an electroluminescent europium metal complex or organo metallic complex and (v) a second electrode.

25 The electroluminescent europium metal complex or organo metallic complex preferably has the formula  $(L\alpha)_3\text{Eu}$  where  $L\alpha$  is an organic complex.

Preferred electroluminescent compounds which can be used in the present invention are of formula



30

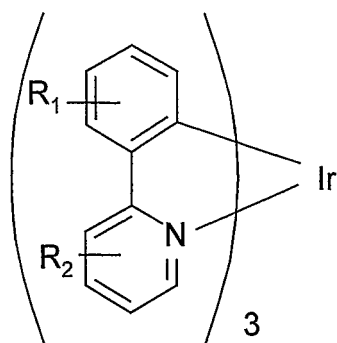
(AI)

where  $L\alpha$  and  $Lp$  are organic ligands and  $Lp$  is a neutral ligand. The ligands  $L\alpha$  can be the same or different and there can be a plurality of ligands  $Lp$  which can be the same or different.

- 5 For example  $(L_1)(L_2)(L_3)Eu(Lp)$  where  $(L_1)(L_2)(L_3)$  are the same or different organic complexes and  $(Lp)$  is a neutral ligand and the different groups  $(L_1)(L_2)(L_3)$  may be the same or different,  $Lp$  can be monodentate, bidentate or multidentate and there can be one or more ligands  $Lp$ .
- 10 Further electroluminescent compounds which can be used in the present invention are of general formula  $(L\alpha)_nEuM_2$  where  $M_2$  is a non rare earth metal,  $L\alpha$  is as herein and  $n$  is the combined valence state of  $Eu$  and  $M_2$ . The complex can also comprise one or more neutral ligands  $Lp$  so the complex has the general formula  $(L\alpha)_nEuM_2(Lp)$ , where  $Lp$  is as herein. The metal  $M_2$  can be any metal which is not a rare earth.
- 15 Lanthanide or an actinide examples of metals which can be used include lithium, sodium, potassium, rubidium, caesium, beryllium, magnesium, calcium, strontium, barium, boron, copper (I), copper (II), silver, gold, zinc, cadmium, boron, aluminium, gallium, indium, germanium, tin (II), tin (IV), antimony (II), antimony (IV), lead (II), lead (IV) and metals of the first, second and third groups of transition metals in
- 20 different valence states, e.g. manganese, iron, ruthenium, osmium, cobalt, nickel, palladium(II), palladium(IV), platinum(II), platinum(IV), cadmium, chromium, titanium, vanadium, zirconium, hafnium, tantalum, molybdenum, rhodium, iridium, titanium, niobium, scandium, yttrium.
- 25 A preferred europium complex is  $Eu(DBM)_3OPNP$ .

Preferred iridium complexes are iridium acetylacetonate, iridium di-acetylacetonate and  $Ir(dpp)_3$

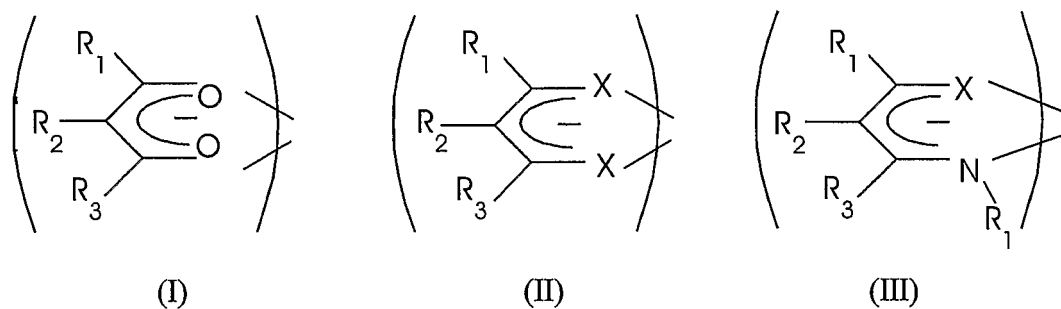
- 9 -



where  $R_1$  and  $R_2$  are as above.

Preferably  $L\alpha$  is selected from  $\beta$  diketones such as those of formulae

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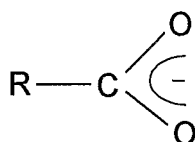
- where  $R_1$ ,  $R_2$  and  $R_3$  can be the same or different and are selected from hydrogen, and substituted and unsubstituted hydrocarbyl groups such as substituted and unsubstituted aliphatic groups, substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups;  $R_1$ ,  $R_2$  and  $R_3$  can also form substituted and unsubstituted fused aromatic, heterocyclic and polycyclic ring structures and can be copolymerisable with a monomer, e.g. styrene. X is Se, S or O, Y can be hydrogen, substituted or unsubstituted hydrocarbyl groups, such as substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorine, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups or nitrile.

- 10 -

Examples of  $R_1$  and/or  $R_2$  and/or  $R_3$  include aliphatic, aromatic and heterocyclic alkoxy, aryloxy and carboxy groups, substituted and substituted phenyl, fluorophenyl, biphenyl, phenanthrene, anthracene, naphthyl and fluorene groups alkyl groups such as t-butyl, heterocyclic groups such as carbazole.

5

Some of the different groups  $L_\alpha$  may also be the same or different charged groups such as carboxylate groups so that the group  $L_1$  can be as defined above and the groups  $L_2, L_3, \dots$  can be charged groups such as

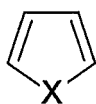


10

(IV)

where R is  $R_1$  as defined above or the groups  $L_1, L_2$  can be as defined above and  $L_3, \dots$  etc. are other charged groups.

$R_1, R_2$  and  $R_3$  can also be



15

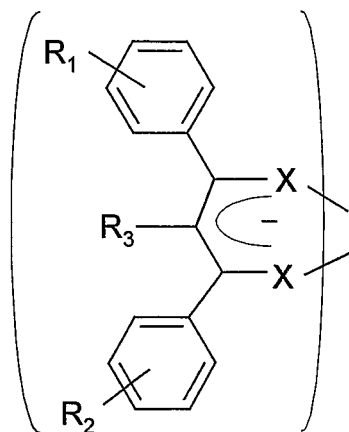
where X is O, S, Se or NH.

(V)

A preferred moiety  $R_1$  is trifluoromethyl  $\text{CF}_3$  and examples of such diketones are, benzoyltrifluoroacetone, p-chlorobenzoyltrifluoroacetone, p-bromotrifluoroacetone, p-phenyltrifluoroacetone, 1-naphthoyltrifluoroacetone, 2-naphthoyltrifluoroacetone, 2-phenathoyltrifluoroacetone, 3-phenanthoyltrifluoroacetone, 9-anthroyltrifluoroacetone, cinnamoyltrifluoroacetone, and 2-thenoyltrifluoroacetone.

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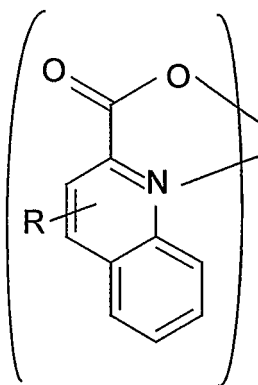
The different groups  $L\alpha$  may be the same or different ligands of formulae



(VI)

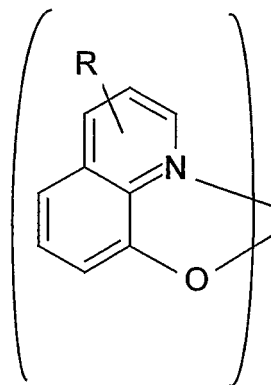
5 where X is O, S, or Se and  $R_1$ ,  $R_2$  and  $R_3$  are as above.

The different groups  $L\alpha$  may be the same or different quinolate derivatives such as



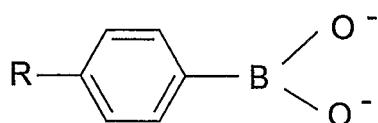
(VII)

or

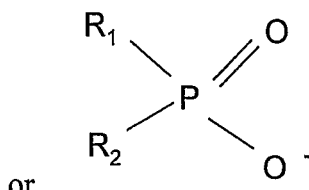


(VIII)

10 where R is hydrocarbyl, aliphatic, aromatic or heterocyclic carboxy, aryloxy, hydroxy or alkoxy, e.g. the 8 hydroxy quinolate derivatives or



(IX)

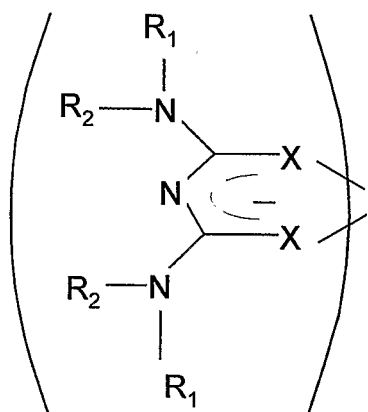


(X)



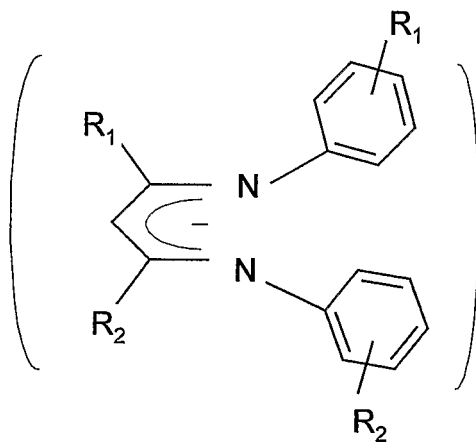
where R is as above, e.g. alkyl, allenyl, amino or a fused ring such as a cyclic or polycyclic ring.

5 The different groups  $L\alpha$  may also be



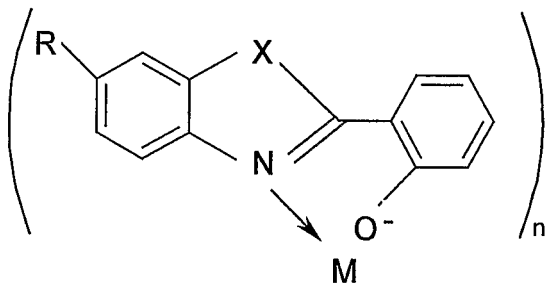
(XV)

or



(XVI)

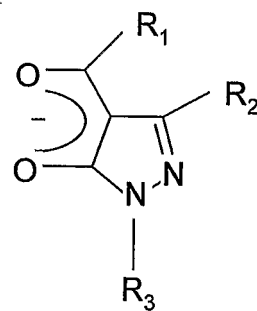
or



where X is O, S or Se

(XVII)

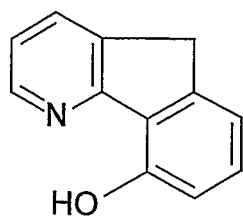
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(XVIIa)

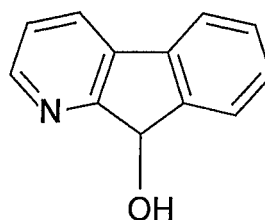
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where R, R<sub>1</sub> and R<sub>2</sub> are as above or



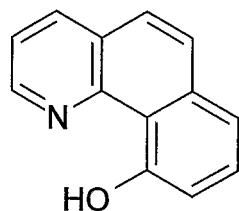
(XVIIb)

or



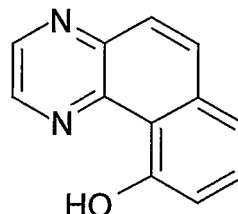
(XVIIc)

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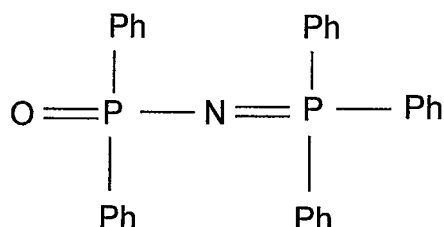
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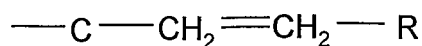
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- 5 The groups  $L_P$  in the formula (A) above can be selected from



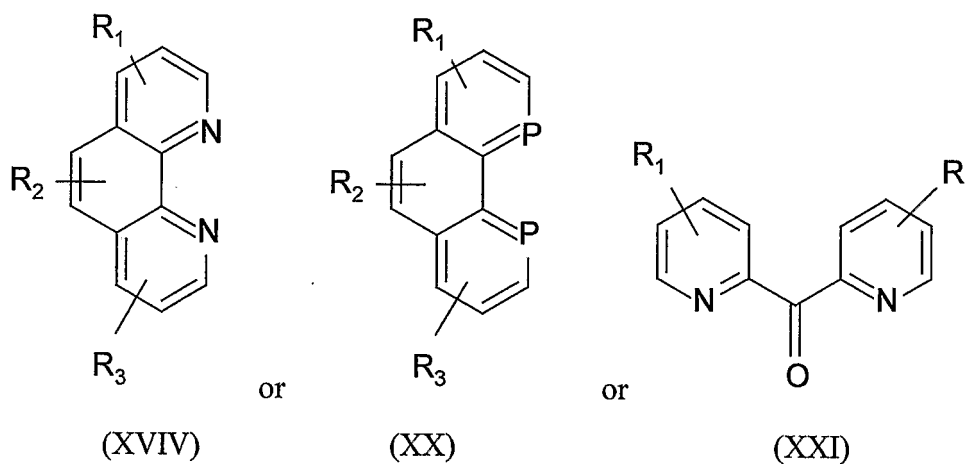
(XVIII)

- 10 where each Ph which can be the same or different and can be a phenyl (OPNP) or a substituted phenyl group, other substituted or unsubstituted aromatic group, a substituted or unsubstituted heterocyclic or polycyclic group, a substituted or unsubstituted fused aromatic group such as a naphthyl, anthracene, phenanthrene or pyrene group. The substituents can be, for example, an alkyl, aralkyl, alkoxy, aromatic, heterocyclic, polycyclic group, halogen such as fluorine, cyano, amino, substituted amino etc. Examples are given in figs. 1 and 2 of the drawings where R,
- 15  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  can be the same or different and are selected from hydrogen, hydrocarbyl groups, substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups; R,  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  can also form substituted
- 20 and unsubstituted fused aromatic, heterocyclic and polycyclic ring structures and can be copolymerisable with a monomer, e.g. styrene. R,  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  can also be unsaturated alkylene groups such as vinyl groups or groups

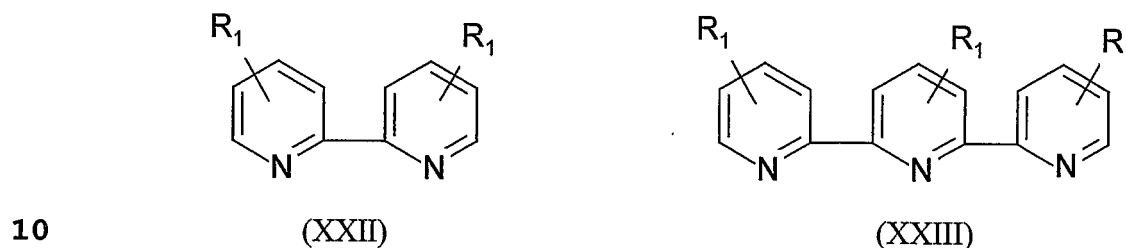


where R is as above.

L<sub>p</sub> can also be compounds of formulae



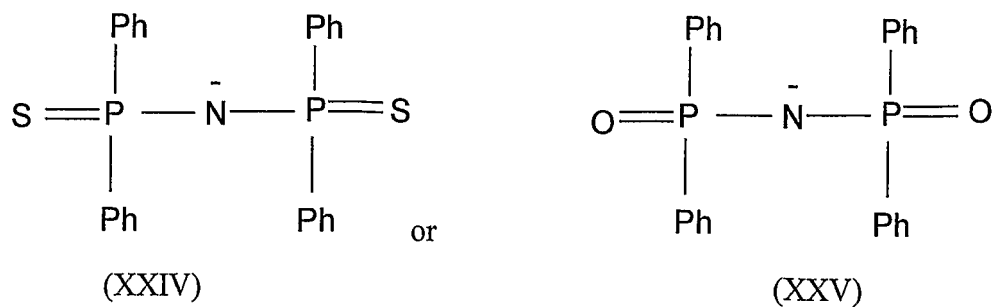
where R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> are as referred to above, for example bathophen shown in fig. 3 of the drawings in which R is as above or



where R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> are as referred to above.

L<sub>p</sub> can also be

**15**



where Ph is as above.

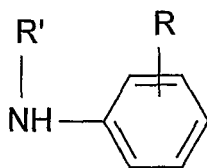
Other examples of  $L_p$  chelates are as shown in figs. 4 and fluorene and fluorene derivatives, e.g. as shown in fig. 5 and compounds of formulae as shown in figs. 6 to 8.

Specific examples of  $L_\alpha$  and  $L_p$  are tripyridyl and TMHD, and TMHD complexes,  $\alpha, \alpha', \alpha''$  tripyridyl, crown ethers, cyclans, cryptans phthalocyanans, porphyrins ethylene diamine tetramine (EDTA), DCTA, DTPA and TTHA, where TMHD is 2,2,6,6-tetramethyl-3,5-heptanedionato and OPNP is diphenylphosponimide triphenyl phosphorane. The formulae of the polyamines are shown in fig. 11.

The first electrode can function as the cathode and the second electrode can function as the anode and preferably there is a layer of a hole transporting material between the anode and the layer of the electroluminescent compound.

The hole transporting material can be any of the hole transporting materials used in electroluminescent devices.

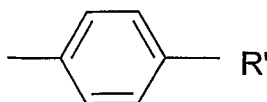
The hole transporting material can be an amine complex such as poly(vinylcarbazole), N, N'-diphenyl-N, N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), an unsubstituted or substituted polymer of an amino substituted aromatic compound, a polyaniline, substituted polyanilines, polythiophenes, substituted polythiophenes, polysilanes etc. Examples of polyanilines are polymers of



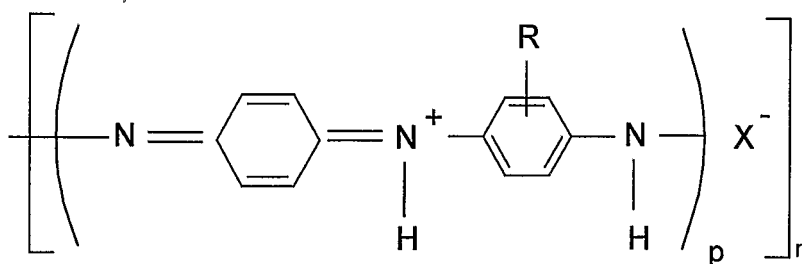
(XXVI)

- 17 -

where R is in the ortho – or meta-position and is hydrogen, C1-18 alkyl, C1-6 alkoxy, amino, chloro, bromo, hydroxy or the group



where R is alkyl or aryl and R' is hydrogen, C1-6 alkyl or aryl with at least one other  
 5 monomer of formula I above, or the hole transporting material can be a polyaniline; polyanilines which can be used in the present invention have the general formula



(XXVII)

where p is from 1 to 10 and n is from 1 to 20, R is as defined above and X is an  
 10 anion, preferably selected from Cl, Br, SO<sub>4</sub>, BF<sub>4</sub>, PF<sub>6</sub>, H<sub>2</sub>PO<sub>3</sub>, H<sub>2</sub>PO<sub>4</sub>, arylsulphonate, arenedicarboxylate, polystyrenesulphonate, polyacrylate alkylsulphonate, vinylsulphonate, vinylbenzene sulphonate, cellulose sulphonate, camphor sulphonates, cellulose sulphate or a perfluorinated polyanion.

15 Examples of arylsulphonates are p-toluenesulphonate, benzenesulphonate, 9,10-anthraquinone-sulphonate and anthracenesulphonate. An example of an arenedicarboxylate is phthalate and an example of arenecarboxylate is benzoate.

20 We have found that protonated polymers of the unsubstituted or substituted polymer of an amino substituted aromatic compound such as a polyaniline are difficult to evaporate or cannot be evaporated, however we have surprisingly found that if the unsubstituted or substituted polymer of an amino substituted aromatic compound is deprotonated then it can be easily evaporated, i.e. the polymer is evaporable.

- 18 -

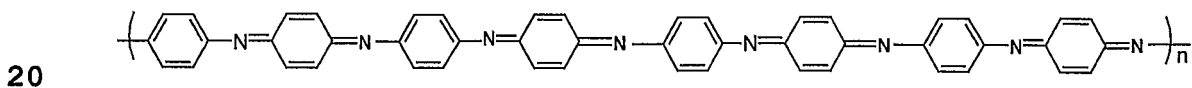
Preferably evaporable deprotonated polymers of unsubstituted or substituted polymer of an amino substituted aromatic compound are used. The de-protonated unsubstituted or substituted polymer of an amino substituted aromatic compound can  
 5 be formed by deprotonating the polymer by treatment with an alkali such as ammonium hydroxide or an alkali metal hydroxide such as sodium hydroxide or potassium hydroxide.

The degree of protonation can be controlled by forming a protonated polyaniline and  
 10 de-protonating. Methods of preparing polyanilines are described in the article by A. G. MacDiarmid and A. F. Epstein, Faraday Discussions, Chem Soc.88 P319 1989.

The conductivity of the polyaniline is dependant on the degree of protonation with the maximum conductivity being when the degree of protonation is between 40 and 60%,  
 15 e.g. about 50%.

Preferably the polymer is substantially fully deprotonated.

A polyaniline can be formed of octamer units i.e. p is four e.g.



The polyanilines can have conductivities of the order of  $1 \times 10^{-1}$  Siemen  $\text{cm}^{-1}$  or higher.

25 The aromatic rings can be unsubstituted or substituted, e.g. by a C1 to 20 alkyl group such as ethyl.

- 19 -

The polyaniline can be a copolymer of aniline and preferred copolymers are the copolymers of aniline with o-anisidine, m-sulphanilic acid or o-aminophenol, or o-toluidine with o-aminophenol, o-ethylaniline, o-phenylene diamine or with amino anthracenes.

5

Other polymers of an amino substituted aromatic compound which can be used include substituted or unsubstituted polyaminonaphthalenes, polyaminoanthracenes, polyaminophenanthrenes, etc. and polymers of any other condensed polyaromatic compound. Polyaminoanthracenes and methods of making them are disclosed in US  
10 Patent 6,153,726. The aromatic rings can be unsubstituted or substituted, e.g. by a group R as defined above.

Other hole transporting materials are conjugated polymer and the conjugated polymers which can be used can be any of the conjugated polymers disclosed or  
15 referred to in US 5807627, PCT/WO90/13148 and PCT/WO92/03490.

The preferred conjugated polymers are poly (p-phenylenevinylene)-PPV and copolymers including PPV. Other preferred polymers are poly(2,5 dialkoxyphenylene vinylene) such as poly (2-methoxy-5-(2-methoxypentyloxy-1,4-phenylene vinylene),  
20 poly(2-methoxypentyloxy)-1,4-phenylenevinylene), poly(2-methoxy-5-(2-dodecyloxy-1,4-phenylenevinylene) and other poly(2,5 dialkoxyphenylenevinylenes) with at least one of the alkoxy groups being a long chain solubilising alkoxy group, poly fluorenes and oligofluorenes, polyphenylenes and oligophenylenes, polyanthracenes and oligo anthracenes, ploythiophenes and oligothiophenes.

25

In PPV the phenylene ring may optionally carry one or more substituents, e.g. each independently selected from alkyl, preferably methyl, alkoxy, preferably methoxy or ethoxy.

Any poly(arylenevinylene) including substituted derivatives thereof can be used and the phenylene ring in poly(p-phenylenevinylene) may be replaced by a fused ring system such as anthracene or naphthylene ring and the number of vinylene groups in each polyphenylenevinylene moiety can be increased, e.g. up to 7 or higher.

5

The conjugated polymers can be made by the methods disclosed in US 5807627, PCT/WO90/13148 and PCT/WO92/03490.

The thickness of the hole transporting layer is preferably 20nm to 200nm.

10

The polymers of an amino substituted aromatic compound such as polyanilines referred to above can also be used as buffer layers with or in conjunction with other hole transporting materials.

15

The structural formulae of some other hole transporting materials are shown in Figures 12 to 16 of the drawings, where  $R_1$ ,  $R_2$  and  $R_3$  can be the same or different and are selected from hydrogen, and substituted and unsubstituted hydrocarbyl groups such as substituted and unsubstituted aliphatic groups, substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups;  $R_1$ ,  $R_2$  and  $R_3$  can also form substituted and unsubstituted fused aromatic, heterocyclic and polycyclic ring structures and can be copolymerisable with a monomer, e.g. styrene. X is Se, S or O, Y can be hydrogen, substituted or unsubstituted hydrocarbyl groups, such as substituted and unsubstituted aromatic, heterocyclic and polycyclic ring structures, fluorine, fluorocarbons such as trifluoromethyl groups, halogens such as fluorine or thiophenyl groups or nitrile.

25

Examples of  $R_1$  and/or  $R_2$  and/or  $R_3$  include aliphatic, aromatic and heterocyclic alkoxy, aryloxy and carboxy groups, substituted and substituted phenyl, fluorophenyl,

biphenyl, phenanthrene, anthracene, naphthyl and fluorene groups alkyl groups such as t-butyl, heterocyclic groups such as carbazole.

- Optionally there is a layer of an electron injecting material between the cathode and the electroluminescent material layer. The electron injecting material is a material which will transport electrons when an electric current is passed through electron injecting materials include a metal complex such as a metal quinolate, e.g. an aluminium quinolate, lithium quinolate,  $Mx(DBM)_n$  where  $Mx$  is a metal and DBM is dibenzoyl methane and  $n$  is the valency of  $Mx$ , e.g.  $Mx$  is aluminium or chromium.
- 5 The electron injecting material can also be a cyano anthracene such as 9,10 dicyano anthracene, cyano substituted aromatic compounds, tetracyanoquinodimethane a polystyrene sulphonate or a compound with the structural formulae shown in figures 9 or 10 of the drawings in which the phenyl rings can be substituted with substituents  $R$  as defined above. Instead of being a separate layer the electron injecting material
- 10 can be mixed with the electroluminescent material and co-deposited with it.
- 15

Optionally the hole transporting material can be mixed with the electroluminescent material and co-deposited with it.

- 20 The hole transporting materials, the electroluminescent material and the electron injecting materials can be mixed together to form one layer, which simplifies the construction.

- The anode is preferably a transparent substrate such as a conductive glass or plastic material which acts as the anode; preferred substrates are conductive glasses such as indium tin oxide coated glass, but any glass which is conductive or has a conductive layer such as a metal or conductive polymer can be used. Conductive polymers and conductive polymer coated glass or plastics materials can also be used as the substrate.
- 25

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The cathode is preferably a low work function metal e.g. aluminium, calcium, lithium, magnesium and alloys thereof such as silver/magnesium alloys, rare earth metal alloys etc; aluminium is a preferred metal. A metal fluoride such as an alkali metal, rare earth metal or their alloys can be used as the second electrode, for example by having a metal fluoride layer formed on a metal.

The invention is illustrated in the examples.

#### Example 1

10 An example of an electroluminescent device according to the invention is shown in figs. 17a, 17b. of the drawings. A pre-etched ITO coated glass piece (10 x 10cm<sup>2</sup> ) was used. The device was fabricated by sequentially forming layers on the ITO, by vacuum evaporation using a Solciet Machine, ULVAC Ltd. Chigacki, Japan; the active area of each pixel was 3mm by 3mm.

15

In fig. 17a on the ITO coated glass anode (1) there are layers in which (2) is a hole transporting layer of TPD, (3) is a layer of Eu(DBM)<sub>3</sub>OPNP (R1), (4) is a layer of Gd(tmhd)<sub>3</sub>Phen, (5) is an electron transmitting layer of aluminium quinolate, (6) is a lithium fluoride layer and (7) is an aluminium cathode.

20

When an electric current is passed through the device red light is emitted via (1).

Various structures were formed and the colour coordinates x:y and their peak efficiencies measured and the results shown in Table 1. The colour coordinates are as on the CIE 1931 Chart.

25

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Table 1

Reference	Cd/m <sup>2</sup>	Cd/A	x	y
1	2.4	1.13	0.66	0.33
2	15.4	2.01	0.66	0.33
3	0.9	3.13	0.66	0.33

where 1 is –

- 5 ITO/TPD(35.5nm)/R1(23.6nm)/Gd(tmhd)<sub>3</sub>Phen(20.3nm)/R1(24.2nm)/Alq3(15.5nm)/Al

2 is –

ITO/TPD(33nm)/R1(23nm)/Gd(tmhd)<sub>3</sub>Phen(10nm)/R1(10nm)/Gd(tmhd)<sub>3</sub>Phen(10nm)/R1(23nm) Alq3(9nm)/Al

- 10 3 is –

ITO/DFDAA(13nm)/ TPD(33nm)/ R1(23nm)/Gd(tmhd)<sub>3</sub>Phen(10nm)/ R1(10nm)/Gd(tmhd)<sub>3</sub>Phen(10nm)/R1(23nm) Alq3(9nm)/Al

where R1 is Eu(DBM)<sub>3</sub>OPNP and DFDAA is a buffer layer.

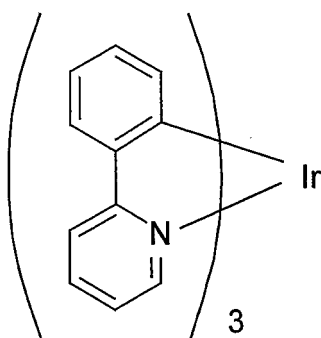
15 Example 2

An electroluminescent device shown in fig. 17a was formed. As in example 1 there are layers 1 to 7 where (1) is ITO, (2) is CuPc (3) is  $\alpha$ -NPB (4) is the electroluminescent mixture (5) is Eu(DBM)<sub>3</sub>OPNP (6) is Alq<sub>3</sub> (7) is Al to form :-

- 20 ITO/CuPc(8nm)/ $\alpha$ -NPB(40nm)/R1(10nm)/ CBP +Ir(dpp)<sub>3</sub>(6%)+ R1(40%)(20nm)/R1(20nm)/BCP(6nm)/Alq3(20nm)/Al

where R1 is Eu(DBM)<sub>3</sub>OPNP and Ir(dpp)<sub>3</sub> is

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An electric current was passed through the device and the properties of the emitted light measured and the results are shown in the table 2 and in figs.18 and 21 to 25 of the drawings as configuration 1.

### Example 3

A device was constructed as in example 1 which had the structure as shown in fig. 17b in which (1) is ITO, (2) is CuPc, (3) is  $\alpha$ -NPB, (4) is the electroluminescent mixture, (5) is Eu(DBM)<sub>3</sub>OPNP, (6) is BCP, (7) is Alq<sub>3</sub> (8) is aluminium. The structure was:-

ITO/CuPc(8nm)/ $\alpha$ -NPB(40nm)/ Ir(diacac)<sub>2</sub>(dpp)<sub>2</sub>(6%)+CBP+R1(40%)(20nm)  
/R1(20nm)/BCP(6nm)/Alq<sub>3</sub>(20nm)/Al

where Ir(diacac)<sub>3</sub> is iridium di-acetylacetonate and CBP is shown in fig. 4b with R being H and is a host compound.

An electric current was passed through the device and the properties of the emitted light measured and the results are shown in Table 2 and in figs. 19 and 21 to 25 of the drawings as configuration 2.

Example 4

A device was constructed as in example 1 which had the structure of fig. 17a and consisted of

- 5 ITO/CuPc(8nm)/ $\alpha$ -NPB(40nm)/R1(40%)+Ir(acac)<sub>3</sub>(6%)+CBP(20nm)/BCP(6nm)/Alq3(20nm)/Al

where Ir(acac)<sub>3</sub> is iridium acetylacetonate and BCP is bathocupron.

- 10 An electric current was passed through the device and the properties of the emitted light measured and the results are shown in Table 2 and in figs. 20 to 25 of the drawings as configuration 3.

Table 2

Best Current Efficiency			
Ref.	cd A <sup>-1</sup>	x	y
Example 1	3.0	0.63	0.35
Example 2	1.8	0.66	0.33
Example 3	0.8	0.63	0.34

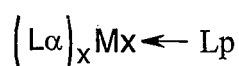
## Claims

1. An electroluminescent device which comprises (i) a first electrode, (ii) a layer of a first electroluminescent metal complex or organo metallic complex, (iii) a layer of a second metal complex or organo metallic complex and (iv) a second electrode and in which the band gap of the second electroluminescent metal complex or organo metallic complex is larger than the band gap of the first electroluminescent metal complex or organo metallic complex.
2. An electroluminescent device as claimed in claim 1 in which the metal in the first and second electroluminescent metal complex or organo metallic complex is selected from Sm(III), Eu(II), Eu(III), Tb(III), Dy(III), Yb(III), Lu(III), Gd (III), U(III), U(VI)O<sub>2</sub>, Tm(III), Th(IV), Ce (III), Ce(IV), Pr(III), Nd(III), Pm(III), Dy(III), Ho(III), Er(III).
3. An electroluminescent device as claimed in claim 1 in which the metal in the first electroluminescent metal complex or organo metallic complex is europium or terbium and the metal in the second electroluminescent metal complex or organo metallic complex is gadolinium or cerium.
4. An electroluminescent device as claimed in claim 1 or 2 in which the metal in the first electroluminescent metal complex or organo metallic complex and the metal in the second electroluminescent metal complex or organo metallic complex are the same.
5. An electroluminescent device as claimed in any one of claims 1 to 4 in which there are more than one layer of each of the first and second electroluminescent metal complex or organo metallic complexes arranged alternatively.
6. An electroluminescent device as claimed in any one of claims 1 to 5 in which the first electroluminescent metal complex or organo metallic complex has the formula  $(L\alpha)_nM1$  where  $L\alpha$  is an organic complex  $M1$  is the metal and  $n$  is the valence state of  $M1$  and the second electroluminescent metal complex or organo metallic complex has

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the formula  $(L\alpha)_mM2$  where  $L\alpha$  is an organic complex,  $M2$  is the metal and  $n$  is the valence state of  $M2$ .

7. An electroluminescent device as claimed in any one of claims 1 to 5 in which the  
5 metal complex or organo metallic complexes have the formula



(A)

where  $Mx$ ,  $x$ ,  $L\alpha$  and  $Lp$  are as defined herein and the ligands  $L\alpha$  can be the same or different and there can be a plurality of ligands  $Lp$  which can be the same or different.

10

8. An electroluminescent device as claimed in any one of claims 1 to 4 in which at least one of the metal complex or organo metallic complexes have the formula  $(L\alpha)_nMxM3$  where  $M3$  is a non rare earth metal,  $L\alpha$  is as defined herein and  $n$  is the combined valence state of  $Mx$  and  $M3$ .

15

9. An electroluminescent device as claimed in any one of claims 1 to 4 in which at least one of the metal complex or organo metallic complexes have the formula  $(L\alpha)_nMxM3(Lp)$ .

20

10. An electroluminescent device as claimed in claim 9 in which the metal  $M3$  is any metal which is not a rare earth, transition metal, lanthanide or an actinide.

25

11. An electroluminescent device as claimed in claim 9 in which the metal  $M3$  is selected from lithium, sodium, potassium, rubidium, caesium, beryllium, magnesium, calcium, strontium, barium, copper (I), copper (II), silver, gold, zinc, cadmium, boron, aluminium, gallium, indium, germanium, tin (II), tin (IV), antimony (II), antimony (IV), lead (II), lead (IV) and metals of the first, second and third groups of transition metals in different valence states, e.g. manganese, iron, ruthenium, osmium, cobalt, nickel, palladium(II), palladium(IV), platinum(II), platinum(IV),

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cadmium, chromium, titanium, vanadium, zirconium, tantalum, molybdenum, rhodium, iridium, titanium, niobium, scandium, yttrium.

12. An electroluminescent device as claimed in any one of claims 1 to 11 in which  $L\alpha$   
5 is of formula (I) to (XVII) herein.

13. An electroluminescent device as claimed in any one of claims 1 to 11 in which  $L\beta$   
is of formula (XVIII) to (XXV) herein or figs. 1 to 9 of the drawings

10 14. An electroluminescent device as claimed in any one of claims 1 to 13 in which  $L\alpha$   
is selected from tripyridyl and TMHD, and TMHD complexes,  $\alpha$ ,  $\alpha'$ ,  $\alpha''$  tripyridyl  
and  $L\beta$  is selected from crown ethers, cyclans, cryptans phthalocyanans, porphyrins  
ethylene diamine tetramine (EDTA), DCTA, DTPA and TTHA.

15 15. An electroluminescent device as claimed in any one of claims 1 to 14 in which the  
europium complex is  $\text{Eu}(\text{DBM})_3\text{OPNP}$ .

16. An electroluminescent device as claimed in any one of claims 1 to 15 in which the  
gadolinium complex is  $\text{Gd}(\text{DBM})_3\text{Phen}$ .

20 17. An electroluminescent device which comprises (i) a first electrode, (ii) a layer of  
an electroluminescent europium metal complex or organo metallic complex mixed  
with an iridium metal complex or organo metallic complex and (iii) a second  
electrode.

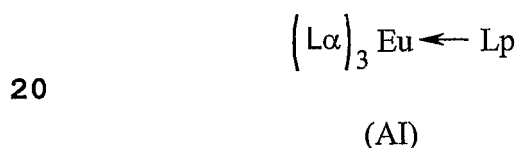
25 18. An electroluminescent device which comprises (i) a first electrode, (ii) a layer of  
an electroluminescent europium metal complex or organo metallic complex, (iii) a  
layer of an electroluminescent europium metal complex or organo metallic complex  
mixed with an iridium metal complex or organo metallic complex and (iv) a second  
30 electrode.

19. An electroluminescent device which comprises (i) a first electrode, (ii) a layer of an electroluminescent europium metal complex or organo metallic complex mixed with an iridium metal complex or organo metallic complex, (iii) a layer of an electroluminescent europium metal complex or organo metallic complex and (iv) a second electrode.

20. An electroluminescent device which comprises (i) a first electrode, (ii) a layer of an electroluminescent europium metal complex or organo metallic complex, (iii) a layer of an electroluminescent europium metal complex or organo metallic complex mixed with an iridium metal complex or organo metallic complex, (iv) a layer of an electroluminescent europium metal complex or organo metallic complex and (v) a second electrode.

21. An electroluminescent device as claimed in any one of claims 17 to 20 in which the europium metal complex or organo metallic complex has the formula  $(L\alpha)_3Eu$  where  $L\alpha$  is an organic complex.

22. An electroluminescent device as claimed in any one of claims 17 to 19 in which the europium metal complex or organo metallic complex has the formula



where  $L\alpha$  and  $Lp$  are organic ligands and  $Lp$  is a neutral ligand, the ligands  $L\alpha$  can be the same or different and there can be a plurality of ligands  $Lp$  which can be the same or different.

23. An electroluminescent device as claimed in any one of claims 17 to 19 in which the europium metal complex or organo metallic complex has the formula  $(L\alpha)_nEuM_2$  where  $M_2$  is a non rare earth metal,  $L\alpha$  is as herein and  $n$  is the combined valence state of  $Eu$  and  $M_2$ .

- 30 -

24. An electroluminescent device as claimed in any one of claims 17 to 19 in which the europium metal complex or organo metallic complex has the formula  $(L\alpha)_n Eu M_2 (Lp)$ , where  $Lp$  is as herein.
- 5 25. An electroluminescent device as claimed in claim 24 in which the metal  $M_2$  is any metal which is not a rare earth, transition metal, lanthanide or an actinide.
26. An electroluminescent device as claimed in claim 24 in which the metal  $M_2$  is selected from lithium, sodium, potassium, rubidium, caesium, beryllium, magnesium, calcium, strontium, barium, boron, copper (I), copper (II), silver, gold, zinc, cadmium, boron, aluminium, gallium, indium, germanium, tin (II), tin (IV), antimony (II), antimony (IV), lead (II), lead (IV) and metals of the first, second and third groups of transition metals in different valence states, e.g. manganese, iron, ruthenium, osmium, cobalt, nickel, palladium(II), palladium(IV), platinum(II), platinum(IV), cadmium, chromium, titanium, vanadium, zirconium, hafnium, tantalum, molybdenum, rhodium, iridium, titanium, niobium, scandium, yttrium.
- 10 27. An electroluminescent device as claimed in any one of claims 17 to 26 in which  $L\alpha$  is of formula (I) to (XVII) herein.
- 20 28. An electroluminescent device as claimed in any one of claims 17 to 26 in which  $Lp$  is of formula (XVIII) to (XXV) herein or figs. 1 to 9 of the drawings.
- 25 29. An electroluminescent device as claimed in any one of claims 17 to 28 in which  $L\alpha$  is selected from tripyridyl and TMHD, and TMHD complexes,  $\alpha$ ,  $\alpha'$ ,  $\alpha''$  tripyridyl and  $Lp$  is selected from crown ethers, cyclans, cryptans phthalocyanans, porphyrins ethylene diamine tetramine (EDTA), DCTA, DTPA and TTHA.
- 30 30. An electroluminescent device as claimed in any one of claims 17 to 29 in which the europium complex is  $Eu(DBM)_3OPNP$ .

31. An electroluminescent device as claimed any one of claims 1 to 30 in which there is a layer of a hole transmitting material between the first electrode and the electroluminescent layer.

5

32. An electroluminescent device as claimed in any one of claims 1 to 30 in which the hole transmitting material is an aromatic amine complex.

33. An electroluminescent device as claimed in any one of claims 1 to 30 in which  
10 the hole transmitting material is a polyaromatic amine complex.

34. An electroluminescent device as claimed in any one of claims 1 to 30 in which the hole transmitting material is a film of a polymer selected from poly(vinylcarbazole),  
N,N'-diphenyl-N,N'-bis (3-methylphenyl) -1,1' -biphenyl -4,4'-diamine (TPD),  
15 polyaniline, substituted polyanilines, polythiophenes, substituted polythiophenes, polysilanes and substituted polysilanes.

35. An electroluminescent device as claimed in any one of claims 1 to 30 in which the hole transmitting material is a film of a compound of formula (XXVI) or (XXVII)  
20 herein or as in figures 4 to 8 of the drawings.

36. An electroluminescent device as claimed in any one of claims 1 to 30 in which the hole transmitting material is a copolymer of aniline, a copolymer of aniline with o-anisidine, m-sulphanilic acid or o-aminophenol, or o-toluidine with o-aminophenol,  
25 o-ethylaniline, o-phenylene diamine or with an amino anthracene.

37. An electroluminescent device as claimed in any one of claims 1 to 30 in which the hole transmitting material is a conjugated polymer.

38. An electroluminescent device as claimed in claim 37 in which the conjugated polymer is selected from poly (p-phenylenevinylene)-PPV and copolymers including PPV, poly(2,5 dialkoxyphenylene vinylene), poly (2-methoxy-5-(2-methoxypentyloxy-1,4-phenylene vinylene), poly(2-methoxypentyloxy)-1,4-phenylenevinylene), poly(2-methoxy-5-(2-dodecyloxy-1,4-phenylenevinylene) and other poly(2,5 dialkoxyphenylenevinylenes) with at least one of the alkoxy groups being a long chain solubilising alkoxy group, poly fluorenes and oligofluorenes, polyphenylenes and oligophenylenes, polyanthracenes and oligo anthracenes, ploythiophenes and oligothiophenes.
39. An electroluminescent device as claimed in any one of claims 31 to 38 in which the electroluminescent compound is mixed with the hole transmitting material.
40. An electroluminescent device as claimed in any one of claims 1 to 39 in which there is a layer of an electron transmitting material between the cathode and the electroluminescent compound layer.
41. An electroluminescent device as claimed in claim 40 in which the electron transmitting material is a metal quinolate.
42. An electroluminescent device as claimed in claim 41 in which the metal quinolate is an aluminium quinolate or lithium quinolate.
43. An electroluminescent device as claimed in claim 39 in which the electron transmitting material is of formula  $Mx(DBM)_n$  where Mx is a metal and DBM is dibenzoyl methane and n is the valency of Mx.
44. An electroluminescent device as claimed in claim 40 in which the electron transmitting material is a cyano anthracene such as 9,10 dicyano anthracene, a

- 33 -

polystyrene sulphonate or a compound of formulae shown in figure 2 or 3 of the drawings.

45. An electroluminescent device as claimed in any one of claims 40 to 44 in which  
5 the electron transmitting material is mixed with the electroluminescent compound.

46. An electroluminescent device as claimed in any one of the claims 1 to 45 in which the first electrode is a transparent electricity conducting glass electrode.

10 47. An electroluminescent device as claimed in any one of the claims 1 to 46 in which the second electrode is selected from aluminium, calcium, lithium, magnesium and alloys thereof and silver/magnesium alloys.

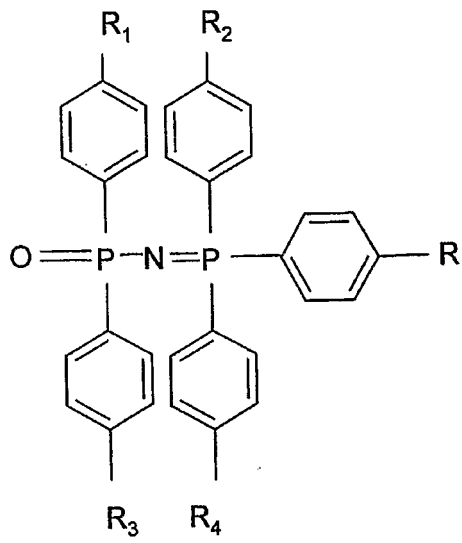


Fig. 1

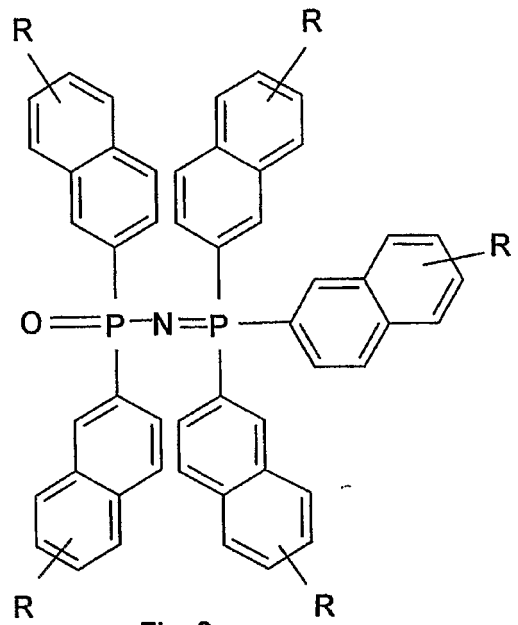


Fig. 2a

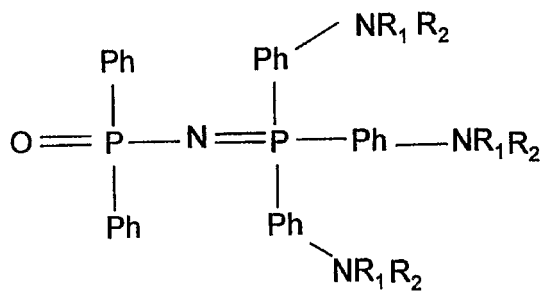


Fig. 2b

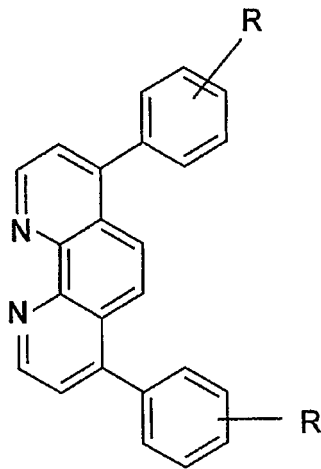


Fig. 3

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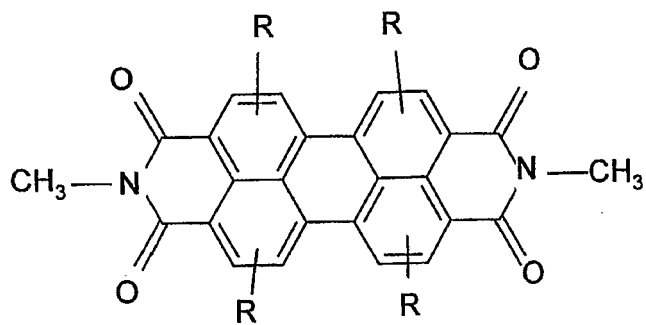


Fig. 4a

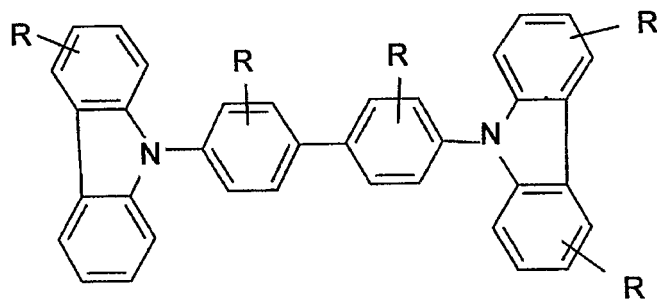


Fig. 4b

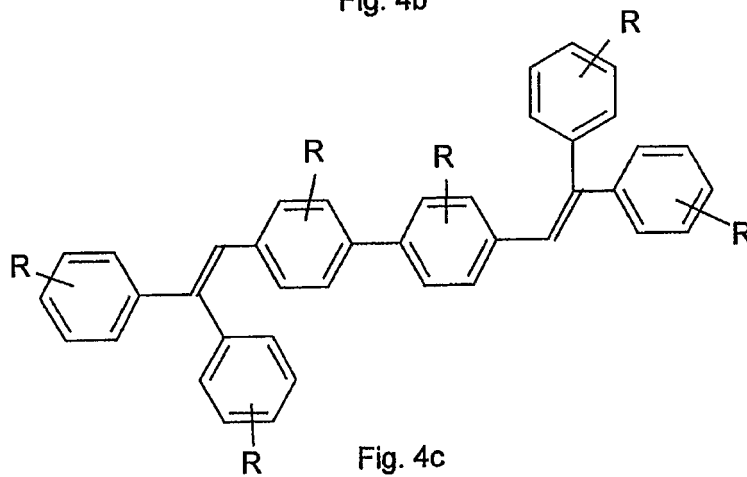


Fig. 4c

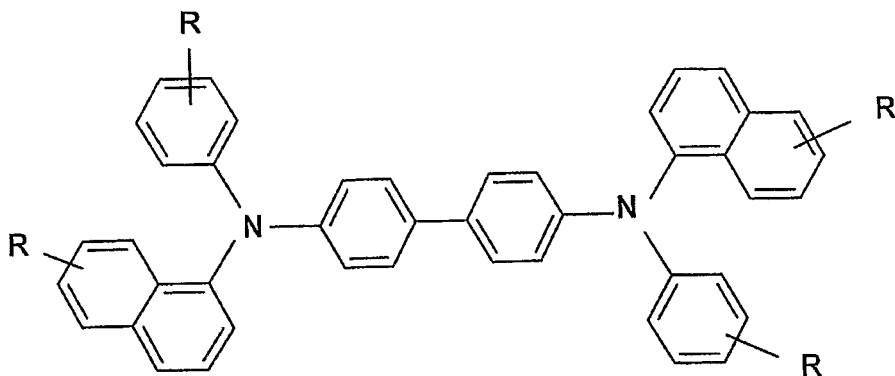


Fig. 4d

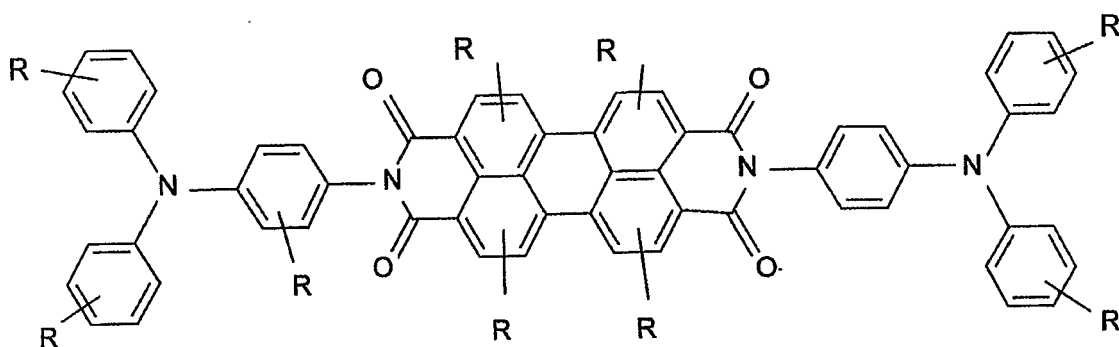


Fig. 4e

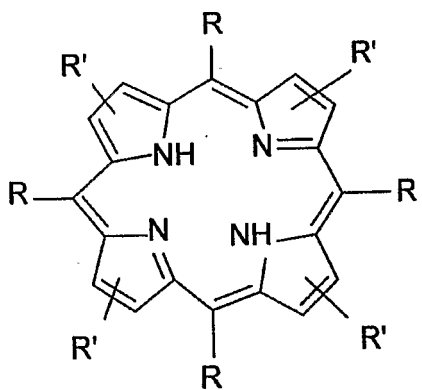


Fig. 4f

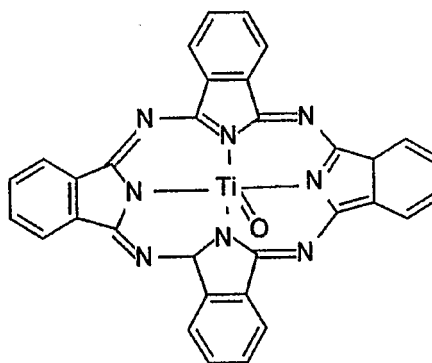


Fig. 4g

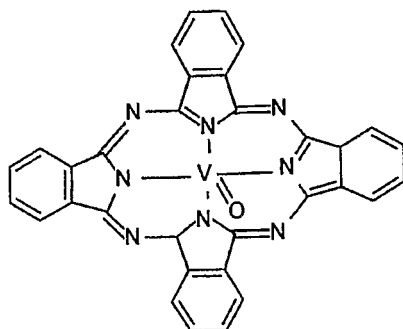


Fig. 4h

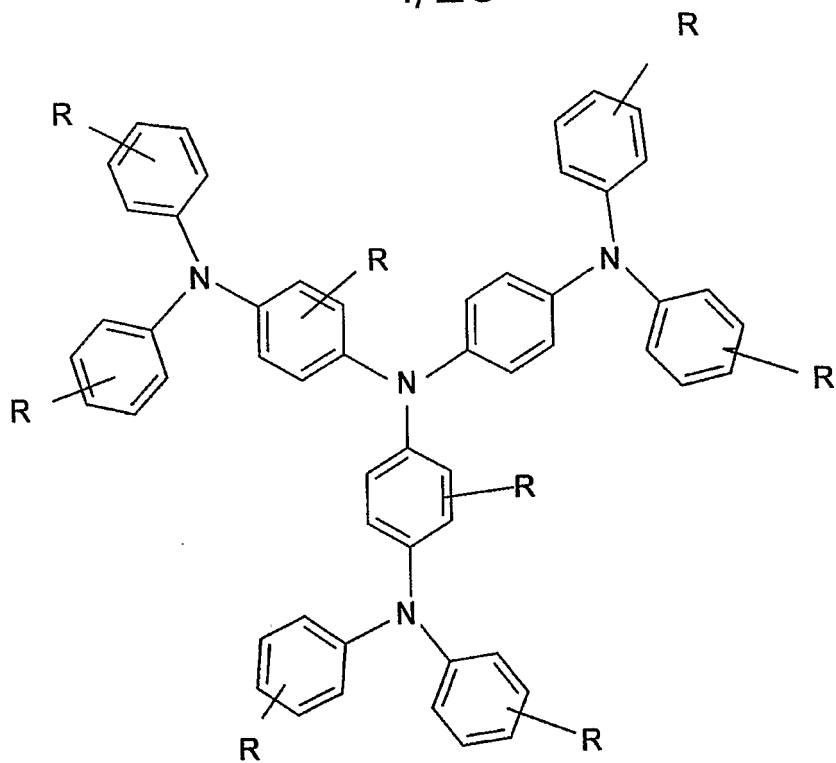


Fig. 4i

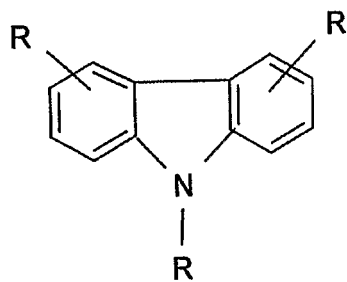


Fig. 4j

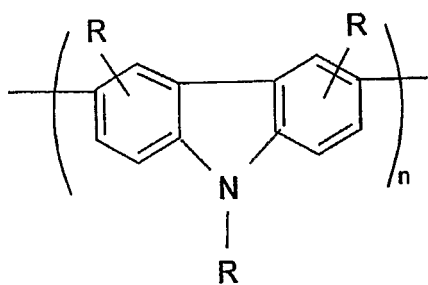


Fig. 4k

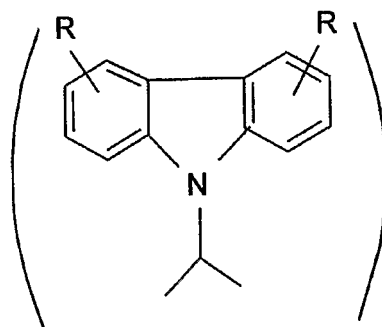


Fig. 4l

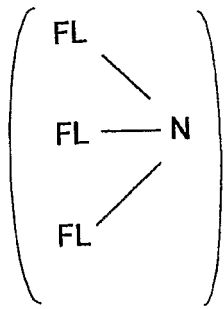


Fig. 5a

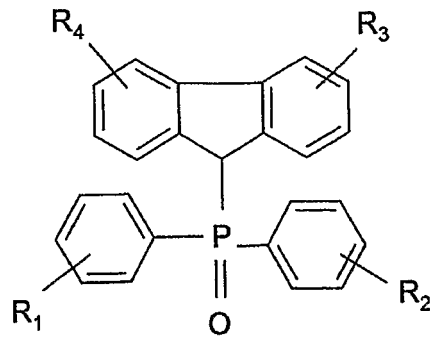


Fig. 5b

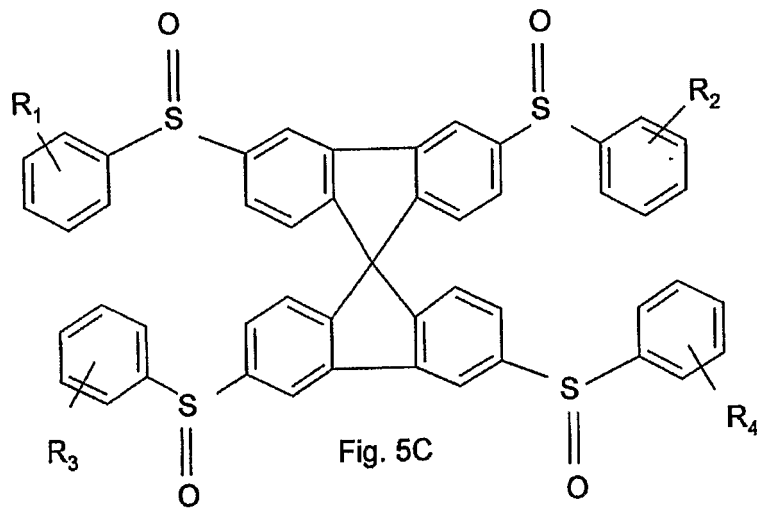


Fig. 5c

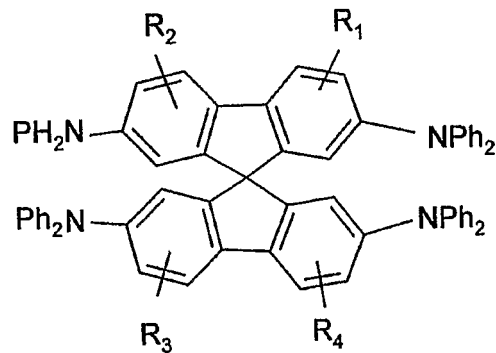


Fig. 5d

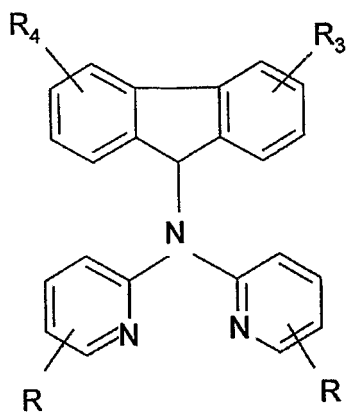


Fig. 5f

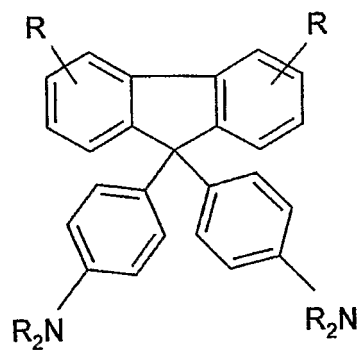


Fig. 5g

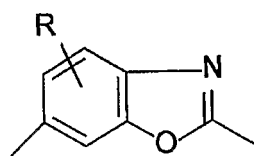


Fig. 6a

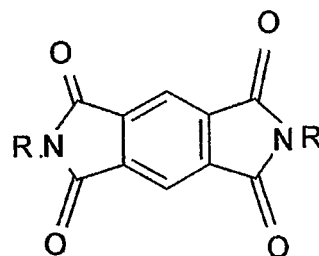


Fig. 6b

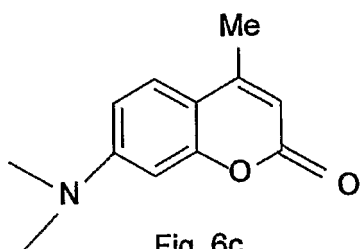


Fig. 6c

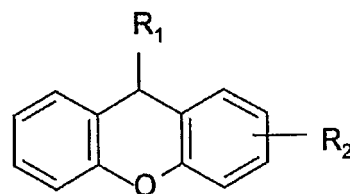


Fig. 6d

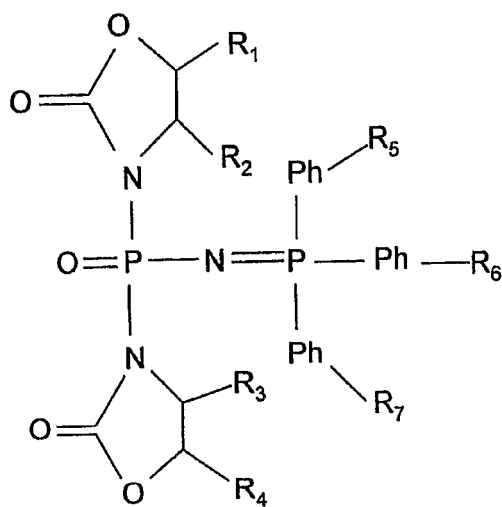


Fig. 6e

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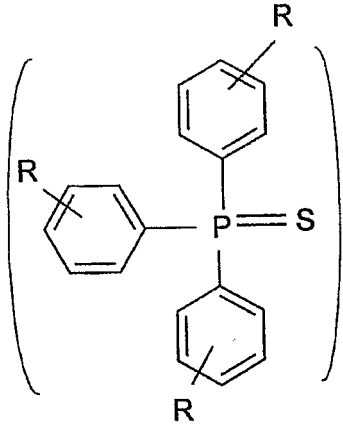


Fig. 7a

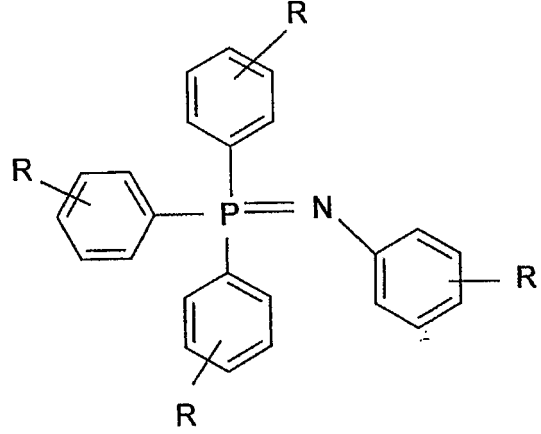


Fig. 7b

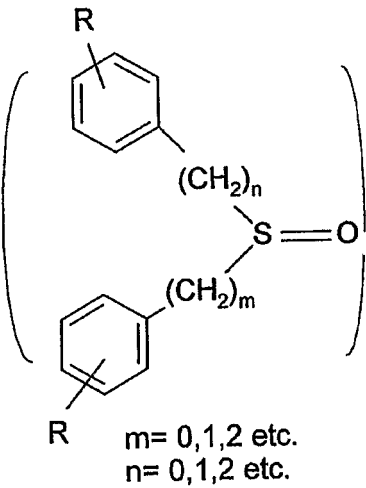


Fig. 7c

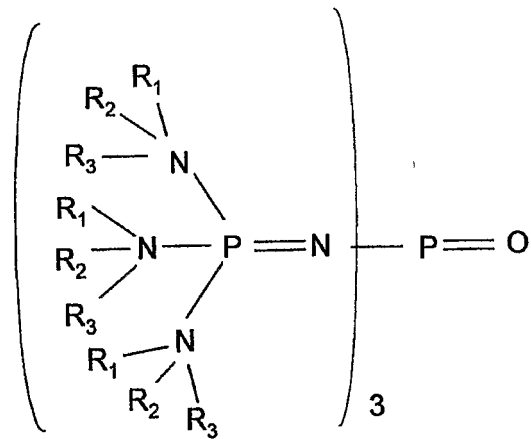


Fig. 7d

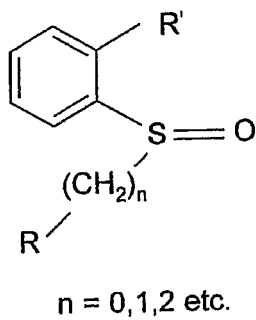


Fig. 7e

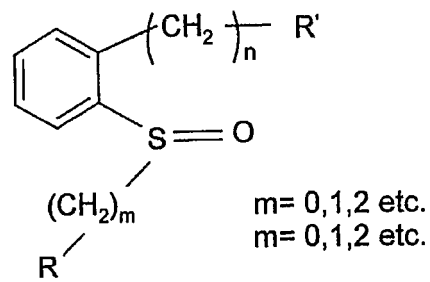


Fig. 7f

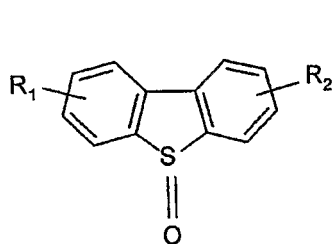


Fig. 8a

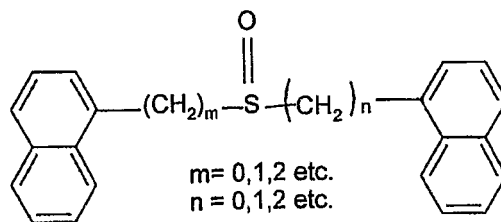


Fig. 8b

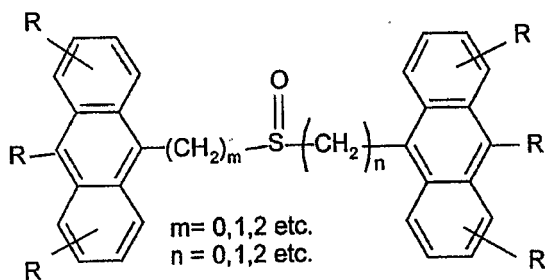


Fig. 8c

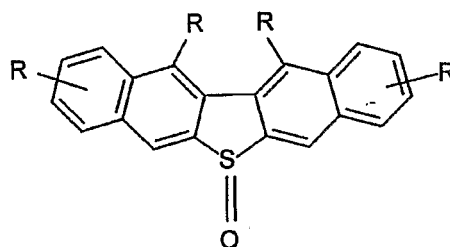


Fig. 8d

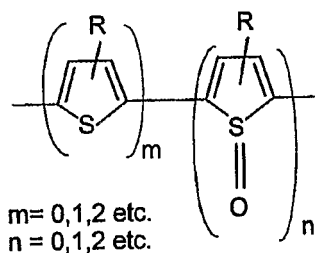


Fig. 8e

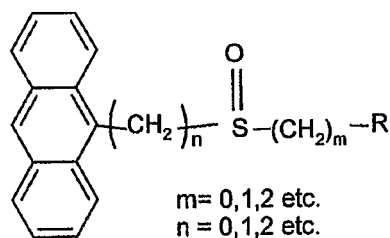


Fig. 8f

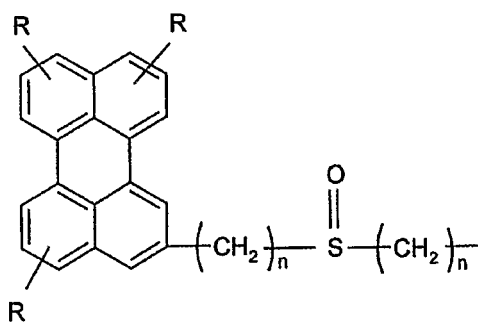


Fig. 8g

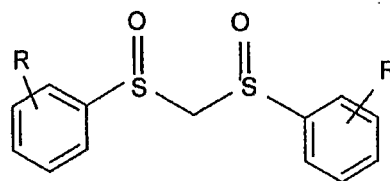
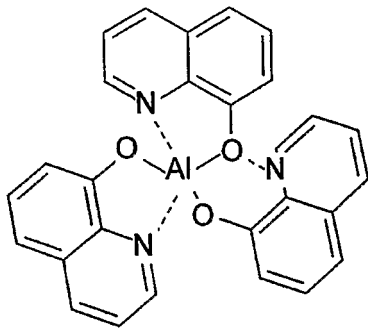
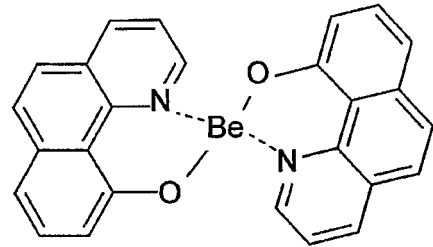


Fig. 8h

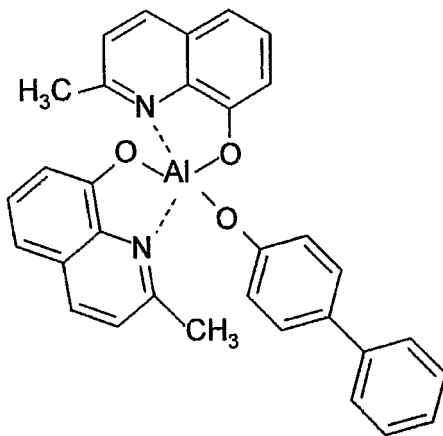
9/25



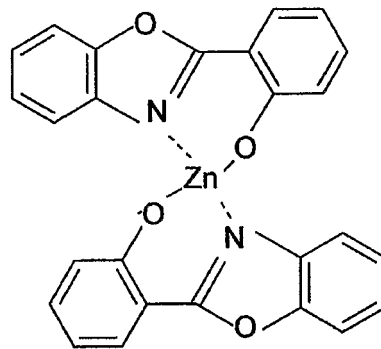
Alq



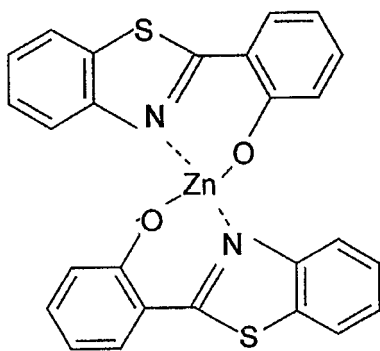
Bebq



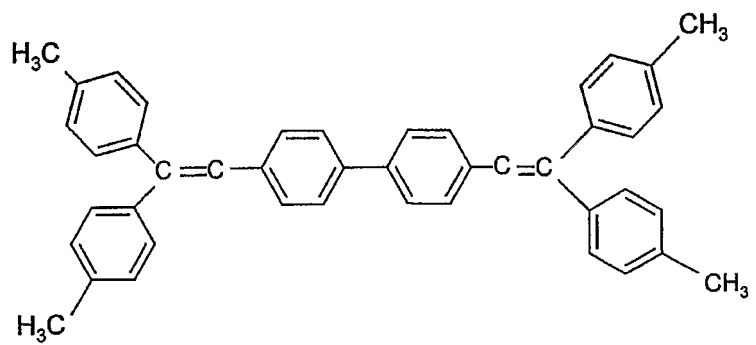
BAlq1



ZnPBO



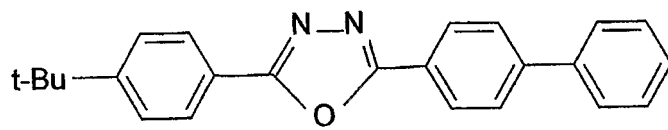
ZnPBT



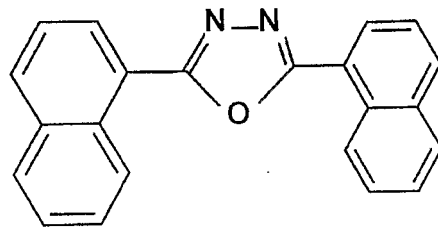
DTVb1

Fig. 9

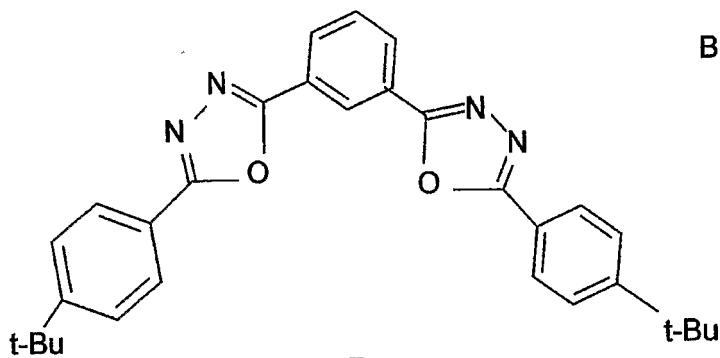
10/25



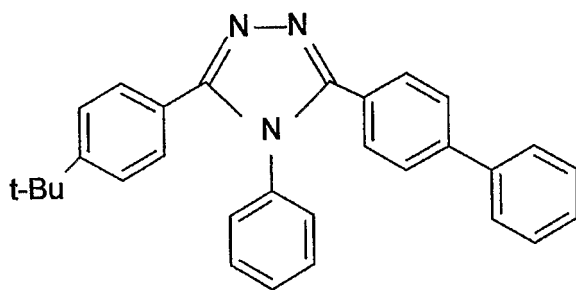
t-Bu-PBD



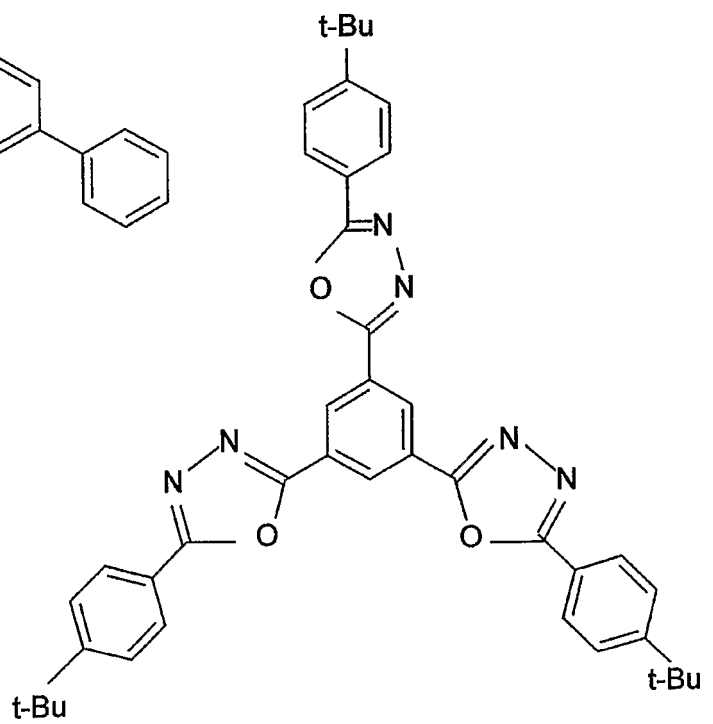
BND



OXD-7



TAZ



OXD-Star

Fig. 10



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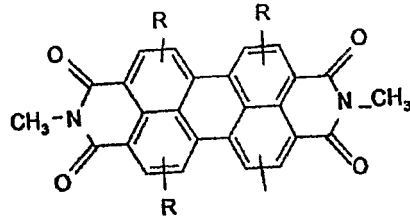


Fig. 12a

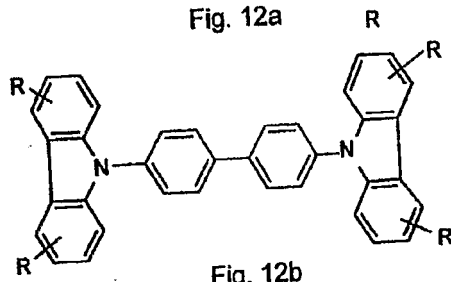


Fig. 12b

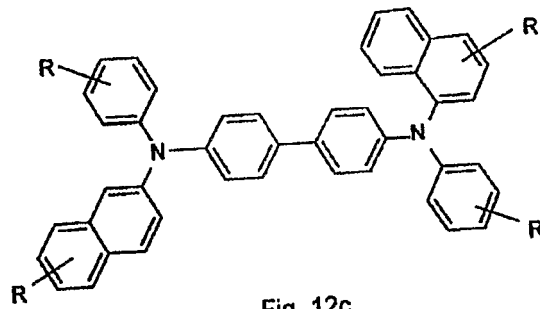


Fig. 12c

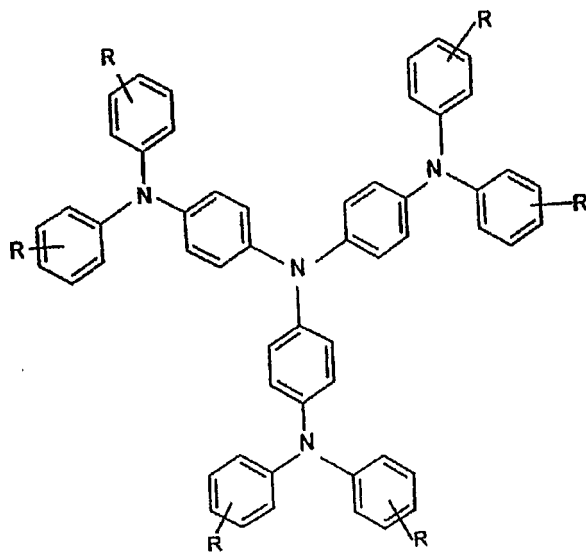
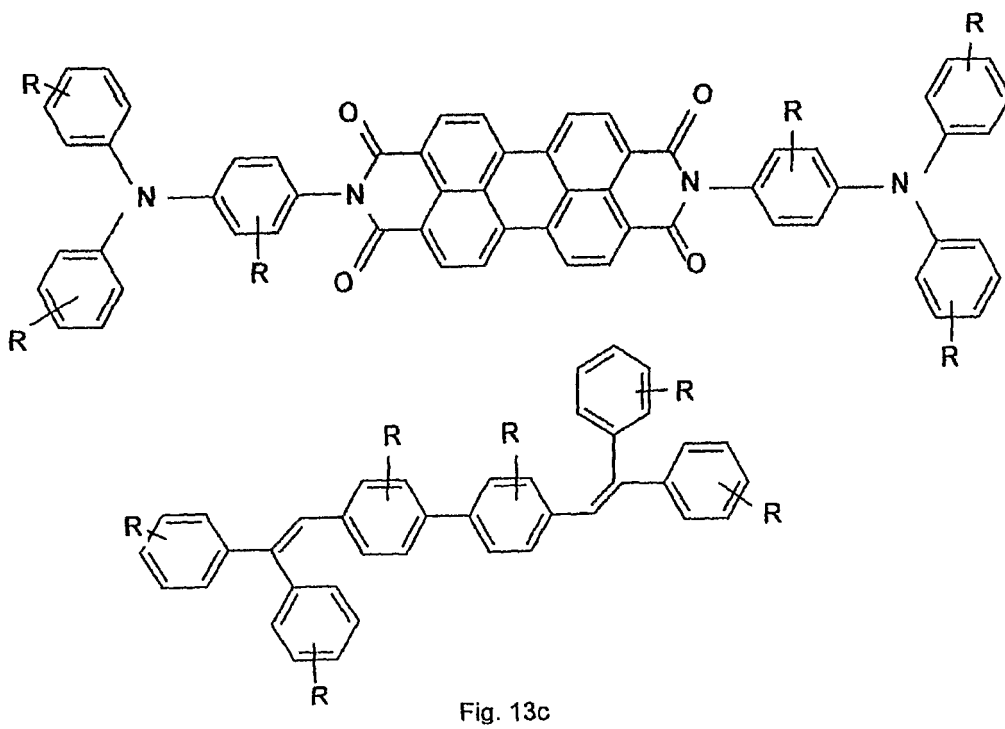
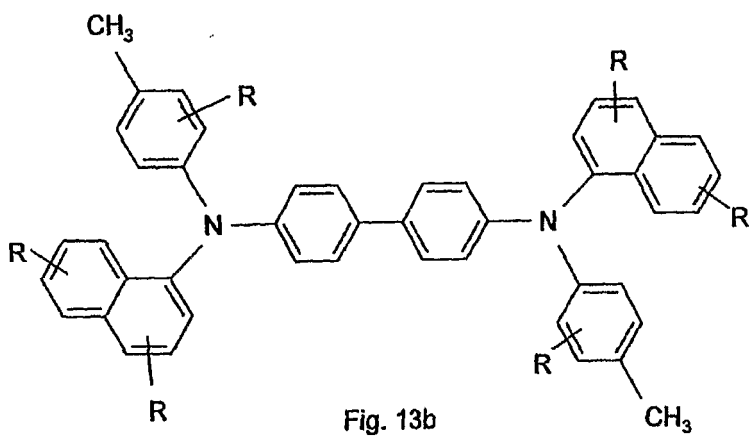
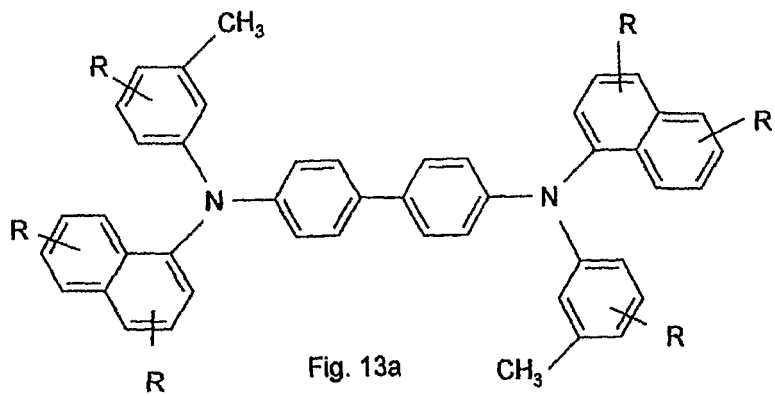


Fig. 12d



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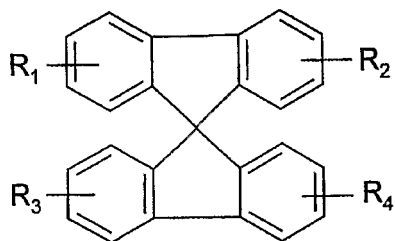


Fig. 14a

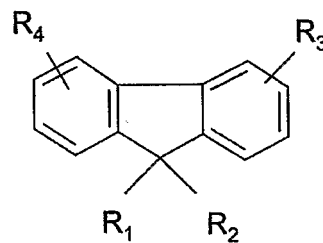
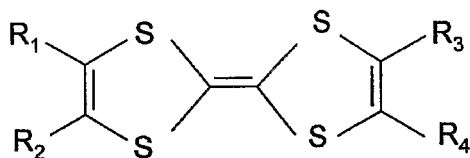


Fig. 14b



or

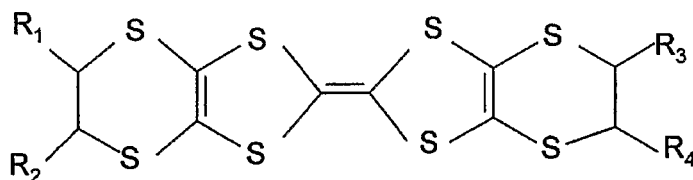


Fig. 14c

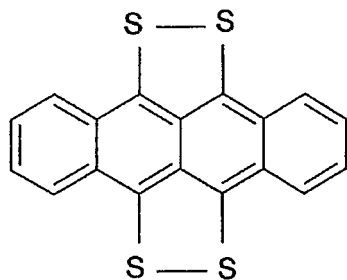


Fig. 14d

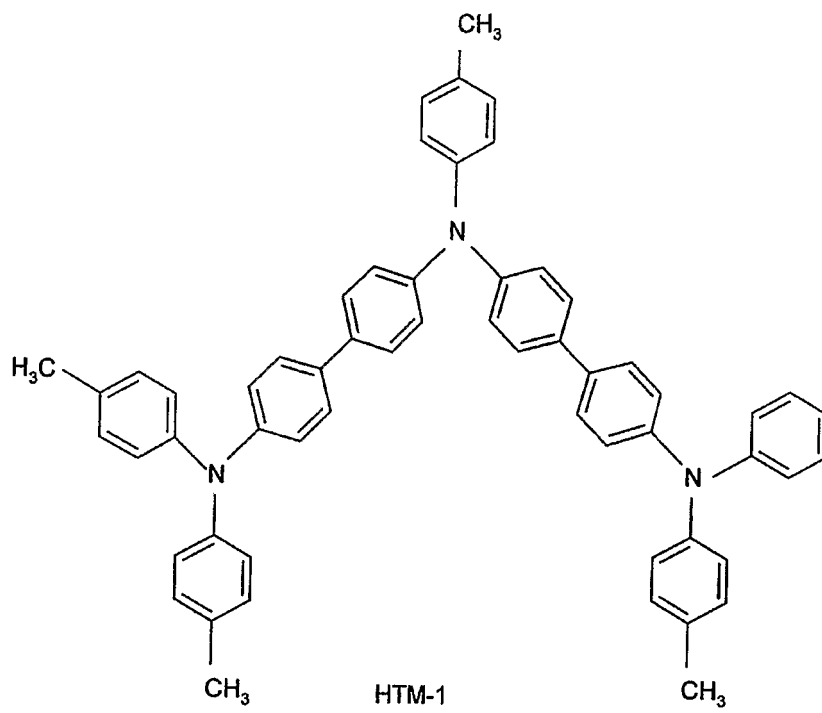


Fig. 15a

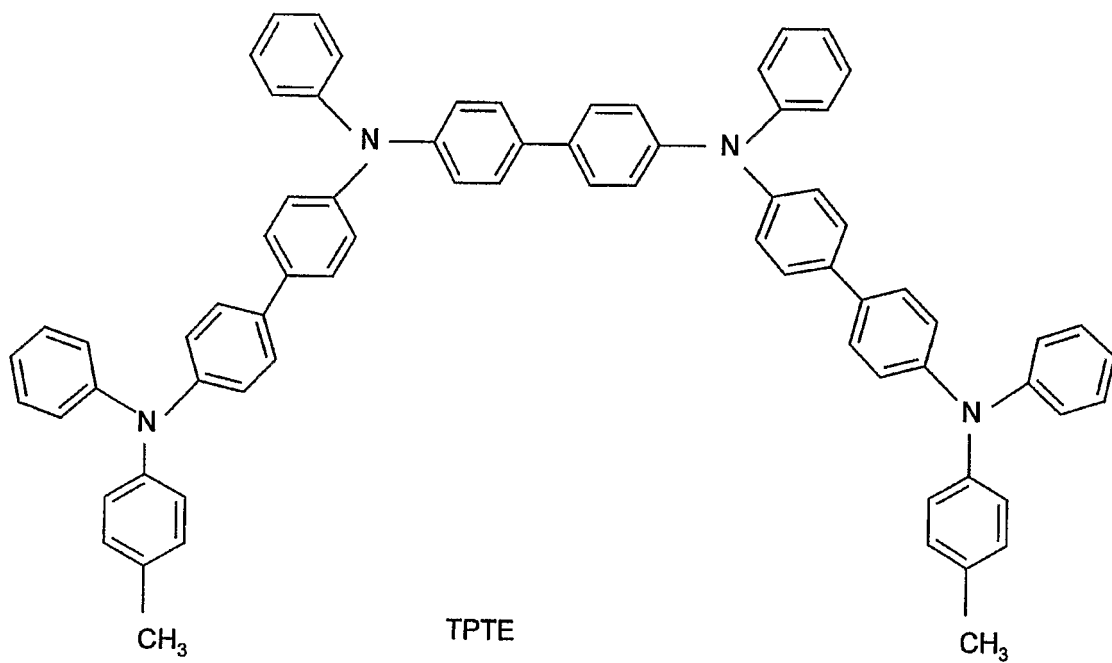
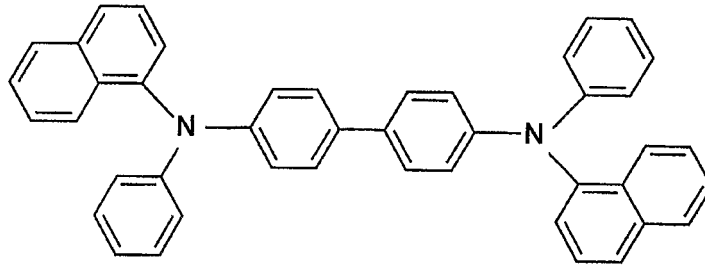


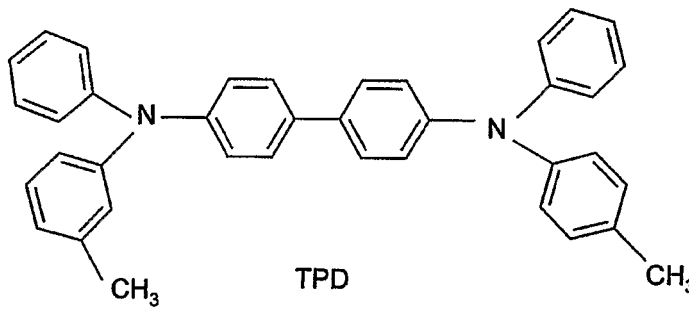
Fig. 15b

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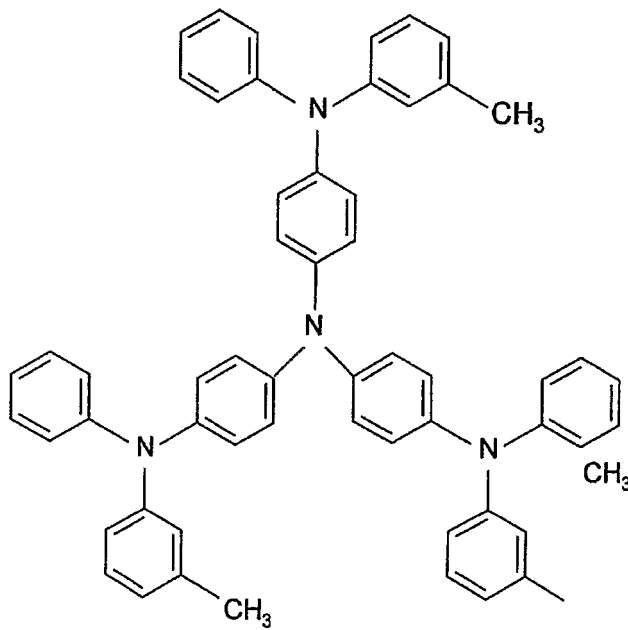
$\alpha$  -NPB

Fig. 16a



TPD

Fig. 16b



mTADATA

Fig. 16c

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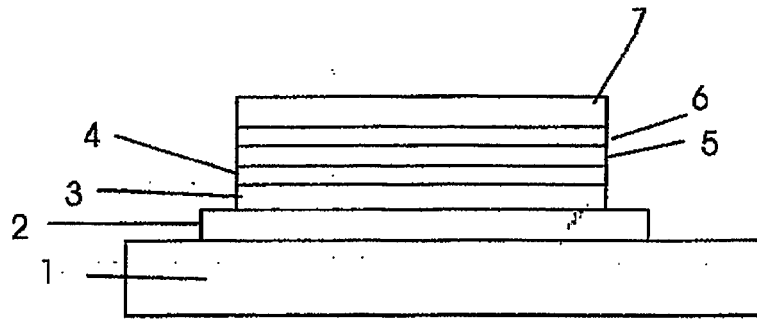


Fig. 17a

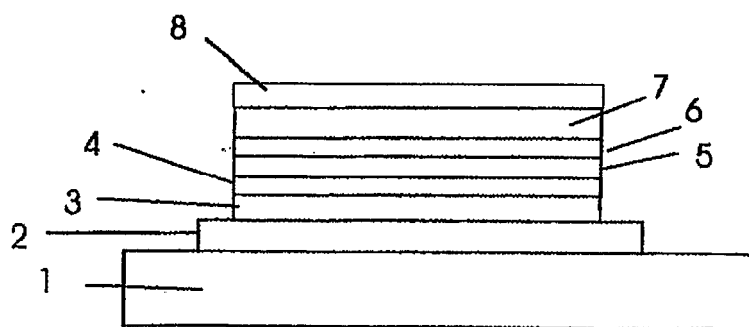
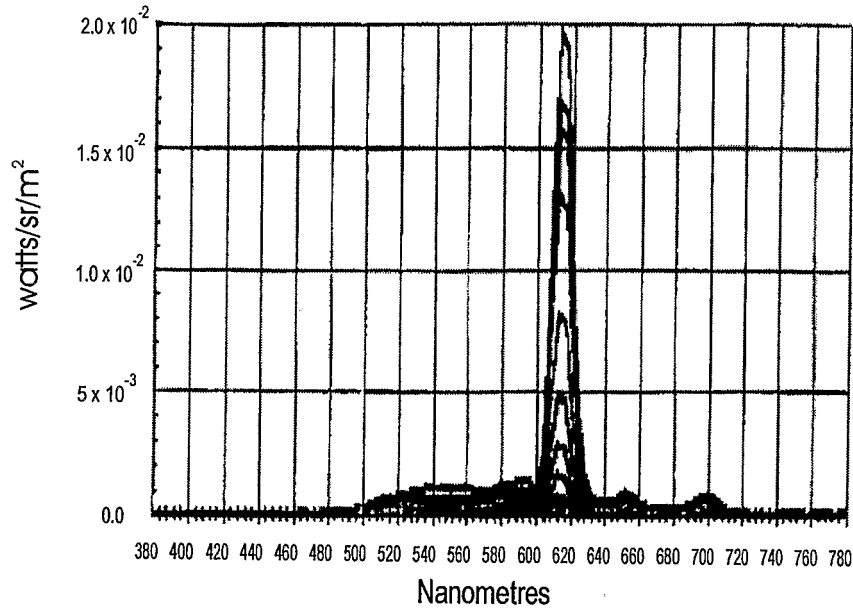


Fig. 17b

Device of example 2



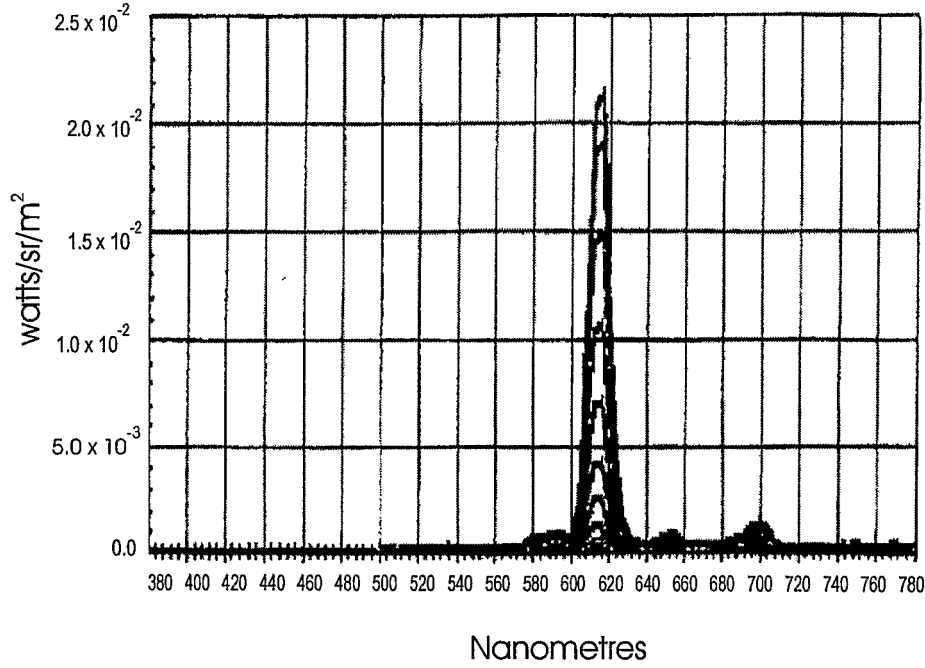
Voltage / V	Colour Co-ordinates	
	x	y
22	0.61	0.33
24	0.62	0.33
26	0.62	0.34
28	0.63	0.35
30	0.63	0.35
33	0.63	0.35
36	0.63	0.35
39	0.63	0.35
42	0.63	0.35
46	0.62	0.36
50	0.62	0.36
54	0.61	0.37
58	0.61	0.37
62	0.60	0.38
66	0.59	0.39

Fig. 18

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Device of example

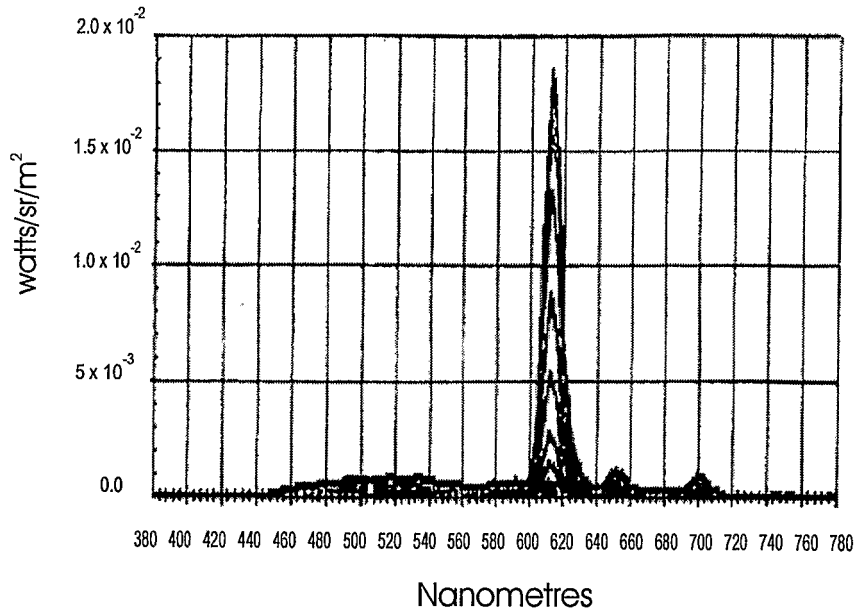
Spectral Radiance



Voltage / V	Colour Co-ordinates	
	x	y
30	0.62	0.32
33	0.62	0.32
36	0.62	0.33
39	0.66	0.33
42	0.66	0.33
46	0.66	0.33
50	0.66	0.33
54	0.66	0.33
58	0.66	0.33
62	0.66	0.33
67	0.66	0.33
72	0.65	0.33
77	0.65	0.33
82	0.65	0.33

Fig. 19

Device of Example 4



Voltage / V	Colour Co-ordinates	
	X	Y
30	0.57	0.34
33	0.60	0.32
36	0.62	0.33
39	0.2	0.33
42	0.63	0.34
45	0.63	0.34
48	0.63	0.34
51	0.63	0.34
55	0.63	0.34
59	0.63	0.34
63	0.62	0.34
67	0.59	0.35
71	0.57	0.36

Fig. 20

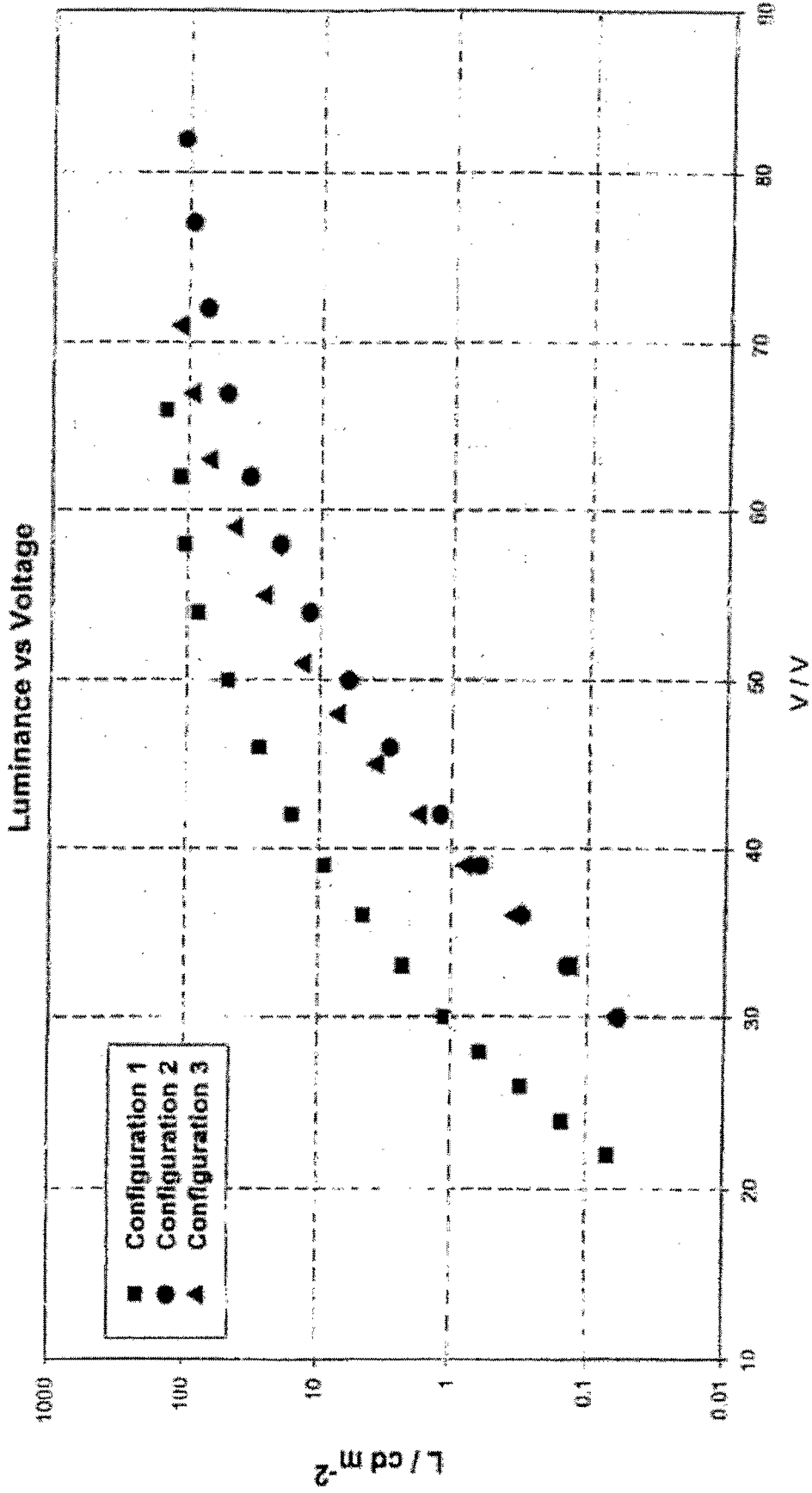


Fig. 21

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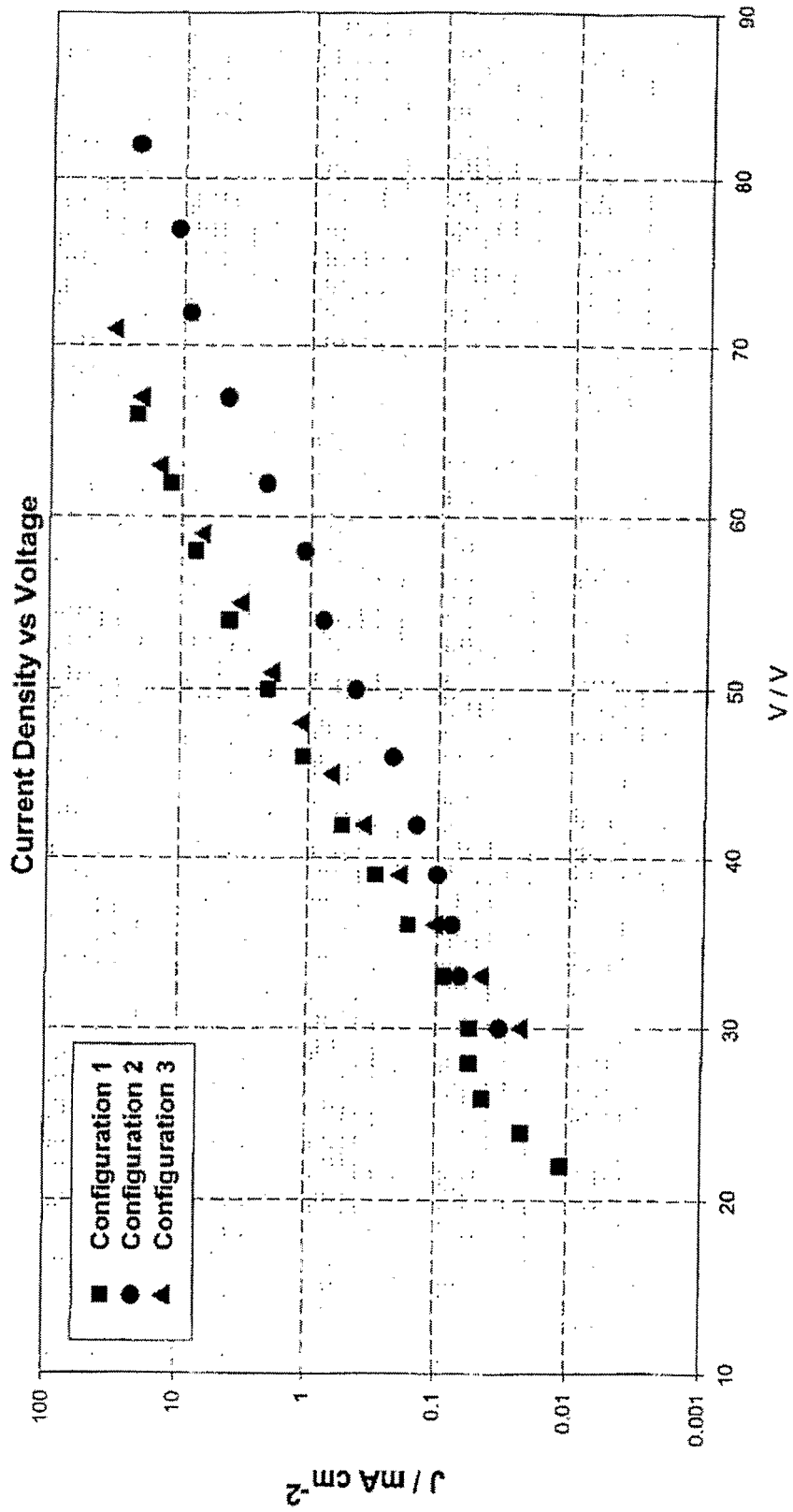


Fig. 22

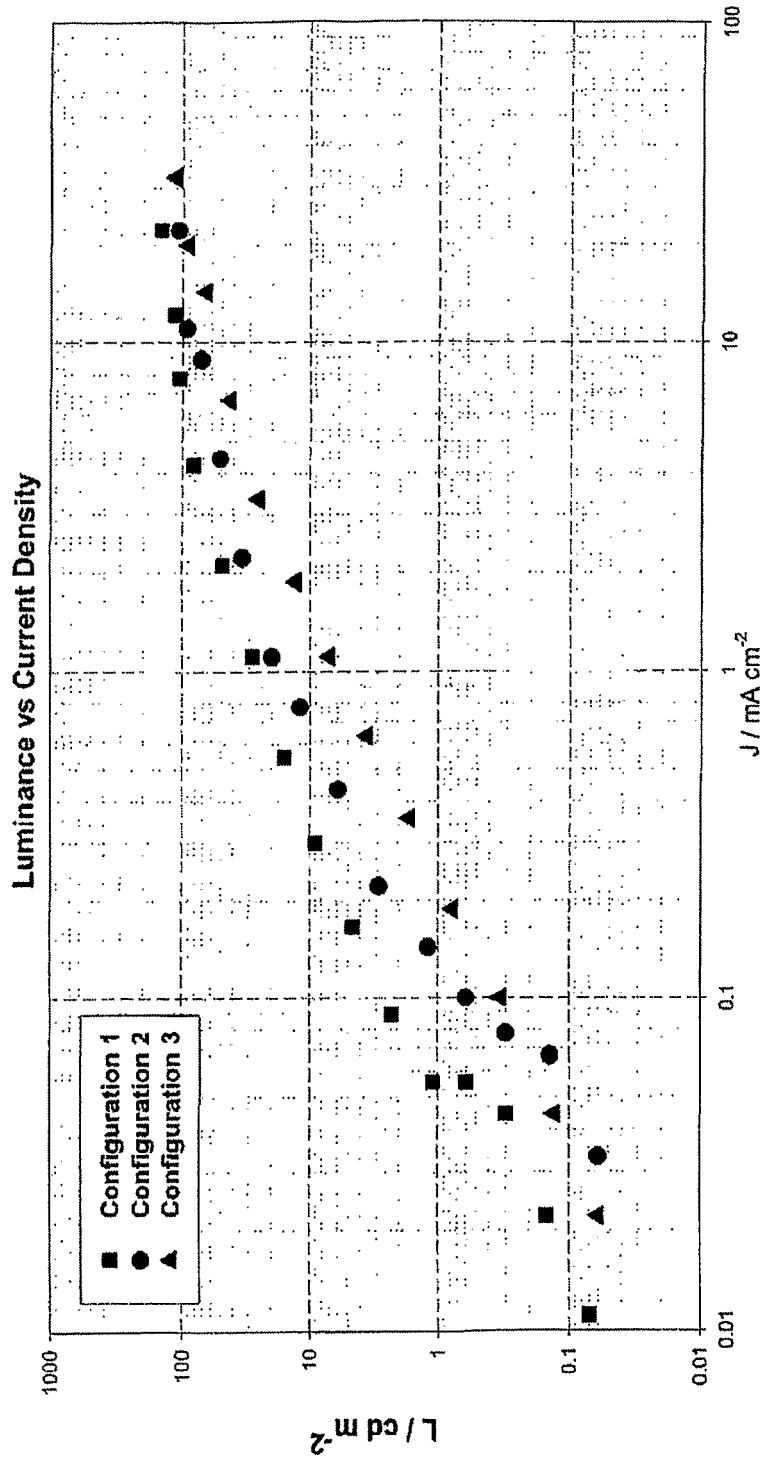


Fig. 23

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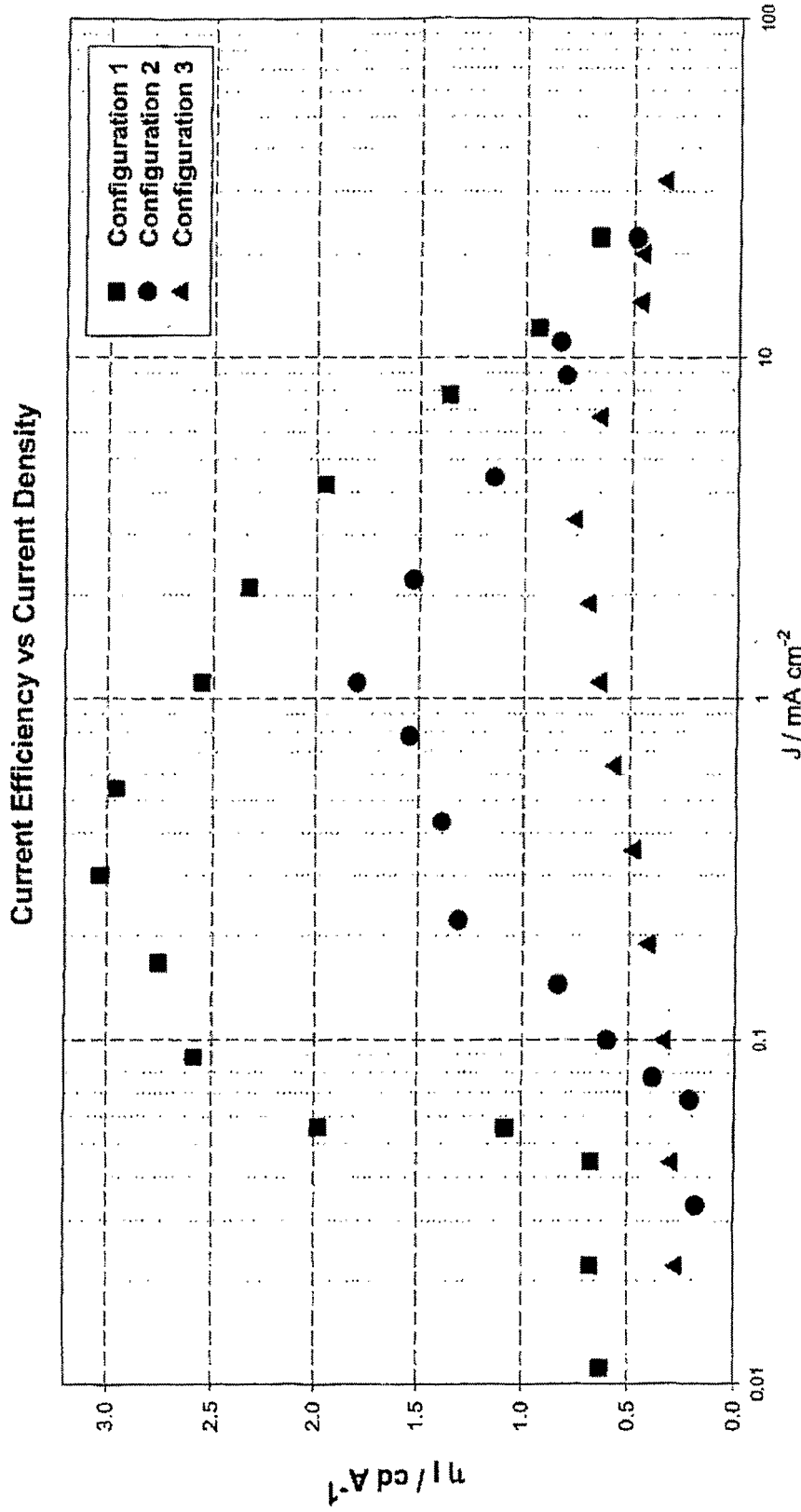


Fig. 24

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J vs V Characteristics

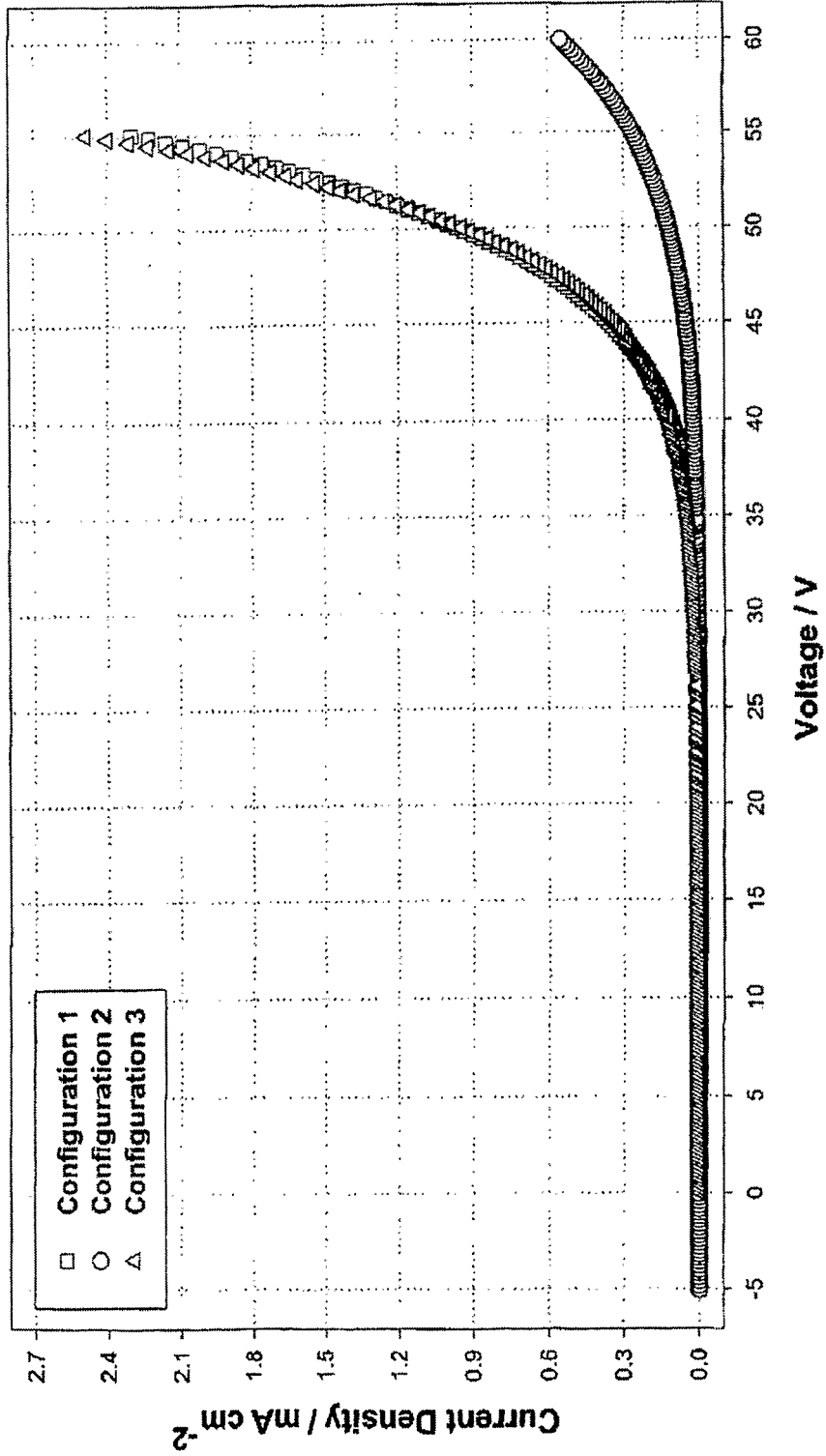


Fig. 25

专利名称(译)	电致发光材料和器件		
公开(公告)号	<a href="#">EP1578886A2</a>	公开(公告)日	2005-09-28
申请号	EP2003782701	申请日	2003-12-23
[标]申请(专利权)人(译)	ELAMt		
申请(专利权)人(译)	ELAM-T有限公司		
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IPC分类号	C09K11/06 H01L51/00 H01L51/30 H05B33/14		
CPC分类号	C09K11/06 C09K2211/1014 C09K2211/1022 C09K2211/1029 C09K2211/1044 C09K2211/1088 C09K2211/182 C09K2211/185 H01L51/005 H01L51/0051 H01L51/0052 H01L51/0053 H01L51/0059 H01L51/0062 H01L51/007 H01L51/0077 H01L51/0078 H01L51/0081 H01L51/0089 H05B33/14 Y10S428/917		
代理机构(译)	LUCAS , BRIAN RONALD		
优先权	2002030074 2002-12-24 GB 2002030077 2002-12-24 GB		
外部链接	<a href="#">Espacenet</a>		

#### 摘要(译)

一种改进的电致发光器件具有一层第一电致发光金属配合物或有机金属配合物和一层第二金属配合物或有机金属配合物，其中第二电致发光金属配合物或有机金属配合物中金属的带隙大于第一电致发光金属配合物或有机金属配合物中金属的带隙。