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(54) ELECTROLUMINESCENT DISPLAY DEVICE

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(57) **ABSTRACT**

The invention is directed to an increase of luminous efficiency of a white organic EL element. A white emissive layer of an organic EL element is formed by laminating a blue emissive layer and a yellow emissive layer. The blue emissive layer emitting blue light having a short wavelength is formed on a side nearer to the anode layer, and the yellow emissive layer emitting yellow light having a longer wavelength than the blue emissive layer is disposed on the blue emissive layer. Under this configuration, the blue light emitted from the blue emissive layer reaches the color filter layer without penetrating through the yellow emissive layer. On the other hand, the yellow light emitted from the yellow emissive layer penetrates through the blue emissive layer. The yellow light has a longer wavelength than the blue light, an absorption amount of the yellow light becomes relatively small. An absorption amount of the blue light also reduces, so that the luminous efficiency increases.

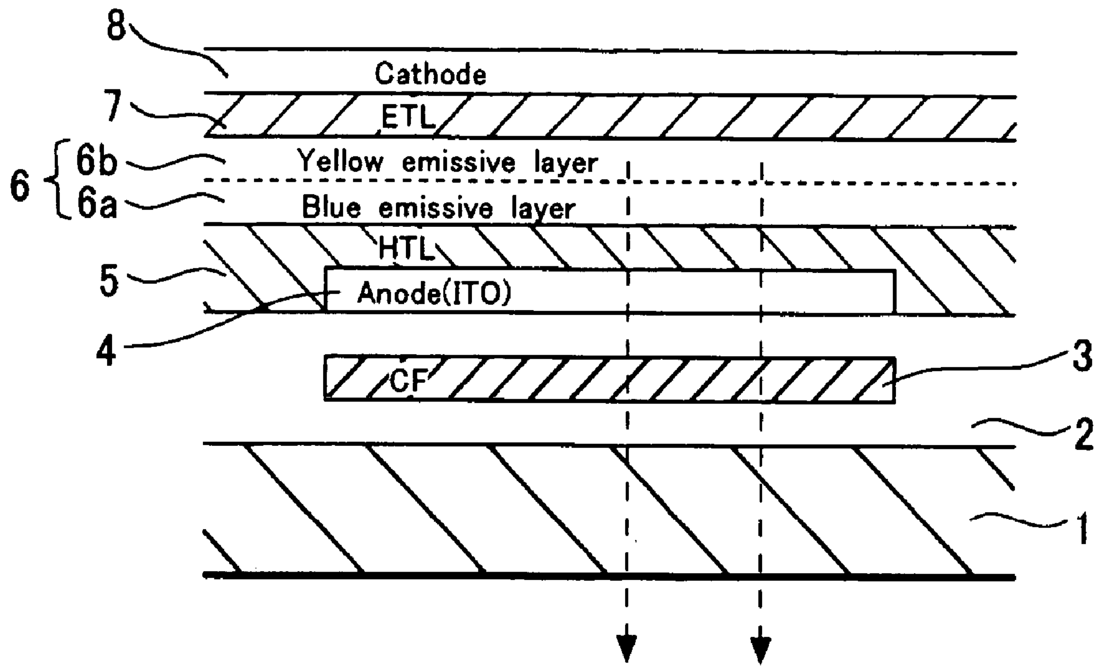


FIG. 1

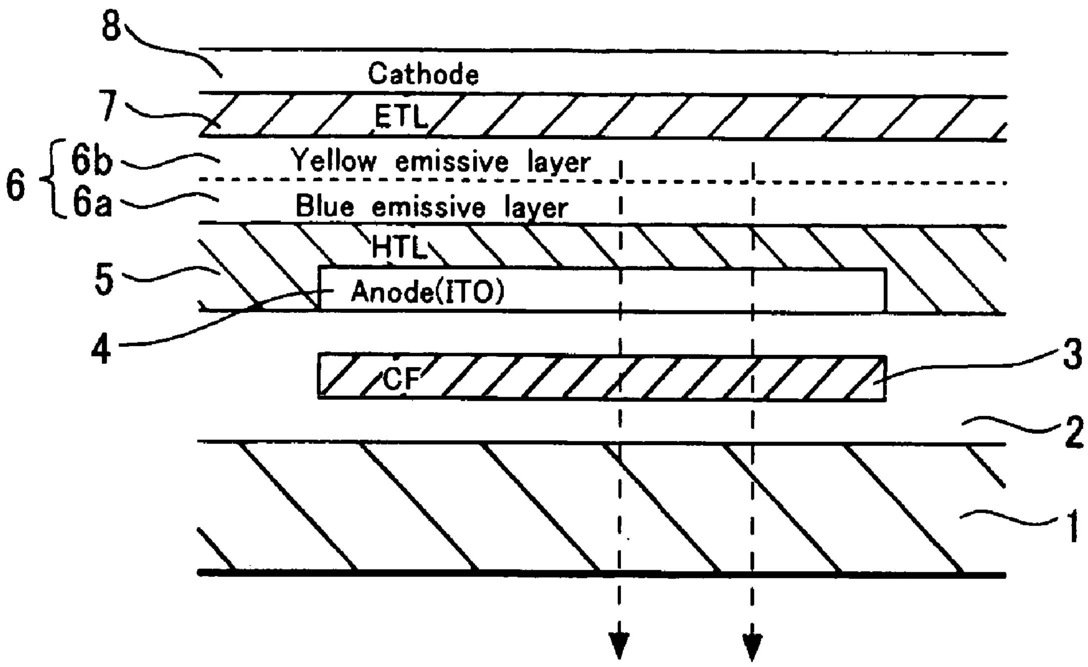

8
Cathode
7
ETL
6
6b
Yellow emissive layer
6a
Blue emissive layer
HTL
5
Anode(ITO)
4
CF
3
2
1

FIG.2

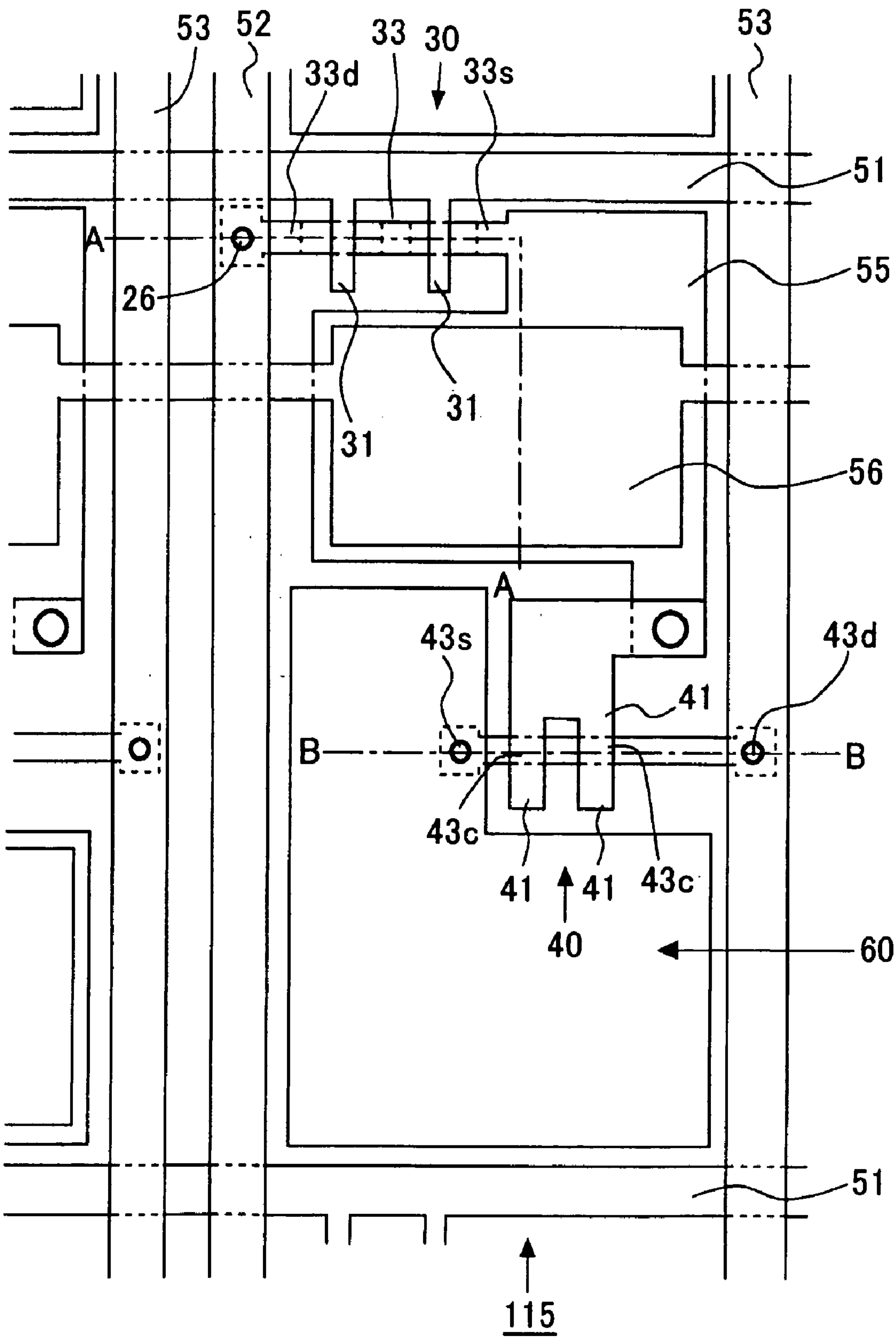

53
52
33
30
33d
33s
53
51
A
26
55
31
31
56
A
43s
43d
41
B
B
43c
41
41
43c
40
60
51
115

FIG.3

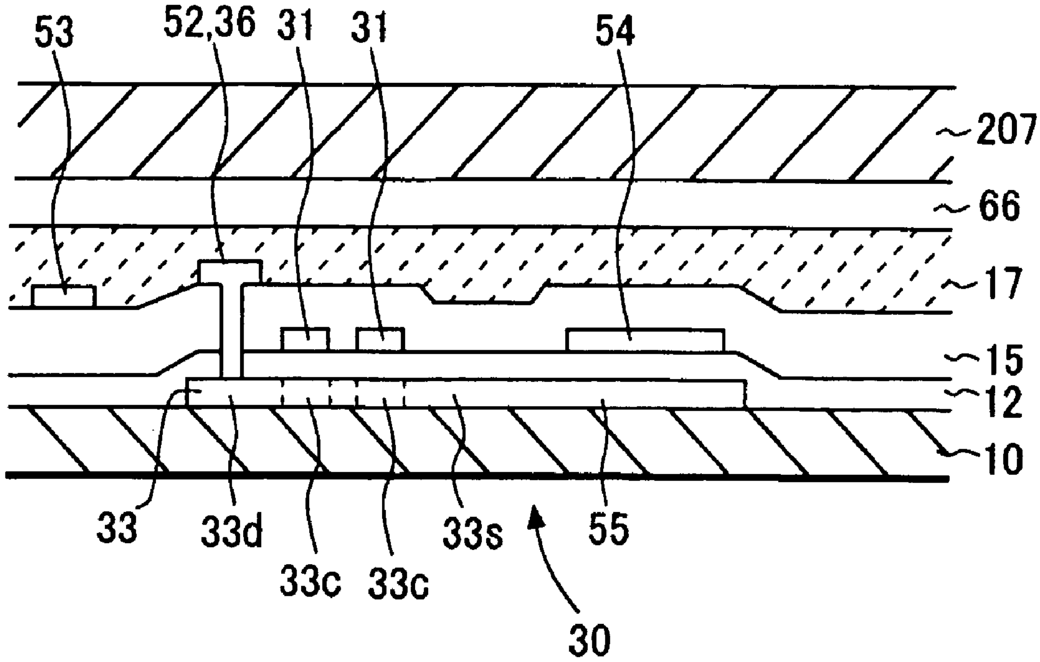


FIG.4

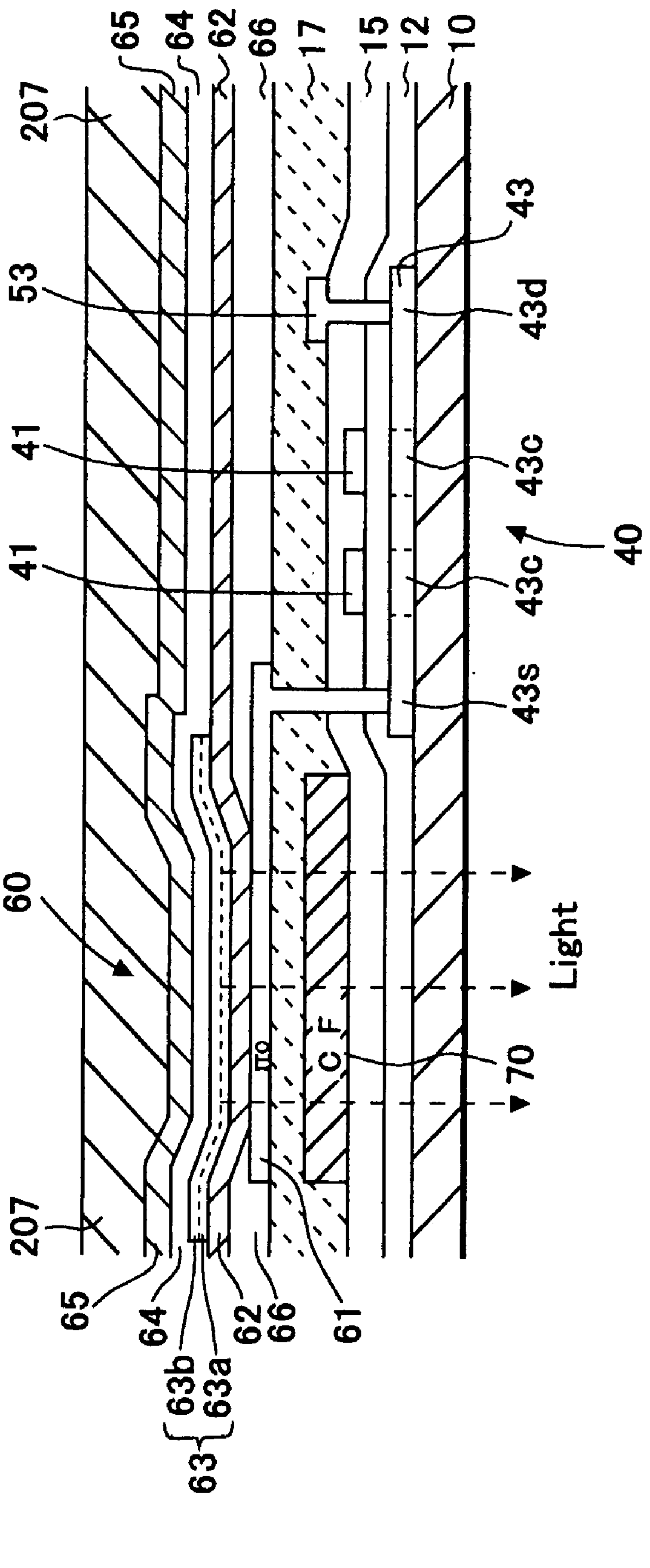

65
64
62
66
17
15
12
10
207
43
53
43d
41
43c
41
43c
40
43s
60
Light
CF
ITO
70
207
65
64
63b
63a
63
62
66
61

FIG.5

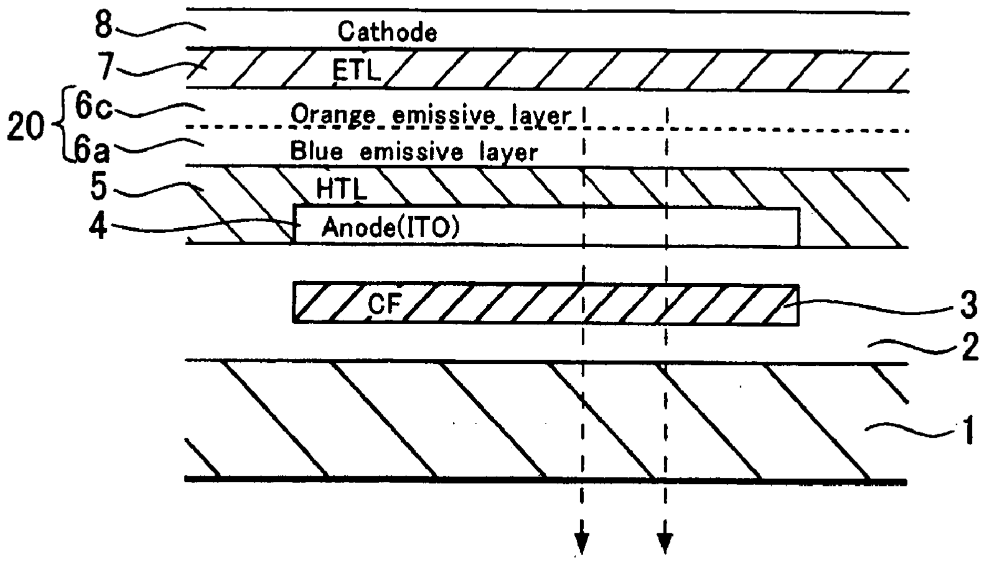

8
Cathode
7
ETL
20
6c
Orange emissive layer
6a
Blue emissive layer
5
HTL
4
Anode(ITO)
CF
3
2
1

FIG.6

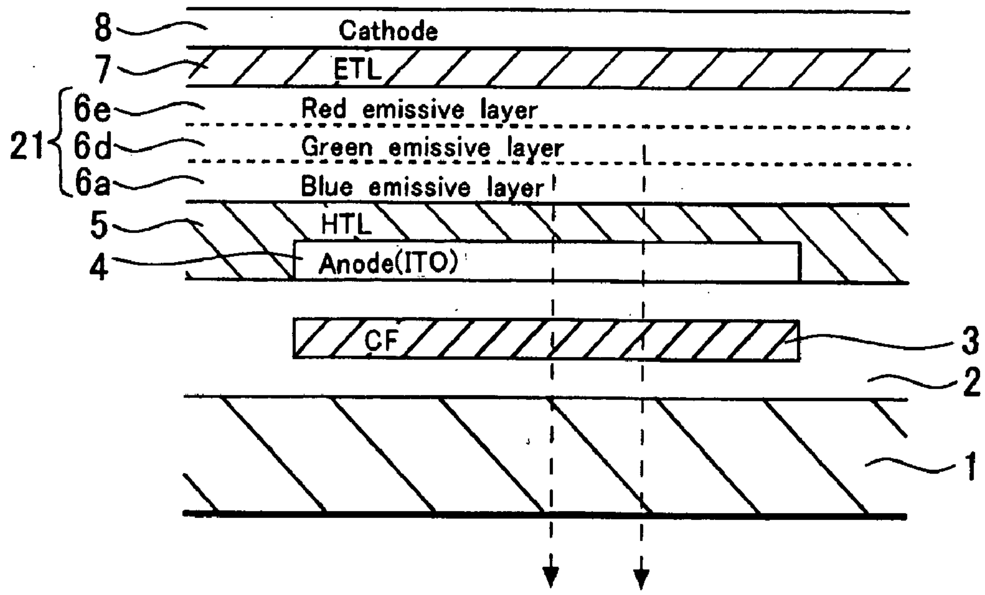
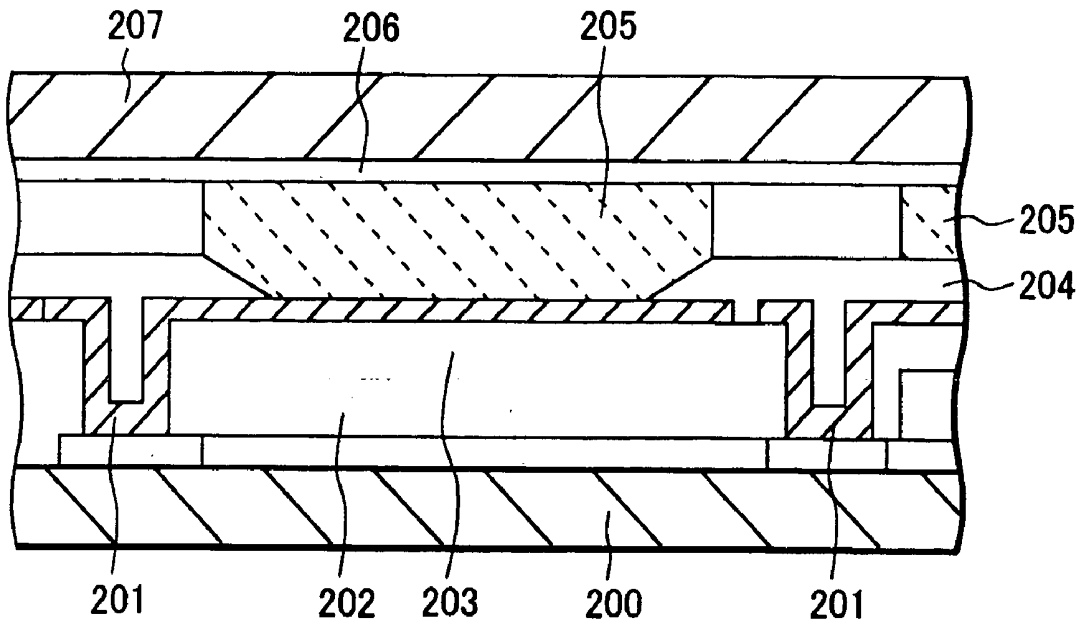

8
Cathode
7
ETL
21
6e
Red emissive layer
6d
Green emissive layer
6a
Blue emissive layer
5
HTL
4
Anode(ITO)
CF
3
2
1

FIG.7

PRIOR ART



ELECTROLUMINESCENT DISPLAY DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to an electroluminescent display device, particularly having a white emissive layer emitting white light.

[0003] 2. Description of the Related Art

[0004] An organic electroluminescent (hereafter, referred to as EL) element is a self-emissive element. In recent years, an organic EL display device using the organic EL elements has been receiving attention as a new display device substituted for a CRT or an LCD.

[0005] **FIG. 7** is a schematic cross-sectional view of a pixel of a full-color organic EL display device of a conventional art. A numeral **200** designates a glass substrate, a numeral **201** designates an organic EL element driving TFT (thin film transistor) formed on the glass substrate **200**, and a numeral **202** designates a first planarization insulating film. A numeral **203** designates an anode layer made of ITO (indium tin oxide) which is connected with the TFT **201** and extends over the first planarization insulating film **202**, and a numeral **204** designates a second planarization insulating film formed so as to cover end portions of the anode layer **203**. A numeral **205** designates R (red), G (green), and B (blue) organic EL layers each formed on the anode layer **203**, and a numeral **206** designates a cathode layer formed on the organic EL layers **205**.

[0006] A glass substrate **207** covers the cathode layer **206**. The glass substrate **207** and the glass substrate **200** are attached at those edges to enclose the R, G, and B organic EL layers **205** therein. Here, the R, G, and B organic EL layers **205** are respectively formed by selectively performing vapor-deposition of organic EL materials which emit each of R, G, and B lights by using a metal mask.

[0007] On the other hand, as a method of realizing a full-color organic EL display device without providing the R, G, and B organic EL layers **205**, a combination of a white emissive layer emitting white light and color filter layers has been proposed. Such a structure is described, for example, Japanese Patent Application Publication No. Hei 8-321380. The characteristics of this structure is that a plurality of emissive layers are combined to generate white light.

SUMMARY OF THE INVENTION

[0008] The invention provides an electroluminescent display device that includes a plurality of pixels, an anode layer provided for each of the pixels, and an electroluminescent layer provided for each of the pixels and disposed above a corresponding anode layer. The electroluminescent layer includes a first emissive layer of a first wavelength and a second emissive layer of a second wavelength that is longer than the first wavelength, and the first emissive layer is disposed closer to the anode layer than the second emissive layer. The device also includes a cathode layer disposed above the electroluminescent layers.

[0009] The invention also provides an electroluminescent display device that includes an insulating substrate, a plurality of pixels disposed on the insulating substrate, and a color filter layer provided for each of the pixels. The color filter layers are disposed above the insulating substrate. The device also includes an anode layer made of a transparent electrode, provided for each of the pixels and disposed above a corresponding color filter layer, and an electroluminescent layer provided for each of the pixels and disposed above a corresponding anode layer. The electroluminescent layer includes a plurality of emissive layers each emitting light of a different wavelength. The emissive layers are disposed so that an emissive layer emitting light of a shorter wavelength is disposed closer to the anode layer than an emissive layer emitting light of a longer wavelength. The device also includes a cathode layer disposed above the electroluminescent layers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** is a cross-sectional view of an organic EL display device of a first embodiment of the invention.

[0011] **FIG. 2** is a plan view of an organic EL display device of the first embodiment.

[0012] **FIG. 3** is a cross-sectional view along line A-A of **FIG. 2**.

[0013] **FIG. 4** is a cross-sectional view along line B-B of **FIG. 2**.

[0014] **FIG. 5** is a cross-sectional view of an organic EL display device of a second embodiment of the invention.

[0015] **FIG. 6** is a cross-sectional view of an organic EL display device of a third embodiment of the invention.

[0016] **FIG. 7** is a cross-sectional view of an organic EL display device of a conventional art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] **FIG. 1** is a cross-sectional view of an organic EL display device of a first embodiment of the invention. An insulating film **2** made of SiO_2 is formed on a glass substrate **1**, and a color filter layer **3** is formed in the insulating film **2**. An anode layer **4** made of ITO and serving as a transparent electrode is formed above the color filter layer **3**. On the anode layer **4**, an electron transport layer (HTL) **5**, a white emissive layer '**6**, a hole transport layer **7**, a cathode layer **8** made of Al (aluminum) are laminated in this order. **FIG. 1** shows only an organic EL element and a color filter layer in a pixel, and other components including an organic EL element driving TFT and a pixel selecting TFT, such as those shown in **FIG. 7**, are omitted.

[0018] When an electric current flows from the anode layer **4** to the cathode layer **8** through an organic EL element driving TFT (not shown in **FIG. 1**), white light is generated from the white emissive layer **6**, and emitted outside through the anode layer **4**, the color filter layer **3**, and the glass substrate **1**. Accordingly, a full-color display can be obtained by forming the R, G, and B color filter layers **3** in each of the pixels.

[0019] In this organic EL display device, the white emissive layer **6** is formed by laminating the blue emissive layer **6*a*** and the yellow emissive layer **6*b***. The blue emissive layer **6*a*** emitting blue light having a short wavelength is formed on the side closer to an anode layer **4** than the yellow emissive layer **6*b***, and the yellow emissive layer **6*b*** emitting yellow light having a longer wavelength than the blue light is disposed on the blue emissive layer **6***a*. Under this configuration, blue light emitted from the blue emissive layer **6***a* reaches the color filter layer **3** without penetrating through the yellow emissive layer **6***b*, and is emitted outside through the color filter layer **3**. On the other hand, yellow light emitted from the yellow emissive layer **6***b* penetrates through the blue emissive layer **6***a* and then the color filter layer **3**. Since the yellow light has a longer wavelength than the blue light, the absorption amount of the yellow light is relatively small. The absorption amount of the blue light also reduces so that the luminous efficiency increases.

[**0020**] On the contrary, if the yellow emissive layer **6***b* and the blue emissive layer **6***a* are formed above the anode layer **4** in this order, blue light emitted from the blue emissive layer **6***a* reaches the color filter layer **3** mainly through the yellow emissive layer **6***b*, the electron transport layer **5** and the anode layer **4**. In this configuration, since the blue light has the shorter wavelength, it is easily absorbed in the above intermediate layers before reaching the color filter layer **3**. This results in a problem of lowering luminous efficiency.

[**0021**] Next, a structure of the organic EL display device will be described based on the first embodiment in detail. **FIG. 2** is a plan view of a pixel of the organic EL display device. **FIG. 3** is a cross-sectional view along line A-A of **FIG. 2**, and **FIG. 4** is a cross-sectional view along line B-B of **FIG. 2**.

[**0022**] A pixel **115** is formed in a region enclosed with a gate signal line **51** and a drain signal line **52**. A plurality of the pixels **115** is disposed in a matrix.

[**0023**] An organic EL element **60** as a self-emissive element, a switching TFT (thin film transistor) **30** for controlling a timing of supplying an electric current to the organic EL element **60**, a driving TFT **40** for supplying an electric current to the organic EL element **60**, and a storage capacitor **56** are placed in the pixel **115**. The organic EL element **60** is formed of an anode layer **61**, a white emissive layer **63** made of a white emissive material, and a cathode layer **65**. A structure of the white emissive layer **63** will be described below.

[**0024**] The switching TFT **30** is provided on a periphery of an intersection of the signal lines **51** and **52**. A source **33***s* of the switching TFT **30** serves as a capacitor electrode **55** for forming a capacitor with a storage capacitor electrode line **54** (**56**?) and is connected with a gate electrode **41** of the driving TFT **40**. A source **43***s* of the driving TFT **40** is connected with the anode layer **61** of the organic EL element **60**, while a drain **43***d* is connected with a driving source line **53** as a source of a current to be supplied to the organic EL element **60**.

[**0025**] A cross-sectional structure of the organic EL display device will be described with reference to **FIGS. 3 and 4**. A structure of the switching TFT **30** will be described first. As shown in **FIG. 3**, an amorphous silicon film (hereafter, referred to as an a-Si film) is formed on a transparent insulating substrate **10** made of a silica glass or a non-alkali glass by a CVD method and so on. The a-Si film is irradiated with laser beams for melting and recrystalizing to form a poly-silicon film (hereafter, referred to as a p-Si film) as an active layer **33**.

[**0026**] On the active layer **33**, a single-layer or a multi-layer of an SiO_2 film and an SiN_x film is formed as a gate insulating film **12**. There are disposed on the gate insulating film **12** the gate signal line **51** made of metal having a high melting point such as Cr (chromium) or Mo (molybdenum) and also serving as a gate electrode **31**, the drain signal line **52** made of Al (aluminum), and the driving source line **53** made of Al and serving as a driving source of the organic EL element **60**.

[**0027**] An interlayer insulating film **15** formed by laminating an SiO_2 film, an SiN_x film and an SiO_2 film sequentially is placed on the whole surfaces of the gate insulating film **12** and the active layer **33**. A drain electrode **36** is provided by filling a contact hole provided corresponding to a drain **33***d* with metal such as Al. Furthermore, a first planarization insulating film **17** for planarizing a surface, which is made of organic resin, is formed on the whole surface.

[**0028**] Next, a structure of the driving TFT **40** will be described. As shown in **FIG. 4**, an active layer **43** formed by poly-crystalizing an a-Si film by radiating laser beams thereto, the gate insulating film **12**, and the gate electrode **41** made of metal having a high melting point such as Cr or Mo are formed sequentially on the transparent insulating substrate **10** made of a silica glass, or a non-alkali glass.

[**0029**] A channel **43***c*, a source **43***s*, and a drain **43***d* are provided in the active layer **43**, the source **43***s* and the drain **43***d* being placed on both sides of the channel **43***c*. The interlayer insulating film **15** formed by laminating an SiO_2 film, an SiN_x film and an SiO_2 film sequentially is placed on the whole surfaces of the gate insulating film **12** and the active layer **43**. The driving source line **53** connected with a driving source is provided by filling a contact hole provided corresponding to the drain **43***d* with a metal such as Al.

[**0030**] A color filter layer **70** is formed on the interlayer insulating film **15** adjacently to the driving TFT **40**. The color filter layer **70** is formed in each of the pixels, having spectral characteristics of R, G or B color. For example, a pixel R includes a color filter layer **70** having spectral characteristics of red.

[**0031**] Furthermore, the planarization insulating film **17** for planarizing a surface, which is made of, for example, an organic resin, is formed on a the whole surface. A contact hole is formed in a position corresponding to the source **43***s* in the planarization insulating film **17**. The anode layer **61** of the organic EL element, which is an transparent electrode made of ITO and is in contact with the source **43***s* through the contact hole, is formed on the planarization insulating film **17**. The anode layer **61** is formed above the color filter layer **70** in each of the pixels, being isolated as an island.

[**0032**] A second planarization insulating film **66** is further formed on the first planarization insulating film **17**, covering end portions of the anode layer **61**. The second planarization insulating film **66** is removed on the light-emitting region of the anode layer **61**.

[**0033**] The organic EL element **60** is formed by laminating the anode layer **61** made of a transparent electrode such as ITO, a hole transport layer **62** made of NPB, an white emissive layer **63**, an electron transport layer **64** made of Alq^3 (8-tris-hydroxyquinoline aluminum) and the cathode layer **65** made of magnesium-indium alloy, Al or Al alloy, in this order. The white emissive layer **63** is formed by laminating a blue emissive layer **63***a* and a yellow emissive layer

63*b*. The blue emissive layer **63***a* is disposed on the side closer to the anode layer **61** than the yellow emissive layer **63***b*. The blue emissive layer **63***a* is made of Zn $(BOX)^2$ which is an abbreviation for bis ((2-hydroxyphenyl) benzoxazole) zinc. The yellow emissive layer **63***b* is formed by adding rubrene as yellow dopant to an NPB (host). The NPB (host) is an abbreviation for N, N'-Di (naphthalene-1-yl)-N, N'-diphenyl-benzidine. The cathode layer **65** is covered with the glass substrate **207**.

[**0034**] In the organic EL element **60**, a hole injected from the anode layer **61** and an electron injected from the cathode layer **65** are recombined in the white emissive layer **63**, and excitons are formed by exciting organic molecules forming the white emissive layer **63**. Blue light and yellow light are emitted from the white emissive layer **63** in a process of radiation of the excitons, combined to be white light, and then released outside after penetrating through the transparent anode layer **61** and the transparent insulating substrate **10**, thereby completing a light-emission.

[**0035**] Since the blue emissive layer **63***a* is placed on the side closer to the anode layer **61** than the yellow emissive layer **63***b*, the blue light emitted from the blue emissive layer **63***a* reaches the color filter layer **70** through the hole transport layer **62**, the anode layer **61** and the first planarization insulating film **17**. Then, the blue light is filtered through the color filter layer **70** and emitted outside through the insulating substrate **10**.

[**0036**] The blue light emitted from the blue emissive layer **63***a* reaches the color filter layer **70** without passing through the yellow emissive layer **63***b* and is emitted outside through the color filter layer **70**. On the other hand, the yellow light emitted from the yellow emissive layer **63***b* passes through the blue emissive layer **63***a* and then the color filter layer **70**. Since the yellow light has a longer wavelength than the blue light, the absorption amount of the yellow light is relatively small. The absorption amount of the blue light also reduces so that the luminous efficiency is improved.

[**0037**] Next, other embodiments will be described with reference to the drawings in detail. **FIG. 5** is a cross-sectional view of the organic EL display device based on the second embodiment. **FIG. 5** shows only an organic EL element and a color filter layer in a pixel, and other components including an organic EL element driving TFT and a pixel selecting TFT are omitted. The same numerals are provided to the same components as those of **FIG. 1**. In this organic EL display device, an orange emissive layer **6***c* is substituted for the yellow emissive layer **6***b* used in the first embodiment. The white emissive layer **20** is formed by laminating the blue emissive layer **6***a* and the orange emissive layer **6***c*. The blue emissive layer **6***a* emitting blue light having a short wavelength is formed on the side closer to the anode layer **4** which is on the light emitting side, and the orange emissive layer **6***c* emitting orange light having a longer wavelength than the blue light is placed on the blue emissive layer **6***a*. The orange emissive layer **6***c* is made by adding 5,12-Bis(4-(benzothiazol-2-yl)phenyl)-6,11-diphenylnaphthacene as an orange dopant to NPB (host).

[**0038**] Under this configuration, the blue light emitted from the blue emissive layer **6***a* reaches the color filter layer **3** without passing through the orange emissive layer **6***c*, and is emitted outside through the color filter layer **3**. On the other hand, the orange light emitted from the orange emissive layer **6***c* passes through the blue emissive layer **6***a* and then the color filter layer **3**. Since the orange light has a longer wavelength than the blue light, the absorption amount of the orange light is relatively small. The absorption amount of the blue light also reduces so that the luminous efficiency is improved.

[**0039**] **FIG. 6** is a cross-sectional view of an organic EL display device of a third embodiment. **FIG. 6** shows only an organic EL element and a color filter layer in a pixel, and other components including an organic EL element driving TFT and a pixel selecting TFT are omitted. The same numerals are provided to the same components as those of **FIG. 1**. In this organic EL display device, the white emissive layer **21** is formed by laminating the blue emissive layer **6***a*, a green emissive layer **6***d* and a red emissive layer **6***e*. The blue emissive layer **6***a* emitting blue light having a short wavelength is formed on the side closer to the anode layer **4**, and the green emissive layer **6***d* emitting green light having a longer wavelength than the blue light is formed on the blue emissive layer **6***a*. Furthermore, the red emissive layer **6***e* emitting red light having longer wavelength than the green light is formed on the green emissive layer **6***d*.

[**0040**] The green emissive layer **6***d* is made by adding 5,12-diphenylnaphthacene as a green dopant to NPB (host). The red emissive layer **6***e* is made by adding 6,13-diphenylpentacene as a red dopant to NPB (host).

[**0041**] Under this configuration, the blue light emitted from the blue emissive layer **6***a* reaches the color filter layer **3** without passing through the other emissive layers, and is emitted outside through the color filter layer **3**. On the other hand, the green light emitted from the green emissive layer **6***d* passes through the blue emissive layer **6***a* and then the color filter layer **3**. Since the green light has a longer wavelength than the blue light, the absorption amount of the green light is relatively small. Furthermore, the red light emitted from the red emissive layer **6***e* passes through the green emissive layer **6***d* and the blue emissive layer **6***a*, and then through the color filter layer **3**. Since the red light has a longer wavelength than the green light, the absorption amount of the red light is relatively small. Therefore, under this configuration, too, the absorption amount of the blue light also reduces so that the luminous efficiency is improved.

[**0042**] As apparent from the first, second, third embodiments, the invention includes a display device having a plurality of emissive layers each emitting light of different wavelength. That is, by laminating the plurality of emissive layers in increasing order of wavelength of emitting light on a light emitting side, the absorption amount of light having a short wavelength can be minimized.

[**0043**] Furthermore, in an organic EL display device of a fourth embodiment, the red emissive layer **6***e* is substituted for the orange emissive layer **6***c* used in the second embodiment. In this embodiment, too, the blue light emitted from the blue emissive layer **6***a* reaches the color filter layer **3** without passing through the red emissive layer **6***e*, and is emitted outside through the color filter layer **3**. On the other hand, the red light emitted from the red emissive layer **6***e* passes through the blue emissive layer **6***a* and then the color filter layer **3**. Since the red light has a longer wavelength than the blue light, the absorption amount of the red light is relatively small. The absorption amount of the blue light also reduces so that the luminous efficiency is improved.

What is claimed is:

1. An electroluminescent display device comprising:

a plurality of pixels;

an anode layer provided for each of the pixels;

an electroluminescent layer provided for each of the pixels and disposed above a corresponding anode layer, the electroluminescent layer comprising a first emissive layer of a first wavelength and a second emissive layer of a second wavelength that is longer than the first wavelength, and the first emissive layer being disposed closer to the anode layer than the second emissive layer; and

a cathode layer disposed above the electroluminescent layers.

2. The electroluminescent display device of claim 1, further comprising a color filter layer disposed so that light emitted from the electroluminescent layer passes through the color filter layer.

3. An electroluminescent display device comprising:

an insulating substrate;

a plurality of pixels disposed on the insulating substrate;

a color filter layer provided for each of the pixels, the color filter layers being disposed above the insulating substrate;

an anode layer made of a transparent electrode, provided for each of the pixels and disposed above a corresponding color filter layer;

an electroluminescent layer provided for each of the pixels and disposed above a corresponding anode layer, the electroluminescent layer comprising a plurality of emissive layers each emitting light of a different wavelength, the emissive layers being disposed so that an emissive layer emitting light of a shorter wavelength is disposed closer to the anode layer than an emissive layer emitting light of a longer wavelength; and

a cathode layer disposed above the electroluminescent layers.

4. The electroluminescent display device of claim 3, further comprising a color filter layer disposed so that light emitted from the electroluminescent layer passes through the color filter layer.

5. The electroluminescent display device of claim 3, wherein the plurality of the emissive layers comprises a blue emissive layer and a yellow emissive layer, and the blue emissive layer is disposed closer to the anode layer than the yellow emissive layer.

6. The electroluminescent display device of claim 3, wherein the plurality of the emissive layers comprises a blue emissive layer and an orange emissive layer, and the blue emissive layer is disposed closer to the anode layer than the orange emissive layer.

7. The electroluminescent display device of claim 3, wherein the plurality of the emissive layers comprises a blue emissive layer, a green emissive layer and a red emissive layer, and the blue emissive layer is disposed on an anode side, the rend emissive layer is disposed on a cathode side and the green emissive layer is disposed between the blue and red emissive layers.

8. The electroluminescent display device of claim 3, wherein the plurality of the emissive layers comprises a blue emissive layer and a red emissive layer, and the blue emissive layer is disposed closer to the anode layer than the red emissive layer.

* * * * *

专利名称(译)	电致发光显示装置		
公开(公告)号	US20040222736A1	公开(公告)日	2004-11-11
申请号	US10/790247	申请日	2004-03-02
[标]申请(专利权)人(译)	三洋电机株式会社		
申请(专利权)人(译)	SANYO ELECTRIC CO. , LTD.		
当前申请(专利权)人(译)	SANYO ELECTRIC CO. , LTD.		
[标]发明人	YONEDA KIYOSHI		
发明人	YONEDA, KIYOSHI		
IPC分类号	H05B33/12 H01L27/32 H01L51/50 H05B33/00 H05B33/14		
CPC分类号	H01L27/322 H01L51/5036 H01L27/3244 H01L51/504 B29L2023/22		
优先权	2003055333 2003-03-03 JP 2004028951 2004-02-05 JP		
外部链接	Espacenet USPTO		

摘要(译)

本发明旨在提高白色有机EL元件的发光效率。通过层压蓝色发光层和黄色发光层形成有机EL元件的白色发光层。发射具有短波长的蓝光的蓝色发光层形成在更靠近阳极层的一侧，并且发射具有比蓝色发光层更长波长的黄色光的黄色发光层设置在蓝色发光层上。在这种配置下，从蓝色发光层发射的蓝光到达滤色器层而不穿透黄色发光层。另一方面，从黄色发光层发射的黄光穿透蓝色发光层。黄光具有比蓝光更长的波长，黄光的吸收量变得相对小。蓝光的吸收量也减少，从而发光效率提高。