

Description

Title of Invention: ORGANIC LIGHT-EMITTING DISPLAY APPARATUS AND METHOD FOR MANUFACTURING THE SAME

Technical Field

[1] **CROSS-REFERENCE TO RELATED APPLICATION**

[2] This application claims the priority of Korean Patent Application No. 2013-0134345 filed on November 6, 2013, in the Korean Intellectual Property Office, and Korean Patent Application No. 2013-0045228 filed on April 24, 2013, in the Korean Intellectual Property Office, and the disclosure of which is incorporated herein by reference.

[3] **BACKGROUND**

[4] **Field of the Invention**

[5] The present invention relates to a display apparatus, and more particularly, to an organic light-emitting display apparatus and a method for manufacturing the display apparatus that is capable of generating colored light without using a color filter.

[6]

[7] **Description of the Related Art**

[8] An organic light-emitting display apparatus (OLED) is a self-emitting display apparatus and has an advantage in terms of power consumption at the time of low-voltage driving. The organic light-emitting display apparatus has been studied as a next-generation display because of its excellent response speed, viewing angle, and contrast ratio.

[9] The organic light-emitting display apparatus is divided into a type in which an organic light-emitting diode for self-emitting red, green and blue is used and a type in which an organic light-emitting diode for emitting white is used, according to a manner for expressing a color. In particular, since there is an advantage in productivity and resolution, the type in which the white organic light-emitting diode is used has been widely studied.

[10] Generally, a set of color filters is usually included in the organic light-emitting display apparatus using the white organic light-emitting diode. Each of the color filters, which may be formed of different materials, transmits only the light within a certain range of wavelengths among the white light emitted from the organic light-emitting diode. Also, forming the set of color filters may require a number of photolithography and etching processes, which can damage the organic light-emitting diode. Accordingly, the color filter is often formed on a separate substrate from the substrate of

the organic-light-emitting diode, and the two substrates are bonded to each other by a sealant.

[11]

[12] **SUMMARY OF THE INVENTION**

[13] The inventors of the embodiments disclosed herein have recognized that such a process for forming the color filters often results in a misalignment between the substrates, ultimately leading to various defects in the organic light-emitting display apparatus.

[14] Accordingly, there is provided an organic-light-emitting display apparatus employing a color control layer on the same substrate as the organic light-emitting diode without damaging the organic light-emitting diode.

[15] In one embodiment, the organic-light-emitting display apparatus include an anode, an organic emissive layer, and a cathode that are sequentially formed on the substrate in the stated order. The cathode formed of two metal layers and a color conversion layer interposed between the two metal layers, in which the color conversion layer has different thicknesses in the first, second and third areas of the organic-light-emitting display apparatus. The color conversion layer can shift wavelength of the light emitted from the organic emissive layer. This allows blue EL light to be converted into green or red fluorescence, for example. Further, the thickness of the color conversion layer causes constructive interference of the light in a certain range of wavelengths. In this configuration, the cathode serves to transform a color of light in addition to its functionality as an electrode. Since the structure for generating colored light is formed on the same substrate as the organic light-emitting diode, defects in the organic light-emitting display apparatus caused by misaligned substrates, such as a color mix problem, can be reduced.

[16] In some embodiments, the organic light-emitting display apparatus includes a fourth area. Similar to the first three areas, the fourth area also includes the anode and the organic emissive layer. However, the cathode in the fourth area does not include the color conversion layer. Accordingly, the fourth area may be used as a pixel for emitting white light.

[17] In some embodiments, the color conversion layer is formed of at least two layers of different refractive indices. For example, the color conversion layer may be formed of a stack of layers having organic material layer having a first refractive index and an inorganic material layer having a second refractive index.

[18] In some embodiments, the two metal layers of the cathode may be connected to each other at a contact area such that the cathode has a lower electrical resistance than that of a single-layered metal cathode. The lower electrical resistance helps the voltage supplied on the cathode to reach further without unwanted voltage drop, enabling more

uniform luminance level, especially for a top emission type organic light-emitting display apparatus.

- [19] In one embodiment, a structure for generating colored light is formed as a separate layered structure rather than being integrated in a cathode. In this case, an organic light-emitting display apparatus includes an anode, an organic emissive layer, a cathode and an encapsulation unit. The encapsulation unit is formed on the cathode, and a color transformation layer is formed on the encapsulation unit. The color transformation layer includes a first metal layer, a second metal layer and a color conversion layer interposed between the first and second metal layers. The color conversion layer may have different thicknesses within the organic-light-emitting display apparatus. Color of the light transmitted from each area is determined by the thickness of the color conversion layer disposed thereon. The range of wavelengths that is transmitted from each area may be determined by the thickness of the color conversion layer in the corresponding area. Further, the color conversion layer may be configured to cause constructive interference such that certain range of wavelengths are amplified.
- [20] In some embodiments, the color conversion layer is formed of at least two layers of different refractive indices. For example, the color conversion layer may be formed of a stack of layers having organic material layer having a first refractive index and an inorganic material layer having a second refractive index.
- [21] In yet another aspect, there is provided a method for manufacturing an organic light-emitting display apparatus. In an exemplary embodiment, an anode and an organic emissive layer are sequentially formed on a substrate. The method further includes forming a first metal layer, a color conversion layer and a second metal layer. The color conversion layer may be formed on the first metal layer through inkjet printing or nozzle printing. The color conversion layer is formed at a thickness capable of transmitting light having a certain wavelength.
- [22] In some embodiments, at least one of the first and second metal layers can be connected to a power source and serve as a cathode of the organic-light-emitting display apparatus.
- [23] Alternatively, the color conversion layer and the second metal layer may be formed separately from the cathode. In this configuration, the method may include a step for forming a cathode and an encapsulation layer on the cathode. Then, the first metal layer, the color conversion layer and the second metal layer may be formed on an encapsulation layer.
- [24] In the method for manufacturing an organic light-emitting display apparatus according to the exemplary embodiment of the present invention, there is no need for bonding of the color filter substrate and the substrate with the organic light-emitting

diode, and thus defects in the organic light-emitting display apparatus due to the misalignment of the two substrates can be reduced.

[25] The benefits of the present invention are not limited to the aforementioned objects, and other objects, which are not mentioned above, will be apparent to those skilled in the art from the following description.

[26]

Brief Description of Drawings

[27] The above and other aspects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[28] FIG. 1a (a) and (b) illustrate cross-sectional views of an organic light-emitting display apparatus according to an exemplary embodiment of the present invention in which a cathode including a color conversion layer is formed;

[29] FIG. 1b (a) and (b) are graphs for describing transmittance in the organic light-emitting display apparatus of FIG. 1a;

[30] FIG. 1c (a) and (b) illustrate cross-sectional views of an organic light-emitting display apparatus including a white sub-pixel area;

[31] FIG. 2a illustrates a cross-sectional view of an organic light-emitting display apparatus according to an exemplary embodiment of the present invention in which a cathode of an organic light-emitting diode is formed as a layer for transforming a color;

[32] FIG. 2b is a graph for describing transmittance in the organic light-emitting display apparatus of FIG. 2a;

[33] FIG. 2c illustrates a cross-sectional view of an organic light-emitting display apparatus in which a cathode including a plurality of color conversion layers is formed;

[34] FIG. 2d is a graph for describing transmittance of incident light in the organic light-emitting display apparatus of FIG. 2c;

[35] FIG. 2e illustrates a cross-sectional view of an organic light-emitting display apparatus in which particles are formed on a cathode of the organic light-emitting display apparatus;

[36] FIG. 3a illustrates a cross-sectional view for describing a color transformation layer formed on an encapsulation unit in an organic light-emitting display apparatus;

[37] FIG. 3c illustrates a cross-sectional view for describing a modified example of the color transformation layer formed on an encapsulation unit in an organic light-emitting display apparatus;

[38] FIG. 4 (a), (b) and (c) are a diagram and graphs for describing a change in wavelength of light by a cathode in an organic light-emitting display apparatus; and

[39] FIGS. 5a to 5d illustrate cross-sectional views of processes for describing a method for manufacturing an organic light-emitting display apparatus according to an exemplary embodiment of the present invention.

[40]

[41] **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[42] Various advantages and features of the present invention and methods accomplishing thereof will become apparent from the following description of embodiments with reference to the accompanying drawings. However, the present invention is not limited to exemplary embodiment disclosed herein but will be implemented in various forms. The exemplary embodiments are provided by way of example only so that a person of ordinary skilled in the art can fully understand the disclosures of the present invention and the scope of the present invention. Therefore, the present invention will be defined only by the scope of the appended claims.

[43] Indicating that elements or layers are “on” other elements or layers include both a case in which the corresponding elements are just above other elements and a case in which the corresponding elements are intervened with other layers or elements.

[44] Although first, second, and the like are used in order to describe various components, the components are not limited by the terms. The above terms are used only to discriminate one component from the other component. Therefore, a first component mentioned below may be a second component within the technical spirit of the present invention.

[45] In the drawings, size and thickness of each element are arbitrarily illustrated for convenience of description, and the present invention is not necessarily limited to those illustrated in the drawings.

[46] Hereinafter, the present invention will be described in detail with reference to the accompanying drawings.

[47] FIG. 1a (a) illustrates a cross-sectional view of an organic light-emitting display apparatus according to an exemplary embodiment of the present invention in which a cathode including a color conversion layer is formed. An organic light-emitting display apparatus 100A is a display apparatus that allows an organic emissive layer 130 to emit light by allowing current to flow in the organic emissive layer 130.

[48] Referring to FIG. 1a (a), the organic light-emitting display apparatus 100A comprises a substrate 110 including a first area, a second area and a third area, thin-film transistors T that are respectively formed in the areas, an overcoat layer 188, anodes 120a, 120b and 120c, the organic emissive layer 130, a cathode 170, and bank layers 115. The cathode 170 includes a first metal layer 140, a color conversion unit 150, and a second metal layer 160.

[49] In FIG. 1a (a), the first area is a red sub-pixel area R, the second area is a green sub-

pixel area G, and the third area is a blue sub-pixel area B. An sub-pixel arrangement of the red sub-pixel area R, the green sub-pixel area G and the blue sub-pixel area B of FIG. 1a (a) is merely defined for the sake of convenience in description, and the colors represented by the areas and the arrangement of the sub-pixels in the organic light-emitting display apparatus may vary from the examples illustrated in the present disclosure.

- [50] The thin-film transistor T may be formed for each of the sub-pixel areas on the substrate 110, and may be independently driven for each of the sub-pixel areas. The thin-film transistors T may be formed on the substrate 110 to allow the organic emissive layer 130 to emit light. Although driving transistors have been illustrated in FIG. 1a (a), it should be appreciated that each of the areas can include one or more switching thin-film transistors used in conjunction with the driving transistors to allow the organic emissive layer 130 to emit light by image information of a data signal input in response to a scan signal.
- [51] In the embodiment shown in FIG. 1a (a), the organic light-emitting diode including the anodes 120a, 120b and 120c, the organic emissive layer 130, and the cathode 170 including the first metal layer 140, the color conversion layer 150 and the second metal layer 160 is formed on the overcoat layer 188. The organic emissive layer 130, which is configured to emit white light, is formed on the anodes 120a, 120b and 120c. The cathode 170 including the first metal layer 140, the color conversion layer 150 and the second metal layer 160 is formed on the organic emissive layer 130.
- [52] The organic light-emitting diode is driven by a principle in which holes supplied from the anodes 120a, 120b and 120c and electrons supplied from the cathode 170 are combined in the organic emissive layer 130 to emit light. In order to supply electrons, the first metal layer 140 of the cathode 170 is made of a material having high electrical conductivity and a low work function. The first metal layer 140 is made of a metal material having a very thin thickness. The first metal layer 140 may be made of a metal material such as silver (Ag), titanium (Ti), aluminum (Al), gold (Au), molybdenum (Mo) or an alloy of silver (Ag) and magnesium (Mg) having a thickness of several hundred angstroms or less. The second metal layer 160 of the cathode 170 is made of the same material as that of the first metal layer 140, and is formed at the substantially same thickness as that of the first metal layer 140. Even though the first metal layer 140 and the second metal layer 160 are made of metals with some degree of light reflectivity, light incident to those metal layers can pass through when the metal layers are sufficiently thin, for example several hundred angstroms or less.
- [53] When the white light emitted from the organic emissive layer is transmitted through the metal layer, the peak of the wavelength may be observed at a region beyond a range of visible light. However, the peak of the wavelength can be shifted by the color

conversion layer 150 in contact with the first metal layer 140. Further, only light having a certain wavelength of the light incident onto the cathode 170 is transmitted by a micro-cavity effect within the color conversion layer 150 between the first metal layer 140 and the second metal layer 160.

- [54] As the light transmitted from the first metal layer 140 strikes the surface of the color conversion layer 150, it is either transmitted or reflected. Light that is transmitted reaches the bottom surface of the second metal layer 160 and may once again be transmitted or reflected. The Fresnel equations provide a quantitative description of how much of the light will be transmitted or reflected at an interface. The light reflected between the first metal layer 140 and the second metal layer 160 will interfere. The degree of constructive or destructive interference between the two light waves depends on the difference in their phase. This difference in turn depends on the thickness of the film layer, the refractive index of the film, and the angle of incidence of the original wave. When the second metal layer 160 and the first metal layer 140 have substantially the same thickness, transmittance of the light having the certain wavelength can be increased.
- [55] Additionally, a phase shift of 180° or π radians may be introduced upon reflection at a boundary depending on the refractive indices of the materials on either side of the boundary. This phase shift occurs if the refractive index of the medium the light is travelling through is less than the refractive of the material it is striking. The pattern of light that results from this interference can appear either as light and dark bands or as colorful bands depending upon the source of the incident light. If the incident light is broadband, or white, such as the light from the white organic emissive layer, interference patterns appear as colorful bands. Different wavelengths of light create constructive interference for different film thicknesses. Different regions of the film appear in different colors depending on the local film thickness.
- [56] As such, the organic emissive layer 130 may be configured to emit white light. The light emitted from the organic emissive layer 130 passes through the cathode 170 including the first metal layer 140, the color conversion layer 150 and the second metal layer 160, light in a limited range of wavelengths is transmitted.
- [57] The color conversion layer 150 is formed between the first metal layer 140 and the second metal layer 160 to come in contact with the metal layers. The color conversion layer 150 should be made sufficiently transparent so that at least some portion of the light emitted from the organic emissive layer 130 can be transmitted through. The color conversion layer 150 may be made of an organic material, a nitride, or an oxide. For example, the color conversion layer 150 may be made of an organic insulating material such as polyimide, photo acryl, or benzocyclobutene (BCB). The color conversion layer 150 may also be made of silicon nitride (SiN_x). Further, the color

conversion layer 150 may be made of molybdenum oxide (MoO_3), silicon oxide (SiO_2), indium zinc oxide (IZO), indium tin oxide (ITO), indium tin zinc oxide (ITZO), or any combination thereof.

[58] In the organic light-emitting display apparatus 100A according to the exemplary embodiment of the present invention, the cathode 170 of the organic light-emitting diode serves as a color filter. Accordingly, there cannot be the color mixture issue from misaligned color filter substrate. In addition, a thinner organic light-emitting display apparatus may be provided by the elimination of the color filters on a separate substrate.

[59] FIG. 1b is a graph for describing transmittance in the organic light-emitting display apparatus illustrated in FIG. 1a (a).

[60] Referring to FIG. 1b (a), in the graph, an x-axis represents a wavelength of transmitted light, and a y-axis represents transmittance of incident light. The graph FIG. 1b (a) is a graph for describing that when the color conversion layer 150 is formed on the first metal layer 140, the wavelength of the transmitted light is shifted depending on a thickness of the color conversion layer 150. In FIG. 1b (a), the first metal layer 140 is made of silver (Ag) having a thickness of 200 angstroms, and the color conversion layer 150 is made of photo acryl having a thickness of 500 angstroms to 1500 angstroms. Line A depicts a case where only the first metal layer made of silver (Ag) having a thickness of 200 angstroms is formed without forming the color conversion layer 150, and line B depicts a case where the color conversion layer 150 having a thickness of 500 angstroms is formed on the first metal layer 140. Line C depicts a case where the color conversion layer 150 having a thickness of 900 angstroms is formed on the first metal layer, and line D depicts that the color conversion layer 150 having a thickness of 1500 angstroms is formed on the first metal layer.

[61] Referring to FIG. 1b (a), a peak of line A appears at about 350 nm, and when the white light is incident and is transmitted through only the first metal layer 140, the highest transmittance is observed at the ultra violet wavelength beyond a range of visible light. Here, the peak means a wavelength having the highest transmittance. When the color conversion layer 150 is formed on the first metal layer 140, the wavelength of the light that has been transmitted through the first metal layer 140 is shifted depending on the thickness of the color conversion layer 150. Referring to lines B, C and D, peaks of each of the lines were observed at wavelengths of 550 nm, 700 nm and 450 nm at the color conversion layer 150 thickness of 500 angstroms, 900 angstroms and 1500 angstroms, respectively.

[62] As described above, the first metal layer 140, the color conversion layer 150 and the second metal layer 160 within the cathode 170 may be configured to create the micro-

cavity effect to increased transmittance of the light within a specific wavelength range. The micro-cavity effect is a phenomenon in which light is repeatedly reflected between two surfaces that are spaced apart by an optical length, which results in an amplification of a certain wavelength range within the light by the constructive interference. The white light incident onto the cathode 170 is repeatedly reflected between the first metal layer 140 and the second metal layer 160, so that the constructive interference for the certain wavelength occurs. Accordingly, the cathode 170 including the first metal layer 140, the color conversion layer 150 and the second metal layer 160 can maximize the transmittance of the light having the certain wavelength.

[63] Since colors have different wavelengths, a resonant distance is set for a wavelength of a certain color in order to cause the constructive interference for the light of the certain color by implementing the micro-cavity effect in the cathode 170. The resonant distance may be set to values corresponding to multiples of a half wave length of the light transmitted through the cathode 170, and the thickness of the color conversion layer 150 is set to be equal to the resonant distance. The resonant distance for causing the constructive interference for the certain wavelength may be calculated from the following equation 1.

[64] [Equation 1]

[65]
$$2L = (m)\left(\frac{\lambda}{n_2}\right)$$

[66] where L is a resonant distance, m is an integer number, λ is a wavelength of light subjected to constructive interference, and n_2 is a refractive index of a material through which light is transmitted. The resonant distance may be calculated by substituting a wavelength of light subjected to constructive interference and a refractive index of a material through which light is transmitted.

[67] Light having a wavelength corresponding to the set resonant distance is amplified by the constructive interference within the color conversion layer 150 and is transmitted to the outside. In contrast, light having wavelengths not corresponding to the set resonant distance disappears by destructive interference within the color conversion layer 150.

[68] Since red visible light, green visible light and blue visible light have different wavelengths from each other, different resonant distances from each other may be set depending on the colors in the organic light-emitting display apparatus 100A. For example, when it is assumed that the color conversion layer 150 is made of the organic material and a refractive index of the organic material is 1.5, since a wavelength of the red visible light is about 650 nm, the resonant distance of red light may be set to multiples of about 217 nm on the basis of Equation 1. Accordingly, in order to sharpen a peak of a red wavelength, a distance (the thickness of the color conversion layer 150) between the first metal layer 140 and the second metal layer 160 may be set to

multiples of about 217 nm.

- [69] FIG. 1b (b) is a graph for describing transmittance in the organic light-emitting display apparatus of FIG. 1a. Referring to FIG. 1b (b), in the graph, an x-axis represents a wavelength of transmitted light, and a y-axis represents transmittance of incident light. The first metal layer 140 and the second metal layer 160 used in the graph FIG. 1b (b) are made of silver (Ag) having a thickness of 200 angstroms, and the color conversion layer 150 formed between the first metal layer 140 and the second metal layer 160 is made of photo acryl having a thickness of 500 angstroms to 2000 angstroms. In FIG. 1b (b), line A depicts transmittance of transmitted light when the first and second metal layers are made of silver (Ag) having a thickness of 200 angstroms, as a comparative example. Lines B, C, D and E depict transmittance of transmitted light when the thickness of the color conversion layer 150 is 500 angstroms, 1000 angstroms, 1500 angstroms, and 2000 angstroms.
- [70] Referring to lines B, C, D and E, when the thickness of the color conversion layer 150 is 500 angstroms, 1000 angstroms, 1500 angstroms, and 2000 angstroms, the cathode 170 transmits the largest amount of light at wavelengths of 420 nm, 570 nm, 700 nm and 480 nm. Moreover, when the thickness of the color conversion layer 150 is equal to or greater than a certain value, a plurality of peaks may be observed as in lines D and E. Since the peaks are observed at wavelengths of 410 nm and 700 nm of visible light in line D, a color mixture may occur. When the color mixture occurs, it may not be suitable for expressing red, green or blue. Although the plurality of peaks is observed in line E, since one peak is observed in a range of visible light, it may be suitable for expressing the colors.
- [71] Referring to FIG. 1b (b), the light transmitted through the cathode 170 has a certain wavelength, and the transmittance of the light having the certain wavelength can be maximized by the micro-cavity effect within the color conversion layer 150 between the first metal layer 140 and the second metal layer 160. Since the wavelength of the light transmitted through the color conversion layer 150 can be controlled depending on the thickness of the color conversion layer 150, vivid color transformation may be implemented through the cathode 170 including the first metal layer 140, the color conversion layer 150 and the second metal layer 160. When the light of desired color is transmitted through the cathode 170 without using the color filter, the manufacturing process of the organic-light-emitting display apparatus may not require bonding of two substrates, and thus various defects from the misalignments of the substrates can be solved.
- [72] In the organic light-emitting display apparatus 100A according to the exemplary embodiment of the present invention, the white light emitted from the organic emissive layer 130 may be transformed into red, green or blue by using the color conversion

layer 150.

- [73] Since the light transmitted through the cathode 170 depends on the thickness of the color conversion layer 150, the thickness of the color conversion layer 150 for applying the micro-cavity effect is determined by taking account of a wavelength of light to be transmitted. Referring to FIG. 1a (a), the color conversion layer 150 is formed at different thicknesses in the sub-pixel areas. In the organic light-emitting display apparatus 100A according to the exemplary embodiment of the present invention, a color conversion layer 150a within the red sub-pixel area R has a thickness capable of transmitting a wavelength of red, a color conversion layer 150b within the green sub-pixel area G has a thickness capable of transmitting a wavelength of green, and a color conversion layer 150c within the blue sub-pixel area B has a thickness capable of transmitting a wavelength of blue. By forming the color conversion layer 150 at the different thicknesses in the sub-pixel areas of the organic light-emitting display apparatus 100A, the sub-pixel areas transmit light having different wavelengths.
- [74] In a top emission type organic light-emitting display apparatus, the cathode is formed at a thin thickness in order to improve transmittance of the cathode, and a resistance of the cathode electrode is increased due to a decrease in the thickness of the cathode. In a large-area organic light-emitting display apparatus, as the resistance of the cathode is high, voltage drop becomes severe at a point far from a power supply. Accordingly, since current supplied to the entire organic emissive layer is not uniform, a problem of non-uniform luminance may be caused. The voltage drop in the present specification means a decrease in a potential difference generated in the organic light-emitting diode, and specifically, means a decrease in a potential difference between the anode and the cathode of the organic light-emitting diode.
- [75] In the organic light-emitting display apparatus 100A according to the exemplary embodiment of the present invention, the first metal layer 140 and the second metal layer 160 are formed to be connected to both sides of the color conversion layer 150. Since the first metal layer 140 and the second metal layer 160 are connected, the resistance of the cathode 170 including the first metal layer 140 and the second metal layer 160 may decrease.
- [76] In order to further reduce the resistance of the cathode 170 of the organic light-emitting display apparatus 100A, the color conversion layer 150 of the organic light-emitting display apparatus 100A according to the exemplary embodiment of the present invention may be made of a conductive material such as indium zinc oxide (IZO), indium tin oxide (ITO), or indium tin zinc oxide (ITZO). When the color conversion layer 150 is made of the conductive material, the color conversion layer 150 may serve to transmit the light having the certain wavelength together with the

first metal layer 140 and the second metal layer 160 and serve to reduce the resistance of the cathode 170 together with the second metal layer 160.

- [77] FIG. 1a (b) illustrates a cross-sectional view of an organic light-emitting display apparatus according to an exemplary embodiment of the present invention in which a cathode is formed. Referring to FIG. 1a (b), black matrices 180 are formed at portions of the second metal layer 160 corresponding to boundaries of the areas. Since the first metal layer 140 and the second metal layer 160 come in contact with each other at the boundaries of the areas, reflectivity by the metal layers 140 and 160 is high. Accordingly, it is possible to minimize reflection of external light by forming the black matrices 180. In addition, the black matrices 180 prevent colors from being mixed at the boundaries of the areas.
- [78] FIG. 1c (a) illustrates a cross-sectional view of an organic light-emitting display apparatus including a white sub-pixel area. Referring to FIG. 1c (a), an organic light-emitting display apparatus 100C includes a substrate 110 including a first area, a second area, a third area and a fourth area, anodes 120a, 120b, 120c and 120d, bank layers 115, an organic emissive layer 130, and a cathode 170. The cathode 170 includes a first metal layer 140, a color conversion layer 150, and a second metal layer 160. In FIG. 1c (a), the first area is a red sub-pixel area R, the second area is a green sub-pixel area G, the third area is a blue sub-pixel area B, and the fourth area is a white sub-pixel area W. In FIG. 1c (a), a sub-pixel structure is merely defined for the sake of convenience in description, and an arrangement of the sub-pixel areas and colors represented by the sub-pixel areas may be variously defined depending on exemplary embodiments. Among components of the organic light-emitting display apparatus 100C illustrated in FIG. 1c (a), the substantially same components as those of the organic light-emitting display apparatus illustrated in FIG. 1a (a) will not be described.
- [79] An organic light-emitting diode including the anode 120d, the organic emissive layer 130 and the first metal layer 140 is formed in the white sub-pixel area W according to the exemplary embodiment of the present invention. The white sub-pixel area W includes the first metal layer 140 formed on the organic emissive layer 130, and is free of the color conversion layer 150 and the second metal layer 160. Accordingly, in the white sub-pixel area W, the micro-cavity effect caused by forming the color conversion layer 150 is not implemented, and a color of white light emitted from the organic emissive layer 130 is not transformed into another color.
- [80] FIG. 1c (b) illustrates a cross-sectional view of a white organic light-emitting display apparatus including a light transmission structure. Referring to FIG. 1c (b), in an organic light-emitting display apparatus 100C according to an exemplary embodiment of the present invention, a light transmission structure 190 is formed on the first metal layer 140 of the white sub-pixel area W. The light transmission structure 190 may be

made of polyimide, photo acryl, benzocyclobutene (BCB), silicon nitride (SiN_x), molybdenum oxide (MoO_3), silicon oxide (SiO_2), indium zinc oxide (IZO), indium tin oxide (ITO), or indium tin zinc oxide (ITZO). Further, the light transmission structure 190 may be made of the same material as that of the color conversion layer 150. According to the material used in forming the light transmission structure 190, its thickness can vary such that broadband light can be emitted from white sub-pixel area W.

- [81] FIG. 2a illustrates a cross-sectional view of an organic light-emitting display apparatus according to an exemplary embodiment of the present invention in which a cathode of an organic light-emitting diode is formed as a layer for transforming a color. An organic light-emitting display apparatus 200A according to the exemplary embodiment of the present invention includes a substrate 210, an anode 220 formed on the substrate 210, an organic emissive layer 230 formed on the anode 220, and a cathode 270A formed on the organic emissive layer 230. The cathode 270A includes a first metal layer 240, a color conversion layer 250, and a second metal layer 260. The substrate 210, the anode 220 and the organic emissive layer 230 of the organic light-emitting display apparatus 200A illustrated in FIG. 2a are substantially same as the substrate 110, the anodes 120a, 120b and 120c, and the organic emissive layer 130 illustrated in FIG. 1a (a), and thus the detailed descriptions thereof will not be presented.
- [82] In FIG. 2a, the color conversion layer 250 of the cathode 270A has a thickness capable of transmitting light having a certain wavelength. Further, the color conversion layer 250 may be formed to be thicker than those of the first metal layer 240 and the second metal layer 260. When the thickness of the color conversion layer 250 is thicker than those of the first metal layer 240 and the second metal layer 260, the cathode 270A can more easily transmit the light having the certain wavelength and more clearly express a desired color. The thickness of the color conversion layer 250 for determining a wavelength of light transmitted through the cathode 270A will be now explained by referring to Table 1.
- [83] Table 1 shows a peak of a wavelength of light transmitted through the cathode 270A depending on the thickness of the color conversion layer 250. The color conversion layer 250 is made of photo acryl having a thickness of 400 angstroms to 3000 angstroms, and the first metal layer 240 and the second metal layer 260 are made of silver (Ag) having a thickness of 250 angstroms.
- [84] [Table 1]
- [85]

Ag 250 angstroms/ first color control layer/ Ag 250 angstroms: thickness of first color control layer	400 angs- troms	500 angs- troms	800 angs- troms	1000 angs- troms	1200 angs- troms	1600 angs- troms	1800 angs- troms	2000 angs- troms	2400 angs- troms	2800 angs- troms	3000 angs- troms
firstpeak(nm)	320	360	360	360	380	420	360	370	400	370	380
second peak(nm)	390	440	500	570	630	770	450	480	540	430	450
third peak(nm)							830	900		610	640
maximum peak(nm)	390	440	500	570	630	420	450	480	540	610	640
color expressable area			blue	green	red			blue	green	red	

- [86] When the cathode 270A of the organic light-emitting display apparatus 200A includes the first metal layer 240, the color conversion layer 250 and the second metal layer 260, a plurality of peaks is measured. The measured peaks may exist within a range of visible light or beyond the range of visible light.
- [87] Referring to Table 1, when the thickness of the color conversion layer 250 is 800 angstroms, peaks are observed at wavelengths of 360 nm and 500 nm, and a maximum peak is observed at a wavelength of 500 nm. Accordingly, the organic light-emitting display apparatus 200A with the cathode 270A including the color conversion layer 250 having a thickness of 800 angstroms can express blue.
- [88] When the thickness of the color conversion layer 250 is 1000 angstroms and 1200 angstroms, peaks are observed at wavelengths of 570 nm and 630 nm within the range of visible light. Accordingly, the organic light-emitting display apparatus 200A with the cathode 270A including the color conversion layer 250 having a thickness of 1000 angstroms can express green, and the organic light-emitting display apparatus 200A including the cathode 270A including the color conversion layer 250 having a thickness of 1200 angstroms can express red.
- [89] Moreover, referring to Table 1, when the thickness of the color conversion layer 250 is 2000 angstroms, 2400 angstroms, and 2800 angstroms, since peaks exist at wavelengths of 480 nm, 540 nm and 610 nm within the range of visible light, the color conversion layer 250 having a thickness of 2000 angstroms, 2400 angstroms, or 2800 angstroms may be used to express blue, green, or red. It should be noted that the range of wavelengths used in defining the colors in the examples above are merely illustrative. As such, usable range of wavelength may vary for different organic-light-emitting display apparatus. For instance, a wavelength range between 380 - 500 may be defined as blue, a wavelength range between 500 - 570 may be defined as

green, and a wavelength range between 600 - 750 may be defined as red color.

- [90] Referring to Table 1, the organic light-emitting display apparatus 200A according to the exemplary embodiment of the present invention can express various colors through the color conversion layer 250 formed at various thicknesses. The color conversion layer 250 may be formed at thicknesses for expressing various colors such as cyan, magenta, and yellow in addition to red, green and blue of Table 1.
- [91] FIG. 2b is a graph for describing transmittance in the organic light-emitting display

apparatus of FIG. 2a. Referring to FIG. 2b, in the graph, an x-axis represents a wavelength of transmitted light, and a y-axis represents transmittance of incident light. Lines A, B and C depict transmittance of light when an ordinary color filter is used. Lines D, E and F depict transmittance of light in the organic light-emitting display apparatus 200A when the cathode 270A of FIG. 2a is used. The first metal layer 240 and the second layer 260 used in the graph of FIG. 2b are made of silver (Ag) having a thickness of 200 angstroms, and the color conversion layer 250 formed between the first metal layer 240 and the second metal layer 260 is made of photo acryl having thicknesses of 2800 angstroms, 2400 angstroms, and 2000 angstroms. Line D depicts a case where the color conversion layer 250 having a thickness of 2800 angstroms is formed, line E depicts a case where the color conversion layer 250 having a thickness of 2400 angstroms is formed, and line F depicts a case where the color conversion layer 250 having a thickness of 2000 angstroms is formed.

[92] As can be seen from lines A, B and C representing a case where the existing color filter is used, the largest amount of light is transmitted at wavelengths of 650 nm, 520 nm, and 450 nm. It can be seen from lines D, E and F that the largest amount of light is transmitted at wavelengths of 620 nm, 530 nm, and 450 nm. When respectively comparing line A with line D, line B with line E, and line C with line F, the cathode 270A of the organic light-emitting display apparatus 200A according to the exemplary embodiment of the present invention has high transmittance for the certain wavelength so as to be suitable to serve as the color filter.

[93] FIG. 2c illustrates a cross-sectional view of an organic light-emitting display apparatus in which a cathode including a plurality of color conversion layers is formed. Referring to FIG. 2c, an organic light-emitting display apparatus 200C includes a substrate 210, an anode 220, an organic emissive layer 230, and a cathode 270C. The cathode 270C includes a first metal layer 240, a color conversion layer 250, a second metal layer 260, an additional color conversion layer 252, and a third metal layer 242. The substrate 210, the anode 220, the organic emissive layer 230, the first metal layer 240 and the color conversion layer 250 of FIG. 2c are same as the substrate 210, the anode 220, the organic emissive layer 230, the first metal layer 240 and the color conversion layer 250 of FIG. 2a, and thus the redundant descriptions thereof will not be presented.

[94] The cathode 270C of the organic light-emitting display apparatus 200C according to the exemplary embodiment of the present invention includes the additional color conversion layer 252 and the third metal layer 242 in addition to the first metal layer 240, the color conversion layer 250 and the second metal layer 260. The additional color conversion layer 252 is formed on the second metal layer 260, and the third metal layer 242 is formed on the additional color conversion layer 252.

- [95] The first metal layer 240, the second metal layer 260 and the third metal layer 242 may be made of the same material. The first metal layer 240 is formed at the same thickness as the third metal layer 242, and the second metal layer 260 is formed at a thickness thicker than those of the first metal layer 240 and the third metal layer 242. The thickness of the second metal layer 260 may be nearly twice the thickness of the first metal layer 240. When the thickness of the second metal layer 260 is about twice the thickness of the first metal layer 240, more narrow range of wavelength can be obtained through the cathode 270C. In other words, higher color accuracy can be achieved.
- [96] The color conversion layer 250 and the additional color conversion layer 252 needs not be formed of the same material. The thickness of the color conversion layer 250 and the additional color conversion layer 252 needs not be the same even though they have been illustrated as having the same thickness. As such, the thickness of the color conversion layer 252 may be different from that of the color conversion layer 250 based on the range of wavelength in light that is transmitted out through the second metal layer 260. Since the micro-cavity effect is repeated two times in the cathode 270C, selectivity for the wavelength of the transmitted light increases, so that sharpness of a color to be expressed can be improved. Transmission characteristics of the cathode 270C will be now described with reference to FIG. 2d.
- [97] FIG. 2d is a graph for describing transmittance of incident light in the organic light-emitting display apparatus of FIG. 2c. Referring to FIG. 2d, in the graph, an x-axis represents a wavelength of transmitted light, and a y-axis represents transmittance of incident light. In FIG. 2d, the cathode 270C is formed by sequentially layering the first metal layer 240, the color conversion layer 250, the second metal layer 260, the additional color conversion layer 252 and the third metal layer 242. The first metal layer 240 and the third metal layer 242 are made of silver (Ag) having a thickness of 200 angstroms, and the second metal layer 260 is made of silver (Ag) having a thickness of 400 angstroms. The color conversion layer 250 and the additional color conversion layer 252 are made of photo acryl having thicknesses of 1800 angstroms, 2300 angstroms, and 1200 angstroms, and the color conversion layer 250 and the additional color conversion layer 252 have the same thickness. Line A depicts a case where the thicknesses of the color conversion layers 250 and 252 are 1800 angstroms, line B depicts a case where the thicknesses of the color conversion layers are 2300 angstroms, and line C depicts a case where the thicknesses of the color conversion layers are 1200 angstroms. The maximum transmittance is observed at a wavelength of 470 nm in line A, the maximum transmittance is observed at a wavelength of 550 nm in line B, and the maximum transmittance is observed at a wavelength of 620 nm in line C.
- [98] Further, when comparing lines A, B and C of FIG. 2d with lines F, E and D of FIG.

2b a lifting phenomenon in which light having an undesired wavelength is transmitted is alleviated, and a transmittance of at least 0.5 or more is maintained at a peak of a wavelength. As described above, since the micro-cavity effect occurs twice, selectivity for the certain wavelength can be improved.

- [99] FIG. 2e illustrates a cross-sectional view of an organic light-emitting display apparatus in which particles are formed on a cathode of an organic light-emitting display apparatus. An organic light-emitting display apparatus 200E according to an exemplary embodiment of the present invention includes a plurality of particles 280 formed on a cathode 270E. A substrate 210, an anode 220, an organic emissive layer 230, a first metal layer 240, a color conversion layer 250 and a second metal layer 260 of FIG. 2e are same as the substrate 210, the anode 220, the organic emissive layer 230, the first metal layer 240, the color conversion layer 250 and the second metal layer 260 of FIG. 2a, and thus the redundant descriptions thereof will not be presented.
- [100] Referring to FIG. 2e, the plurality of particles 280 is formed on the second metal layer 260. The plurality of particles 280 is formed on the second metal layer 260. A top of the second metal layer 260 has a lens shape by the plurality of particles 280 formed. Since transmitted light is concentrated on a top of the organic light-emitting display apparatus 200E by the plurality of particles 280 formed in a lens shape, optical efficiency of the organic light-emitting display apparatus 200E can be improved.
- [101] The plurality of particles 280 may be made of silicon nitride (SiN_x), silicon oxide (SiO_2), transparent particles such as glass, or nano polymer. Alternatively, the plurality of particles 280 may be made of a conductive material such as silver (Ag) and gold (Au). If the plurality of particles 280 is made of the conductive material, when the second metal layer 260 and the first metal layer 240 come in contact with each other, a resistance of the cathode 270E can be decreased. When the resistance of the cathode 270E is decreased, voltage drop is decreased, so that a top emission type large-area organic light-emitting display apparatus having more uniform luminance can be implemented.
- [102] The plurality of particles 280 has a diameter of 200 angstroms or more and 1000 angstroms or less. When the plurality of particles 280 has a diameter of 200 angstroms or more, it is easy for the plurality of particles 280 to sufficiently refract light in a lens shape, and when the plurality of particles has a diameter of 1000 angstroms or less, distortion by the plurality of particles 280 does not occur.
- [103] As illustrated in FIG. 2e, a particle enrooting layer 290 may be formed to cover the plurality of particles 280. The particle enrooting layer 290 may be made of an inorganic film such as silicon nitride (SiN_x) film and silicon oxide (SiO_2) film, or a conductive oxide such as indium zinc oxide (IZO), indium tin oxide (ITO) and indium tin zinc oxide (ITZO). The particle enrooting layer 290 has excellent coverage charac-

teristics and is formed to surround the plurality of particles 280.

- [104] When the particle enrooting layer 290 is made of the same material as that of the plurality of particles 280, for example, when both the particle enrooting layer 290 and the plurality of particles 280 are silicon nitride (SiN_x) films, the plurality of particles 280 is formed in a lens shape, so that the ghost phenomenon can be alleviated.
- [105] FIG. 3a illustrates a cross-sectional view for describing a color transformation layer formed on an encapsulation unit in an organic light-emitting display apparatus. Referring to FIG. 3a, an organic light-emitting display apparatus 300A includes a substrate 310, an anode 320, an organic emissive layer 330, a cathode 340, an encapsulation unit 350, and a color transformation layer 360A. The color transformation layer 360A includes a first metal layer 362, a color conversion layer 364, and a second metal layer 366. The substrate 310, the anode 320 and the organic emissive layer 330 of FIG. 3a is the same as the substrate 210, the anode 220 and the organic emissive layer 230 of FIG. 2a, and thus the redundant descriptions thereof will not be presented.
- [106] In FIG. 3a, the cathode 340 is one metal layer and is formed on the organic emissive layer 330. The encapsulation unit 350 is provided on the cathode 340. The encapsulation unit 350 serves as a support and protection plate disposed on a top of an organic light-emitting diode. The encapsulation unit 350 protects internal devices of the organic light-emitting display apparatus such as a thin-film transistor or an organic light-emitting diode from moisture, air, and impact from the outside.
- [107] The encapsulation unit 350 may be made of an insulating material such as glass or plastic, or may be made of other various materials. The encapsulation unit 350 may be variously provided depending on a manner of encapsulating internal devices of the organic light-emitting display apparatus such as the thin-film transistor and the organic light-emitting diode. For example, the type of encapsulating the organic light-emitting display apparatus may be a metal can encapsulation type, a glass can encapsulation type, a thin-film encapsulation (TFE) type.
- [108] The color transformation layer 360A is formed on the encapsulation unit 350, and the color transformation layer 360A is formed by sequentially layering the first metal layer 362, the color conversion layer 364 and the second metal layer 366. In the organic light-emitting display apparatus 300A, the color transformation layer 360A facilitates generating a colored light from the organic light-emitting diode by the aforementioned micro-cavity effect, but it does not serve as the cathode of the organic light-emitting diode. The color transformation layer 360A is still prepared on the same substrate as the organic-light-emitting diode. Therefore, it is possible to reduce a defect rate of the organic light-emitting display apparatus due to a misalignment of a color filter substrate and a substrate of the organic light-emitting diodes.
- [109] While the color transformation layer 360A is illustrated as being positioned directly

above the encapsulation unit 350 in FIG. 3a, the position of the color transformation layer 360A is not particularly limited. For example, in the organic light-emitting display apparatus 300A, the color transformation layer 360A may be formed on a touch screen panel. In an in-cell structure in which the touch screen panel is embedded in the organic light-emitting display apparatus 300A, the color transformation layer 360A may be formed on the touch screen panel. That is, the color transformation layer 360A, the organic light-emitting diode and the touch screen panel may be formed within one organic light-emitting display apparatus 300A.

[110] Further, at least one of the first metal layer 362 and the second metal layer 366 can serve as an electrode providing a certain functionality. In way of an example, capacitance can be formed by at least one of the first metal layer 362 and the second metal layer 366, and one or more transistors within a pixel may be electrically coupled to at least one of the first metal layer 362 and the second metal layer 366 to utilize the capacitance in driving the organic-light-emitting diode. Also, at least one of the first metal layer 362 and the second metal layer 366 may be used in providing the touch sensing functionality.

[111] FIG. 3b illustrates a cross-sectional view of a color transformation layer formed on an encapsulation unit in an organic light-emitting apparatus 300B as a modified example. The organic light-emitting display apparatus 300B according to an exemplary embodiment of the present invention includes a substrate 310, an anode 320, an organic emissive layer 330, a cathode 340, an encapsulation unit 350, and a color transformation layer 360B. The color transformation layer 360B is formed by sequentially layering a first metal layer 362, an organic material layer 364a, an inorganic material layer 364b, and a second metal layer 366. The substrate 310, the anode 320, the organic emissive layer 330, the cathode 340, the encapsulation unit 350, the first metal layer 362 and the second metal layer 366 of FIG. 3b are substantially same as the substrate 310, the anode 320, the organic emissive layer 330, the cathode 340, the encapsulation unit 350, the first metal layer 362 and the second metal layer 366 of FIG. 3a, and thus the redundant descriptions thereof will not be presented.

[112] The color transformation layer 360B includes the organic material layer 364a and the inorganic material layer 364b that are alternately layered between the two metal layers 362 and 366. Such a structure in which the organic material layer and the inorganic material layer are alternately layered may support the encapsulation unit 350, providing an enhanced thin-film encapsulation unit for the organic-light-emitting display apparatus. The thin-film encapsulation unit is an encapsulation unit used in a flexible display apparatus. Unlike an encapsulation unit made of glass, the thin-film encapsulation unit is capable of being bent and has a moisture permeability preventing effect and a foreign substance covering effect.

- [113] The organic material layer 364a and the inorganic material layer 364b of the color transformation layer 360B have the same functions as the organic material layer and the inorganic material layer used in the thin-film encapsulation unit. That is, the organic material layer 364a of the color transformation layer 360B also covers foreign substances generated during a process to prevent the foreign substances from degrading the internal light-emitting diode. Further, the inorganic material layer 364b also serves to prevent external moisture or external air from permeating the organic light-emitting diode. The organic material layer 364a and the inorganic material layer 364b are alternately layered in the color transformation layer 360B, so that the color transformation layer 360B also serves as the thin-film encapsulation unit.
- [114] The organic material layer 364a may be made of a material selected from organic materials such as polyimide, photo acryl and benzocyclobutene. The inorganic material layer 364b may be made of a material having refined glass fine particles, or a material selected from inorganic materials such as metal, oxide, nitride, and ceramic.
- [115] In addition, the micro-cavity effect between the first metal layer 362 and the second metal layer 366 depends on the thicknesses of the organic material layer 364a and the inorganic material layer 364b. Accordingly, only light having a certain wavelength of light incident onto the color transformation layer 360B is transmitted, and the color transformation layer 360B serves to generate a colored light from the light emitted from the organic emissive layer. That is, even though different materials, such as the organic material layer 364a and the inorganic material layer 364b, are formed between the first metal layer 362 and the second metal layer 366, the color transformation layer can shift the peak wavelength of the light. Further, in FIG. 3b, it has been illustrated that the inorganic material layer 364b is layered on the organic material layer 364a, a layering sequence of the two layers may be changed so long as the micro-cavity effect can be maintained.
- [116] Furthermore, in the organic light-emitting display apparatus 300B of FIG. 3b, the color transformation layer 360B formed on the encapsulation unit may further include an additional organic material layer, an additional inorganic material layer, and a third metal layer.
- [117] One or more stacks of the organic material layer and the inorganic material layer may be formed. The organic material layer may be formed of a material one which provides foreign substance covering property and the inorganic material layer may formed of a material having higher moisture permeability barrier property than the organic material layer.
- [118] Sequentially layering the additional organic material layer, the additional inorganic material layer and the third metal layer on the second metal layer 366 can generate yet another micro-cavity in the organic-light-emitting display apparatus. Accordingly, se-

lectivity for the wavelength of the transmitted light is increased to improve sharpness of an expressed color. Furthermore, the moisture permeability preventing effect and the foreign substance covering effect are improved by the plurality of layers. A layering sequence of the additional organic material layer and the additional inorganic material layer may be changed.

[119] The color transformation layer of the organic light-emitting display apparatus in which the organic material layer, the inorganic material layer and the metal layer are formed in multiple layers can implement vivid color separation to be able to replace the color filter depending on the thickness of the color transformation layer. Since the color transformation layer can implement the function of the thin-film encapsulation unit and the color conversion function, when the present color transformation layer is applied to a flexible organic light-emitting display apparatus, it is possible to improve reliability of the flexible organic light-emitting display apparatus.

[120] A diagram and graphs for describing a change in wavelength of light by a cathode in an organic light-emitting display apparatus are illustrated in FIGs. 4 (a), (b) and (c). FIG. 4 (a) is a schematic diagram of an organic light-emitting display apparatus 400.

[121] The organic light-emitting display apparatus 400 according to an exemplary embodiment of the present invention includes an organic light-emitting diode. The organic light-emitting diode includes an anode 420, a white organic emissive layer 430 formed on the anode 420 and a cathode 440 formed on the white organic emissive layer 430. The organic light-emitting diode is configured to emit white light. The cathode 440 includes two metal layers and a transparent material 442 interposed between the two metal layers. The cathode 440 including the transparent material 442 supplies electrons to the organic light-emitting diode and transmits only light having a certain wavelength of the white light which has been emitted from the organic light-emitting diode and has been incident onto the cathode 440. Referring to FIG. 4 (a), when light 412 emitted from the white organic emissive layer 430 passes through the cathode 440, only light 414 having a certain wavelength is transmitted.

[122] The cathode 440 of the organic light-emitting display apparatus 400 according to the exemplary embodiment of the present invention has the highest transmittance at a wavelength of visible light. In other words, the peak of the wavelength is within the range of visible light wavelengths. Accordingly, the organic light-emitting display apparatus 400 can implement colors through the cathode 440, and a user can recognize colors transformed by the cathode 440.

[123] The cathode 440 of the organic light-emitting display apparatus 400 according to the exemplary embodiment of the present invention has a transmittance of 60% or more for the certain wavelength. When transmittance of the transmitted light having the certain wavelength is 60% or more, the organic light-emitting display apparatus can

implement vivid colors.

- [124] FIG. 4 (b) is a graph representing a wavelength of the light 412 emitted from the white organic emissive layer 430 illustrated in FIG. 4 (a). FIG. 4 (c) is a graph representing a wavelength of the light 414 of the light 412 which has been emitted from the white organic emissive layer 430 illustrated in FIG. 4 (a) and has been transmitted through the cathode 440. In (b) and FIG. 4 (c), a y-axis represents intensity of normalized light, and an x-axis represents a wavelength thereof. As shown in FIG. 4 (b), a wavelength of the light 412 emitted from the white organic emissive layer 430 has averagely high intensity at all wavelengths in the range of visible light.
- [125] As stated above, when the light 412 having the wavelength represented in FIG. 4 (b) is transmitted through the cathode 440, the light having the certain wavelength is transmitted. Referring to FIG. 4 (c), when a thickness of the transparent material 442 is about 2800 angstroms, the transmitted light 414 has the highest intensity at a wavelength of 610 nm. That is, the white light transmitted through the cathode 440 is converted into red light.
- [126] FIGS. 5a to 5d illustrate cross-sectional views of processes for describing a method for manufacturing an organic light-emitting display apparatus 500 according to an exemplary embodiment of the present invention. First, referring to FIG. 5a, anodes 520a, 520b and 520c are respectively formed in a red sub-pixel area R, a green sub-pixel area G and a blue sub-pixel area B on a substrate 510. The anodes 520a, 520b and 520c may be formed by a photolithography method. Bank layers 515 are formed at boundaries of the anodes 520a, 520b and 520c. Subsequently, an organic emissive layer 530 is formed on the anodes 520a, 520b and 520c and the bank layers 515. The organic emissive layer 530 is formed by depositing blue and various kinds of organic luminous materials which can express white by being mixed with blue.
- [127] Thereafter, referring to FIG. 5b, a first metal layer 540 is formed on the organic emissive layer 530. The first metal layer 540 may be formed by depositing a metal material on the organic emissive layer 530, and may be formed on the entire surface of the substrate 510.
- [128] Referring to FIG. 5c, color conversion layers 550a, 550b and 550c may be formed at different thicknesses in the sub-pixel areas. Each of the color conversion layers 550a, 550b and 550c has a thickness capable of transmitting light having a certain wavelength. The color conversion layers 550a, 550b and 550c may be formed by using a FMM (Fine Metal Mask) method, an inkjet method, a nozzle printing method, or a screen printing method. The color conversion layer 550a, 550b and 550c may be formed by selecting a process without damaging the organic emissive layer 530. Referring to FIG. 5d, a second metal layer 560 is formed on the color conversion layer 550. The second metal layer 560 may be formed by depositing a metal material on the

organic emissive layer 530, and may be formed on the entire surface of the substrate 510. Moreover, an encapsulation unit may be provided on the second metal layer 560.

[129] Referring to FIGS. 5a to 5d, in the organic light-emitting display apparatus 500 according to the exemplary embodiment of the present invention, since the cathode 570 that includes the first metal layer 540, the color conversion layer 550 and the second metal layer 560 and transforms a color is formed on the substrate 510 on which the organic light-emitting diode is formed, there is an advantage in terms of a process. Since color filters are formed for colors to be expressed on a separate substrate at the time of forming the color filter, at least three masks are needed to express red, green and blue. However, according to the present invention, since the color conversion layer 550 can be formed through the nozzle printing, manufacturing cost can be reduced. In addition, when the color filter is used, in order to prevent the organic emissive layer 530 from being damaged, the color filter needs to be formed on a separate substrate 510, and the substrate 510 on which the color filter is formed needs to be aligned with the substrate 510 on which the organic emissive layer 530 is formed. In the organic light-emitting display apparatus 500 of the present invention, since the organic emissive layer 530 and the color transformation layer are formed on one substrate, there is an effect of reducing a defect rate of the organic light-emitting display apparatus due to a misalignment of two substrates.

[130] In another exemplary embodiment, an encapsulation unit may be formed on an organic light-emitting diode including an anode, an organic emissive layer and a cathode, and a first metal layer, a color conversion layer and a second metal layer are sequentially formed on the encapsulation unit.

[131] The organic light-emitting display apparatus according to the exemplary embodiment of the present invention may be a bottom emission type organic light-emitting display apparatus. The bottom emission type organic light-emitting display apparatus may include a substrate; an anode including a first metal layer formed on the substrate, an organic material layer formed on the first metal layer and a second metal layer formed on the organic material layer; an organic emissive layer formed on the anode; and a cathode formed on the organic emissive layer.

[132] Here, the anode may be made of a transparent conductive material, and the cathode may be made of metal. Since and the first metal layer, the organic material layer and the second metal layer that are capable of serving as the color filter and the organic light-emitting diode are formed on the same substrate, there is no misalignment problem, and it is possible to provide a thinner organic light-emitting display apparatus.

[133] Hereinafter, various characteristics of the organic light-emitting display apparatus of the present invention will be described.

- [134] According to another characteristic of the present invention, the first area is a red pixel area, the second area is a green pixel area, and the third area is a blue pixel area, and wherein the first color conversion layer formed on the first area has a thickness for causing constructive interference of light within a first range of wavelengths, the second color conversion layer formed on the second area has a thickness for causing constructive interference of light within a second range of wavelengths, and the third color conversion layer formed on the third area has a thickness for causing constructive interference of light within a third range of wavelengths.
- [135] According to still another characteristic of the present invention, the organic light-emitting display apparatus further comprising a fourth area on the substrate, the fourth area including the anode, the organic emissive layer and the first metal layer of the cathode.
- [136] According to still another characteristic of the present invention, the organic light-emitting display apparatus further includes a contact area in which the first metal layer and the second metal layer are in contact with each other.
- [137] According to still another characteristic of the present invention, the organic light-emitting display apparatus further comprising a black matrix positioned at the contact area in which the first metal layer and the second metal layer are in contact with each other.
- [138] According to still another characteristic of the present invention, wherein the first metal layer and the second metal layer have substantially the same thickness.
- [139] According to still another characteristic of the present invention, wherein the color conversion layer has a thickness thicker than a thickness of the first metal layer and a thickness of the second metal layer.
- [140] According to still another characteristic of the present invention, wherein the cathode further includes an additional color conversion layer formed on the second metal layer, and a third metal layer formed on the additional color conversion layer.
- [141] According to still another characteristic of the present invention, wherein the second metal layer has a thickness that is greater than a thickness of the first metal layer and a thickness of the third metal layer.
- [142] According to still another characteristic of the present invention, wherein the cathode has a light transmittance rate of 60% or more for the predetermined range of wavelength.
- [143] According to another characteristic of the present invention, wherein a thickness of the color conversion layer is different in a plurality of areas within the organic light-emitting display such that the color conversion layer in each area is configured to cause constructive interference of light within a limited range of wavelengths.
- [144] According to still another characteristic of the present invention, wherein the color

transformation layer further includes a second color conversion layer disposed on the second metal layer, and includes a third metal layer disposed on the second color conversion layer.

- [145] According to still another characteristic of the present invention, wherein the color conversion layer includes a stack of an organic material layer and an inorganic material layer.
- [146] According to still another characteristic of the present invention, wherein the color transformation layer further includes a stack of an organic material layer and an inorganic material layer disposed on the second metal layer, and includes a third metal layer disposed on the second stack of the organic material layer and the inorganic material layer.
- [147] According to still another characteristic of the present invention, wherein at least one of the first metal layer and the second metal layer is configured to serve as a cathode.
- [148] According to another characteristic of the present invention, the method further comprising: forming a cathode on the organic emissive layer; and forming an encapsulation unit on the cathode, wherein the first metal layer, the color conversion layer and the second metal layer are disposed on the encapsulation unit.
- [149] The present invention has been described in more detail with reference to the exemplary embodiments, but the present invention is not limited to the exemplary embodiments. It will be apparent to those skilled in the art that various modifications can be made without departing from the technical spirit of the invention. Accordingly, the exemplary embodiments disclosed in the present invention are used not to limit but to describe the technical spirit of the present invention, and the technical spirit of the present invention is not limited to the exemplary embodiments. Therefore, the exemplary embodiments described above are considered in all respects to be illustrative and not restrictive. The protection scope of the present invention must be interpreted by the appended claims and it should be interpreted that all technical spirits within a scope equivalent thereto are included in the appended claims of the present invention.

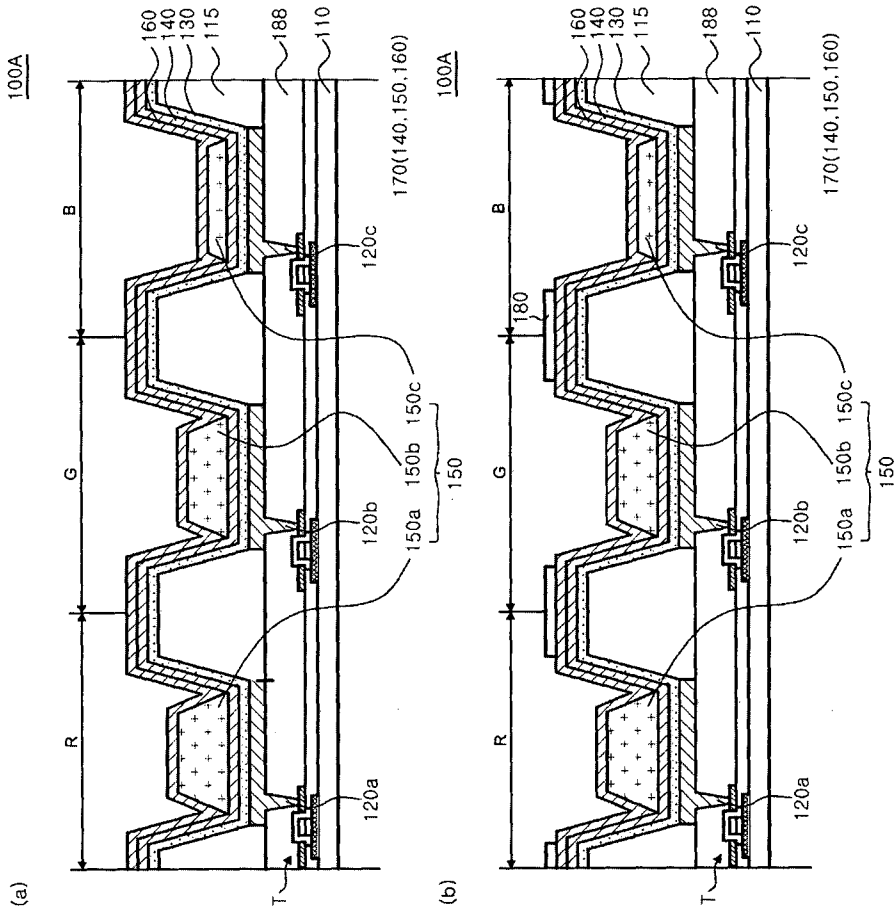
Claims

- [Claim 1] An organic light-emitting display apparatus comprising:
a substrate that includes a first area, a second area, and a third area;
an anode formed on the substrate;
an organic emissive layer formed on the anode; and
a cathode formed on the organic emissive layer,
wherein the cathode includes:
a first metal layer,
a second metal layer, and
a first color conversion layer interposed between the first and second metal layer in the first area,
a second color conversion layer interposed between the first and second metal layer in the second area,
a third color conversion layer interposed between the first and second metal layer in the third area, and wherein each of the color conversion layers having a thickness that is different from each other.
- [Claim 2] The organic light-emitting display apparatus of claim 1, wherein the first area is a red pixel area, the second area is a green pixel area, and the third area is a blue pixel area, and wherein the first color conversion layer formed on the first area has a thickness for causing constructive interference of light within a first range of wavelengths, the second color conversion layer formed on the second area has a thickness for causing constructive interference of light within a second range of wavelengths, and the third color conversion layer formed on the third area has a thickness for causing constructive interference of light within a third range of wavelengths.
- [Claim 3] The organic light-emitting display apparatus of claim 2, further comprising a fourth area on the substrate, the fourth area including the anode, the organic emissive layer and the first metal layer of the cathode.
- [Claim 4] The organic light-emitting display apparatus of claim 3, further includes a contact area in which the first metal layer and the second metal layer are in contact with each other.
- [Claim 5] The organic light-emitting display apparatus of claim 4, further comprising a black matrix positioned at the contact area in which the first metal layer and the second metal layer are in contact with each other.

- [Claim 6] The organic light-emitting display apparatus of claim 5, wherein the first metal layer and the second metal layer have substantially the same thickness.
- [Claim 7] The organic light-emitting display apparatus of claim 5, wherein the color conversion layer has a thickness thicker than a thickness of the first metal layer and a thickness of the second metal layer.
- [Claim 8] The organic light-emitting display apparatus of claim 5, wherein the cathode further includes an additional color conversion layer formed on the second metal layer, and a third metal layer formed on the additional color conversion layer.
- [Claim 9] The organic light-emitting display apparatus of claim 8, wherein the second metal layer has a thickness that is greater than a thickness of the first metal layer and a thickness of the third metal layer.
- [Claim 10] The organic light-emitting display apparatus of claim 5, wherein the cathode has a light transmittance rate of 60% or more for the predetermined range of wavelength.
- [Claim 11] An organic light-emitting display apparatus comprising:
a substrate;
an anode formed on the substrate;
an organic emissive layer formed on the anode;
a cathode formed on the organic emissive layer;
an encapsulation unit formed on the cathode; and
a color transformation layer formed on the encapsulation unit,
wherein the color transformation layer includes a first metal layer, a color conversion layer formed on the first metal layer, and a second metal layer formed on the color conversion layer.
- [Claim 12] The organic light-emitting display apparatus of claim 11, wherein a thickness of the color conversion layer is different in a plurality of areas within the organic light-emitting display such that the color conversion layer in each area is configured to cause constructive interference of light within a limited range of wavelengths.
- [Claim 13] The organic light-emitting display apparatus of claim 11, wherein the color transformation layer further includes a second color conversion layer disposed on the second metal layer, and includes a third metal layer disposed on the second color conversion layer.
- [Claim 14] The organic light-emitting display apparatus of claim 11, wherein the color conversion layer includes a stack of an organic material layer and an inorganic material layer.

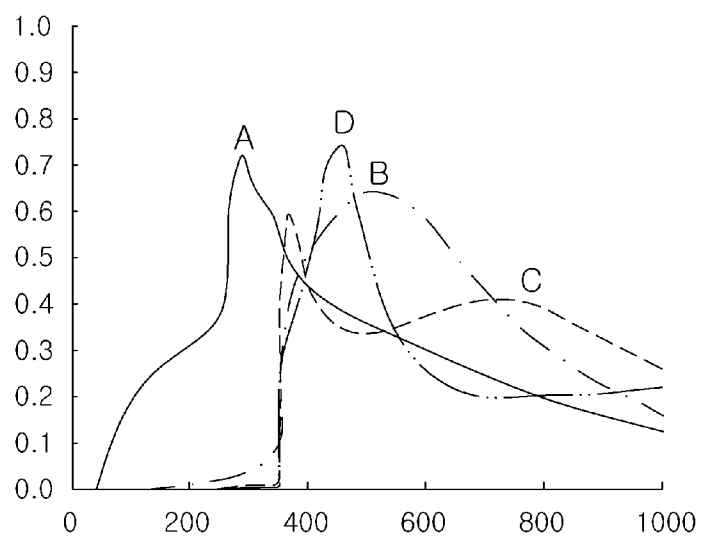
- [Claim 15] The organic light-emitting display apparatus of claim 11, wherein the color transformation layer further includes a stack of an organic material layer and an inorganic material layer disposed on the second metal layer, and includes a third metal layer disposed on the second stack of the organic material layer and the inorganic material layer.
- [Claim 16] A method for manufacturing an organic light-emitting display apparatus, comprising:
forming an anode on a substrate;
forming an organic emissive layer; and
forming a color conversion layer interposed between a first metal layer and a second metal layer.
- [Claim 17] The method of claim 16, wherein at least one of the first metal layer and the second metal layer is configured to serve as a cathode.
- [Claim 18] The method of claim 16, further comprising:
forming a cathode on the organic emissive layer; and
forming an encapsulation unit on the cathode,
wherein the first metal layer, the color conversion layer and the second metal layer are disposed on the encapsulation unit.

[Fig. 1a]

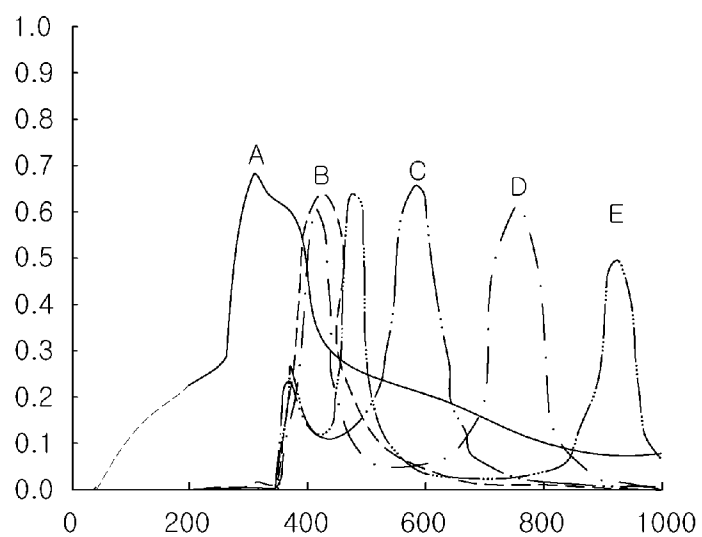


[Fig. 1b]

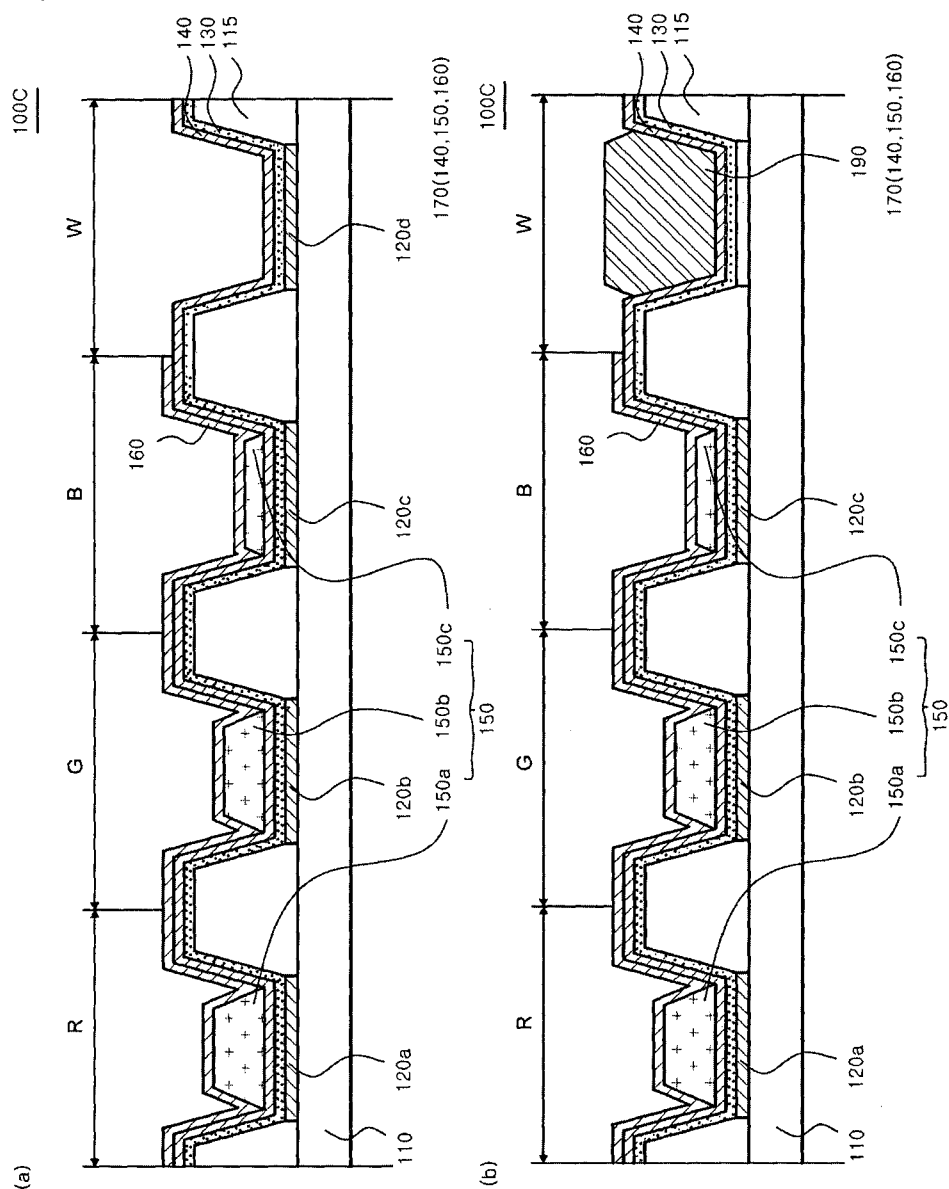
(a)



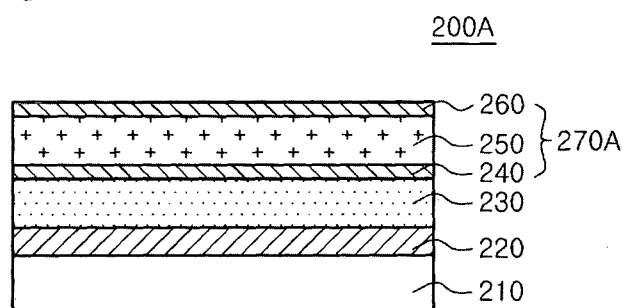
(b)



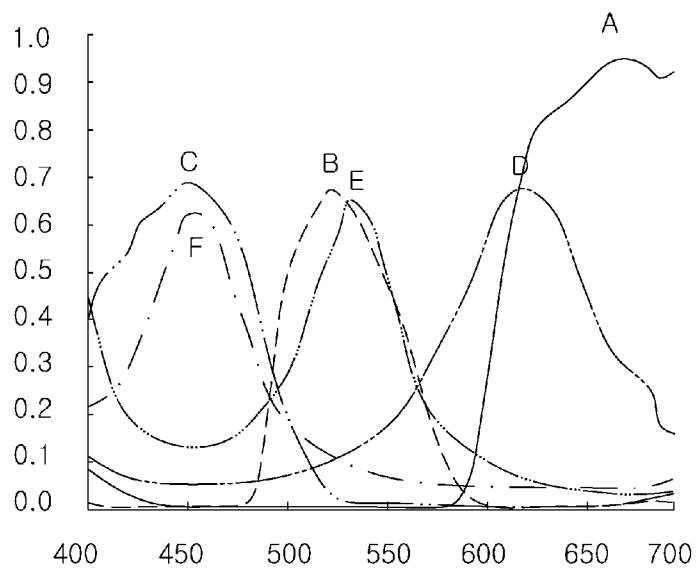
[Fig. 1c]



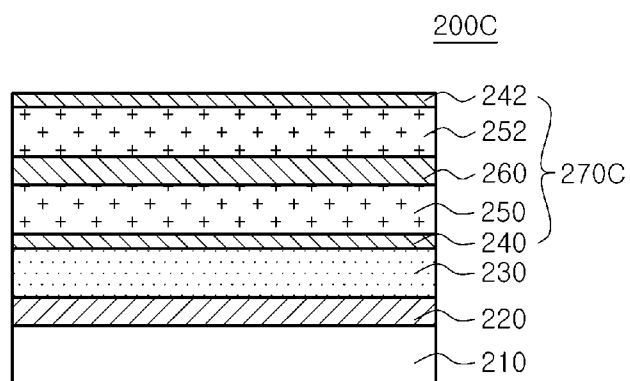
[Fig. 2a]



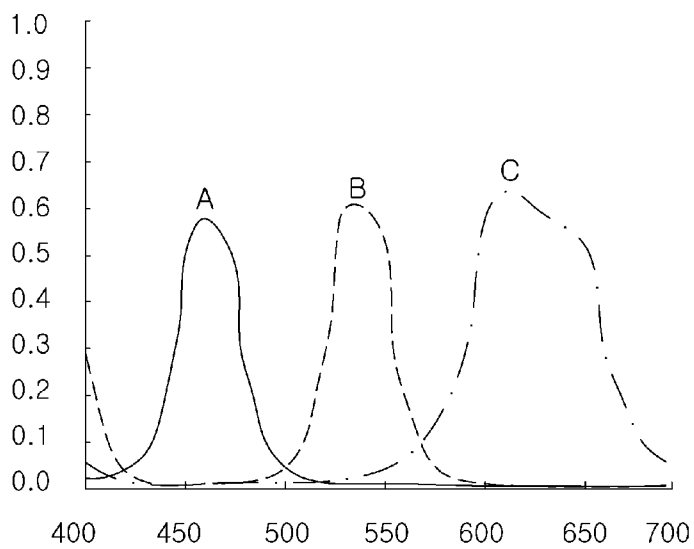
[Fig. 2b]



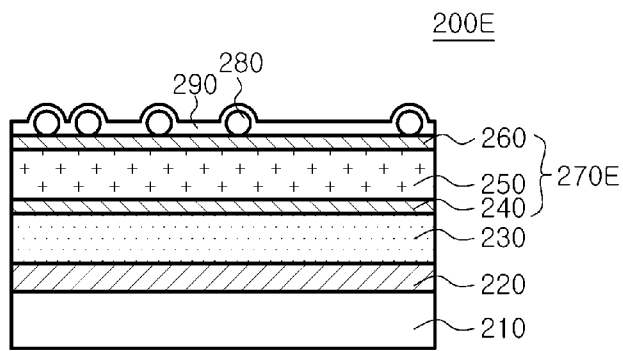
[Fig. 2c]



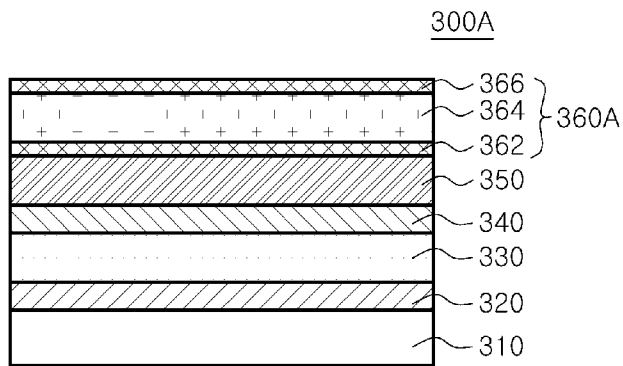
[Fig. 2d]



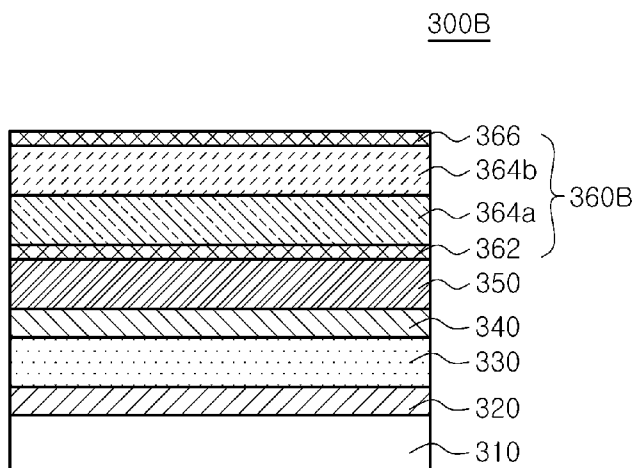
[Fig. 2e]



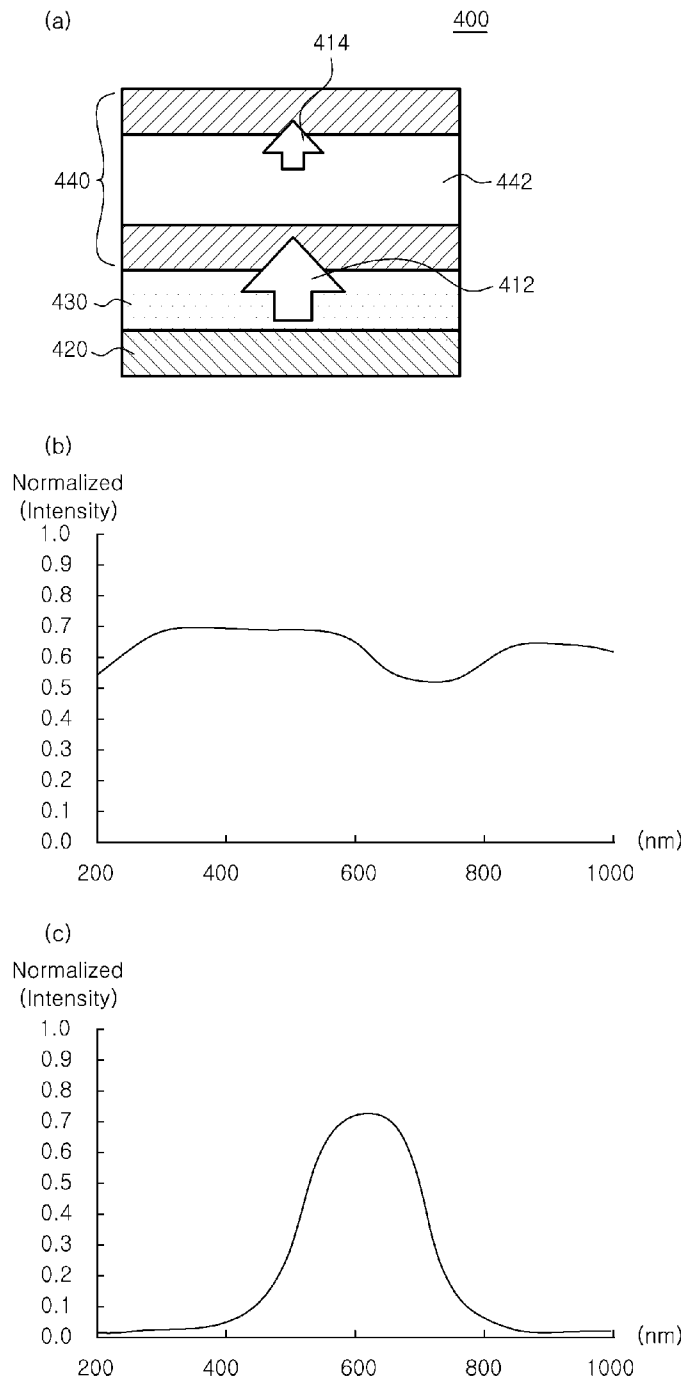
[Fig. 3a]



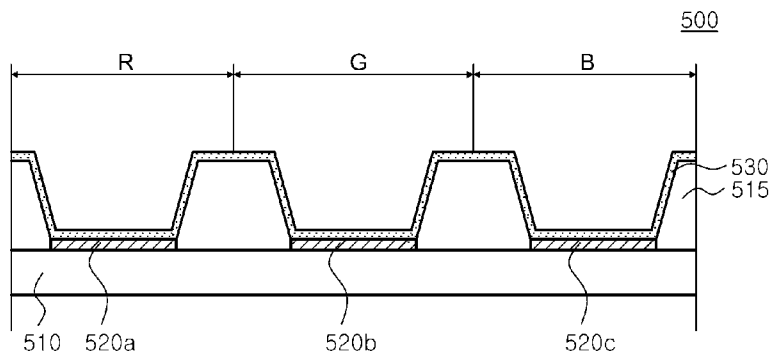
[Fig. 3b]



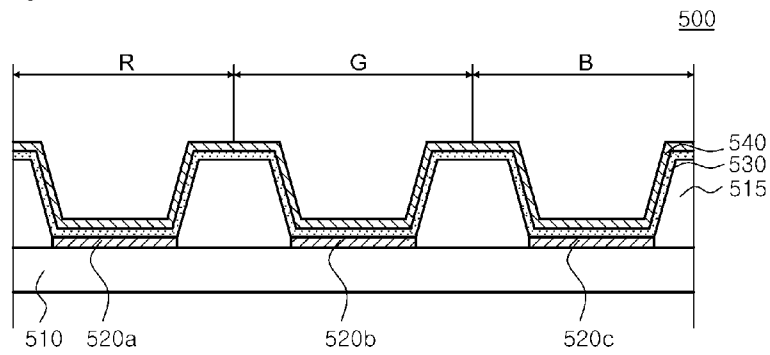
[Fig. 4]



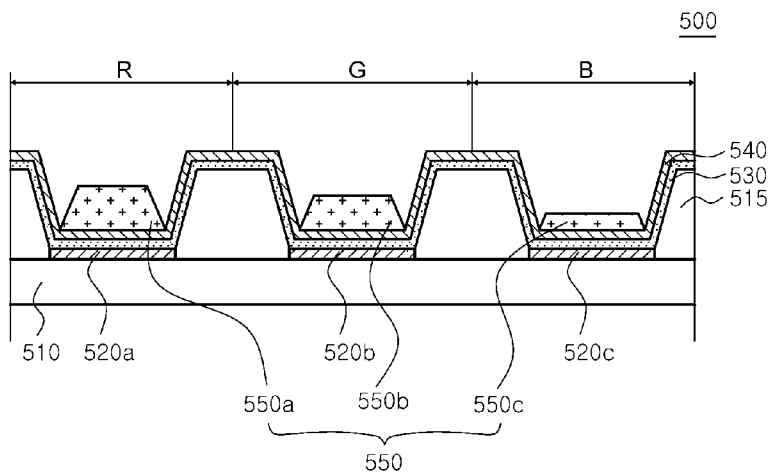
[Fig. 5a]



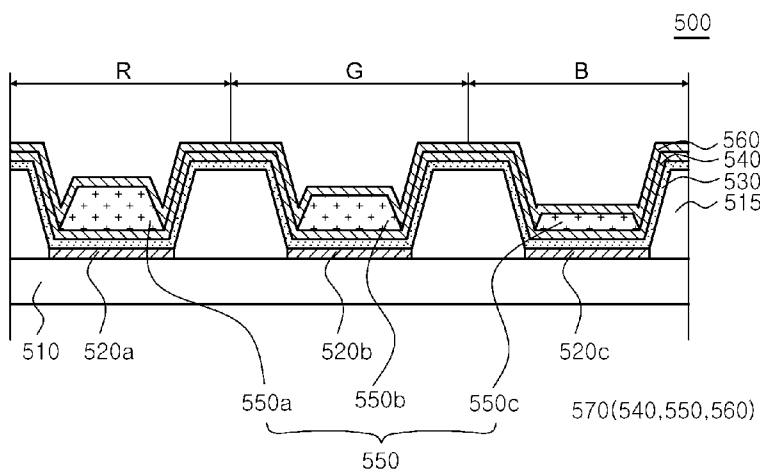
[Fig. 5b]



[Fig. 5c]



[Fig. 5d]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2014/003601**A. CLASSIFICATION OF SUBJECT MATTER****H01L 51/50(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 51/50; H05B 33/00; G02B 5/22; H05B 33/28; H05B 33/12; H05B 33/14; H05B 33/22; H05B 33/10; H05B 33/20; H05B 33/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: organic light-emitting display, anode, organic emissive layer, cathode, color conversion layer and interpose

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005-0140276 A1 (JAE YONG PARK) 30 June 2005 See paragraphs [0027]–[0038]; claims 1-6; and figure 2.	1-18
A	KR 10-2010-0056735 A (SAMSUNG ELECTRONICS CO., LTD.) 28 May 2010 See paragraphs [0031], [0074]–[0078]; claims 1-14 and figure 9.	1-18
A	JP 2004-281088 A (FUJI ELECTRIC HOLDINGS CO., LTD.) 07 October 2004 See abstract; paragraphs [0031]–[0074]; claims 1-6; and figures 1(a)–1(c).	1-18
A	KR 10-2010-0033749 A (SAMSUNG ELECTRONICS CO., LTD.) 31 March 2010 See paragraphs [0089]–[0119]; claims 1-8; and figure 2.	1-18
A	US 2013-0038205 A1 (HIDEYO NAKAMURA et al.) 14 February 2013 See paragraphs [0050]–[0060]; claims 1-12; and figures 1A-1E.	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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