

CERTIFICATE OF TRANSLATION ACCURACY

I am a professional reviewer and editor specializing in translating Japanese, Korean, and Chinese to English and vice versa.

I served as Chief Examiner of the certified court interpreter test for the State of California and as a translator and interpreter for various federal agencies through the U.S. Department of State for more than a decade. I served as an instructor at the University of California at Berkeley and the Middlebury Institute of International Studies at Monterey (MIIS) Graduate Program in Translation.

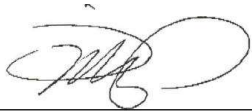
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I certify under penalty of perjury that the foregoing is true and correct.

Executed this 28th day of April 2024 in Contra Costa County of the State of California.

By:



Alex N. Jo
Member, ATA

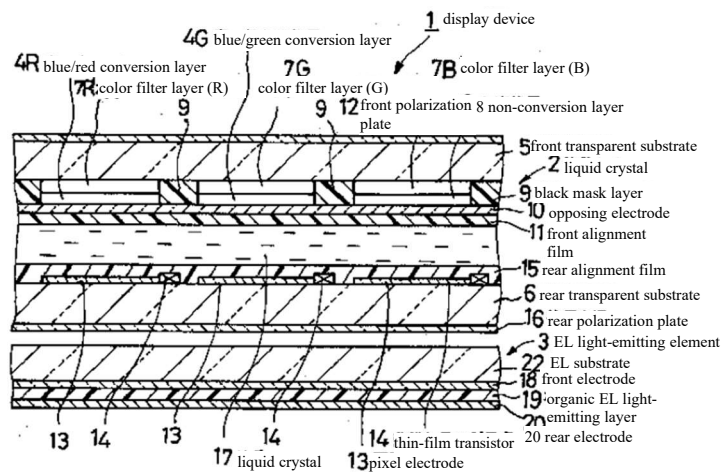
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						CASIO COMPUTER CO., LTD.		
						1-6-2 Honmachi, Shibuya-ku, Tokyo		
						(72) Inventor:		
						Masaharu Shiotani		
						% CASIO COMPUTER CO., LTD.		
						Ome Operations Center		
						3-10-6 Imai, Ome, Tokyo		
						(72) Inventor:		
						Tomoyuki Shirasaki		
						% CASIO COMPUTER CO., LTD.		
						Ome Operations Center		
						3-10-6 Imai, Ome, Tokyo		
						(72) Inventor:		
						Hiroyasu Yamada		
						% CASIO COMPUTER CO., LTD.		
						Ome Operations Center		
						3-10-6 Imai, Ome, Tokyo		
						(74) Attorney or Agent:		
						Jiro Sugimura, patent attorney		

(54) (TITLE) **DISPLAY DEVICE**

(57) (ABSTRACT)

(PROBLEM) To provide a display device capable of color display with high light energy utilization efficiency and low power consumption.

(MEANS TO SOLVE THE PROBLEM) An EL light-emitting element 3 that emits surface light is arranged behind a liquid crystal cell 2. A rear electrode 20 of the EL light-emitting element 3 is light-reflective and reflects external light. A color filter layer 7R that transmits only red light, a color filter layer 7G for green, and a color filter layer 7B for blue are arranged on the front transparent substrate 5 side, and a blue/red conversion layer 4R, a blue/green conversion layer 4G, and a non-conversion layer 8 are laminated so as to correspond, respectively, to the color filter layers. This configuration enables color display with high reflection efficiency by reflecting external light. Also, in the case of transmissive display, the color conversion layer efficiently transmits the light generated by the EL light-emitting element 3, thus enabling display with high light energy utilization efficiency.



(CLAIMS)

(CLAIM 1) A display device provided with an electrode that forms, on the opposing inside surfaces of relatively opposing front and rear substrates, a pixel region mutually opposing the other substrate side, and with a liquid crystal cell in which liquid crystal is sealed in a gap between the substrates, wherein a light-emitting layer is provided that receives light in a prescribed wavelength band and emits light in a longer wavelength band.

(CLAIM 2) The display device set forth in claim 1 characterized in that the light-emitting layer is arranged at each prescribed pixel region.

(CLAIM 3) The display device set forth in claim 2 characterized in that a color filter layer is arranged at each of the pixel regions and a color light-emitting [*sic*: a light-emitting] layer is arranged behind the color filter layer.

(CLAIM 4) The display device set forth in any of claims 1 to 3 characterized in being equipped with a reflecting plate that reflects external light and emits that light as display light.

(CLAIM 5) The display device set forth in any of claims 1 to 4 characterized in that a backlight is arranged behind the liquid crystal cell.

(CLAIM 6) The display device set forth in claim 5 characterized in that the backlight is an EL light-emitting element.

(CLAIM 7) The display device set forth in claim 5 or 6 characterized in that the reflection plate is arranged at the rear of the backlight.

(CLAIM 8) The display device set forth in claim 6 characterized in that the EL light-emitting element comprises an EL light-emitting layer sandwiched between a front electrode having light transmissivity and a rear electrode.

(CLAIM 9) The display device set forth in claim 8 characterized in that the reflection plate is the rear electrode and the front electrode is transparent.

(CLAIM 10) The display device set forth in claim 8 or 9 characterized in that the EL light-emitting layer is made of an organic EL material.

(CLAIM 11) The display device set forth in any of claims 1 to 10 characterized in that the color filter layer and the light-emitting layer are arranged on the front substrate side.

(CLAIM 12) The display device set forth in any of claims 1 to 10 characterized in that the color filter layer and the light-emitting layer are arranged on the rear substrate side.

(CLAIM 13) The display device set forth in any of claims 5 to 10 characterized in that the backlight emits blue light and the light-emitting layer comprises a red light-emitting layer that receives blue light and emits red light and a green light-emitting layer that receives blue light and emits green light.

(CLAIM 14) The display device set forth in any of claims 5 to 12 characterized in that the backlight emits light containing ultraviolet light, and the light-emitting layer comprises a red light-emitting layer that receives ultraviolet light and emits red light and a green light-emitting layer that receives ultraviolet light and emits green light.

(DETAILED DESCRIPTION OF THE INVENTION)

(0001)

(TECHNICAL FIELD) The present invention relates to a display device, and in further detail, relates to a liquid crystal display device provided with a color conversion layer capable of color display, which can be used for both reflective and transmissive applications.

(PRIOR ART AND PROBLEM THE INVENTION IS TO SOLVE)

(0002) Examples of conventional reflective display devices capable of color display include a liquid crystal display device that displays color using an elliptical polarization effect based on the birefringence of liquid crystal without using a color filter, and a liquid crystal display device provided with a color filter in the liquid crystal cell to spectrally display reflected light in color. These reflective display devices are provided with a reflector at the rear and use the reflection of external light for display. However, such liquid crystal displays have the problems of low display luminance and poor visibility in dark locations.

(0003) Therefore, as a liquid crystal display device that can be selectively used in a reflective or transmissive application, a liquid crystal display having a semi-transmissive, semi-reflective plate between the liquid crystal cell and the backlight has been proposed. In addition to this, a liquid crystal display using a backlight in which a sidelight is arranged on the side of the light-guiding reflecting plate is also known. Backlights that generate white light are used in these liquid crystal display devices.

(0004) However, the liquid crystal display having a semi-transmissive, semi-reflective plate has the problem that the reflection intensity of light and the transmittance of light from the backlight are lower than in a liquid crystal display device exclusively for reflective applications. In the case of the liquid crystal display using a backlight, since the light guide plate is imparted with reflective characteristics, there is the problem that the backlight becomes thicker, which is contrary to the compactness of the device. In addition, in these liquid crystal devices, it was extremely difficult to achieve both reflectance in reflective displays and transmittance in transmissive displays. Furthermore, when color filters are combined with these liquid crystal devices, white light from the white light source is selectively absorbed by wavelength components other than R, G, and B when passing through the R, G, and B color filters, producing a color display, such that there is the problems of extremely low luminance of the displayed light compared to the luminance of the white light from the backlight and low light transmission efficiency.

(0005) The problem to be solved by the present invention is how to obtain a display device capable of multicolor display with high light energy utilization efficiency and low power consumption.

(0006)

(PROBLEM THE INVENTION IS TO SOLVE) The invention set forth in claim 1 is characterized by a display device provided with an electrode that forms, on the opposing inside surfaces of relatively opposing front and rear substrates, a pixel region mutually opposing the other substrate side and with a liquid crystal cell in which liquid crystal is sealed in a gap between the substrates, wherein a light-emitting layer that receives light in a prescribed wavelength band and emits light in a longer wavelength band. The invention set forth in claim 2 is characterized in that the light-emitting layer is arranged at each prescribed pixel region.

(0007) In the inventions set forth in claims 1 and 2, the color of the display light emitted from a prescribed pixel region can be set in a light-emitting layer by wavelength conversion of light from a light source such as, for example, a backlight or external light. Since the light-emitting layer is used to set the color, absorption of the light source or external light in each pixel region can be suppressed. Therefore, energy loss in each pixel region can be suppressed.

(0008) The invention set forth in claim 3 is characterized in that a color filter layer is arranged at each of the pixel regions and a light-emitting layer is arranged behind the color filter layer. In the invention set forth in claim 3, the color purity can be improved by passing light through the light-emitting layer, color converting, and passing the result through the color filter layer.

(0009) The invention set forth in claim 4 is characterized in being equipped with a reflecting plate that reflects external light and emits it as display light. In the invention set forth in claim 4, the color of the display light can be changed by converting the external light wavelength with the color conversion layer, and color display can be performed.

(0010) The invention set forth in claim 5 is characterized in that a backlight is arranged behind the liquid crystal cell. In the invention set forth in claim 5, light from the backlight is wavelength-converted in the color conversion layer to set the color of the display light emitted from the predetermined pixel region, enabling color display.

(0011) The invention set forth in claim 6 is characterized in that the backlight is an EL light-emitting element. In the invention set forth in claim 6, the backlight is composed of an EL light-emitting element, thereby making the entire device thinner.

(0012) The invention set forth in claim 7 is characterized in that the reflection plate is arranged at the rear of the backlight. In the invention set forth in claim 7, for use as a reflective display device, external light is transmitted through the backlight, reflected by the reflection plate and passed through the color conversion layer, and the display light is converted to a predetermined color and emitted. Here, since light absorption in the color conversion layer is small, the light energy utilization efficiency can be improved.

(0013) The invention set forth in claim 8 is characterized in that the EL light-emitting element comprises an EL light-emitting layer sandwiched between a front electrode and a rear electrode. The invention set forth in claim 9 is characterized in that the reflection plate is the rear electrode and the front electrode is transparent. The invention set forth in claim 10 is characterized in that the EL light-emitting layer is made of an organic EL material. In these inventions, the rear electrode of the EL light-emitting element is used as a reflecting plate, allowing external light to pass through the front electrode and EL light-emitting layer and be reflected by the rear electrode, thus making it possible to construct a reflective liquid crystal display device. In dark areas, the EL light-emitting element can be driven for use as a transmissive liquid crystal display device.

(0014) The invention set forth in claim 11 is characterized in that the color filter layer and the light-emitting layer are arranged on the front substrate side. The invention set forth in claim 12 is characterized in that the color filter layer and the light-emitting layer are arranged on the rear substrate side.

(0015) The invention set forth in claim 13 is characterized in that the backlight emits blue light and the light-emitting layer comprises a red light-emitting layer that receives blue light and emits red light

and a green light-emitting layer that receives blue light and emits green light.

(0016) The invention set forth in claim 14 is characterized in that the backlight emits light containing ultraviolet light, and the light-emitting layer comprises a red light-emitting layer that receives ultraviolet light and emits red light and a green light-emitting layer that receives ultraviolet light and emits green light.

(0017)

(EMBODIMENTS) The display device according to the invention is described below in detail on the basis of the embodiments shown in the drawings.

(EMBODIMENT 1) FIG. 1 is a cross-sectional view of an embodiment 1 of the display device according to the present invention. In the drawing, 1 is a display device, which is roughly composed of a liquid crystal cell 2 and an EL light-emitting element 3 as a backlight, and the liquid crystal cell 2 is provided with color conversion layers 4 (4R, 4G) in a predetermined arrangement.

(0018) FIG. 1 is used to describe the structure of liquid crystal cell 2. The liquid crystal cell 2 has a front transparent substrate 5 and a rear transparent substrate 6 that face each other, and a plurality of pixel regions are set within the display area. On the rear surface of the front transparent substrate 5, color filter layers 7 (7R, 7G, 7B) are arranged corresponding to the pixel regions. The color filter layer 7R transmits light in the red wavelength region and absorbs light in other wavelength regions when light containing light in the red wavelength region is incident, the color filter layer 7G transmits light in the green wavelength region and absorbs light in other wavelength regions when light containing light in the green wavelength region is incident, and the color filter layer 7B transmits light in the blue wavelength region and absorbs light in other wavelength regions when light containing light in the blue wavelength region is incident. The blue/red conversion layer 4R is arranged on the rear surface of the color filter layer 7R, the blue/green conversion layer 4G is arranged on the rear surface of the color filter layer 7G, and the non-conversion layer 8 is arranged on the rear surface of the color filter layer 7B. The blue/red conversion layer 4R is excited when light in the blue wavelength range is incident and emits light in the red wavelength region with luminance corresponding to the amount of light in the blue wavelength region, the blue/green conversion layer 4G is excited when light in the blue wavelength range is incident and emits light in the green wavelength region with luminance corresponding to the amount of light in the blue wavelength region, and the non-conversion layer 8 shows transparency in the blue wavelength region. Here, the amount of light in the blue wavelength range depends on the wavelength region, the luminance, and the incident time of the light. Furthermore, as shown in FIG. 1, between the pixel regions where each of these color filter layers 7 and the color conversion layers 4 are formed, the color conversion layers 4 and color filter layers 7 are shielded from each other. For example, a black mask layer 9 made of resin is formed. On the rear surface of each color conversion layer 4, the non-conversion layer 8 and the black mask layer 9, an opposing electrode 10 made of ITO is formed across the entire display region. In addition, a front alignment film 11 is formed on the rear surface of the front transparent electrode 10. A front polarizer 12 is arranged on the front surface of the front transparent substrate 5.

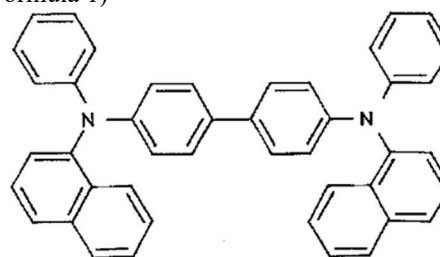
(0019) On the front side of the rear transparent substrate 6, a plurality of pixel electrodes 13 made of ITO are formed corresponding to the color conversion layers 4 and the non-conversion layer 8 formed in each pixel region on the front transparent substrate 5 side described above. Also, a thin-film transistor 14 as a switching element is formed to connect to each of the pixel electrodes 13. Although not shown in the figure, the thin-film transistor 14 has a so-called bottom-gate structure of the reverse staggered type. On the front surface of the rear transparent substrate 6 on which the pixel electrodes 13 and the thin-film transistors 14 are formed in a matrix, a rear alignment film 15 is formed over the entire display region. A rear polarizing plate 16, which is a counterpart to the front polarizing plate 12 described above, is arranged on the rear side of the rear transparent substrate 6.

(0020) The front transparent substrate 5 side and the rear transparent substrate 6 side are interposed therebetween with a spacer (not shown) and are sealed with a sealant (not shown) around the display region so that the alignment films 11 and 15 face each other through a predetermined gap, and liquid crystal 17 is sealed in the gap between the two substrates to form the liquid crystal cell 2.

(0021) Next, we the configuration of the EL light-emitting element 3 is described. As shown in FIG. 1, the EL light-emitting element 3 is formed by sequentially laminating a front electrode 18 made of transparent ITO, an organic EL light-emitting layer 19, and a light-reflective rear electrode 20 across the entire display region on the rear surface of an EL substrate 22 made of transparent glass.

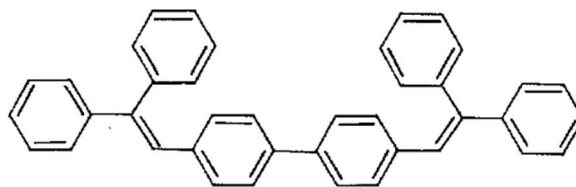
(0022) Here, the organic EL light-emitting layer 19 is formed of an organic EL material that generates blue light when a predetermined voltage is applied between the front and rear electrodes 18 and 20. The organic EL light-emitting layer 19 is configured from three layers which are, in order from the front electrode 18 side, a hole transport layer comprising N, N'-di(α -naphthyl)-N, N'-diphenyl-1, 1'-biphenyl-4, 4'-diamine (hereinafter α -NPD), a light-emitting layer comprising 4, 4'-bis(2, 2'-diphenylvinylene)biphenyl (hereinafter DPVBi) of 96 wt% and 4, 4'-bis(2-carbazolevinylene)biphenyl (hereinafter BCzVBi) of 4 wt%, and an electron transport layer comprising tris(8-hydroxyquinoline)aluminum (hereinafter Alq3). The structural formulas of α -NPD, DPVBi, BCzVBi, and Alq3 are shown below.

(Formula 1)



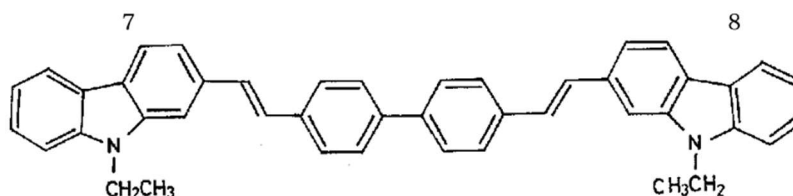
α -NPD

(Formula 2)



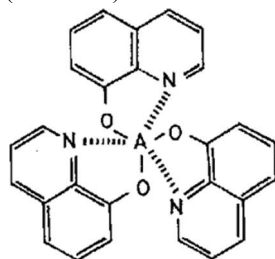
DPVBi

(Formula 3)



BCzVBi

(Formula 4)



Alq3

As for the organic EL light-emitting layer 19, various structures can be applied such as a single-layer structure or a multiple-layer laminated structure as long as blue light is generated.

(0023)

The rear electrode 20 is formed of a light-reflective material with a low work function, such as AlLi or MgIn. The rear electrode 20 is preferably covered with a protective film to prevent oxidation.

(0024) Now that the configuration of the display device 1 in the present embodiment has been described, the action of the embodiment is described with reference to the illustrations shown in FIG. 2 and FIG. 3. FIG. 2 is an illustration of the display device 1 used in a reflective display, and FIG. 3 is an illustration of the display device 1 used in a transmissive display.

(0025) (Reflective display) First, the case where the display device 1 is used in a reflective display is described with reference to FIG. 2. The color filter layers 7R, 7G, and 7B limit the incident light wavelength bandwidth of a (white) light flux L incident from the outside, such as external light, and only the red (R) light component LR passes through the color filter layer 7R, the green (G) light component LG passes through the color filter layer 7G, and the blue (B) light component LB passes through the color filter layer 7B.

(0026) Light incident from each of these color filter layers to the corresponding blue/red conversion layer 4R, blue/green conversion layer 4G, and non-conversion layer 8 transmits through these layers with sufficiently high efficiency. In other words, since the blue/red conversion layer 4R absorbs only the blue light band, a red light component LR1 can be efficiently transmitted. Also, since the blue/green conversion layer 4G absorbs only the blue light band, the green light component LG1 can be efficiently transmitted. Furthermore, the blue light component LB1 can be transmitted through the non-conversion layer 8 with almost no loss.

(0027) The red light component LR1 and the green light component LG1 are light in the wavelength region where light that excites the

blue/red conversion layer 4R and the blue/green conversion layer 4G is absorbed by the color filters 7R and 7G, respectively, so the blue/red conversion layer 4R and the blue/green conversion layer 4G do not emit light due to the incident light L. The light components LR2, LG2, and LB2 that pass through the blue/red conversion layer 4R, the blue/green conversion layer 4G, and the non-conversion layer 8 reach the rear electrode 20 following the liquid crystal 17 and the rear polarizing plate 16 arranged according to the voltage corresponding to the respective pixel electrodes 13, and light components LR3, LG3, and LB3 are reflected by the rear electrode 20 to again pass through the rear polarization plate 16 and the liquid crystal 17 and reach the blue/red conversion layer 4R, the blue/green conversion layer 4G, and the non-conversion layer 8, respectively, but do not emit light because there is practically no light in the wavelength range that excites the blue/red conversion layer 4R and the blue/green conversion layer 4G. Light components LR4, LG4, and LB4 that pass through the blue/red conversion layer 4R, the blue/green conversion layer 4G, and the non-conversion layer 8 reach the color filters 7R, 7G, and 7B unchanged, and light components LR5, LG5, and LB5 have their color level determined substantially by the spectral effects of the color filters 7R, 7G, and 7B, respectively, and a mixture of each color component can be displayed by modulating the electric field in each pixel portion of the liquid crystal cell 2. In particular, by controlling the gradation of each color component, a wide chromaticity range can be achieved. In the EL light-emitting element 3, the EL substrate 22, the front electrode 18, and the organic EL light-emitting layer 19 are extremely thin and have high transmissivity of visible light, so there is little loss due to absorption of light by these members and favorable reflection is possible. In addition, since each color conversion layer does not emit light in response to the external light L, the luminance at the time of dark display can be set to remain at a low level.

(0028) (Transmissive display) Next, the display is described with reference to FIG. 3 when the display device 1 is used in transmissive display, that is, when the EL light-emitting element 3 is used as the backlight of the liquid crystal cell 2. When a predetermined voltage is applied between the front electrode 18 and the rear electrode 20 of the EL element 3, the organic EL light-emitting layer 19 emits a light component LB0 that excites the blue/red conversion layer 4R, a light component LA1 that does not excite the blue/red conversion layer 4R, and a blue light component LB0 and a light component LA1 in a slightly different wavelength range over the entire display region. This blue light LB0 enters the blue/red conversion

layer 4R through the polarizing action of the liquid crystal 17 and the rear polarizing plate 16, and is converted to the long wavelength side for emission as a red light L_{R6} to the color filter layer 7R side. The blue/red conversion layer 4R emits a very small amount of light in another wavelength L_{A2} and the light component L_{A1} transmitted without absorption along with the red light L_{R6} . When the red light L_{R6} , the light component L_{A2} , and the light component L_{A1} enter the color filter layer 7R, these lights undergo some spectral shaping (absorption of components other than R) and are emitted forward as a red light L_{R7} with excellent color purity. In other words, the color filter layer 7R absorbs a part of the light component L_{R6} in addition to the light component L_{A1} emitted by the EL light-emitting element 3 and the light component L_{A2} emitted by the blue/red conversion layer 4R, and emits a red light component L_{R7} with high red color purity. As the light component L_{R6} incident on the color filter layer 7R thus contains a high proportion of light in the red wavelength range, it is possible to maintain color purity and achieve a higher transmittance than white light, i.e., a display with higher purity. Energy loss in this pixel region can be kept low. As shown in FIG. 3, the color conversion efficiency of the blue/red conversion layer 4R is as high as 3.0, and the light intensity of the emitted light component L_{R7} is comparable to that of the EL light-emitting element 3.

(0029) In the blue/green conversion layer 4G, the light components ($L_{B0'}$ and $L_{A1'}$) from the EL emitting element 3 are incident. Here, the light component $L_{B1'}$ is a light component that excites the blue/green conversion layer 4G, and the light component $L_{A1'}$ is a light component that does not excite the blue/green conversion layer 4G. The blue light $L_{B0'}$ is converted to the long wavelength side in this blue/green conversion layer 4G and emitted as a green light L_{G6} to the color filter layer 7G side. The light component $L_{A1'}$ passes through the blue/green conversion layer 4G substantially unabsorbed. A very small amount of light L_{A3} in other wavelength ranges is also emitted from the blue/red conversion layer 4R. When the green light L_{G6} , the light L_{A3} , and the light $L_{A1'}$ enter the color filter layer 7G, these lights undergo some spectral shaping (absorption of components other than G) and are emitted forward as a green light L_{G7} with excellent color purity. In other words, the color filter layer 7G absorbs a portion of the light component L_{G6} in addition to the light component $L_{A1'}$ emitted by the EL light-emitting element 3 and the light component L_{A3} emitted by the blue/green conversion layer 4G, and emits a green light component L_{G7} with high green color purity. As the light component L_{G6} incident on the color filter layer 7G thus contains a high proportion of light in the red wavelength range, it is possible to maintain color purity and achieve higher transmittance than white light, i.e., a display with higher purity. Energy loss in this pixel region can be kept low. As shown in FIG. 3, the color conversion efficiency of the EL light-emitting element 3 and the blue/green conversion layer 4G is as high as 5.1, and [the light intensity of the emitted light component L_{G7}] is comparable to that of the EL light-emitting element 3.

(0030) Furthermore, the light components $L_{B0''}$ and $L_{A1''}$ from the EL light-emitting element 3 incident on the non-conversion layer 8 enter the color filter layer 7B unchanged and are emitted after removal of some light components ($L_{A1''}$) other than the B component. Therefore, the loss of light energy is naturally kept low. As the light component L_{B6} incident on the color filter layer 7B contains a high proportion of light in the blue wavelength range, it is possible to maintain color purity and achieve higher transmittance

than white light, i.e., a display with higher purity. Incidentally, since (light component $L_{B0} + \text{light component } L_{A1}$), (light component $L_{B0'} + \text{light component } L_{A1'}$), and (light component $L_{B0''} + \text{light component } L_{A1''}$) are identical to each other, the front electrode 18, organic EL light-emitting layer 19, and the rear electrode 20 do not need to be patterned to emit different light according to the pixel electrode 13.

(0031) Thus, it is clear that even in transmissive display, the colors of each pixel can be mixed and displayed by modulating the electric field of the liquid crystal cell 2. In particular, a wide chromaticity range can be achieved by controlling the gradation of each color.

(0032) As described above, in the display device 1 of the present embodiment, the light-emission energy from the EL light-emitting element 3 is converted into color components that match the respective regions of the color filter layers 7R, 7G, and 7B, thereby increasing the light energy utilization efficiency. In the liquid crystal cell 2, the opposing electrode 10 and the pixel electrode 13 are formed directly under the front alignment film 11 and the rear alignment film 15, respectively, making it easy to apply an electric field to the liquid crystal 17, and thus making it possible to reduce the drive voltage. In the present embodiment, the color filter layers 7R, 7G, and 7B, the color conversion layers 4R and 4G, and the non-conversion layer 8 are between the front transparent substrate 5 and the opposing electrode 10, but may also be between the opposing electrode 10 and the front alignment film 11.

(0033) (Embodiment 2) FIG. 4 is a cross-section view showing embodiment 2 of the display device according to the present invention. In the present embodiment, the color conversion layer 4, the non-conversion layer 8, and the color filter 7 are arranged on the rear transparent substrate 6 side in the configuration of embodiment 1 described above. A protective film 21 is interposed between the color filter layer 7, the pixel electrode 13, and the thin-film transistor 14. Other configurations, actions, operations, and effects are similar to those in embodiment 1 above, and are not described here. In the present embodiment, the color filter layers 7R, 7G, and 7B, the color conversion layers 4R and 4G, and the non-conversion layer 8 are between the rear transparent substrate 6 and the pixel electrode 13, but may also be between the front transparent substrate 5 and the opposing electrode 10 or between the pixel electrode 13 and the rear alignment film 15.

(0034) (Embodiment 3) FIG. 5 is a cross-section view of embodiment 3 of the display device according to the present invention. In the present embodiment, the EL light-emitting element 3, as a backlight, generates light including blue light in the ultraviolet light. The color conversion layer and the color filter layer are formed on the rear transparent substrate 22 side. In particular, the color conversion layer is set so as to function differently from in embodiment 1 described above. In further detail, an ultraviolet/red conversion layer 23R that converts ultraviolet light to red light and a color filter layer 7R that transmits only red light components are laminated and formed on the rear transparent substrate 22 in the blue pixel region. An ultraviolet/green conversion layer 23G that converts ultraviolet light to green light and a color filter layer 7G that transmits only green light components are laminated and formed on the rear transparent substrate 22 in the green pixel region. An ultraviolet/blue conversion layer 23B that converts ultraviolet light to blue light and a color filter layer 7B that transmits only blue light components are laminated and formed on the rear transparent substrate 22 in the blue pixel region. Otherwise, the configuration is the same as in embodiment 2 above, so the description is omitted.

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(0035)

Next, the action of the display device of the present embodiment is described with reference to FIG. 6.

(Transmissive display) First, as shown in the drawing, when light L_{EL} generated from the EL element 3 enters the ultraviolet/red conversion layer 23R, the light L_{EL} is converted to the long wavelength side and red light L_{R1} is emitted toward the color filter layer 7R. The color filter layer 7R enhances the color purity of red light L_{R8} . When the light L_{EL} generated from the EL element 3 enters the ultraviolet/green conversion layer 23G, the light L_{EL} is converted to the long wavelength side and green light L_{G8} is emitted toward the color filter layer 7G. The color filter layer 7G enhances the color purity of green light L_{G8} . When the light L_{EL} generated from the EL element 3 enters the ultraviolet/blue conversion layer 23B, the light L_{EL} is converted to the long wavelength side and blue light L_{B8} is emitted toward the color filter layer 7B. The color filter layer 7B enhances the color purity of blue light L_{B8} . The light-emission energy from the EL light-emitting element 3 is converted into color components that match the regions of the color filter layers 7R, 7G, and 7B, thus increasing the light energy utilization efficiency. In the liquid crystal cell 2, the opposing electrode 10 and the pixel electrode 13 are formed directly under the front alignment film 11 and the rear alignment film 15, respectively, which makes it easy to apply an electric field to the liquid crystal 17, thus making it possible to reduce the drive voltage.

(0036) (Reflective display) In the present embodiment, the color filter layers 7R, 7G, and 7B transmit only the respective R, G, and B components to the corresponding color conversion layers 23R, 23G, and 23B, so even if the external incoming light contains ultraviolet light, little ultraviolet light enters the color conversion layers and is emitted by the color conversion layers. Therefore the luminance can be set to remain low during dark display. Since light absorption in the color conversion layers is limited to the ultraviolet band, the R, G, and B components can be efficiently transmitted.

(0037) In the present embodiment, the light-emission energy from the EL light-emitting element 3 is converted into color components that match the regions of the color filter layers 7R, 7G, and 7B, thus increasing the light energy utilization efficiency. In the liquid crystal cell 2, the opposing electrode 10 and the pixel electrode 13 are formed directly under the front alignment film 11 and the rear alignment film 15, respectively, which makes it easy to apply an electric field to the liquid crystal 17, thus making it possible to reduce the drive voltage. In addition, since each color conversion layer consists of a material that converts wavelengths to the long wavelength side, a wider range of fluorescent dyes can be selected.

(0038) In embodiment 3, the color filter layers 7R, 7G, and 7B and the color conversion layers 23R, 23G, and 23B are between the rear transparent substrate 6 and the pixel electrode 13, but may be between the pixel electrode 13 and the rear alignment film 15, between the front transparent substrate 5 and the opposing electrode

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10, or between the opposing electrode 10 and the front alignment film 11.

(0039) (Embodiment 4) FIG. 7 is a cross-section view showing an embodiment 4 of the display device according to the present invention. In the present embodiment, only yellow (Y), magenta (M), and cyan (C) are used as color filter layers for transmission, and blue light excitation is used for a color conversion layer. Since the configuration of other parts is the same as that in embodiment 1, the same symbols are used and descriptions are omitted.

(0040) Three types of color filter layers are arranged in this embodiment: a color filter layer 24Y that transmits only the Y component; a color filter layer 24M that transmits only the M component; and a color filter layer 24C that transmits only the C component. Three types of color conversion layers are arranged: a color conversion layer 25Y that converts the B (blue) component light into Y component light; a color conversion layer 25M that converts the B component light into M component light; and a color conversion layer 25C that converts the B component light into C component light. As shown in the figure, the color filter layer 24Y and the color conversion layer 25Y are laminated, the color filter layer 24M and the color conversion layer 25M are laminated, and the color filter layer 24C and the color conversion layer 25C are laminated.

(0041) Here, the color conversion layer 25Y is a mixture of a color conversion layer that converts the B component light into R component light and a color conversion layer that converts the B component light into G component light to obtain Y, a color mixture of the R and G component light. The color conversion layer 25M is essentially a color conversion layer that converts the B component light into R component light, but is set to convert only about half of the incident B component intensity into R component light in consideration of absorbance. This produces magenta (M), which is a mixture of the converted light R and the unconverted light (transmitted light) B. Furthermore, the color conversion layer 25C is essentially a color conversion layer that converts the B component light into G component light, but is set to convert only about half of the incident B component intensity into G component light in consideration of absorbance. This produces cyan (C), which is a mixture of the converted light G and the unconverted light (transmitted light) B.

(0042) Next, the operation of the display device 1 of the present embodiment is described with reference to FIG. 8 and FIG. 9.

(Reflective display) The operation in the case of reflective display is explained below with reference to FIG. 8. First, the color filter layers 24Y, 24M, and 24C restrict the bandwidth of the (white) light flux incident from the outside. That is, as shown in the drawing, R component light (single-dotted lines) and G component light (dashed lines) pass through in the Y area. The R component light and B component light (practice [*sic*: solid lines]) pass through the M area. The G component light and the B component light pass through the C area.

(0043) The passing light fluxes from the Y, M, and C areas enter color conversion layers 25Y, 25M, and 25C, respectively, and when doing so, may undergo color conversion for the following reasons. First, in the Y area, the incident light passes through the color conversion layer 25Y directly below. At this time, since the absorption in the color conversion layer 25Y is only in the B component bandwidth, the R and G components can be transmitted efficiently. In the M area, the incident light passes through the color conversion layer 25M directly below. At this time, since the absorption in the color conversion layer 25M is only in the B component bandwidth, the G component can be transmitted efficiently, but the B component undergoes conversion to the G component when absorbed, so the B component light decreases and the G component light increases.

(0044) The light that has passed through each color conversion layer is then reflected by the 20 rear electrode of the EL light-emitting element 3. The rear electrode 20 has an extremely high reflectivity, which suppresses the loss of light. The reflected light is then emitted back along the same path once more. At this time, the reflected light undergoes color conversion in the color conversion layers 25Y, 25M, and 25C, so that the B component is reduced in the M area and converted mostly to the R component. In the C area, the B component is reduced and almost completely converted to the G component. Therefore, the three primary colors in this embodiment are the Y in the Y area, the substantial R in the M area, and the substantial G in the C area. Here, by modulating the electric field in the liquid crystal cell 2, it is possible to display a mixture of the Y, R, and G colors. According to the present embodiment, the brightness of the display is greater than in Embodiment 1 above, but the chromaticity range is more limited than in Embodiment 1. In addition, in the present embodiment, a reflectance of up to 66% can be obtained, excluding losses in the liquid crystal mode. The present embodiment differs from Embodiment 1 in that the maximum luminance display is Y display instead of white display.

(0045) (Transmittance display) In the present embodiment, the light generated from the EL light-emitting element 3 is blue light. This blue light is converted to the long wavelength side by the color conversion layers 25Y, 25M, and 25C to obtain Y, M, and C light, as shown in FIG. 9. Then, after undergoing some spectral shaping in the color filter layers 24Y, 24M, and 24C, the Y light, the M light, and the C light are emitted as complementary rays of the three primary colors with excellent color purity. Then, each color can be mixed and displayed by modulating the electric field of the liquid crystal 17 in the liquid crystal cell 2. Also, up to 66% transmittance can be obtained, excluding losses in the liquid crystal mode. This can greatly reduce the power consumption of the EL light-emitting element 3 as a backlight. In the case of transmissive display, unlike the case of reflective display, white display is possible through mixing of the color components Y, M, and C.

(0046) In the display device 1 of the present embodiment as described above for Embodiment 4, the light emission energy from the EL light-emitting element 3 is converted into color components that match the regions of the color filter layers 24Y, 24 M, and 24C,

thereby increasing the light energy utilization efficiency. In particular, the present embodiment has the advantage that the brightness of the display can be greater than in Embodiment 1. Excluding losses in the liquid crystal mode, a reflectance and transmittance of up to 66% can be obtained, allowing bright reflective display and greatly reducing the power consumption of the EL light-emitting element 3 as a backlight. In the present embodiment, the color filter layers 24Y, 24C, and 24M and the color conversion layers 25Y, 25C, and 25M are between the front transparent electrode 5 and the opposing electrode 10, but may be provided between the opposing electrode 10 and the front alignment film 11, between the rear transparent electrode 6 and the pixel electrode 13, or between the pixel electrode 13 and the rear alignment film 15.

(0047) (Embodiment 5) FIG. 10 is an explanatory drawing showing Embodiment 5 of the display device according to the present invention. In the present embodiment, the color conversion layers 25Y, 25M, and 25C in Embodiment 4 above are replaced with color conversion layers 26Y, 26M, and 26C with ultraviolet light excitation, and the EL light-emitting element 3 is set to generate ultraviolet light. The other configurations are similar to those in Embodiment 4 above, so the descriptions are omitted. In the present embodiment, the color conversion layer 26Y is set to convert ultraviolet light into Y component light, the color conversion layer 26M is set to convert ultraviolet light into M component light, and the color conversion layer 26C is set to convert ultraviolet light into C component light.

(0048) The color conversion layer 26Y is a mixture of a color conversion layer that converts ultraviolet light into R component light and a color conversion layer that converts ultraviolet light into G component light. This yields Y, a mixture of R and G colors. The color conversion layer 26M is a mixture of a color conversion layer that converts ultraviolet light into R component light and a color conversion layer that converts ultraviolet light into B component light. This yields M, a mixture of R and B colors. Furthermore, the color conversion layer 26C is a mixture of a color conversion layer that converts ultraviolet light into B component light and a color conversion layer that converts ultraviolet light into G component light. This yields C, a mixture of B and G colors.

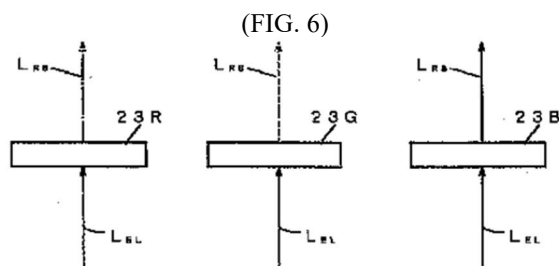
(0049) (Reflective display) Since the absorption of the color conversion layers 26Y, 26M, and 26C in the present embodiment is only in the ultraviolet band, the Y, M, and C components can be transmitted efficiently. Then, by modulating the electric field in the liquid crystal cell 2, it is possible to display a mixture of the Y, M, and C colors. The operation during reflective display in the present embodiment is the same as in embodiment 4 above, so the description is omitted. In the present embodiment, the brightness of the display can also be brighter than in Embodiment 1. In addition, a maximum reflectance of 66% can be obtained in the present embodiment, excluding losses in the liquid crystal mode. Furthermore, unlike Embodiment 4 above, the present embodiment has the advantage that white display can also be performed in reflective display.

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(0050) (Transmissive display) The light emitted from the EL light-emitting element 3 in the present embodiment is ultraviolet light. This light enters each color conversion layer and undergoes conversion to the long wavelength side to obtain Y, M, and C light fluxes. Then, after undergoing some spectral shaping in each color filter layer, the light fluxes are emitted as complementary rays of the three primary colors with excellent color purity. Furthermore, the electric field in the liquid crystal 17 is modulated in the liquid crystal cell 2, allowing each color to be mixed for color display.

(0051) In the present embodiment, the light-emission energy from the EL light-emitting element 3 is converted into color components matching the respective regions of the color filter layers 24Y, 24M, and 24C, thereby increasing the light energy utilization efficiency. A reflectance and transmittance of up to 66% can be obtained, excluding losses in the liquid crystal mode, allowing bright reflective display and greatly reducing the power consumption of the EL light-emitting element 3 as a backlight. In the present embodiment, the color filter layers 24Y, 24C, and 24M and the color conversion layers 25Y, 25C, and 25M are between the front transparent electrode 5 and the opposing electrode 10, but may be provided between the opposing electrode 10 and the front alignment film 11, between the rear transparent electrode 6 and the pixel electrode 13, or between the pixel electrode 13 and the rear alignment film 15.

(0052) Embodiments 1 to 5 were described above, but the invention is not limited to these embodiments, but can be modified in various ways associated with the gist of the constitution of the invention. For example, in each of the embodiments, the liquid crystal cell 2 is configured with two polarizing plates, but the liquid crystal cell 2 can be suitably changed to a single polarizing plate or no polarizing plate depending on the liquid crystal mode. Various liquid crystal modes such as TN liquid crystal mode, STN liquid crystal mode, ECB liquid crystal mode, ferroelectric liquid crystal mode, and GH liquid crystal mode can also be employed as appropriate. Furthermore, the configuration of the EL light-emitting element 3 is not limited to the configuration in which the EL substrate 22 is positioned in front, but may of course be provided on the rear side of the rear electrode 20. Also, in the organic EL light-emitting layer 19,



various materials and various structures such as a single layer or multiple layers can be applied.

(0053)

(EFFECT OF THE INVENTION) As is clear from the description above, the invention has the effect of achieving a display device capable of multicolor display with high light energy utilization efficiency and low power consumption.

(BRIEF DESCRIPTION OF THE DRAWINGS)

(FIG. 1) A cross-section view showing Embodiment 1 of the display device of the present invention.

(FIG. 2) An explanatory drawing showing reflective display in Embodiment 1.

(FIG. 3) An explanatory drawing showing transmissive display in Embodiment 1.

(FIG. 4) A cross-section view showing Embodiment 2 of the display device of the present invention.

(FIG. 5) A cross-section view showing Embodiment 3 of the display device of the present invention.

(FIG. 6) An explanatory drawing of the color conversion layers of Embodiment 3.

(FIG. 7) A cross-section view showing Embodiment 4 of the display device of the present invention.

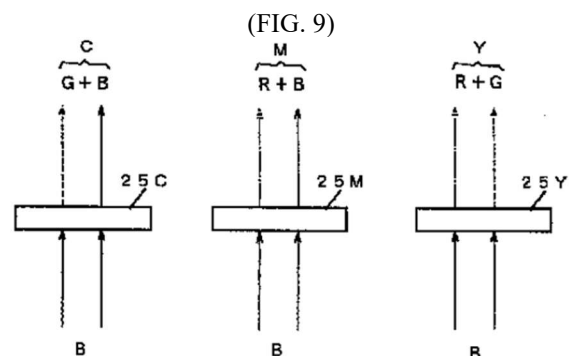
(FIG. 8) An explanatory drawing showing reflective display in Embodiment 4.

(FIG. 9) An explanatory drawing showing transmissive display in Embodiment 4.

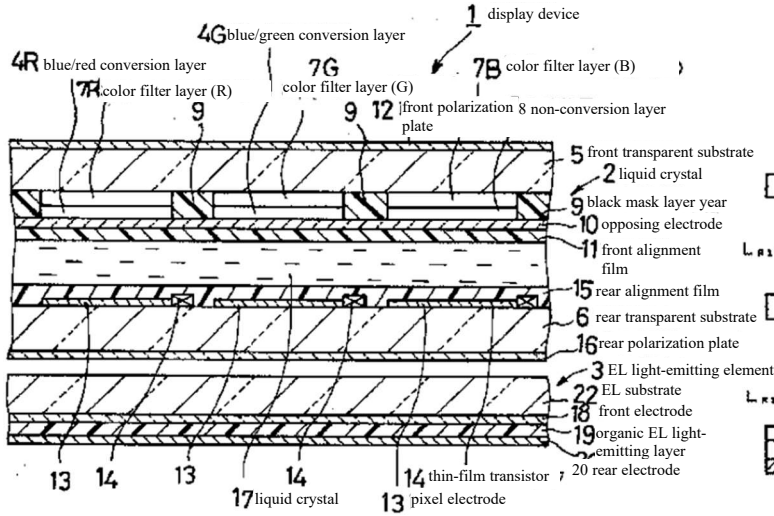
(FIG. 10) An explanatory drawing of the color conversion layers in Embodiment 5 of the display device of the present invention.

(DESCRIPTION OF THE REFERENTIAL CODES OR SYMBOLS)

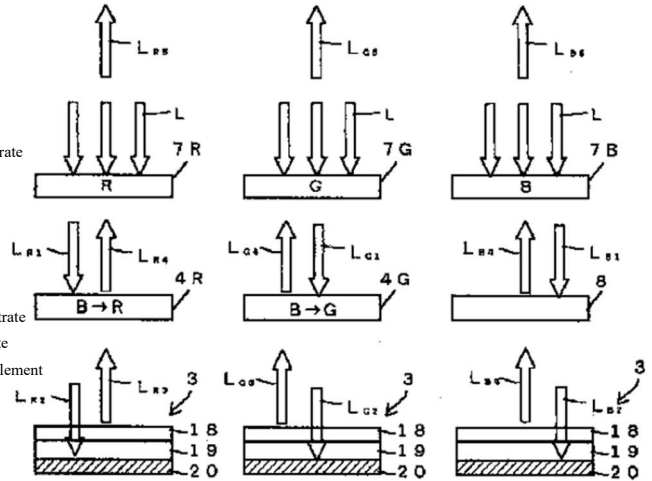
1	display device
2	liquid crystal cell
3	EL light-emitting element
4R	blue/red conversion layer
4G	blue/red conversion layer
7R, 7G, 7B	color filter layers
8	non-conversion layer
10	opposing electrode
13	pixel electrode
14	thin-film transistor
17	liquid crystal
18	front electrode
19	organic EL light-emitting layer
20	rear electrode (reflecting plate)



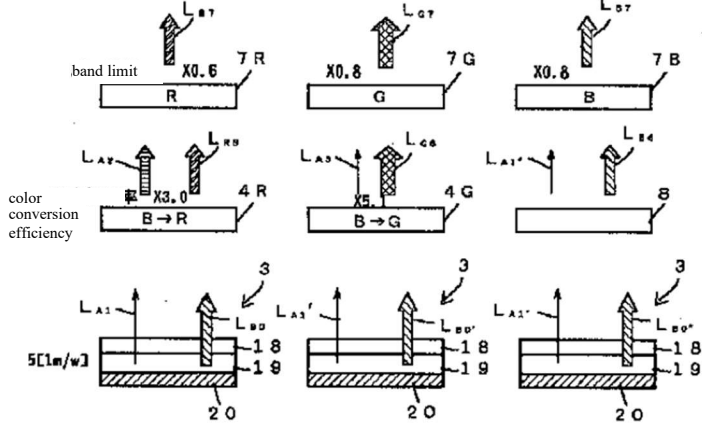
(FIG. 1)



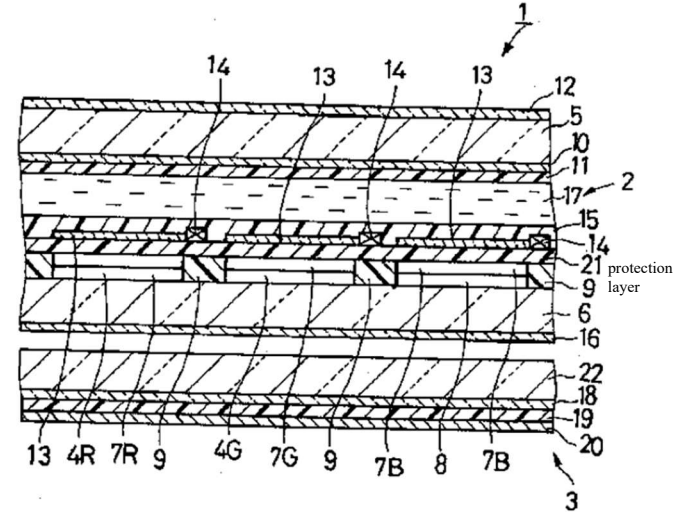
(FIG. 2)



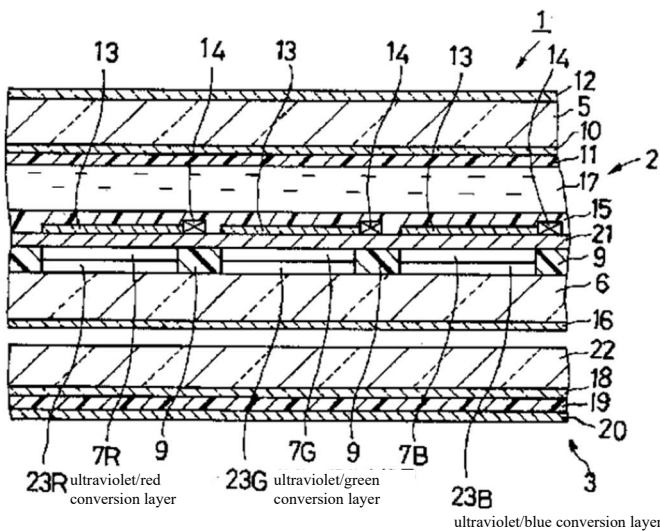
(FIG. 3)



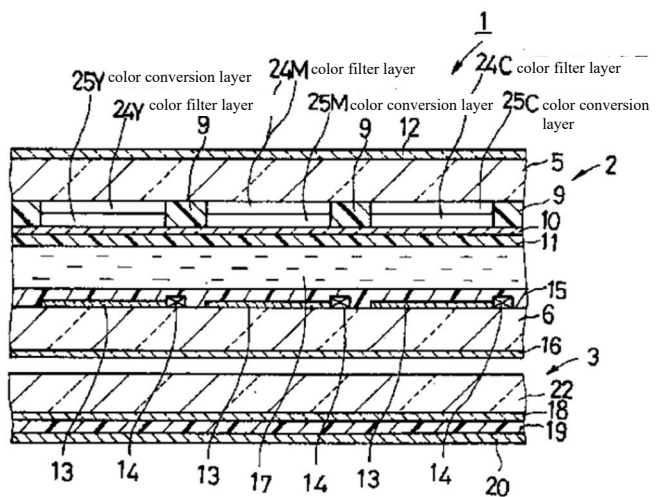
(FIG. 4)

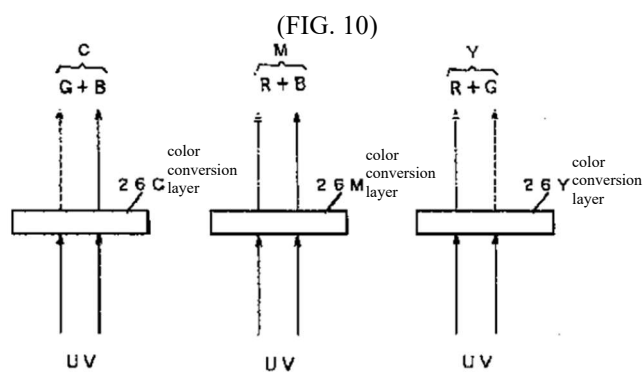
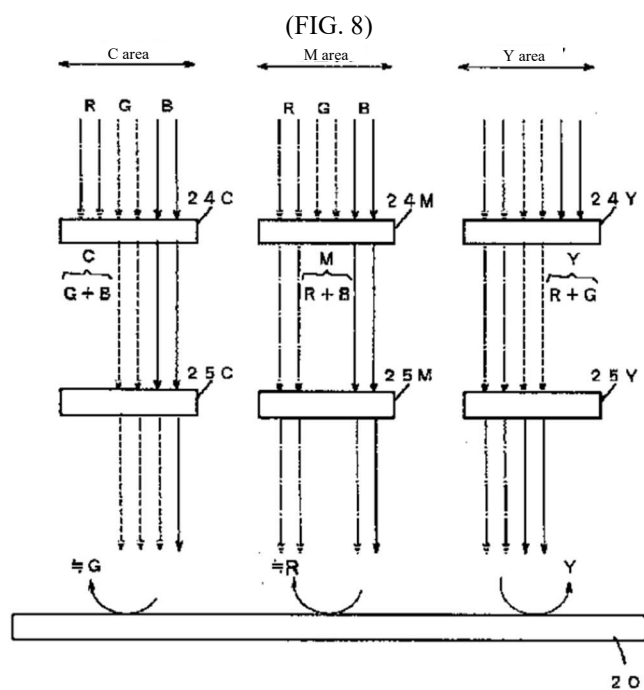


(FIG. 5)



(FIG. 7)





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