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(54) **Polymer organic light emitting device with improved color control**

Lichtemittierende Vorrichtung auf Polymerbasis mit verbesserter Farbkontrolle

Dispositif émetteur de lumière à base de polymères avec contrôle de couleur amélioré

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- **BERGGREN M ET AL: "POLYMER LIGHT-EMITTING DIODES PLACED IN MICROCAVITIES" SYNTHETIC METALS, ELSEVIER SEQUOIA, LAUSANNE, CH, vol. 76, no. 1-3, 22 May 1995 (1995-05-22), pages 121-123, XP000992227 ISSN: 0379-6779**
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Description

Field of the Invention

5 **[0001]** The present invention relates to electroluminescent devices, and more particularly, to the fabrication of organic light emitting diodes having more predictable colors.

Background of the Invention

10 **[0002]** Organic polymer-based electroluminescent devices (OLEDs) have the potential for providing inexpensive alternatives to alpha-numeric displays and x-y addressable displays. Typically, an OLED consists of a transparent substrate coated with a transparent conducting material, such as Indium Tin oxide (ITO), one to five organic layers and a cathode made by evaporation or sputtering a metal of low work function characteristics, such as Ca or Mg. The organic layers are chosen so as to provide charge injection and transport from both electrodes to the electroluminescent organic layer (EL) where charges recombine emitting light. Usually there are one or two organic hole transport layers (HTL) between the ITO and EL, as well as one or two electron injection and transporting layers (EL) between the cathode and the EL.

15 **[0003]** The output spectrum generated by such devices often differs significantly from that predicted from the chemical structure of the material used for the EL layer. When the device output spectrum differs from the design spectrum, the designer typically adjusts the composition of the EL material and tries again. This hit or miss approach substantially increases the design cost.

20 **[0004]** GB 2 349 979 A relates to an organic light emitting device (OLED) comprising an anode electrode layer formed of indium-tin oxide ITO, a hole transport layer over the anode electrode layer, an electroluminescent layer over the hole transport layer, and a cathode electrode layer over the electroluminescent layer. An optical cavity is formed between surfaces of reflective layers that face towards the OLED.

25 **[0005]** Carter et al. in Appl. Phys. Lett. Vol. 71, No. 9 (1997), pages 1145-1147 reports an improved photovoltaic efficiency when C60 nanoparticles or TiO₂ nanoparticles are blended with electroluminescent organics.

30 **[0006]** Tokito et al in J. Appl. Phys., Vol. 86, No. 5 (1999), pages 2407-2411 discloses a microcavity OLED wherein a microcavity is defined by a top metal layer acting as a mirror and a dielectric mirror formed on a glass substrate.

35 **[0007]** Berggren et al. in Synthetic Metals, Vol. 76 (1996), pages 121-123 discloses polymer light-emitting diodes placed in microcavities. The microcavity comprises an aluminum layer as a first mirror and a 30 nm Calcium-Aluminum layer acting second electrode and as a semitransparent mirror. A BCB spacer is located between a double-layer electrode made of gold and chromium and the aluminum layer, i.e. the first mirror.

40 **[0008]** In full color pixelated displays, the designer must provide three colors of pixels, and hence, the problems of unpredictable color output are increased. In addition, the color pixels must provide similar light outputs for any given drive current.

45 **[0009]** Broadly, it is the object of the present invention to provide an improved OLED.

50 **[0010]** It is a further object of the present invention to provide an OLED that has a predictable color output.

55 **[0011]** These objects are achieved by an OLED according to claim 1.

60 **[0012]** These and other objects of the present invention will become apparent to those skilled in the art from the following detailed description of the invention and the accompanying drawings.

Summary of the Invention

65 **[0013]** The present invention is an OLED for emitting light at a predetermined peak wavelength, λ . The OLED includes an anode layer, a cathode layer and an electroluminescent layer constructed from an organic light emitting compound that generates light, including light having a wavelength in a band around λ , by the recombination of holes and electrons. The electroluminescent layer is electrically connected to the anode and the cathode layers and is located between the anode and cathode layers. The OLED includes first and second reflectors, displaced from one another. The anode or cathode layers can serve as one of the reflectors. A spacer layer constructed from a material that is transparent at λ is included between the reflectors and has a thickness that is adjusted such that the optical path length between the first and second reflectors is equal to $N\lambda/2$, where N is a positive integer. The spacer layer includes a hole transport material mixed with transparent particles and located between the electroluminescent layer and the anode.

Brief Description of the Drawings

70 **[0014]**

Figure 1 is a cross-sectional view of an OLED 10.

Figure 2 is a cross-section of another OLED 100 not claimed in the present invention.

Figure 3 is a cross-sectional view of another OLED 200 not claimed in the present invention.

Figure 4 is a cross-sectional view of an embodiment of an OLED according to the present invention.

Detailed Description of the Invention

[0015] The present invention may be more easily understood with reference to Figure 1, which is a cross sectional view of an OLED 10. OLED 10 includes an electron injection electrode 12 (the cathode), an electron transport layer 14, an electroluminescent layer 16, a hole transport layer 18, and finally a hole injection electrode 20. The electron transport and hole transport layers are usually designed to facilitate charge transport and assist charge balance to optimize charge recombination in the electroluminescent layer. The anode is typically a transparent electrode, such as a layer of indium tin-oxide on top of a transparent support (glass or plastic). The cathode is typically a vapor deposited metal, preferably with a work-function closely matching the energy level of the electron transport layer. It should be noted that the electron transport layer is optional. The most commonly used polymeric materials for the electroluminescent layer are derivatives of p-phenylene vinylene such as Poly[2-dicholestanoxy-p-phenylene-vinylene] (BCHA-PPV) and poly (2-methoxy-5-(2'-ethyl-hexoxy)-1,4-phenylene vinylene) (MEHPPV).

[0016] The present invention is based on the observation that the two electrodes form the mirrored ends of an optical cavity that distorts the output spectrum of the EL layer. Even when a transparent electrode such as ITO is utilized, the difference in index of refraction between the hole injection layer material and the anode, or between the transparent substrate and the surrounding air, results in the anode reflecting a significant fraction of the light striking the anode back toward the cathode. The cathode is typically a metal, and hence, reflects light striking it back toward the anode. While only a few reflections are present due to absorption of the light by the EL layer, there are sufficient reflections to provide constructive interference at wavelengths, λ , such that

$$N\lambda = 2D, \quad (1)$$

where D is the optical path length between the reflecting surfaces. If the output spectrum of the EL layer includes wavelengths that satisfy Eq. (1), that portion of the spectrum will be accentuated, and the resulting spectrum will differ significantly from that predicted from the chemical composition of the EL layer.

[0017] The present invention makes use of this constructive interference to tune the output spectrum of the OLED. To provide an OLED with an output spectrum that is peaked at λ , an EL material having a broad output spectrum with a significant output at λ is chosen, and distance between the reflecting ends of the cavity is chosen to satisfy Eq. (1). In general, this will require that the ends of the cavity be moved further apart relative to the distance between the electrodes normally utilized in OLEDs.

[0018] In addition, the number of reflections is increased by placing a reflecting coating or other form of mirror under the anode when a transparent anode such as ITO is utilized. The reflecting coating, or the cathode, is chosen such that part of the light generated in the device can still exit through the coating or cathode.

[0019] In one embodiment of the present invention, the distance between the reflecting ends is adjusted by adjusting the thickness of one or more of the layers. In this regard, it should be noted that the layer chosen must have two properties. First, the material must be highly conductive compared to the other layers. In general, the thickness of the layer in question will be much greater than that of the EL layer. If the layer has a resistance that is comparable to that of the EL layer, the voltage drop across this layer will increase the voltage required to operate the device. -In addition, the power loss across the layer will be substantial, and hence, the overall device efficiency will be low. In general, the resistivity of the EL layer is too great to allow the EL layer to be used for adjusting the optical path length.

[0020] Second, the material in the layer that is chosen must be transparent at the desired wavelength. In general, the EL layer is not highly transparent. Hence, the chosen layer must be much more transparent than the EL layer to assure that the additional material does not result in a loss of efficiency due to light absorption.

[0021] In the present invention, the hole transport layer (HTL) is chosen as the adjustment layer. For example, the HTL layer may be constructed from poly(3,4-ethylenedioxythiophene) (PEDOT). PEDOT has sufficient transparency and has a resistivity that is much less than that of the compounds typically utilized for the EL layer. To obtain a more transparent layer the PEDOT is mixed with more transparent particles as described below to provide a layer with a higher transparency.

[0022] Refer now to Figure 2, which is a cross-section of an OLED 100 not falling under the present invention. OLED 100 is constructed on a substrate 102, which has a layer 104 of aluminum deposited thereon. The aluminum layer

provides one of the mirrors that define the optical cavity. A transparent anode 106 is deposited on the aluminum mirror. The anode is preferably ITO. The HTL 108 is then deposited on the anode. The HTL is preferably constructed from a layer of PEDOT. Next, the EL layer 110 is deposited over the HTL 108. Finally, a semi-transparent cathode 112 is deposited over the EL layer. The cathode layer is preferably constructed from a thin layer of Ca covered with a thin layer of gold. The thickness of the HTL is chosen such that the optical path length between the anode and cathode satisfies Eq. (1) with λ equal to the desired output wavelength for the OLED.

[0023] Refer now to Figure 3, which shows another OLED not falling under the claimed invention, where the spacer layer is not located between the anode and cathode. Figure 3 is a cross-sectional view of an OLED 200 similar to OLED 100 discussed above in that it is constructed from a transparent anode 206 which is preferably a layer of indium tin oxide (ITO). A HTL 208, EL layer 210, and cathode 12 are deposited in that order on anode 206. OLED 200 differs from OLED 100 in that anode 206 is deposited on a transparent spacer layer 220 such as SiO_2 which is deposited on a reflecting layer 202 that acts as the end mirror that defines the optical cavity together with cathode 212. Reflecting layer 202 may be a metallic layer or a mirror constructed from layers having different indices of refraction. Such mirrors are well known in laser arts, and hence, will not be discussed in detail here. In either case, the distance between the top reflecting electrode and mirror reflecting layer 202 is set such that the optical path length between these two reflecting surfaces is an integer multiple of $\lambda/2$. In this case, the spacer layer need not be constructed from an electrically conducting material.

[0024] According to the invention the spacer layer is constructed from a mixture of components to provide increased clarity. Refer now to Figure 4, which is a cross-sectional view of an embodiment of an OLED according to the present invention. OLED 300 is similar to OLED 100 shown in Figure 2. To simplify the following discussion, those elements that serve the same function in OLED 300 as elements in OLED 100 have been given the same numeric designations. In OLED 300, the HTL layer 308 acts as the spacing layer. Spacer layer 308 can be constructed from a mixture of glass beads 310 and PEDOT. The PEDOT fills the area 312 between the beads, and hence, provides the necessary conductivity. The PEDOT provides a close enough match to the index of refraction of the beads to assure that the layer appears to be a single layer with transmission characteristics near those of glass. Since the transparency of the glass beads is much greater than that of the PEDOT, the resulting layer has a transparency that is substantially greater than that of a layer of the same thickness constructed from PEDOT.

[0025] Various modifications to the present invention will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Accordingly, the present invention is to be limited solely by the scope of the following claims.

Claims

1. An OLED (300) for emitting light at a predetermined wavelength, λ , said OLED (300) comprising:

an anode layer (106);
 a cathode layer (112);
 an electroluminescent layer (110) comprising an organic light emitting compound for generating light including light of said predetermined wavelength by the recombination of holes and electrons, said electroluminescent layer (110) being electrically connected to said anode and said cathode and being located between said anode and cathode; and
 a first reflector (104);
 a second reflector (112), said second reflector (112) being partially reflecting and being displaced from said first reflector (104),
 such that the optical path length between said first and second reflectors is D ;
 a spacer layer (308) comprising a material that is transparent at λ ,

wherein $D = N \lambda/2$, N being a positive integer;

wherein said spacer (308) comprises a hole transport material located between said electroluminescent layer (110) and said anode layer (106); and

wherein said spacer (308) further comprises transparent particles (310) mixed with said hole transport material.

2. The OLED (300) of Claim 1 wherein said first reflector (104) comprises either said anode layer (106) or said cathode layer (112).

3. The OLED (100, 200, 300) of Claim 1 or 2 wherein said second reflector (112) comprises either said anode layer (106) or said cathode layer (112).

4. The OLED (300) of Claim 1 wherein said hole transport material comprises PEDOT.
5. The OLED (300) of one of the preceding Claims wherein said spacer (308) lies between said cathode layer and one of said first and second reflectors.
6. The OLED (300) of one of Claims 1 to 4 wherein said spacer-layer (308) lies between said anode layer (106) and one of said first reflector (104) and second reflector (112).
7. The OLED (300) of one of the preceding Claims wherein said transparent particles (310) are of electrically-insulating material.

Patentansprüche

1. OLED (300) zum Emittieren von Licht bei einer vorbestimmten Wellenlänge, λ , die OLED (300) enthaltend:
 - eine Anodenschicht (106);
 - eine Kathodenschicht (112);
 - eine Elektrolumineszenzschicht (110) enthaltend eine organische Licht emittierende Verbindung zum Erzeugen von Licht enthaltend Licht der vorbestimmten Wellenlänge durch die Rekombination von Löchern und Elektronen, wobei die Elektrolumineszenzschicht (110) mit der Anode und der Kathode elektrisch verbunden ist und zwischen der Anode und der Kathode angeordnet ist; und
 - einen ersten Reflektor (104);
 - einen zweiten Reflektor (112), wobei der zweite Reflektor (112) teilweise reflektierend ist und versetzt von dem ersten Reflektor (104) ist, so dass die optische Pfadlänge zwischen den ersten und zweiten Reflektoren D ist;
 - eine Abstandsschicht (308) enthaltend ein Material, welches bei λ transparent ist,

wobei $D = N \lambda / 2$, wobei N eine positive Ganzzahl ist;

wobei der Abstandhalter (308) ein Lochtransportmaterial aufweist, welches zwischen der Elektrolumineszenzschicht (110) und der Anodenschicht (106) angeordnet ist; und

wobei der Abstandhalter (308) ferner transparente Partikel (310) aufweist, welche mit dem Lochtransportmaterial gemischt sind.
2. OLED (300) nach Anspruch 1, wobei der erste Reflektor (104) entweder die Anodenschicht (106) oder die Kathodenschicht (112) aufweist.
3. OLED (100, 200, 300) nach Anspruch 1 oder 2, wobei der zweite Reflektor (112) entweder die Anodenschicht (106) oder die Kathodenschicht (112) aufweist.
4. OLED (300) nach Anspruch 1, wobei das Lochtransportmaterial PEDOT aufweist.
5. OLED (300) nach einem der vorhergehenden Ansprüche, wobei der Abstandhalter (308) zwischen der Kathodenschicht und einem der ersten und zweiten Reflektoren liegt.
6. OLED (300) nach einem der Ansprüche 1 bis 4, wobei die Abstandsschicht (308) zwischen der Anodenschicht (106) und einem von dem ersten Reflektor (104) und dem zweiten Reflektor (112) liegt.
7. OLED (300) nach einem der vorhergehenden Ansprüche, wobei die transparenten Partikel (310) aus elektrisch isolierendem Material sind.

Revendications

1. Dispositif à diodes électroluminescentes organiques (OLED) (300) destiné à émettre de la lumière à une longueur d'onde prédéterminée, λ , ledit dispositif à diodes électroluminescentes organiques (300) comprenant :
 - une couche d'anode (106) ;

une couche de cathode (112) ;
 une couche électroluminescente (110) comprenant un composé d'émission de lumière organique destiné à
 générer de la lumière comprenant la lumière de ladite longueur d'onde prédéterminée par la recombinaison de
 trous et d'électrons, ladite couche électroluminescente (110) étant électriquement reliée à ladite anode et à
 ladite cathode et étant située entre ladite anode et ladite cathode ; et
 un premier réflecteur (104) ;
 un second réflecteur (112), ledit second réflecteur (112) réfléchissant en partie le premier réflecteur (104) et
 étant en partie décalé par rapport à celui-ci, de sorte que la longueur du chemin optique entre lesdits premier
 et second réflecteurs est D ;
 une couche d'espacement (308) comprenant un matériau qui est transparent à λ ,

où $D = N \lambda / 2$, N étant un entier négatif ;

où ladite pièce d'espacement (308) comprend un transporteur de trous situé entre ladite couche électroluminescente
 (110) et ladite couche d'anode (106) ; et

où ladite pièce d'espacement (308) comprend en outre des particules transparentes (310) mélangées avec ledit
 transporteur de trous.

2. Dispositif à diodes électroluminescentes organiques (300) selon la revendication 1 dans lequel ledit premier réflecteur
 (104) comprend soit ladite couche d'anode (106) soit ladite couche de cathode (112).
3. Dispositif à diodes électroluminescentes organiques (100, 200, 300) selon la revendication 1 ou 2, dans lequel ledit
 second réflecteur (112) comprend soit ladite couche d'anode (106) soit ladite couche de cathode (112).
4. Dispositif à diodes électroluminescentes organiques (300) selon la revendication 1, dans lequel ledit transporteur
 de trous comprend du poly-3,4-éthylènedioxythiophène (PEDOT).
5. Dispositif à diodes électroluminescentes organiques (300) selon l'une des revendications précédentes dans lequel
 ladite pièce d'espacement (308) se situe entre ladite couche de cathode et l'un desdits premier et second réflecteurs.
6. Dispositif à diodes électroluminescentes organiques (300) selon l'une des revendications 1 à 4, dans lequel ladite
 couche d'espacement (308) se situe entre ladite couche d'anode (106) et l'un desdits premier réflecteur (104) et
 second réflecteur (112).
7. Dispositif à diodes électroluminescentes organiques (300) selon l'une des revendications précédentes dans lequel
 des particules transparentes (310) sont conçues dans un matériau d'isolation électrique.

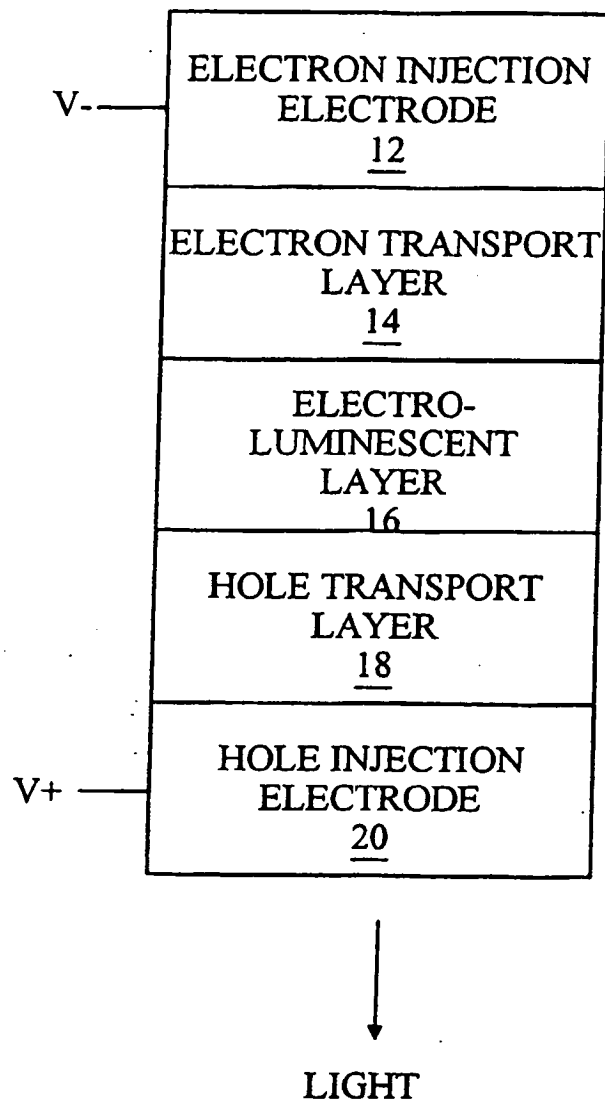


FIGURE 1
(PRIOR ART)

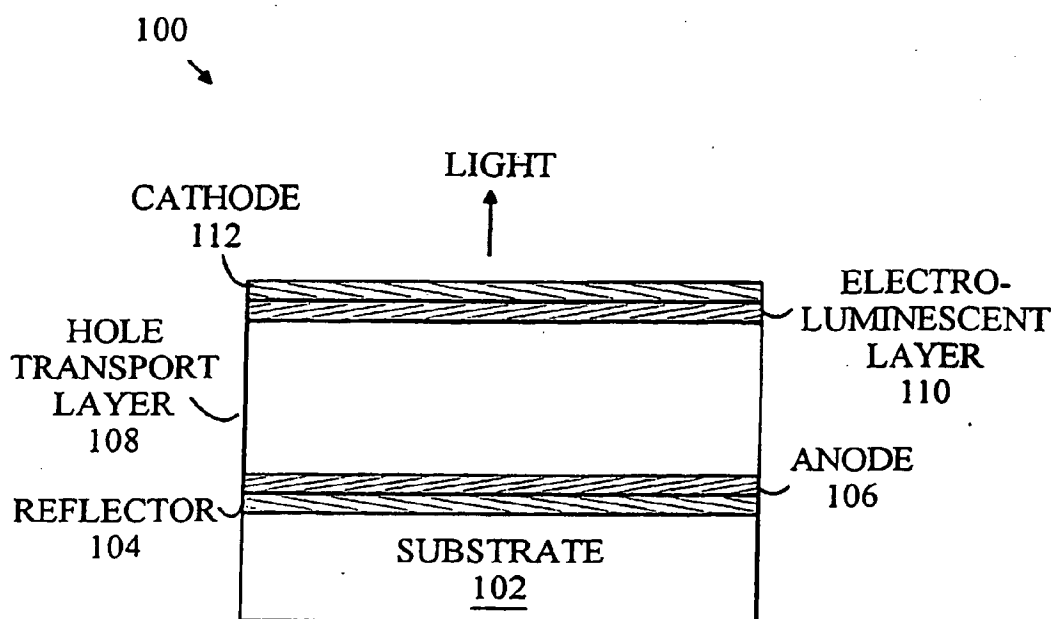


FIGURE 2

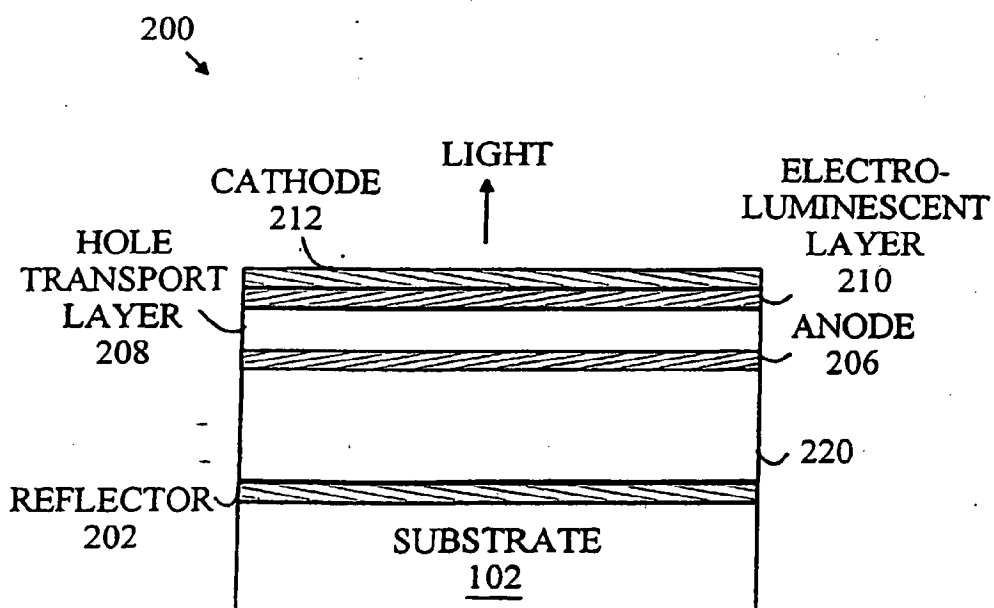


FIGURE 3

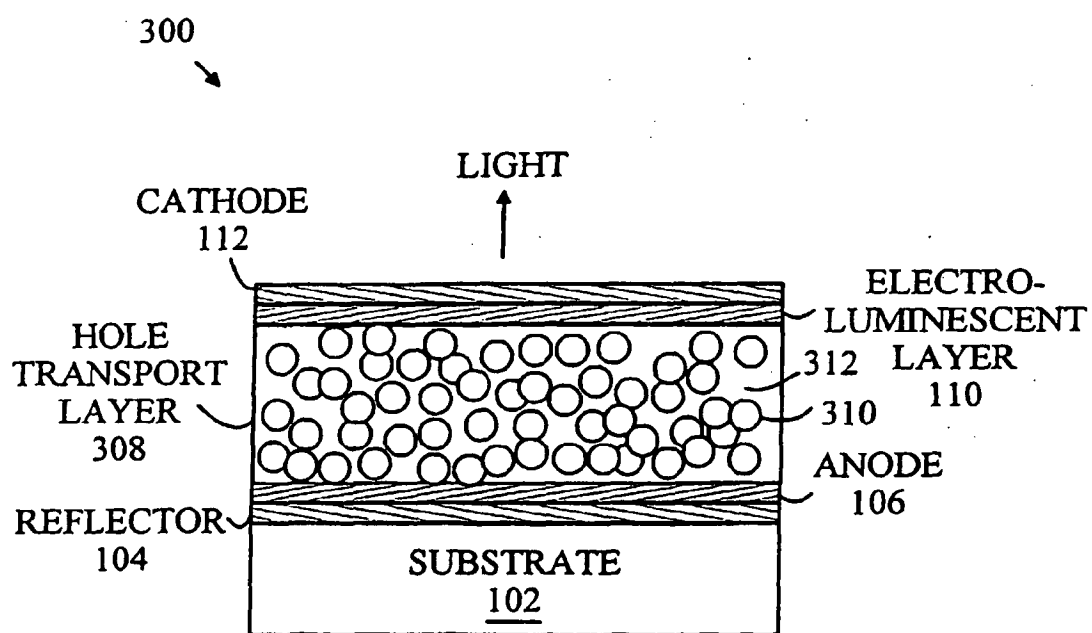


FIGURE 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 2349979 A [0004]

Non-patent literature cited in the description

- **Carter et al.** *Appl. Phys. Lett.*, 1997, vol. 71 (9), 1145-1147 [0005]
- **Tokito et al.** *J. Appl. Phys.*, 1999, vol. 86 (5), 2407-2411 [0006]
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专利名称(译)	具有改进的颜色控制的聚合物有机发光装置		
公开(公告)号	EP1244153B9	公开(公告)日	2009-11-11
申请号	EP2001130337	申请日	2001-12-19
[标]申请(专利权)人(译)	安捷伦科技有限公司		
申请(专利权)人(译)	安捷伦科技公司 (以下简称特拉华州公司)		
当前申请(专利权)人(译)	AVAGO TECHNOLOGIES ECBU IP (SINGAPORE) PTE. LTD.		
[标]发明人	ROITMAN DANIEL B ANTONIADIS HOMER		
发明人	ROITMAN, DANIEL B. ANTONIADIS, HOMER		
IPC分类号	H01L51/50 H01J1/62 H01J63/04 H05B33/02 H05B33/14 H05B33/22 H05B33/24		
CPC分类号	H01L51/5265 H01L51/5012		
优先权	09/814381 2001-03-21 US		
其他公开文献	EP1244153A2 EP1244153A3 EP1244153B1		
外部链接	Espacenet		

摘要(译)

OLED [100,200,300]，用于以预定的峰值波长 λ 发光。OLED [100,200,300]包括阳极层[106,206]，阴极层[112,212]和由产生光的有机发光化合物构成的电致发光层[110,210]，包括具有光的有机发光化合物通过空穴和电子的复合，波长等于 λ 。电致发光层[110,210]电连接到阳极层[106,206]和阴极层[112,212]并且位于阳极和阴极层之间。OLED [100,200,300]包括彼此移位的第一反射器[104,202]和第二反射器。阳极层[106,206]或阴极层[112,212]可以用作反射器之一。由在 λ 处透明的材料构成的间隔层[108,208,220]包括在反射器之间，并且具有调整的厚度，使得第一和第二反射器之间的光程长度等于 $N\lambda/2$ ，其中N是正整数。间隔物[108,208,220]可以包括位于电致发光层[110,210]和阳极层之间的空穴传输材料。间隔物[108,208,220]也可以由位于阳极或阴极层与反射器之一之间的层构成。如果间隔层[108,208,220]位于阳极层和阴极层之间，则间隔层[108,208,220]由导电材料构成。

$N\lambda/2$

(1)