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(54) ORGANIC EL DISPLAY

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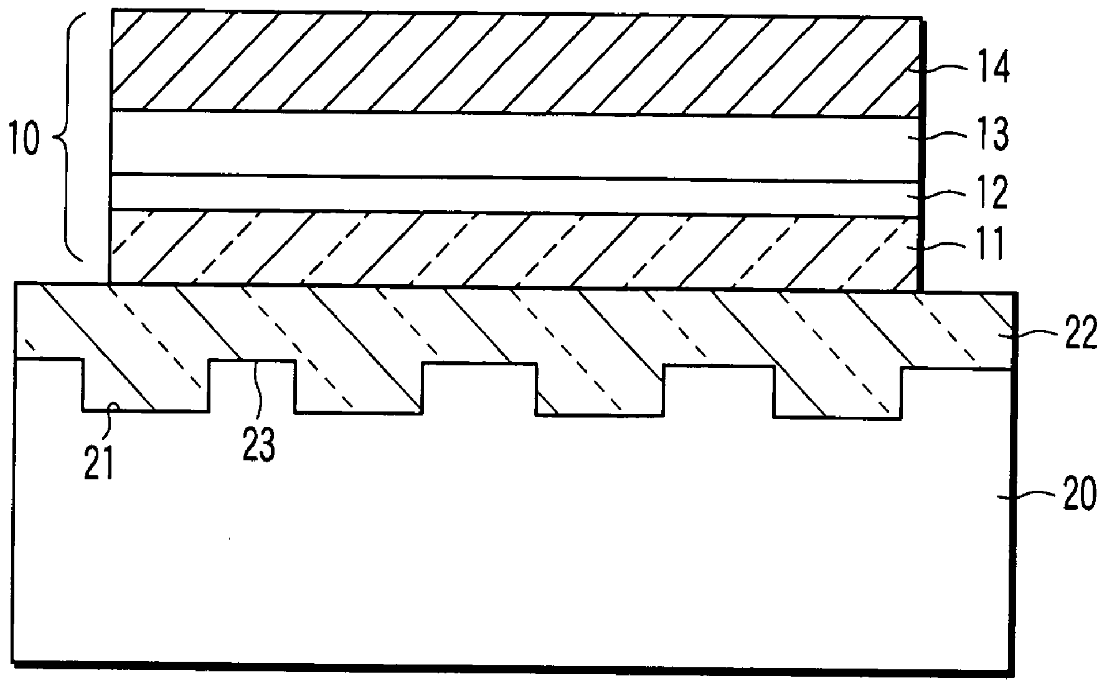
(57) **ABSTRACT**

In an organic EL display provided with a transparent substrate, a buffer layer provided on the transparent substrate, and an organic EL element provided on the buffer layer, the buffer layer is formed of a material having the same refractive index as the transparent electrode of the EL element, and has a two-dimensional diffraction grating having two grating periods.



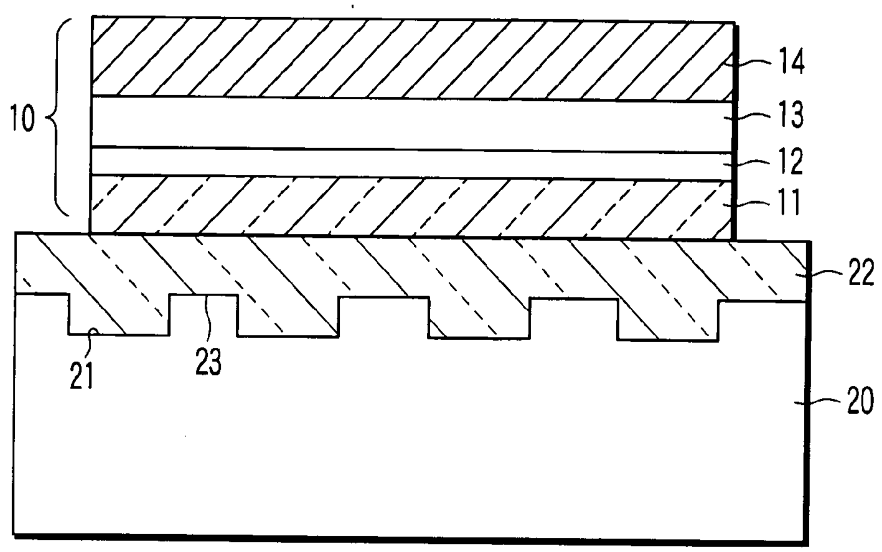


FIG. 1

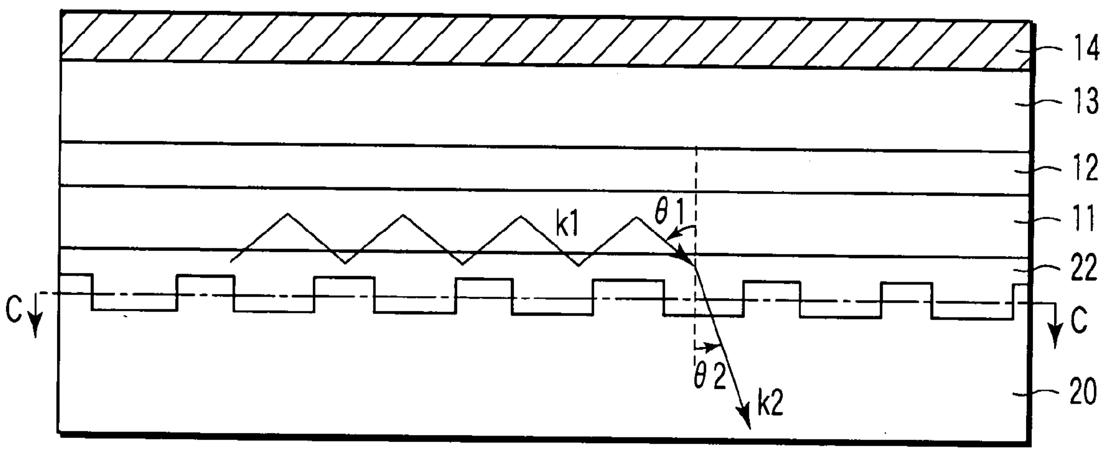


FIG. 2

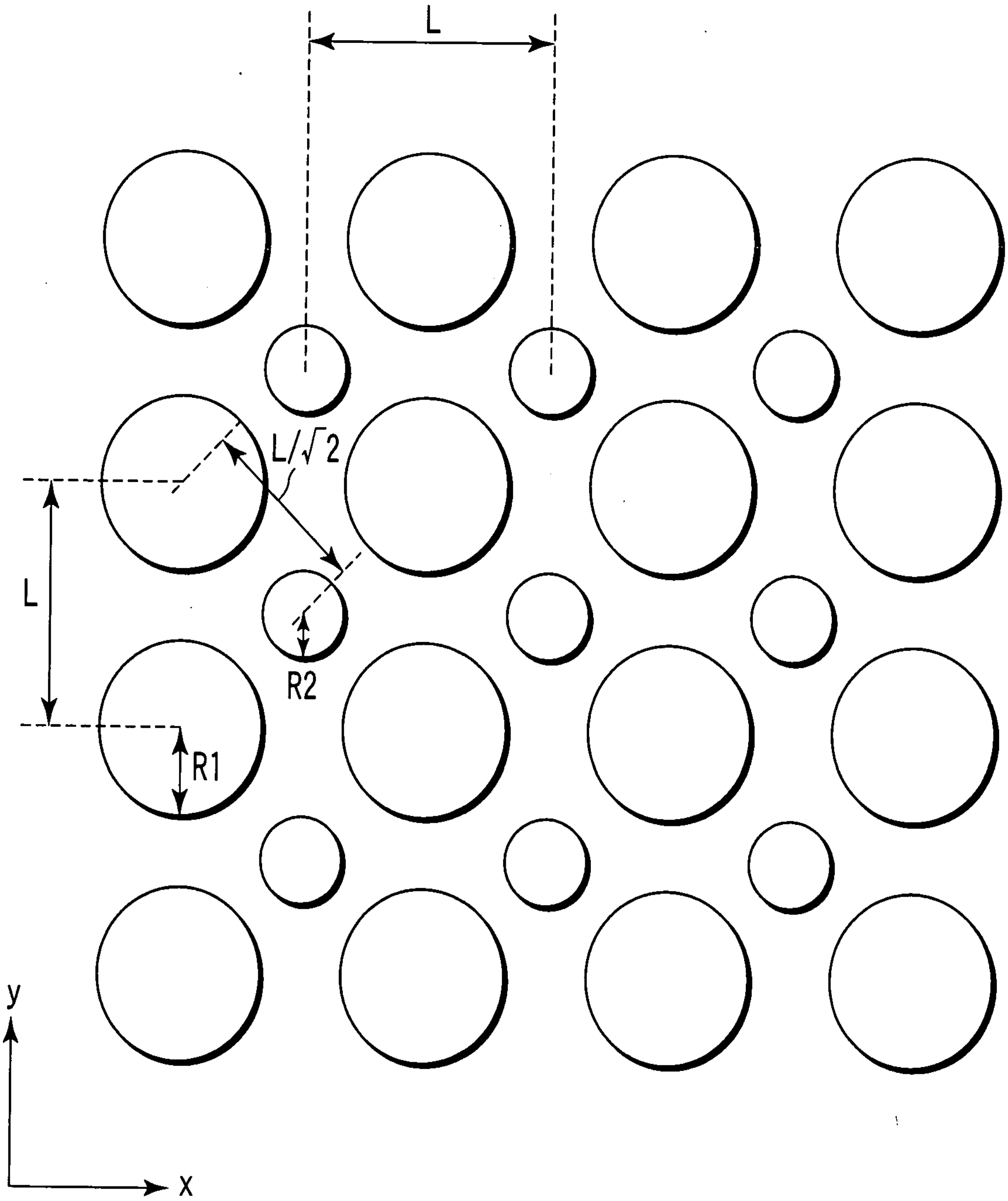


FIG. 3

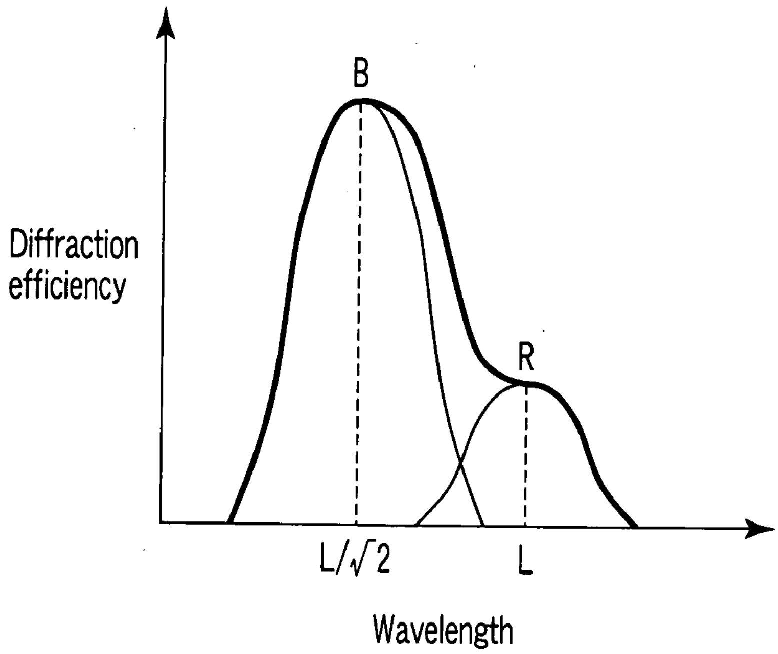

B
R
Diffraction efficiency
L/√2
L
Wavelength

FIG. 4A

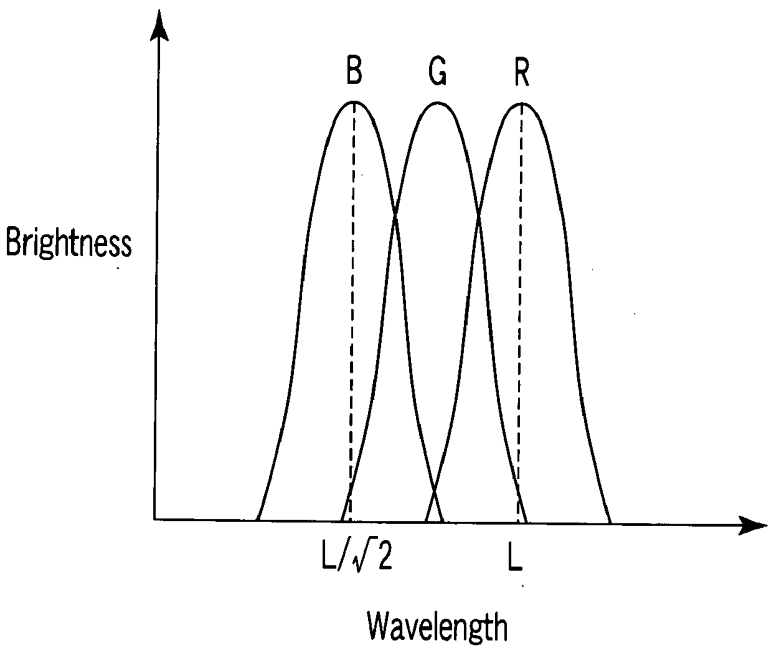

B
G
R
Brightness
L/√2
L
Wavelength

FIG. 4B

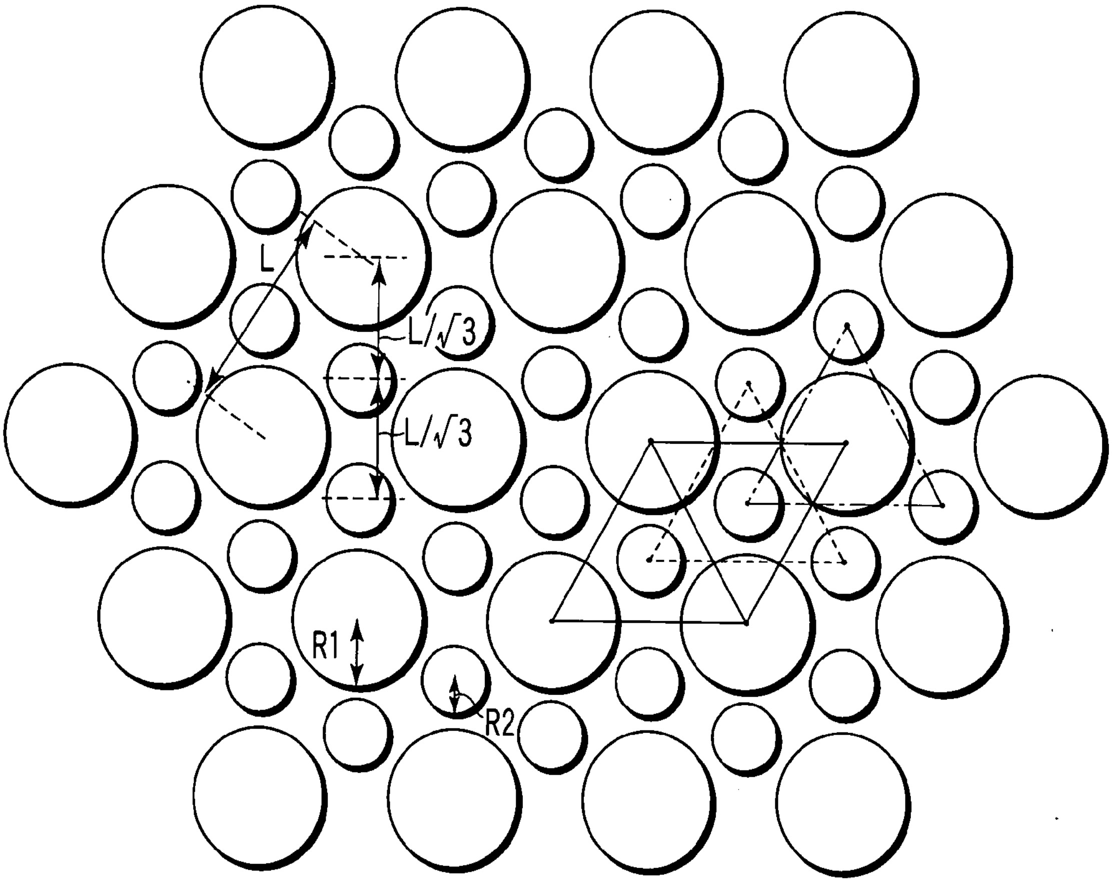


FIG. 5

FIG. 6A

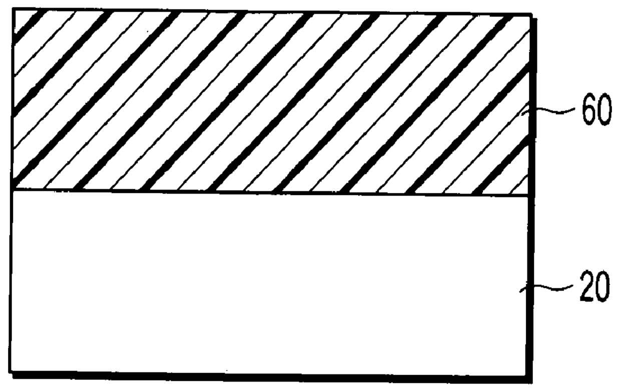


FIG. 6B

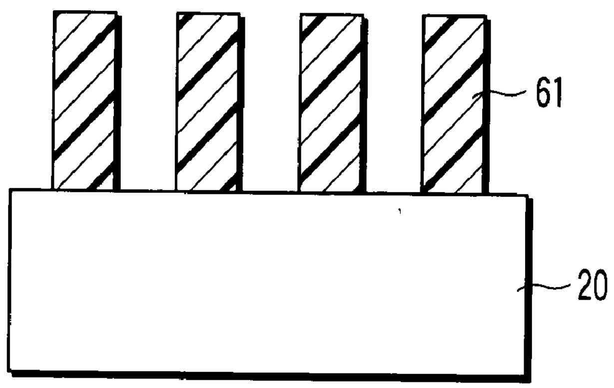


FIG. 6C

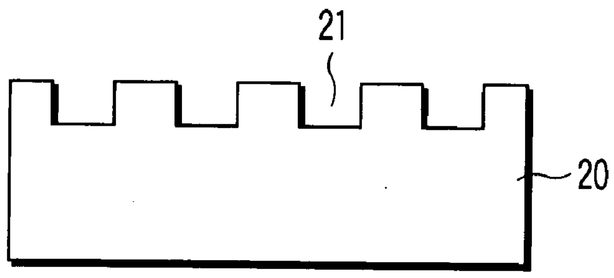


FIG. 6D

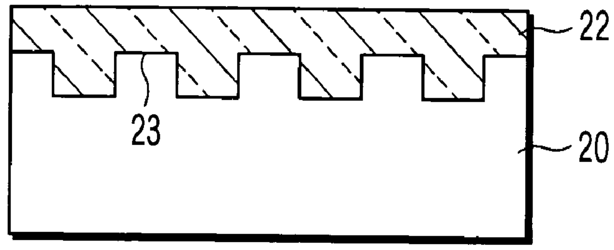


FIG. 7A

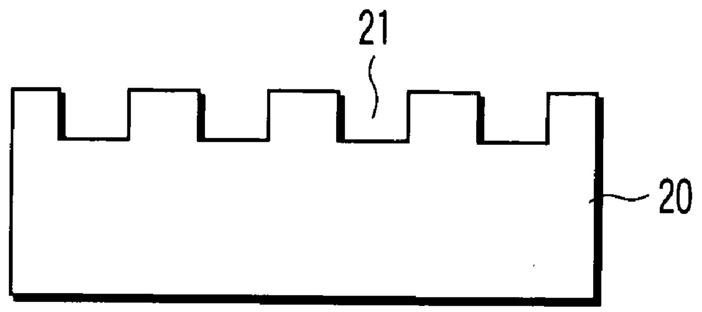


FIG. 7B

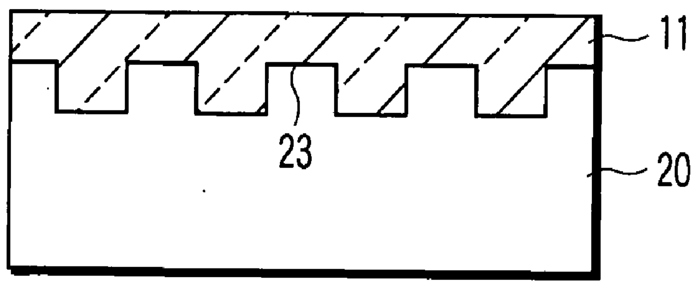
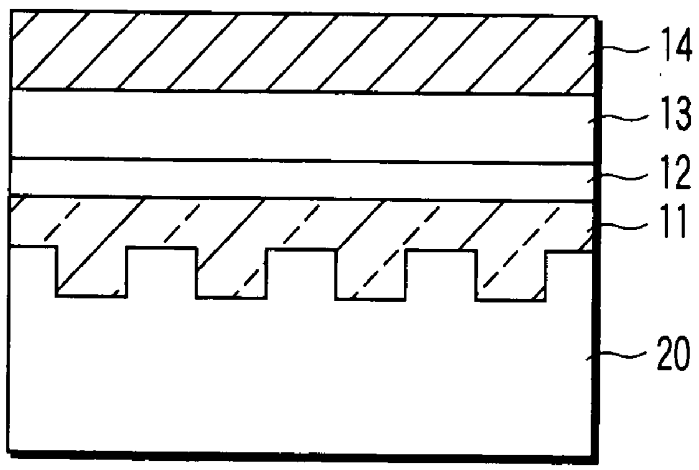


FIG. 7C



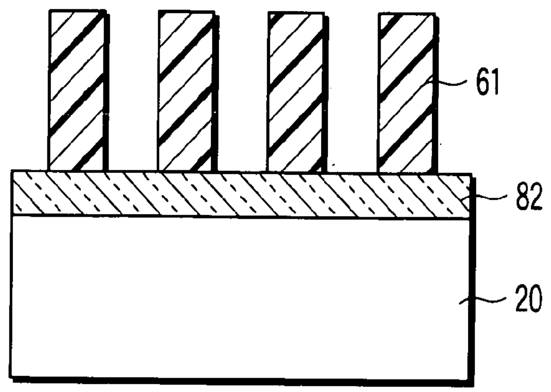


FIG. 8A

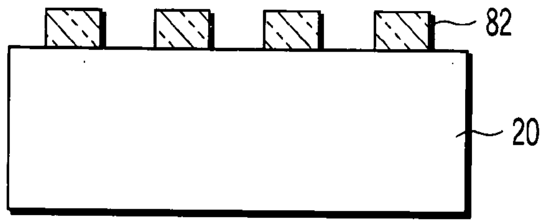


FIG. 8B

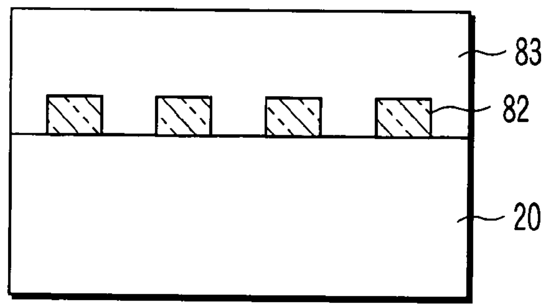


FIG. 8C

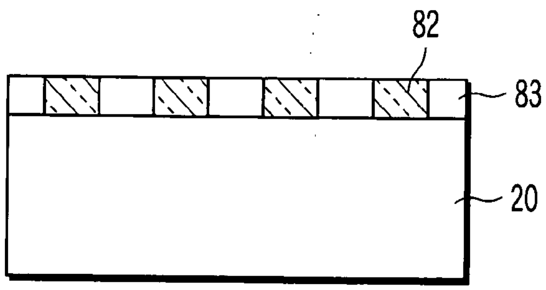


FIG. 8D

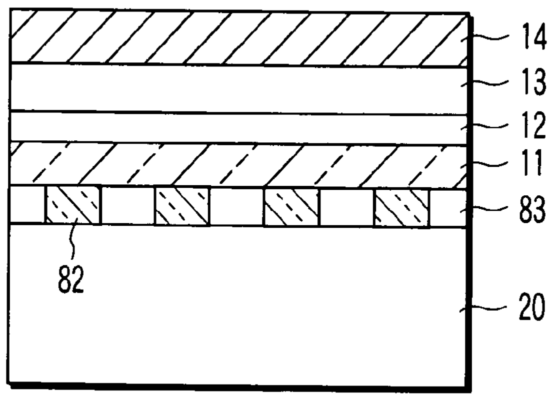


FIG. 8E

ORGANIC EL DISPLAY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2005-034582, filed Feb. 10, 2005, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a full-color organic EL display, and more particularly, to an organic EL display improved in a light extraction portion.

[0004] 2. Description of the Related Art

[0005] Organic EL displays generally comprise a glass substrate, a transparent electrode (high-refractive-index section) as an anode, a hole injection layer (hole transport layer), an emission layer formed of an organic film, and a cathode. The transparent electrode has a refractive index of about 2, which is greater than the refractive index, 1.5 to 1.7, of the glass substrate or the organic film (emission layer). Accordingly, the transparent electrode inevitably serves as a waveguide for guiding light therein, which causes about 50% light loss in the electrode. As a result, the light extraction efficiency of the organic EL displays is as low as about 18% at present.

[0006] To extract, to the outside, the light propagating through the transparent electrode, there is a technique for providing, on a transparent electrode of indium tin oxide (ITO), a diffraction grating made of a material having substantially the same refractive index as ITO, and extracting the light propagating through the electrode, using the grating. This technique is disclosed in Applied Physics Letters, 3779, vol. 82, 2003.

[0007] However, the diffraction grating diffracts light of particular wavelengths determined from the period size of the grating, namely, does not diffract all visible light (with wavelengths of 400 to 700 nm). Therefore, the method for providing a single diffraction grating on the front surface of a display is not necessarily effective.

[0008] To overcome this problem, there is a method for providing plurality of diffraction gratings respectively corresponding to the wavelengths of R, G and B pixels (see Jpn. Pat. Appln. KOKAI Publication No. 2003-163075). In this method, however, severaly types of diffraction gratings respectively corresponding to pixels must be prepared, which makes the manufacturing process very complex and hence the resultant products very expensive. It is difficult to put the method into practical use.

[0009] Furthermore, in general organic EL displays of a low-molecular-weight type, R pixels have a lower brightness than G and B pixels. To balance the brightness of the R, G and B pixels, much power must be supplied to the R pixels. This increases the power consumption of the displays, and reduces their lifetime.

[0010] As described above, in full-color organic EL displays, to enhance the light extraction efficiency, it is necessary to prepare diffraction gratings of sizes (pitches) corresponding to R, G and B pixels. This inevitably makes the manufacturing process very complex and the resultant products very expensive.

BRIEF SUMMARY OF THE INVENTION

[0011] In accordance with an aspect of the invention, there is provided an organic EL display comprising:

[0012] a transparent substrate;

[0013] an organic EL element provided on the transparent substrate and including a transparent electrode on a side of the transparent substrate; and

[0014] a two-dimensional diffraction grating provided on a surface of the transparent substrate on the side of the transparent electrode, and having two kinds of grating periods.

[0015] In accordance with another aspect of the invention, there is provided an organic EL display comprising:

[0016] a transparent substrate;

[0017] a buffer layer provided on the transparent substrate and including a two-dimensional diffraction grating having two kinds of grating periods on a side of the transparent substrate; and

[0018] an organic EL element provided on the buffer layer and including on a side of the buffer layer a transparent electrode having a refractive index equal to that of the buffer layer.

[0019] In accordance with yet another aspect of the invention, there is provided an organic EL display comprising:

[0020] a transparent substrate having a major surface formed in concavo-convex shape to form a two-dimensional diffraction grating having two kinds of grating periods;

[0021] a buffer layer deposited on the major surface of the transparent substrate, and including a concavo-convex surface having a reversed concavo-convex pattern of the concavo-convex shape of the major surface to form a two-dimensional diffraction grating having two kinds of grating periods and a flat surface opposite to the concavo-convex surface; and

[0022] an organic EL element provided on the buffer layer and including on a side of the buffer layer a transparent electrode having a refractive index equal to that of the buffer layer.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0023] **FIG. 1** is a sectional view schematically illustrating the structure of an organic EL display according to an embodiment of the invention;

[0024] **FIG. 2** is a sectional view useful in explaining light extraction by a diffraction grating;

[0025] **FIG. 3** is a plan view illustrating diffraction grating examples of two sizes;

[0026] **FIG. 4A** is a graph illustrating the relationship between the wavelength and the diffraction efficiency;

[0027] **FIG. 4B** is a graph illustrating the relationship between the wavelength and the brightness;

[0028] **FIG. 5** is a plan view illustrating other diffraction grating examples of two sizes;

[0029] **FIGS. 6A** to **6**D are sectional views illustrating a process for manufacturing an organic EL display as example 1;

[0030] **FIGS. 7A** to **7**C are sectional views illustrating a process for manufacturing an organic EL display as example 2; and

[0031] **FIGS. 8A** to **8**E are sectional views illustrating a process for manufacturing an organic EL display as example 3.

DETAILED DESCRIPTION OF THE INVENTION

[0032] An embodiment of the invention will be described in detail with reference to the accompanying drawings.

[0033] **FIG. 1** is a sectional view schematically illustrating the structure of an organic EL display according to the embodiment of the invention.

[0034] In **FIG. 1**, reference numeral **10** denotes an organic EL element. The organic EL element **10** comprises a transparent electrode (anode) **11**, a hole injection layer (hole transport layer) **12**, an organic film (emission layer) **13**, and a cathode **14**, which are stacked in this order. Further, reference numeral **20** denotes a transparent substrate of glass or plastic. A diffraction grating **21** is formed as the uneven (concavo-convex) upper surface of the substrate **20**.

[0035] A buffer layer (high-refractive index layer) **22** formed of a material having the same refractive index as the transparent electrode **11** is provided on the transparent substrate **20** to fill the diffraction grating **21**. As a result, the high-refractive index layer **22** has a diffraction grating **23**. The organic EL element **10** is provided on the high-refractive index layer **22**, with the transparent electrode **11** positioned at the lowest position. Instead of the high-refractive index layer **22**, the transparent electrode **11** may have the diffraction grating **23**.

[0036] Further, the organic EL element **10** may incorporate an electron injection layer (electron transport layer) as well as the hole injection layer (hole transport layer) **12**. That is, the organic EL element **10** can have the following typical layer structures:

[0037] 1) Transparent-electrode(anode)/emission-layer/electrode (cathode)

[0038] 2) Transparent-electrode(anode)/emission-layer/electron-injection-layer/electrode(cathode)

[0039] 3) Transparent-electrode(anode)/hole-injection-layer/emission-layer/electron-injection-layer/electrode-(cathode), or

[0040] 4) Transparent-electrode(anode)/hole-injection-layer/emission-layer/electrode(cathode)

[0041] The transparent electrode **11** as an anode may be formed of a conductive material, such as indium tin oxide (ITO), which has a large work function, and generally has a thickness of about 100 to 300 nm.

[0042] The hole injection layer **12** is formed on the transparent electrode **12** by, for example, vacuum evaporation, and then an electron injection layer is formed thereon when necessary. The electron injection layer and hole injection layer are provided to serve as layers having a charge injection property, charge transport property or charge barrier property. These layers may be formed of an organic or non-organic material, and may have a thickness of 10 to 300 nm.

[0043] In the emission layer **13**, electrons and holes are recombined to thereby emit light. The cathode **14** may be formed of a metal having a small work function, such as aluminum, magnesium, indium, silver, or an alloy thereof, and may have a thickness of 10 to 500 nm.

[0044] The principle of the embodiment will now be described in detail.

[0045] **FIG. 2** is a sectional view useful in explaining light extraction by a diffraction grating. In **FIG. 2**, k_1 is the wave vector, in the direction of propagation, of light guided in a high-refractive index section when no diffraction grating is provided. Further, k_2 is the wave vector of light when the light is extracted from the high-refractive index section. Assuming that A represents the pitch of the diffraction grating, light is emitted from the high-refractive-index section if the following condition is satisfied.

$$k_1 \sin \theta_1 + m(2\pi/\Lambda) = k_2 \sin \theta_2 \quad (1)$$

where $k_1 = n_1 \times 2\pi/\lambda$, $k_2 = n_2 \times 2\pi/\lambda$, n_1 is the refractive index of the high-refractive-index section, n_2 is the refractive index of the emission section, θ_1 is the incident angle at the high-refractive-index section, θ_2 is the light-outgoing angle at the emission section, and λ is the wavelength of emitted light. Further, m is the order of diffraction and an integer. As can be understood from the above equation (1), when light is guided in a certain mode in the high-refractive-index section, diffracted light having a wavelength corresponding to the pitch of the grating is generated. In other words, the light guided in the high-refractive-index section cannot be sufficiently extracted, depending upon the wavelength of the light. Namely, a single diffraction grating does not contribute to extraction of light having a plurality of wavelengths.

[0046] In light of this, such a diffraction grating having two types of square grating components as shown in **FIG. 3** is employed. **FIG. 3** shows a schematical view of cross section C-C of **FIG. 2**. Specifically, the diffraction gating of **FIG. 3** has a pattern including large circles (scattering portions) arranged with a pitch L in the X- and Y-directions, and small circles (scattering portions) arranged with the same pitch in the X- and Y-directions. However, the large and small circles are deviated from each other by a pitch L/2 in the X- and Y-directions. In the case of the diffraction grating **21** shown in **FIG. 1**, which is formed of depression and projections, the scattering portions correspond to the depressions or projections.

[0047] A description will then be given of the diffraction efficiency of the diffraction grating with respect to wavelength.

[0048] The shorter the wavelength, the more easily light scatters. The scattering efficiency of light is inversely proportional to the wavelength of the light to the fourth power. Accordingly, blue light scatters several times easily compared to red light. Further, the scattering efficiency is proportional to the square of the area of a scattering portion.

Therefore, the scattering efficiency of light of each wavelength can be adjusted by providing diffraction grating components (scattering portions) with a pitch corresponding to each wavelength, and changing the size of the scattering portions.

[0049] For instance, such a diffraction grating formed of two types of square grating components as shown in **FIG. 3** is prepared. In this case, the first-type square grating components are each formed of large circles of a radius R_1, and the second-type square grating components are each formed of small circles of a radius R_2. The distance between adjacent large circles is L, and that between adjacent small circles is also L. The distance L serves as a grating period. On the other hand, the distance between a large circle and a small circle adjacent thereto is $L/\sqrt{2}$. The distance $L/\sqrt{2}$ serves as another grating period. Further, the distance L corresponds to the wavelength of red light, and the distance $L/\sqrt{2}$ corresponds to the wavelength of blue light.

[0050] A description will now be given of the scattering efficiency of light of each wavelength. The scattering portions corresponding to the distance L are large circles or small circles. The interference of light between large circles or between small circles corresponds to the square of the radius, i.e., corresponds to R_1^2 or R_2^2. Since the two types of square grating components are identical in pitch, light is diffracted by them at the same angle. In contrast, the scattering portions corresponding to the distance $L/\sqrt{2}$ are large and small circles, therefore the interference of light between them corresponds to $R_1 \times R_2$.

[0051] From the above, the diffraction efficiency of red light is given by

$$I(\text{red}) \propto L^{-4} \times (R_1^2 + R_2^2) \quad (2)$$

[0052] Similarly, the diffraction efficiency of blue light is given by

$$I(\text{blue}) \propto (L/\sqrt{2})^{-4} \times (R_1 \times R_2) \times 2 \quad (3)$$

[0053] If the grating is designed to satisfy the above conditions, the acquisition intensities of red light and blue light can be adjusted individually.

[0054] The following Table 1 shows the intensities I of red light and blue light acquired when R_1 and R_2 are varied, with L set to 650 nm that is determined from equations (2) and (3).

TABLE 1

L (nm)	L/√2(nm)	R1 (nm)	R2 (nm)	I (Red)	I (Blue)	I (Red)/I (Blue)
650	459.6194078	150	50	1.4E−07	3.36E−07	0.416666667
650	459.6194078	150	100	1.82E−07	6.72E−07	0.270833333
650	459.6194078	200	50	2.38E−07	4.48E−07	0.53125
650	459.6194078	200	100	2.8E−07	8.96E−07	0.3125
650	459.6194078	200	150	3.5E−07	1.34E−06	0.260416667
650	459.6194078	250	50	3.64E−07	5.6E−07	0.65
650	459.6194078	250	100	4.06E−07	1.12E−06	0.3625
650	459.6194078	250	150	4.76E−07	1.68E−06	0.283333333
650	459.6194078	250	200	5.74E−07	2.24E−06	0.25625
650	459.6194078	300	50	5.18E−07	6.72E−07	0.770833333
650	459.6194078	300	100	5.6E−07	1.34E−06	0.416666667
650	459.6194078	300	150	6.3E−07	2.02E−06	0.3125

[0055] It can be understood from Table 1 that when the number of large scattering portions existing per unit area is equal to that of small ones, the scattering efficiency of blue light is higher than that of red light. To balance the brightness of blue and red light, it is desirable that the ratio of the number of large scattering portions and that of small scattering portions per unit area should be set to from 5:1 to 1:1.

[0056] For example, the square-grating pattern shown in **FIG. 3** will be described in more detail. Assume here that L=650 nm, R_1=250 nm, R_2=100 nm, and the ratio of the number of large scattering portions and that of small scattering portion per unit area should be set to 1:1. In this case, I(red)/I(blue)=0.362, which means that the diffraction efficiency of blue light is substantially three times that of red light. From this, the relationship between the wavelength and the diffraction efficiency is as shown in **FIG. 4A**. As is evident from **FIG. 4A**, the diffraction efficiency is increased when the wavelengths of red and blue light are combined. Further, it is further increased by combining the wavelengths of red, blue and green light. Thus, all R, G and B light can be increased in brightness by the diffraction grating including two types of grating components.

[0057] Where R, G and B light are equal in brightness without grating, their brightness are enhanced using the above diffraction grating. However, the ratio of the brightness levels is R:G:B=0.363:0.363:1. To balance the brightness, it is sufficient if the ratio of the number of large scattering portions and that of small scattering portions per unit area is set to about 3:1. At this time, the diffraction efficiency of R light is increased, whereby the brightness of R, G and B light are made to be substantially equal as shown in **FIG. 4B**.

[0058] In the above, it is described that the diffraction grating shown in **FIG. 3** comprises two types of square grating components. The first-type square grating components are each formed of four large circles, and the second-type square grating components are each formed of four small circles. From another point of view, it can be described that the diffraction grating of **FIG. 3** is constructed in the following manner. That is, large and small circles as scattering portions are alternately arranged with a certain grating pitch ($L/\sqrt{2}$) in the X- and Y-directions. Groups of large circles each include four large circles and form a first square grating component, while groups of four small circles each include four small circles and form a second square grating component. Namely, in the diffraction grating of **FIG. 3**, scattering portions of two sizes are arranged at the four grating points of each square grating component of a certain grating pitch ($L/\sqrt{2}$), such that scattering portions of different sizes are arranged at adjacent grating points.

[0059] Referring now to **FIG. 5**, a brief description will be given of the diffraction efficiency of a triangular grating as another example of the diffraction grating having two types of triangular grating components. In the case of **FIG. 5**, the first-type triangular grating components are each formed of three large circles of a radius R_1, and the second-type triangular grating components are each formed of three small circles of a radius R_2. The distance between adjacent large circles is L, that between adjacent small circles is $L/\sqrt{3}$, and that between adjacent large and small circles is $L/\sqrt{3}$.

[0060] In this case, the diffraction efficiency of red light is given by

$$I(\text{red}) \propto L^{-4} \times 12R_1^2 \quad (4)$$

[0061] Similarly, the diffraction efficiency of red light is given by

$$I(\text{blue}) \propto (L/\sqrt{3})^{-4} \times (3R_2^2 + 9R_1 \times R_2) \quad (5)$$

[0062] Also in this case, even if the brightness of R light material is low, the brightness of R, G and B light can be balanced by appropriately setting L, R_1 and R_2 to appropriately set the diffraction efficiencies of red and blue light. The invention is not limited to the above-described grating including square grating components or triangular grating components. Other diffracting gratings of a two-dimensional structure, which include, for example, honeycomb-shaped grating components, may be employed.

[0063] As described above, in the embodiment, the diffraction grating **23** having two grating periods (e.g. L and $L/\sqrt{2}$, or L and $L/\sqrt{3}$), which appropriately corresponds to R, G and B light, is provided at the high-refractive-index layer **22** formed between the organic EL element **10** and the transparent electrode **20**. In this case, it is not necessary to provide respective diffraction gratings for R, G and B light, and it is sufficient if a single diffraction grating is provided on the entire display surface.

[0064] In other words, a diffraction grating that has grating components of sizes (grating intervals) corresponding to R, G and B light can be manufactured at a time, which can simplify the manufacturing process and reduce the manufacturing cost, resulting in realization of a cost-effective high-brightness organic EL display using a diffraction grating. Further, in the embodiment, the diffraction efficiency of R light can be enhanced by increasing the ratio of the number of diffraction grating components corresponding to R light to those of B and G light. As a result, the brightness of R, G and B light can be balanced, which suppresses the power consumption of the display and hence increases the lifetime of the display.

[0065] The uneven surface of the high-refractive-index layer in the organic EL display of **FIG. 1** is formed, for example, in the following manner.

[0066] Firstly, as shown in **FIG. 6A**, an electron-beam resist layer **60** is formed about 300 nm thick on a glass substrate **20**.

[0067] Subsequently, the resist layer **60** is drawn by an electron beam using a mask having two types of diffraction grating components as shown in **FIG. 3**. After that, the resultant structure is developed. As a result, the resist pattern **61** as shown in **FIG. 6B** is acquired.

[0068] Thereafter, using the developed resist pattern **61** as a mask, the glass substrate is dry etched by reactive ion etching (RIE) using CF4. After etching the structure by about 100 nm, the remaining resist pattern **61** is removed by ashing, thereby forming holes of two sizes (diffraction grating **21**) in the surface of the glass substrate **20**, as shown in **FIG. 6C**.

[0069] After that, as shown in **FIG. 6D**, an SiN film (high-refractive-index layer) **22** is deposited about 500 nm thick by plasma CVD (chemical vapor etching on the glass substrate **20** with the diffraction grating **21**. As a result, a diffraction grating **23** is formed as the surface of the SiN film **22**.

[0070] After that, an ITO film **11** is deposited on the SiN film **22** by sputtering, thereby forming an anode. Further, a hole injection layer **12**, an emission layer **13** and a cathode **14** are formed thereon by a evaporation method. Thus, an organic EL display having the two types of diffraction grating components as shown in **FIGS. 1 and 3** is acquired.

[0071] The hole injection layer **12** and emission layer **13** may be formed by spin coating, casting, etc. In this case, an organic or non-organic material is solved by a volatile solvent to thereby prepare a raw solution. A transparent substrate with an anode formed thereon is coated with the raw solution, while it is rotated as occasion demands. After that, the solvent is evaporated to acquire a thin film. The electron injection layer, which is not employed in the case of **FIG. 1**, is formed in the same manner as this.

[0072] The invention will be described in more detail, using examples. In the examples described below, to simply estimate the effect of enhancing the brightness of R, G and B light by the diffraction grating including two types of grating components, R, G and B organic EL elements of 1 cm^2 were formed on a substrate provided with the diffraction grating, and the resultant structure was compared with a structure with no diffraction grating.

EXAMPLE 1

[0073] An electron-beam resist layer **60** (EEP-301 produced by Fuji Film Corporation) was formed 300 nm thick on the glass substrate **20** (**FIG. 6A**). Subsequently, the resist layer **60** was processed by an electron-beam exposure apparatus equipped with a pattern generator and utilizing an acceleration voltage of 50 kV, thereby forming the pattern shown in **FIG. 3** (**FIG. 6B**). In this case, the pattern was designed such that L=650 nm, R_1=250 nm, R_2=100 nm and the ratio of the number of large scattering portions and that of small scattering portions per unit area was 1:1. After that, using the resultant structure as a mask, the glass substrate **20** was dry etched by RIE for two minutes at a pressure of 1.33 Pa (10 mTorr), a power of 100 W, and a CF_4 flow of 30 sccm. After RIE, the remaining resist was removed by θ_2 ashing (**FIG. 6C**). The etching depth was 100 nm.

[0074] Subsequently, an SiN film (n=1.9) **22** was formed 500 nm thick on the glass substrate **20** with the uneven pattern by plasma CVD (**FIG. 6D**). By this process, the surface of the SiN film was made flat. An ITO film **11** serving as an anode was formed 150 nm thick on the SiN film **22** by sputtering.

[**0075**] Thereafter, R, G and B organic EL elements were prepared in the following manner:

[**0076**] (R)

[**0077**] On the ITO film **11**, N,N'-diphenyl-N,N'-bis(3-methlfenyl)1-1'biphenyl-4,4'diamine (hereinafter referred to as "TPD") was deposited 50 nm thick by evaporation. A tris (8-hydroxyquinoline) aluminum (hereinafter referred to "Alq3") layer doped with 2% DCM 2 was deposited 100 nm thick on the resultant structure by evaporation. Lastly, an Mg:Ag (5%) electrode **14** was deposited 150 nm thick on the resultant structure by evaporation, thereby forming a red element. The peak wavelength of the light emitted from the red element was 650 nm.

[**0078**] (G)

[**0079**] TPD serving as the hole injection layer **12** was deposited 50 nm thick on the ITO film **11** by evaporation. On the layer **12**, Alq3 serving as the emission layer **13** was deposited 100 nm thick by evaporation. Lastly, an Mg:Ag (5%) electrode **14** was deposited 150 nm thick on the resultant structure by evaporation, thereby forming a green element. The peak wavelength of the light emitted from the green element was 530 nm.

[**0080**] (B)

[**0081**] Triphenylamine tetramer (TPTE) serving as the hole injection layer **12** was deposited 50 nm thick on the ITO film **11** by evaporation. On the layer **12**, a pyrene adamantan derivative serving as the emission layer **13** was deposited 100 nm thick by evaporation. Lastly, LiF(1 nm)/Al(150 nm) serving as an electrode **14** was deposited on the resultant structure by evaporation, thereby forming a blue element. The peak wavelength of the light emitted from the blue element was 450 nm.

[**0082**] It was confirmed that the brightness of the R, G and B elements with grating increased 1.3 times, 1.5 times, and 1.7 times compared with those without grating, respectively.

EXAMPLE 2

[**0083**] In the same manner as in example 1, an electron-beam resist layer **60** was formed on the glass substrate **20** and the pattern shown in **FIG. 3** was formed. Using this pattern as a mask, the glass substrate was dry etched by RIE for two minutes at a pressure of 1.33 Pa (10 mTorr), a power of 100 W, and a CF_4 flow of 30 sccm. After RIE, the remaining resist pattern **61** was removed by O_2 ashing. As a result, holes of two sizes (diffraction grating **21**) were formed in the surface of the glass substrate **20**. The etching depth was 100 nm.

[**0084**] Subsequently, as shown in **FIG. 7B**, an ITO film (n=1.9) **11** serving as a transparent electrode was formed 300 nm thick by sputtering on the glass substrate **20** with the uneven pattern. By this process, a diffraction grating **16** was formed as the lower surface of the ITO film **11**, and the surface of the ITO film **11** was made flat.

[**0085**] After that, as shown in **FIG. 7C**, the organic layer **13** and cathode **14** of each of R, G and B organic EL elements were formed by the same processes as in example 1.

[**0086**] It was confirmed that the brightness of the R, G and B elements with grating increased 1.25 times, 1.4 times, and 1.65 times compared with those without grating, respectively.

EXAMPLE 3

[**0087**] As shown in **FIG. 8A**, an SiN (n=1.9) film **82** was formed 200 nm thick on the glass substrate **20** by plasma CVD. On the film **82**, an electron-beam resist layer **60** was formed on the glass substrate **20** and the pattern was drawn by electron-beam, and the resist was developed. Thereby a resist pattern **61** having the pattern shown in **FIG. 3**, as in example 1 was formed.

[**0088**] Using the resist pattern **61** as a mask, the glass substrate was dry etched by RIE for ten minutes at a pressure of 1.33 Pa (10 mTorr), a power of 100 W, and a CF_4 flow of 30 sccm. After RIE, the remaining resist pattern **61** was removed by O_2 ashing. As a result, a diffraction pattern of the SiN film **82** having a thickness of 200 nm was formed as shown in **FIG. 8B**.

[**0089**] Subsequently, as shown in **FIG. 8C**, spin on glass (SOG) as organic silica while it is rotated at 2000 rpm was coated on the resultant structure, and then was baked at 150° C. Thereby an SOG film **83** with a thickness of 300 nm was formed. By this process, the surface of the film **83** was made flat.

[**0090**] Thereafter, the SOG film **83** was dry etched by RIE for three minutes at a pressure of 1.33 Pa (10 mTorr), a power of 100 W, and a CF_4 flow of 30 sccm, thereby exposing the surface of the SiN film **82**. As a result, a diffraction pattern of the SiN film **82** was formed as shown in **FIG. 8D**.

[**0091**] After that, the same processes as in example 1 were performed to form the anode **11**, hole injection layer **12**, organic (emission) layer **13** and cathode **14** of each of R, G and B organic EL elements. As a result, the organic EL display as shown in **FIG. 8E** was acquired.

[**0092**] It was confirmed that the brightness of the R, G and B elements with grating increased 1.5 times, 1.7 times, and 1.9 times compared with those without grating, respectively.

EXAMPLE 4

[**0093**] An electron-beam resist layer **60** (EEP-301 produced by Fuji Film Corporation) was formed 300 nm thick on the glass substrate **20** (**FIG. 6A**). Subsequently, the resist layer **60** was processed by an electron-beam exposure apparatus equipped with a pattern generator and utilizing an acceleration voltage of 50 kV, thereby forming the triangular-grating pattern shown in **FIG. 5** (**FIG. 6B**). Using this pattern as a mask, the glass substrate was dry etched by RIE for two minutes at a pressure of 1.33 Pa (10 mTorr), a power of 100 W, and a CF_4 flow of 30 sccm. After RIE, the remaining resist was removed by O_2 ashing (**FIG. 6C**). The etching depth was 100 nm.

[**0094**] Subsequently, an SiN film (n=1.9) **22** was formed 500 nm thick on the glass substrate **20** with the uneven pattern by plasma CVD (**FIG. 6D**). By this process, the surface of the SiN film was made flat. An ITO film **11** was formed 150 nm thick on the SiN film **22** by sputtering.

[0095] Thereafter, the hole injection layer **12**, organic (emission) layer **13** and cathode **14** of each of R, G and B organic EL elements were prepared by the same processes as in example 1.

[0096] It was confirmed that the brightness of the R, G and B elements with grating increased 1.3 times, 1.35 times, and 1.7 times compared with those without grating, respectively.

EXAMPLE 5

[0097] A description will be given of the control of the balance of R, G and B brightness.

[0098] If no diffraction grating is provided for the R, G and B organic EL elements of example 1, and the same power is applied to the elements, their brightness ratio is R:G:B=0.5:1:1.

[0099] As in the case of example 1, the electron-beam resist layer **60** was formed on the glass substrate **20**, and the resist pattern **61** was formed using the electron-beam exposure apparatus. The resultant diffraction pattern was similar to that shown in **FIG. 3**, but the ratio of the number of large scattering portions and that of small scattering portions per unit area was set to 3:1.

[0100] Using this pattern as a mask, the surface of the glass substrate **20** was dry etched by RIE for three minutes at a pressure of 1.33 Pa (10 mTorr), a power of 100 W and a CF_4 flow of 30 sccm. After RIE, the remaining resist pattern **61** was removed by O_2 ashing. The etching depth was 150 nm.

[0101] Subsequently, an SiN film (n=1.9) **22** was formed 500 nm thick on the glass substrate **20** with the uneven pattern by plasma CVD. By this process, the surface of the SiN film was made flat. An ITO film **11** was formed 150 nm thick on the SiN film **22** by sputtering. Thereafter, the hole injection layer **12**, organic (emission) layer **13** and cathode **14** of each of R, G and B organic EL elements were prepared by the same processes as in example 1.

[0102] It was confirmed that when the same power was supplied to the thus-acquired R, G and B elements, the ratio of the brightness was R:G:B=1:0.95:0.95. Thus, the use of the diffraction grating including two types of grating components significantly improves the balance of the brightness of the R, G and B elements.

[0103] (Modification)

[0104] The invention is not limited to the above-described embodiment. In the embodiment, the two-dimensional diffraction grating includes square or triangular grating components. However, other grating components may be employed. It is sufficient if the diffraction grating includes two types of grating components of different grating periods (pitches).

[0105] Further, the embodiment employs grating pitches of 650 nm and 460 nm (or 375 nm). However, it is sufficient if one of the two pitches corresponds to the wavelength of red light ranging from 600 nm to 700 nm, and the other pitch corresponds to the wavelength of blue, blue-violet or violet light of 350 nm to 460 nm. In addition, the ratio of the number of scattering portions corresponding to the longer pitch and that of small scattering portions corresponding to the shorter pitch may be changed in accordance with the specifications of the device. In general, this ratio may be selected from the range of 5:1 to 1:1.

[0106] The structure of the organic EL element is not limited to that of **FIG. 1**, and may be modified in accordance with the specifications.

[0107] Additional advantages and modifications or differences will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. An organic EL display comprising:

a transparent substrate having a surface;

an organic EL element provided on or above the surface of the transparent substrate and including a transparent electrode disposed on or beside the surface of the transparent substrate; and

a two-dimensional diffraction grating provided on the surface of the transparent substrate, and having two kinds of grating periods.

2. The organic EL display according to claim 1, wherein one of the two kinds of grating periods corresponds to light with a wavelength of 600 nm to 700 nm, and the other of the two kinds of grating periods corresponds to light with a wavelength of 350 nm to 460 nm.

3. The organic EL display according to claim 1, wherein the diffraction grating includes a plurality of square grating components or a plurality of triangular grating components.

4. The organic EL display according to claim 1, wherein the diffraction grating includes a first square grating component and a second square grating component, an averaged X-directional interval of the first square grating component being equal to an averaged Y-directional interval of the first square grating component, an averaged X-directional interval of the second square grating component and an averaged Y-directional interval thereof being substantially equal to the X-directional interval of the first square grating component and the Y-directional interval thereof, the second square grating component being deviated from the first square grating component by substantially half a grating period of the first square grating component in an X-direction and a Y-direction.

5. The organic EL display according to claim 4, wherein the first square grating component and the second square grating component include respective scattering portions arranged in the X-direction and the Y-direction with the averaged X-directional interval and the averaged Y-directional interval, the scattering portions of the first square grating component having a size different from a size of the scattering portions of the second square grating component.

6. The organic EL display according to claim 1, wherein the diffraction grating includes scattering portions of two sizes provided at grating points arranged with regular X-directional intervals and regular Y-directional intervals, the scattering portions of the two sizes being alternately arranged at adjacent ones of the grating points.

7. The organic EL display according to claim 6, wherein a ratio of number of first scattering portions included in the scattering portions to a ratio of number of second scattering portions included in the scattering portions is set to 5:1 to 1:1, the first scattering portions being larger than the second scattering portions.

8. The organic EL display according to claim 1, wherein the diffraction grating is formed of a concavo-convex surface formed on the surface of the transparent substrate.

9. The organic EL display according to claim 1, wherein the organic EL element is formed of a hole injection layer formed on the transparent electrode as an anode, an organic film formed as an emission layer on the hole injection layer, and a cathode formed on the organic film.

10. An organic EL display comprising:

a transparent substrate comprising a surface;

a buffer layer provided on or above the surface of the transparent substrate and including a two-dimensional diffraction grating having two kinds of grating periods on or beside the surface of the transparent substrate; and

an organic EL element provided on or above the buffer layer and including a transparent electrode, the transparent electrode having a refractive index substantially equal to that of the buffer layer and formed on or beside the buffer layer.

11. The organic EL display according to claim 10, wherein one of the two kinds of grating periods corresponds to light with a wavelength of 600 nm to 700 nm, and the other corresponds to light with a wavelength of 350 nm to 460 nm.

12. The organic EL display according to claim 10, wherein the diffraction grating includes a plurality of square grating components or a plurality of triangular grating components.

13. The organic EL display according to claim 10, wherein the diffraction grating includes a first square grating component and a second square grating component, an averaged X-directional interval of the first square grating component being substantially equal to an averaged Y-directional interval of the first square grating component, an averaged X-directional interval of the second square grating component and an averaged Y-directional interval thereof being substantially equal to the X-directional interval of the first square grating component and the Y-directional interval thereof, the second square grating component being deviated from the first square grating component by substantially half a grating period of the first square grating component in an X-direction and a Y-direction.

14. The organic EL display according to claim 13, wherein the first square grating component and the second square grating component include respective scattering portions arranged in the X-direction and the Y-direction with the averaged X-directional interval and the averaged Y-directional interval, the scattering portions of the first square grating component having a size different from a size of the scattering portions of the second square grating component.

15. The organic EL display according to claim 10, wherein the diffraction grating includes scattering portions of two sizes provided at grating points arranged with regular X-directional intervals and regular Y-directional intervals, the scattering portions of the two sizes being alternately arranged at adjacent ones of the grating points.

16. The organic EL display according to claim 15, wherein a ratio of number of first scattering portions included in the scattering portions to number of second scattering portions included in the scattering portions is set to 5:1 to 1:1, the first scattering portions being larger than the second scattering portions.

17. The organic EL display according to claim 10, wherein the diffraction grating is formed by an interface between a concavo-convex surface formed on the surface of the transparent substrate and the buffer layer deposited on the concavo-convex surface of the transparent substrate.

18. The organic EL display according to claim 10, wherein the organic EL element is formed of an hole injection layer formed on the transparent electrode as an anode, an organic film formed as an emission layer on the hole injection layer, and a cathode formed on the organic film.

19. An organic EL display comprising:

a transparent substrate having a surface formed in concavo-convex shape to form a two-dimensional diffraction grating having two kinds of grating periods;

a buffer layer deposited on or above the surface of the transparent substrate, and including a concavo-convex surface having a reversed concavo-convex pattern of the concavo-convex shape of the surface of the transparent substrate and a flat surface opposite to the concavo-convex surface; and

an organic EL element provided on or above the buffer layer and including a transparent electrode, the transparent electrode having a refractive index substantially equal to that of the buffer layer and formed on or beside the buffer layer.

20. The organic EL display according to claim 19, wherein the diffraction grating of the buffer layer includes a first square grating component and a second square grating component, an averaged X-directional interval of the first square grating component being equal to an averaged Y-directional interval of the first square grating component, an averaged X-directional interval of the second square grating component and an averaged Y-directional interval thereof being substantially equal to the averaged X-directional interval of the first square grating component and the averaged Y-directional interval thereof, the second square grating component being deviated from the first square grating component by substantially half a grating period of the first square grating component in an X-direction and a Y-direction.

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摘要(译)

在具有透明基板，设置在透明基板上的缓冲层和设置在缓冲层上的有机EL元件的有机EL显示器中，缓冲层由具有与透明电极相同的折射率的材料形成。 EL元件，具有两个光栅周期的二维衍射光栅。