

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
30 May 2003 (30.05.2003)

PCT

(10) International Publication Number
WO 03/044877 A2

(51) International Patent Classification⁷: **H01L 51/30**

(21) International Application Number: PCT/GB02/05176

(22) International Filing Date:
15 November 2002 (15.11.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0127461.2 16 November 2001 (16.11.2001) GB
0220844.5 7 September 2002 (07.09.2002) GB

(71) Applicant (for all designated States except US): **CDT OXFORD LIMITED** [GB/GB]; 8 Begbroke Business & Science Park, Sandy Lane, Yarnton, Oxford OX5 1PF (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **PILLOW, Jonathan, Nigel, Gerard** [GB/GB]; CDT Oxford

Limited, 8 Begbroke Business & Science Park, Sandy Lane, Yarnton, Oxford OX5 1PF (GB). **FRAMPTON, Michael, John** [GB/GB]; CDT Oxford Limited, 8 Begbroke Business & Science Park, Sandy Lane, Yarnton, Oxford OX5 1PF (GB).

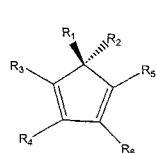
(74) Agent: **EASTWOOD, Simon, Christopher**; Stevens Hewlett & Perkins, 1 St. Augustine's Place, Bristol BS1 4UD (GB).

(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, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

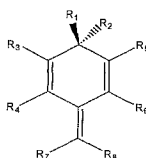
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK,

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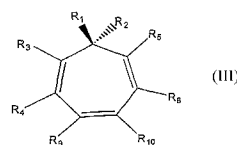
(54) Title: LIGHT EMITTING DEVICE AND COMPOUNDS FOR USE THEREIN



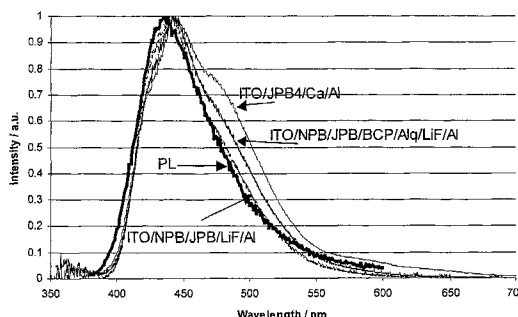
(I)



(II)



(III)



(57) Abstract: There is disclosed a light emitting device comprising at least one compound of formula (I), (II) or (III): wherein R_1 and R_2 , which may be the same or different, are organic substituents not including H, and wherein R_3 and R_5 are each independently selected from halo and organic substituents not including H, and wherein R_4 , R_6 , R_7 , R_8 , R_9 and R_{10} are each independently selected from H, halo, and organic substituents, wherein any two or more of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 and R_{10} may optionally be fused together to form a ring system, provided that one of R_3 and R_5 is not part of a fused ring system, and provided that R_1 and R_2 are not fused to each other to form a ring system, and wherein one but not both of either (a) R_3 and R_4 , or (b) R_5 and R_6 , are fused to each other to form a ring system.



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TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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.

Published:

— *without international search report and to be republished upon receipt of that report*

LIGHT EMITTING DEVICE AND
COMPOUNDS FOR USE THEREIN

This invention relates to a light emitting device, in particular an organic electroluminescent device, and compounds primarily, although not exclusively, for use therein. These devices may be utilised in flat-panel displays.

Organic Electroluminescent (EL) displays (or organic light emitting diodes (OLEDs)) have been attracting much attention as a potential alternative to liquid-crystal displays for a number of flat panel display applications. In essence an organic EL device comprises a thin organic layer sandwiched between two electrodes, such that when a current is passed between the electrodes light is emitted from the organic material. The organic material can be macromolecular or a molecular species. In the most efficient devices there are typically a number of organic layers between the electrodes, for example a hole transporting layer, a luminescent layer and an electron transporting layer.

Volatile molecular compounds have the advantage that they can be deposited by thermal evaporation. This allows known techniques (e.g. shadow masking) to be used to form pixellated displays. The luminescent layer may be a homogeneous film, or may consist of a host and a dopant.

Although OLEDs have been under development since the late 1980s there is still scope for improved emissive and charge transporting materials. To make a full-colour display there is a need for efficient blue, red and green emitters that meet the NIST or PAL colour coordinate standards, and that these materials have a long operating lifetime. The lifetime of current blue emitters is less than is required for many applications.

It is known that recrystallization of the organic films is one failure mechanism and hence that a high glass transition temperature (T_g) is a necessary requirement for a long device lifetime.

Amongst the best-known blue emitting compounds for organic EL devices are stilbene and triarylethylene derivatives such as 4,4'-bis(2,2'-

diphenylvinyl)biphenyl (DPVBi) (Idemitsu Kosan US 5130603 and App. Phys. Lett. 1995, 67(26), 3853-3855). DPVBi devices can be made more efficient by doping the DPVBi layer with a blue dye, but this adds complexity to the device fabrication. The resulting colour will depend on the blue dye used. The spiro compound spiro-DPVBi has an improved Tg relative to DPVBi; however the colour is still not as blue as is desired for a full-colour display. The emission maximum is at 470nm and the FWHM (Full Half Width Maximum) is greater than 80nm (Proceedings of SPIE Vol 4105 (2001) p125 – 133).

It would be advantageous to enhance the colour purity, efficiency and lifetime, particularly of blue emitting EL devices.

The non-planar structure of the compounds of this invention makes the compounds surprisingly volatile for their size which allows larger molecules to be used which have a greater chance of having a high Tg. This allows stable amorphous films to be formed by thermal evaporation. Some of the compounds are optically active, which can have the benefit that a mixture of enantiomers will tend to form a glassy film rather than a polycrystalline film. Alternatively a non-optically active compound may be easier to purify.

EL devices have been made with novel molecules that emit deep blue light.

The indenenes included in the present invention were designed to offer superior advantages over compounds that contain the more standard stilbene group. Many stilbene-containing compounds have been shown to have excellent emission characteristics in electroluminescent devices. There are however two significant disadvantages with the stilbene system. Firstly, although some twisting does occur around the axial bonds, the molecules are comparatively planar. This means that neighbouring molecules can be packed closely together – a process that is well known to allow the introduction of intermolecular electronic orbitals, the broadening of electronic spectra, and the reduction of luminescent efficiency. Close approach of molecules can also enhance intermolecular electrochemical reactions, which are likely to be a significant cause of electroluminescent lifetime loss.

The second problem with stilbene systems is associated with the slightly twisted nature of the stilbene. Twisting oscillations (libration) along the axis means that there is a bigger distribution of molecular orbitals, which leads to a broadening of the electronic spectra of the material.

The compounds of the present invention were therefore designed to address both these problems, with the aim of preparing a family of molecules that have narrower electronic spectra – particularly in the electroluminescence spectra – and that have better electrochemical stability that could provide longer EL lifetimes.

Indenes differ from the stilbenes by including the disubstituted bridging carbon atom. This achieves two purposes. Firstly, because half of the former stilbene is now enclosed in a 5-membered ring, the indene molecule is significantly more rigid which means that there are far fewer degrees of freedom for the molecule, leading to narrower electronic spectra. Secondly, because the two substituting groups overhang the faces of the indenenes, the main molecular orbitals of the indene are protected from the approach of other molecules, so that intermolecular effects should be greatly reduced.

The idea of using bulky groups in inhibiting molecular packing has been known for a long time. A more relevant case is that of fluorene, where there are also overhanging groups that can protect the molecular faces from packing. However, the use of fluorene in place of biphenyl is a very specific process that cannot be used to enhance the performance of stilbene containing molecules, which are an extremely important separate class of materials for use in OLEDs.

By allowing the development of enhanced versions of stilbene derivatives, this invention opens up significant and novel possibilities for designing compounds for electroluminescent applications.

US 5840217 discloses the use of spiro compounds as electroluminescence materials. The compounds are said to have a good solubility in customary organic solvents, improved film-forming properties and a significantly reduced tendency to crystallize. This leads to an increased service life of electroluminescence devices including such compounds.

US 5077142 discloses electroluminescent devices comprising a wide variety of compounds which include an aromatic benzene ring, including unsubstituted indenenes.

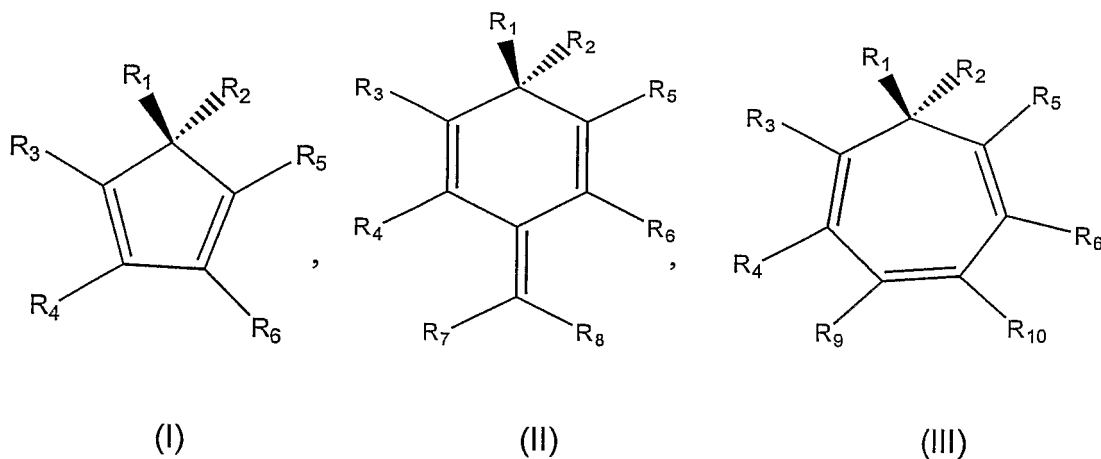
JP 3-168294 describes a compound in which fused cyclic systems are bound to a 5-membered ring having a tetrahedral carbon atom.

Spiro compounds for use in OLEDs are also disclosed in Spreitzel et al, Organic Light-Emitting Materials and Devices Vol 4105 (2001) pp125 – 133.

US 5085946 discloses the use of various cyclopentadiene derivatives in OLEDs. The substituents are not linked to form a ring system and the operating voltages of the devices disclosed are undesirably high.

JP 2001-307880 discloses spiro compounds for use in OLEDs. Such compounds can be quite difficult to synthesise and limit the substituents that can be used at the tetrahedral carbon position.

Thus, according to the present invention, there is provided a light emitting device comprising at least one compound of formula (I), (II) or (III):



wherein R_1 and R_2 , which may be the same or different, are organic substituents not including H,

and wherein R_3 and R_5 are each independently selected from halo and organic substituents not including H,

and wherein R_4 , R_6 , R_7 , R_8 , R_9 and R_{10} are each independently selected from H, halo, and organic substituents,

wherein any two or more of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 and R_{10} may optionally be fused together to form a ring system, provided that one of R_3 and R_5 is not part of a fused ring system, and provided that R_1 and R_2 are not fused to each other to form a ring system,

and wherein one but not both of either (a) R_3 and R_4 , or (b) R_5 and R_6 , are fused to each other to form a ring system.

Thus, whilst R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 and R_{10} may be selected as indicated above, when two or more are fused to form a ring system, such a ring system is organic.

The presence of R_1 and R_2 on the tetrahedral carbon atom hinders both faces of the conjugated region, helping to prevent pi-stacking and thereby improving the colour purity of the emission. Furthermore, by excluding spiro compounds, the synthesis of the compounds is simplified and a greater variety of substituents at the tetrahedral carbon position can be obtained which may allow optimisation of the properties. For example, R_1 and R_2 could be charge-transporting groups.

There is only one tetrahedral carbon position in each of the 5, 6 or 7-membered rings, and the double bonds are in conjugation.

By way of examples, in formula (II) R_4 and R_7 , or R_3 and R_4 and R_7 , or R_6 and R_8 , may be fused to each other to form a ring system, and in formula (III) R_9 and R_{10} may be fused to each other to form a ring system.

Preferably, the light emitting device comprises a compound of formula (I).

Preferably R_3 , R_4 , R_5 and R_6 are organic substituents. R_7 , R_8 , R_9 and R_{10} are preferably independently H or organic substituents.

The organic substituents may be any appropriate group, examples being alkyl, aryl and heteroaryl, each of which may be substituted or unsubstituted. For example, when the substituents are aryl or heteroaryl, they may be substituted by any appropriate group, examples being aryl, heteroaryl, diarylamine, alkyl, cycloalkyl, a fused ring system, halo or haloalkyl groups. Throughout this invention the substituents may themselves optionally be substituted. Similar rings may be formed when any of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 ,

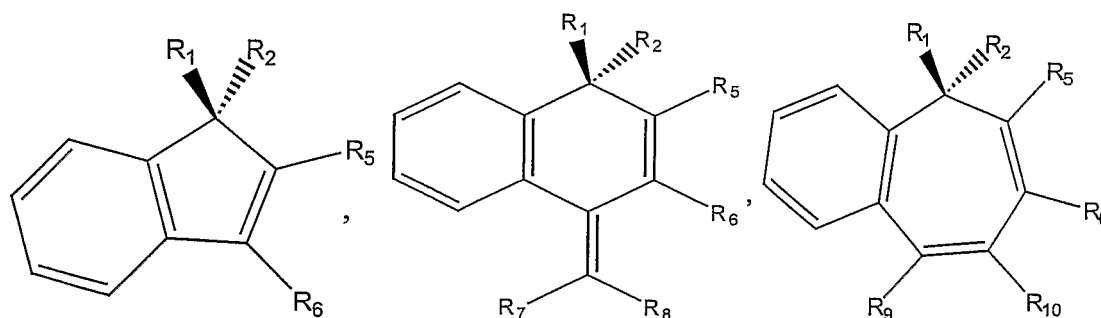
R_7 , R_8 , R_9 and R_{10} are fused together to form a ring system, which system is preferably a fused aromatic ring, which may contain a heteroatom.

The alkyl substituent is preferably a C_{1-6} alkyl and may be straight or branched chain, examples being methyl, ethyl, t-butyl or the like.

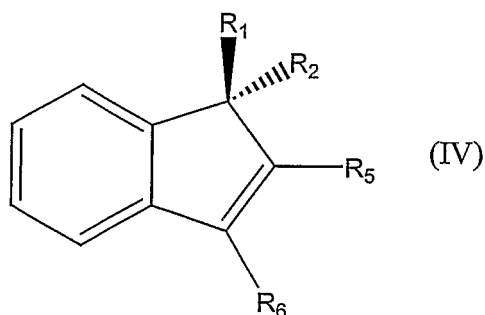
The aryl groups may, for example, be C_{6-15} aryl groups such as phenyl, 1-naphthyl, 2-naphthyl, fluorene or the like.

The other of R_3 and R_4 , or R_5 and R_6 , which do not form the fused ring system, may in one embodiment be (substituted or unsubstituted) aryl, for example phenyl.

The fused ring system may comprise a fused aromatic ring, for example a benzene ring. Thus, in a preferred embodiment, the light emitting device comprises at least one of the following compounds:



Preferably, the light emitting device comprises a compound of formula (IV):



R_1 , R_2 , R_5 and R_6 are defined as above. It may have the preferred features mentioned above. In one embodiment R_1 , R_2 , R_5 and R_6 are independently selected from substituted or unsubstituted aryl, benzyl or alkyl and when they are alkyl, they are preferably C_{1-6} alkyl. R_1 and R_2 are preferably each

(substituted or unsubstituted) aryl. R_5 and R_6 are preferably each (substituted or unsubstituted) aryl, for example phenyl.

It is preferred that the compound evaporates or sublimes in the temperature range of 200 - 400°C at a reduced pressure, for example 10^{-6} mbar.

Preferably, the glass transition temperature of the compound is greater than 80°C and the melting point is preferably greater than 100°C, for example greater than 130°C.

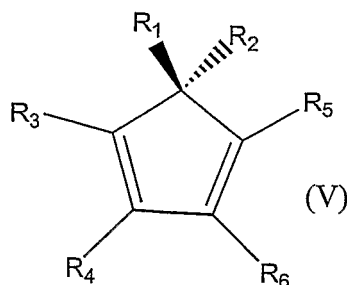
The light emitting device is generally an organic electroluminescent device and further comprises an anode and a cathode, wherein the compound is sandwiched therebetween.

According to a further aspect of the present invention, there is provided the use of a compound of formula (I), (II) or (III) as a luminescent material in a light emitting device.

According to a further aspect of the present invention, there is provided the use of a compound of formula (I), (II) or (III) as an electron transport material in a light emitting device.

According to a further aspect of the present invention, there is provided the use of a compound of formula (I), (II) or (III) as a hole transport material in a light emitting device.

According to a further aspect of the present invention there is provided a compound of formula (V):



wherein R_3 and R_4 are fused to each other to form a substituted or unsubstituted fused aromatic ring,

and wherein R_1 , R_2 , R_5 and R_6 , which may be the same or different, are independently selected from aryl or heteroaryl, each of which is optionally substituted by aryl, heteroaryl, diarylamine, alkyl, cycloalkyl, a fused ring system, halo, haloalkyl, cyano and alkyloxy groups, provided that R_1 and R_2 are not fused to each other to form a ring system, and provided that R_5 and R_6 are not fused to each other to form a ring system, and provided that R_1 , R_2 , R_5 and R_6 are not all phenyl.

Such compounds are particularly useful when used in a light emitting device, although other uses are not excluded.

Each substituent may itself be substituted as necessary.

In a preferred embodiment, the aryls are C_{6-15} aryls, specific examples being phenyl, 1-naphthyl, 2-naphthyl, and fluorene. The heteroaryls are preferably selected from oxadiazole, carbazole, triazole, oxazole, thiazole or benzothiazole and, in general, aryl groups are more preferred than heteroaryl groups.

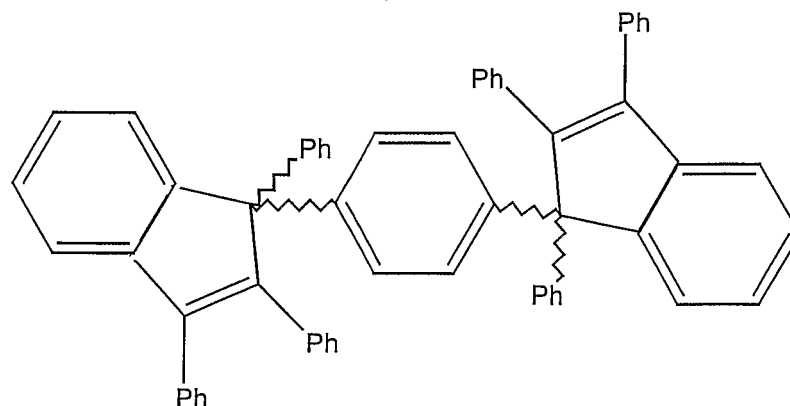
The alkyl substituent is preferably a C_{1-6} straight or branch chain alkyl group, specific examples being methyl, ethyl, and t-butyl.

In a preferred embodiment, the fused ring system substituent is a hydrocarbon ring system. Preferably, at least one ring of the fused ring system substituent is not aromatic, examples being indene, perinaphthene, tetrahydronaphthalene.

Diarylamine substituents are preferably selected from diphenylamine, ditolylamine, dinaphthylamine, phenyltolylamine, phenylnaphthylamine, or the like.

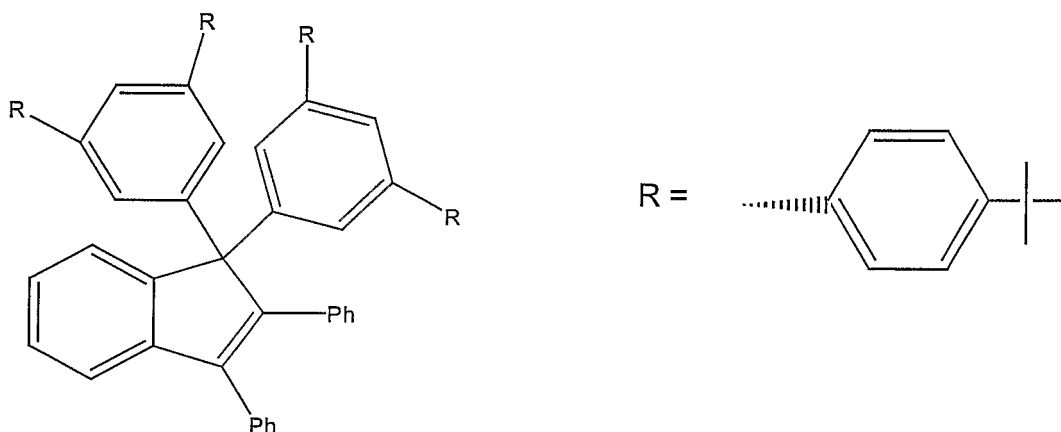
In a preferred embodiment, R_3 and R_4 are fused to each other to form a 6-membered aromatic (benzene) ring. The ring may be substituted by any suitable substituent, even including one or more further rings fused to it.

The following compound has been found to be particularly useful in the present invention:



This compound has two chiral centres and can therefore exist in (S,S), (R,R) and (S,R) stereoisomers. It has been found that two reaction products can be isolated, having crystalline and glassy forms, and it is believed that these correspond to the (S,R) and mixed (S,S) and (R,R) isomers respectively. Both molecules show bright blue fluorescence. The crystalline form has a melting point of 349°C and a T_g of 149°C.

An alternative compound which has been found to be useful in the present invention is:

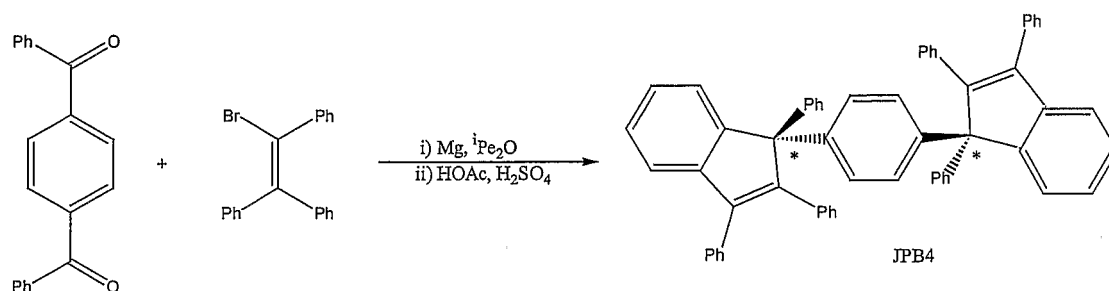


The R₁ and R₂ substituents at the tetrahedral carbon position are 3,5-bis(4-*tert*-butylphenyl)phenyl groups which are a type of first generation dendron. The attachment of dendrons at these positions provides a way of making the compound soluble and suitable for solution processing, and features of the dendrons can be modified to control the processing properties without significantly altering the emission characteristics. This particular

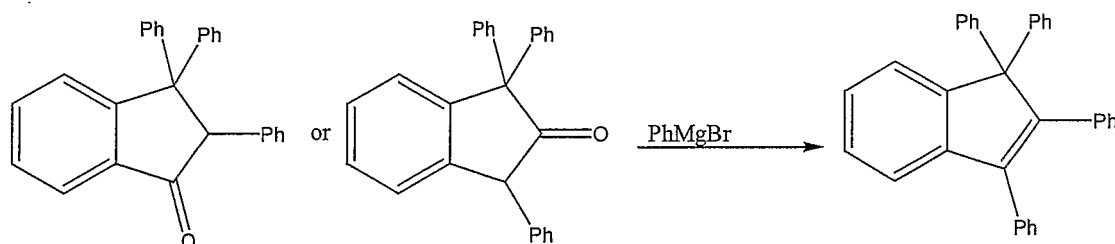
compound can be spin-coated to form a good quality film, and has a blue PL (photoluminescence) emission spectrum.

A variety of methods can be used to prepare compounds of the present invention, and the following are examples.

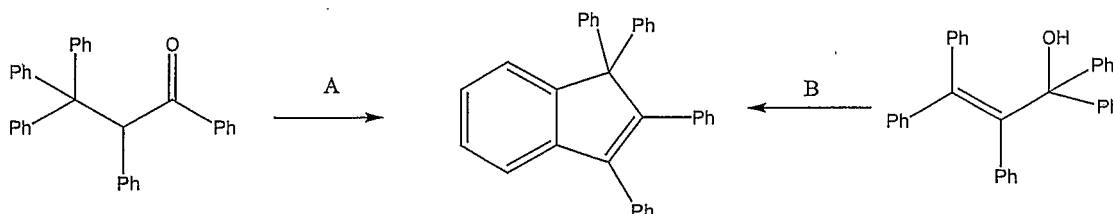
i)



ii) Grignard attack onto indanones

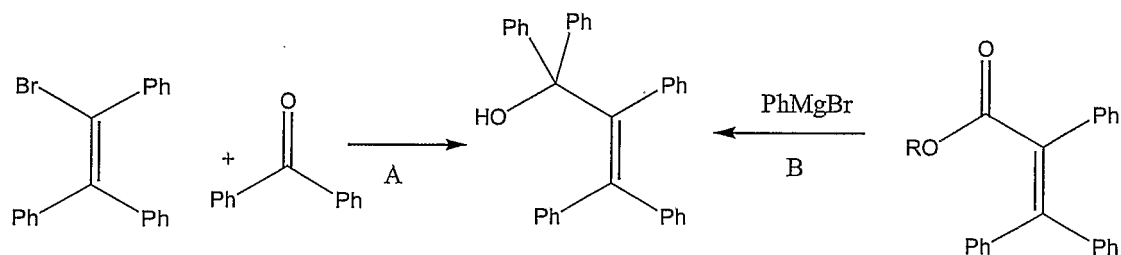


iii) Cyclisation of pentaarylpropanones (A):



iv) Closure of pentaarylallyl alcohols (B):

Preparation of the starting allyl alcohol has been demonstrated from the bromoethylene:



v) Pd catalysed addition to o-bromoaldehydes.

A reaction between 2-bromobenzaldehyde and diphenylacetylene has reportedly given 2,3-diphenylindenone in good yield (Larock et al, J. Org. Chem. 1993, 58, 4579-4583). This simple reaction should work easily with other systems, including the more complicated 2,5-dibromoterephthalaldehyde.

vi) Friedel-Krafts cyclisation with acyl chlorides

A similar, but simpler reaction involves the Friedel-Krafts reaction of an acyl chloride with diphenylacetylene.

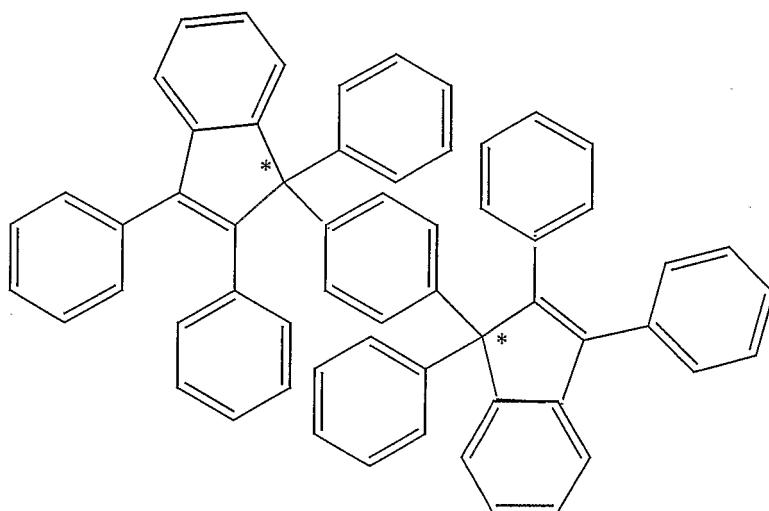
In general, an organic electroluminescent device comprises an anode and a cathode separated from each other by an organic layer that comprises at least one luminescent material that emits light when a voltage is applied across the electrodes. The organic layer comprises, in its simplest common form, a hole injecting and transporting zone adjacent to the anode and an electron injecting and transporting zone adjacent to the cathode. More usually, however, the organic layer will comprise several layers or zones, each performing as is well known in the art a different function from its neighbouring zone. As is also well known in the art, the luminescent zone may comprise a homogeneous material or a host material containing a luminescent dopant. In these respects, reference is made to US 4769292 and US 5061569. The compounds of the present invention have utility in such electroluminescent devices in the luminescent zone, in a hole injecting and transporting zone or in an electron injecting and transporting zone.

Several general problems have been encountered in many OLED materials, which this invention may go some way towards addressing:

- Thermal stability: It is important that the molecule can be stable as an amorphous film at temperatures up to 130°C, while still being sufficiently volatile for simple evaporation. The molecules described in this invention are known to be extremely thermally stable. Due to the non-planar nature of the molecules, even large types of this molecule are surprisingly volatile, which allows larger molecules to be used which have a greater chance of having a high T_g. Alternatively, the ease with which optical activity can be introduced means that fully amorphous glasses can be synthesised that have no tendency to crystallise at all.
- Colour purity: Many planar organic molecules can form π -stacking aggregates, either with each other or with materials in neighbouring films. The result is the introduction of lower energy excitation states that can broaden the emission spectrum (sometimes considerably) and give reduced light intensity. The tetrahedral carbon atom in the compounds of the present invention limits the approach of other molecules, reducing this π -stacking and allowing much purer colours to be emitted. Molecules show excellent blue emission in PL. Optimisation to give other colours is believed to be comparatively simple.
- Brightness: Compared with a triarylethylene or with a stilbene, in some instances indenenes have been shown to have much higher PL efficiencies. This has been explained by their much more rigid structure, which reduces rotations that can lead to non-radioactive decay.
- Colour tuning: By having what is effectively a triarylethylene compound, a significant amount of conjugation area can be confined

to a relatively small volume, so that the same emission colour can be achieved from a smaller molecule than would be possible with existing systems. The possibilities for extending the conjugation length to obtain colours such as green, orange and yellow, while still having a volatile molecule, are therefore increased. More subtle effects on the emission colour can be achieved by minor adjustments to the bond angles and to the exact nature of the substituents, thereby allowing accurate tuning of the band-gap and the colour of the emission.

Example 1



[JPB4a = (R,S) isomer; JPB4b = mixed (S,S) and (R,R) isomers]

Preparation of (R,S)-1,4-bis(1,2,3-triphenyl-1H-inden-1-yl)benzene, (code JPB4a)

A mixture of bromotriphenylethylene (73.00g, 218mmoles), magnesium turnings (5.292g, 218mmoles) and anhydrous *iso*amyl ether (~200cm³) was heated slowly over 90 minutes until almost at reflux, by which time almost all of the magnesium had disappeared. 1,4-dibenzoylbenzene (21.00g, 73.3mmoles) was then added and the reaction mixture was heated in an oil bath at 165°C for 2 hours. After cooling, aqueous ammonium chloride (1M, 350cm³) and dichloromethane (350cm³) were added. The aqueous layer was separated and extracted with dichloromethane (5 x 100cm³) and the

combined organic layers were washed with aqueous ammonium chloride (2 x 100cm³) and water (3 x 100cm³) and evaporated to give an orange oil. This oil was triturated with diethyl ether (300cm³), left to stand overnight, filtered, rinsed with diethyl ether and dried under suction to give a pale pink powder. The crude product (15.36g) was then recrystallised from dichloromethane/hexane to give a white powder (10.01g) of 1,4-bis(1-hydroxy-1,2,3,3 tetraphenylprop-2-en-1-yl)benzene. This powder was mixed with acetic acid (250cm³) and heated to reflux. Sulphuric acid (concentrated, 5cm³) was then added and the reaction mixture was heated at reflux for a further 80 minutes and then allowed to cool. The white precipitate was filtered from the supernatant liquid which was used subsequently for the preparation of the mixed (*S,S*) and (*R,R*) isomers. Meanwhile, the isolated white precipitate was rinsed with acetic acid/water (1:1), water, ethanol and diethyl ether before being dried under suction to give a white powder (6.02g), of which the infra-red spectrum did not show the presence of any peaks at ~3600cm⁻¹ that could correspond to the continued presence of the hydroxyl moiety. The white solid was recrystallised from dichloromethane/hexane to give white crystals (2.43g) and these were sublimed twice in succession at 5 x 10⁻⁸ mbar and 300°C to give white crystals (1.40g, 3%, m.p. 346-347°C) that co-chromatographed with and had an identical i.r. spectrum to an authentic sample of (*R,S*)-1,4-bis(1,2,3-triphenyl-1*H*-inden-1-yl)benzene, m.p. 346-49°C (Found: C, 93.9; H, 5.5. C₆₀H₄₂ requires C, 94.5; H, 5.6%; δ H(500 MHz; CDC1₃) 6.7-7.3 (42 H, m, molecule); ν max (DATR)/cm⁻¹ 694s, 1028w, 1443m, 1489m, 1598w, 3057w; m/z(FAB) 762.4 (M⁺, 25%); DSC (T_g = 149°C, T_m = 353°C); TGA (stable in air >350°C); Solid PL (CIE x=0.16, y=0.10).

Example 2**Preparation of (R,R;S,S)-1,4-bis(1,2,3-triphenyl-1H-inden-1-yl)benzene, (Code JPB4b)**

The acetic acid mother liquor from the procedure described above was diluted with water and the precipitate thereby released was filtered, combined with the mother liquors from the recrystallisations in the previous procedure and dried under vacuum. Purification was by a combination of repeated recrystallisations and evaporations in a manner similar to that for the (R,S) isomer described above, which gave a pale yellow glass (2.173g, 4%) of a racemic mixture of (S,S)-1,4-bis(1,2,3-triphenyl-1H-inden-1-yl)benzene and (R,R)-1,4-bis(1,2,3-triphenyl-1H-inden-1-yl)benzene, m.p. 130-150°C (Found: C, 94.5; H, 5.5 C₆₀H₄₂ requires C, 94.5; H, 5.6%); δ H(500 MHz; CDCl₃) 6.6-7.5 (42 H, m, molecule); ν max (DATR)/cm⁻¹ 695s, 1029w, 1422m, 1490m, 1597w, 3056w; DSC (T_m = 130-140°C); TGA (stable in air >350°C); Solid PL (CIE x=0.15, y=0.10).

Example 3**Experimental****Device Fabrication and Testing**

Indium tin oxide (ITO) coated glass substrates, which can be purchased from several suppliers, for example Applied Films, USA or Merck Display Technology, Taiwan, are cleaned and patterned using a standard detergent and standard photolithography processes. The substrates used in the following examples measured 4" x 4" and 0.7mm thick, the ITO was 120nm thick, and the ITO is patterned to produce 4 devices on each substrate each with an active light emitting area of 7.4 cm². After the final stage of the photolithography process, i.e., the removal of the photoresist, the substrates are cleaned in a detergent (3 vol.% Decon 90), thoroughly rinsed in deionised water, dried and baked at 105°C until required. Immediately prior to the formation of the device the treated substrate is oxidised in an oxygen plasma etcher. By way of example an Emitech K1050X plasma etcher operated at 100 Watts for two minutes is adequate. The substrate and shadow mask is

then immediately transferred to a vacuum deposition system where the pressure is reduced to below 10^{-6} mbar. The organic layers are evaporated at rates between 0.5-1.5 Å/s. Then the mask is changed to form a cathode with a connection pad and no direct shorting routes. The cathode is deposited by evaporating 1.5nm of LiF at a rate of 0.2 Å/s followed by 150nm of aluminium evaporated at a rate of 2 Å/s.

Some devices were encapsulated at this stage using an epoxy gasket around the edge of the emissive area and a metal lid. This procedure was carried out in dry nitrogen atmosphere. The epoxy was a UV curing epoxy from Nagase, Japan.

Current/Voltage, Brightness/Voltage measurements were performed using a Keithley 2400 Source measure unit and a calibrated photodiode through a Keithley multimeter programmed from an IBM compatible PC. The EL emission spectrum was measured using an Oriel ccd camera.

Results

Seven devices using JPB4 have been made:

	Device	Colour	CIE coords	Cd/A	Lm/W
1	ITO/JPB4a/Al	Blue			
2	ITO/JPB4a/Ca/Al	Blue-purple	0.19,0.17		
3	ITO/NPB/JPB4a/LiF/Al	Blue	0.16,0.11	0.2	0.08
4	ITO/NPB/JPB4a/Alq/LiF/Al	Blue → green with current		2.8	1.4
5	ITO/NPB/JPB4a/BCP/Alq/LiF/Al	Blue	0.16,0.12	1.6	0.6
6	ITO/JPB4a/Alq/LiF/Al	Alq green	0.32,0.56	3.4	1.9
7	ITO/JPB4b/Alq/LiF/Al	Alq green		3.5-4.6	1.3-1.9

ITO = indium tin oxide

NPB = N,N'-di(1-naphthyl)-N,N'-diphenyl-{1,1'-biphenyl}-4,4'-diamine

Alq = tris(8-quinolino)aluminium

Figure 1 shows a EL emission spectra of devices 2, 3 and 5 and the photoluminescence emission spectrum of JPB4a (solid powder). All devices are un-optimised. The following features are to be noted.

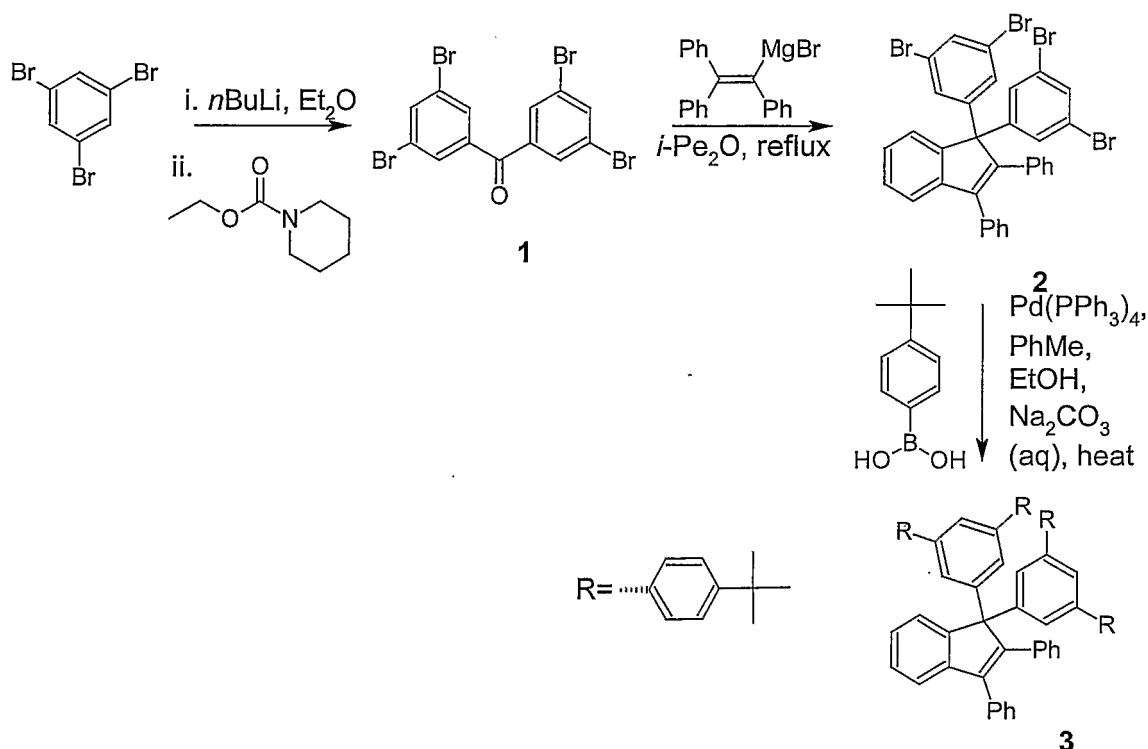
Comparatively efficient blue emission is exhibited 0.6lm/W (or 1.6cd/A). The EL blue emission of JPB4a (devices 3 and 5) is almost identical to PL emission (both solid state).

Excellent PAL blue colour is shown, which is similar to PL where the CIE coordinates are (0.16,0.10).

A narrow emission spectrum (about 75nm) half-width is shown.

Almost no broadening suggests that the 3D structure of JPB4a limits π -stacking and hence excimers. In addition, if excimers are removed, then intermolecular reactions should also be removed, therefore leading to an improved lifetime of the device.

When JPB4a or JPB4b is used as a hole transporting layer with Alq as the emissive layer (device 6 and 7 respectively), efficient Alq emission is observed and the device is almost equivalent to those using NPB as a hole transporting layer.

Example 4**Preparation of 3,5,3',5'-Tetrabromobenzophenone (1)**

A solution of 1,3,5-tribromobenzene (50.0 g, 160 mmol) in dry ether (1000 cm^3) was cooled to -90°C under nitrogen in a toluene/liquid nitrogen bath. n -Butyllithium (1.6 M in hexanes, 100 cm^3 , 160 mmol) was added dropwise before stirring in the cold bath for 1 h. Ethyl piperidine-1-carboxylate (10.061 g, 64.0 mmol) was added dropwise over 20 min and the mixture stirred in the cold bath for a further 20 min, before the mixture was allowed to warm to room temperature and then heated briefly to reflux. Aqueous hydrochloric acid (20%, 500 cm^3) was added slowly and the reaction was stirred vigorously and allowed to stand overnight. The aqueous layer was separated and extracted with dichloromethane. The organic layers were combined and the solvent removed. The residue was passed through a plug of silica with dichloromethane. The solvent was removed and the solid was washed with ether and dried under suction. The crude product was then sublimed under vacuum (220°C , 4×10^{-7} mbar), then recrystallised from dichloromethane/hexane to give **1** (18.40 g, 58%) as a crystalline powder, mp $208\text{--}209^\circ\text{C}$.

Preparation of 2,3-Diphenyl-1,1-bis(3,5-dibromophenyl)-1H-indene (2)

A mixture of bromotriphenylethylene (14.143 g, 42.19 mmol), magnesium (903 mg, 37.2 mmol) and *i*-pentylether (100 cm³) was heated to reflux for 1.75 h. Heating was temporarily removed and **1** (14.00 g, 28.12 mmol) was added. The mixture was heated to reflux under nitrogen for 20 h and then allowed to cool. Hexane (100 cm³) was added and the mixture was allowed to stand for 30 min. The resultant precipitate was collected and washed with hexane. The solid was mixed with dichloromethane (200 cm³) and aqueous ammonium chloride (1 M, 200 cm³) and stirred until fully dissolved. The aqueous layer was separated and extracted with dichloromethane (3 × 30 cm³) and the combined organic layers washed with aqueous ammonium chloride (1 M, 100 cm³) and water (100 cm³), dried over anhydrous magnesium sulphate, filtered and the solvent removed. The residue was triturated with boiling ethanol, cooled and filtered to give **2** (16.34 g, 79%) as a white solid.

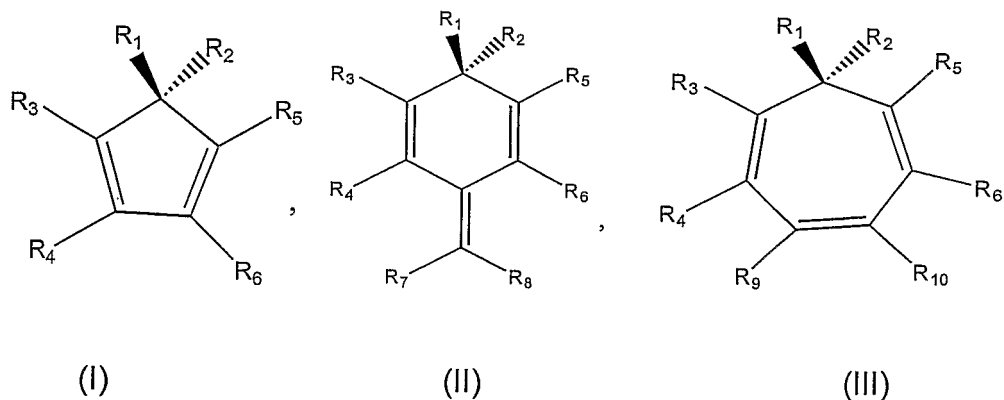
Preparation of 2,3-Diphenyl-1,1-bis[3,5-bis(4-*tert*-butylphenyl)phenyl]-1H-indene (3)

A mixture of 4-*tert*-butylphenylboronic acid (5.00 g, 28.08 mmol), **2** (3.45 g, 4.68 mmol), tetrakis(triphenylphosphine)palladium(0) (1.08 g, 0.937 mmol), toluene (44 cm³), ethanol (15 cm³) and aqueous sodium carbonate (2 M, 15 cm³) was degassed then heated to 100 °C under nitrogen for 69 h and allowed to cool. The organic layer was separated and washed with aqueous hydrochloric acid (3 M, 20 cm³), water (20 cm³) and brine (20 cm³) and the solvent removed. The residue was dissolved in dichloromethane (150 cm³) and the yellow insoluble material discarded. The filtrate was concentrated and recrystallised from a dichloromethane/ethanol mixture. The resultant solid was purified by column chromatography over silica with dichloromethane/hexanes (1:2) as eluent, and recrystallised from a dichloromethane/ethanol mixture to give **3** (3.69 g, 83%) as a white crystalline solid. ¹H NMR (CDCl₃, 400 MHz, ppm): 1.28 (36 H, s, *t*-butyl), 7.02-7.39 (30 H, m, aromatic H), 7.53 (4 H, d, *J* 1.5, branch phenyl 2,6-H) and 7.63 (2 H, dd, *J* 1.5, branch phenyl 4-H).

Compound **3** is photoluminescent and the CIE coordinates of the emission are (0.154,0.104) for solution (THF), and (0.16,0.17) for film (spun from chloroform).

CLAIMS

1. A light emitting device comprising at least one compound of formula (I), (II) or (III):



wherein R_1 and R_2 , which may be the same or different, are organic substituents not including H,

and wherein R_3 and R_5 are each independently selected from halo and organic substituents not including H,

and wherein R_4 , R_6 , R_7 , R_8 , R_9 and R_{10} are each independently selected from H, halo, and organic substituents,

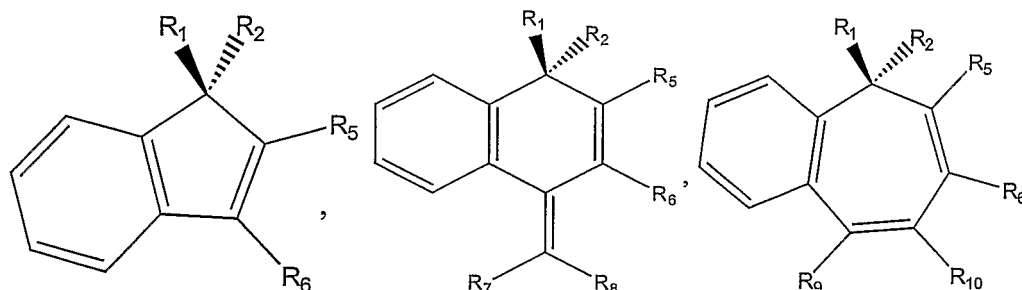
wherein any two or more of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 and R_{10} may optionally be fused together to form a ring system, provided that one of R_3 and R_5 is not part of a fused ring system, and provided that R_1 and R_2 are not fused to each other to form a ring system,

and wherein one but not both of either (a) R_3 and R_4 , or (b) R_5 and R_6 , are fused to each other to form a ring system.

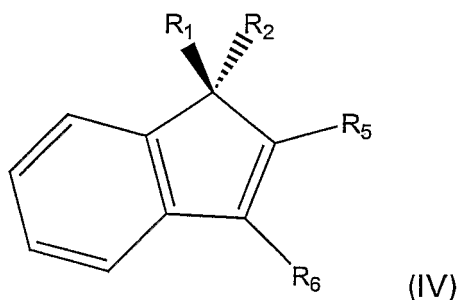
2. A light emitting device according to claim 1, comprising a compound of formula (I).
3. A light emitting device according to claim 1 or 2, wherein R_3 , R_4 , R_5 and R_6 are organic substituents.

4. A light emitting device according to any preceding claim, wherein R_7 , R_8 , R_9 and R_{10} are independently H or organic substituents.
5. A light emitting device according to any preceding claim, wherein R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 and R_{10} are independently selected from alkyl, aryl or heteroaryl substituents each of which may be substituted or unsubstituted.
6. A light emitting device according to claim 5, wherein the alkyl substituent is a C_{1-6} alkyl.
7. A light emitting device according to claim 5 or 6, wherein R_1 and R_2 comprise an aryl group.
8. A light emitting device according to any preceding claim, wherein the other of either (a) R_3 and R_4 , or (b) R_5 and R_6 , which do not form the fused ring system are each substituted or unsubstituted aryl.
9. A light emitting device according to claim 8, wherein the other of either (a) R_3 and R_4 , or (b) R_5 and R_6 , which do not form the fused ring system are each phenyl.
10. A light emitting device according to any preceding claim, wherein the fused ring system comprises a fused aromatic ring.
11. A light emitting device according to claim 10, wherein the fused aromatic ring is a benzene ring.

12. A light emitting device according to any preceding claim, comprising at least one of the following compounds:



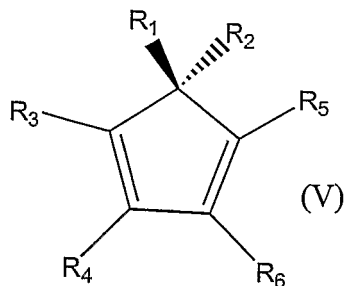
13. A light emitting device according to any preceding claim comprising a compound of formula (IV):



14. A light emitting device according to claim 12 or 13, wherein R_1 , R_2 , R_5 and R_6 are independently selected from unsubstituted or substituted aryl, benzyl or alkyl and when they are alkyl, they are C_{1-6} alkyl.
15. A light emitting device according to any one of claims 12 to 14, wherein R_1 and R_2 are each substituted or unsubstituted aryl.
16. A light emitting device according to any one of claims 12 to 15, wherein R_5 and R_6 are each substituted or unsubstituted aryl.
17. A light emitting device according to claim 16, wherein R_5 and R_6 are each phenyl.

18. A light emitting device according to any preceding claim, wherein the compound evaporates or sublimes in the temperature range of 200-400°C at a reduced pressure.
19. A light emitting device according to claim 18, wherein the reduced pressure is about 10^{-6} mbar.
20. A light emitting device according to any preceding claim, wherein the compound has a glass transition temperature of >80°C.
21. A light emitting device according to any preceding claim, wherein the compound has a melting point >100°C.
22. A light emitting device according to any preceding claim, wherein the compound has a melting point >130°C.
23. A light emitting device according to any preceding claim, further comprising an anode and a cathode, wherein at least one compound of formula (I), (II) or (III) is sandwiched therebetween.
24. Use of a compound of formula (I), (II) or (III) as a luminescent material in a light emitting device.
25. Use of a compound of formula (I), (II) or (III) as an electron transport material in a light emitting device.
26. Use of a compound of formula (I), (II) or (III) as a hole transport material in a light emitting device.

27. A compound of formula (V):



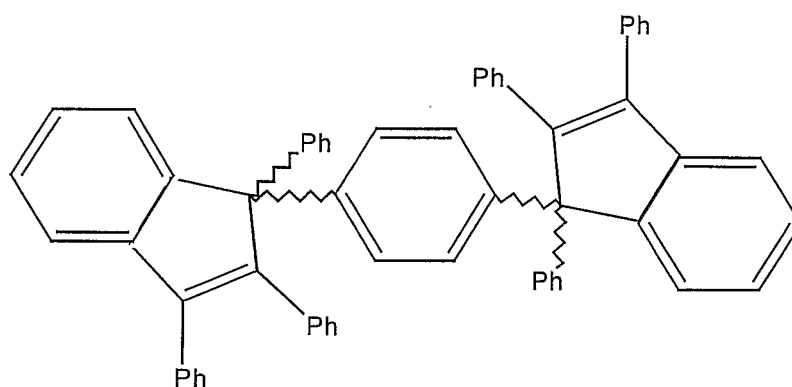
wherein R_3 and R_4 are fused to each other to form a substituted or unsubstituted fused aromatic ring,

and wherein R_1 , R_2 , R_5 and R_6 , which may be the same or different, are independently selected from aryl or heteroaryl, each of which is optionally substituted by aryl, heteroaryl, diarylamine, alkyl, cycloalkyl, a fused ring system, halo, haloalkyl, cyano and alkyloxy groups, provided that R_1 and R_2 are not fused to each other to form a ring system, and provided that R_5 and R_6 are not fused to each other to form a ring system, and provided that R_1 , R_2 , R_5 and R_6 are not all phenyl.

28. A compound according to claim 27, wherein the aryls are C_{6-15} aryls.
29. A compound according to claim 27 or 28, wherein the heteroaryls are selected from oxadiazole, carbazole, triazole, oxazole, thiazole or benzothiazole.
30. A compound according to any one of claims 27 to 29, wherein the alkyl substituent is a C_{1-6} straight or branch chain alkyl group.
31. A compound according to any one of claims 27 to 30, wherein the fused ring system substituent is a hydrocarbon ring system.

32. A compound according to any one of claims 27 to 31, wherein at least one ring of the fused ring system substituent is not aromatic.
33. A compound according to any one of claims 27 to 32, wherein R_3 and R_4 are fused to each other to form a 6-membered aromatic ring.

34.



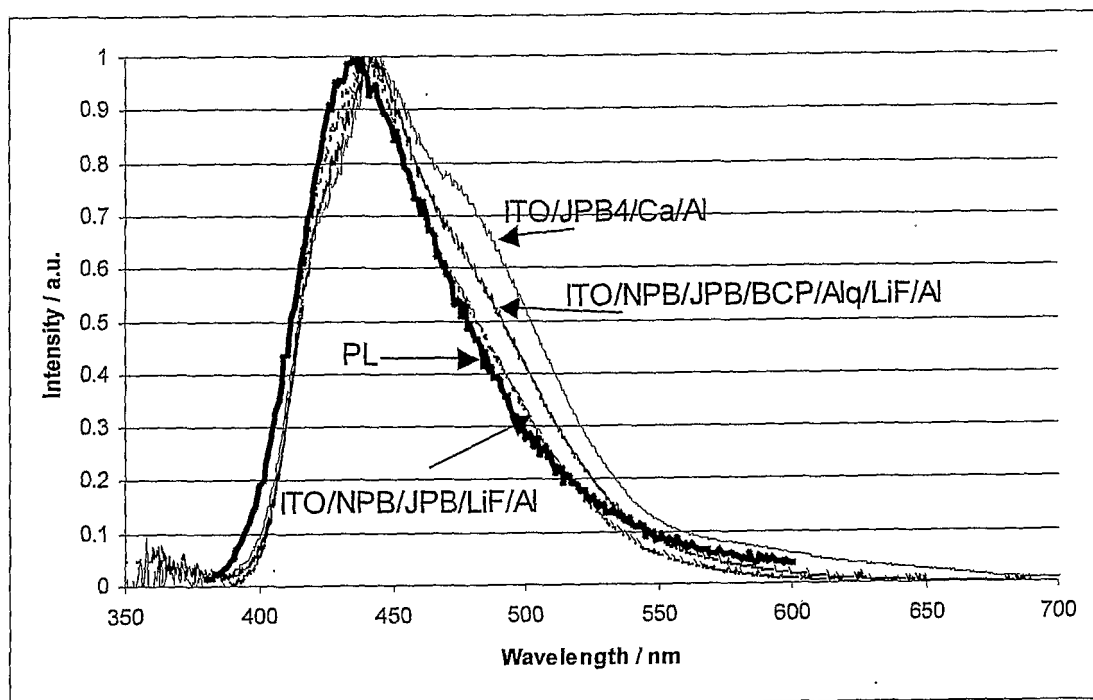


FIGURE 1

专利名称(译)	发光器件和其中使用的化合物		
公开(公告)号	EP1444739A2	公开(公告)日	2004-08-11
申请号	EP2002777550	申请日	2002-11-15
[标]申请(专利权)人(译)	CDT牛津有限公司		
申请(专利权)人(译)	CDT OXFORD LIMITED		
当前申请(专利权)人(译)	CDT OXFORD LIMITED		
[标]发明人	PILLOW JONATHAN NIGEL GERARD CDT OXFORD LIMITED		
发明人	PILLOW, JONATHAN NIGEL GERARD,CDT OXFORD LIMITED FRAMPTON, MICHAEL JOHN,CDT OXFORD LIMITED		
IPC分类号	H01L51/50 H01L51/54 C07C13/45 C07C13/465 C07C17/26 C07C45/56 C07D209/82 C07D263/00 C07D271/00 C07D277/00 C07D277/62 C09K11/06 H01L51/30 H05B33/14		
CPC分类号	C09K11/06 C07C13/465 C07C17/2632 C07C45/56 C07C2602/08 C09K2211/1003 C09K2211/1007 C09K2211/1011 H01L51/0052 H01L51/0057 H01L51/0081 H01L51/5012 H01L51/5048 H01L2251/308 Y10S428/917		
代理机构(译)	WILKINSON , STEPHEN JOHN		
优先权	2001027461 2001-11-16 GB 2002020844 2002-09-07 GB		
其他公开文献	EP1444739B1		
外部链接	Espacenet		

摘要(译)

公开了一种发光装置，其包含至少一种式 (I) ， (II) 或 (III) 的化合物：其中R 1为氢。R 2和R 2可以相同或不同，是不包括H的有机取代基，并且其中R 3和R 3可以相同或不同。和R ? 5 ? 各自独立地选自不包括H的卤素和有机取代基，并且其中R 4 , R 6 , R 7 , R 8 , R 9和R 4分别独立地选自卤素和有机取代基。和R ? 10 ? 各自独立地选自H，卤素和有机取代基，其中R 1 , R 2 , R 3' , R 4' , R 5' , R 6' , R 中的任何两个或多个取代基。¿7 ? , R ? 8 ? , R ? 9 ? 可任选地将它们耦合在一起以形成环系统，条件是R 3中的一个 ? 不是融合环系统的一部分，只要R ? 1 ? 和R ? 2 ? 没有相互融合形成一个环系统，其中一个但不是两个都是 (a) R ? 3 ? 和R ? 4 ? , 或 (b) R ? 5 ? 和R 6'相互融合形成环系。