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- H01L 2933/0041; H01L 51/0097; H01L 51/5253; H01L 2251/5338; H01L 27/3244; H01L 51/5246; H01L 27/3267; H01L 27/3262; H01L 27/3258

See application file for complete search history.

- (56)
- References Cited**

U.S. PATENT DOCUMENTS

- | | | | | |
|--------------|-----|--------|--------------|-------------|
| 7,545,466 | B2 | 6/2009 | Lee | |
| 8,426,227 | B1 | 4/2013 | Bibl et al. | |
| 2017/0194304 | A1* | 7/2017 | Takeya | H01L 25/167 |

- FOREIGN PATENT DOCUMENTS

This patent is subject to a terminal disclaimer.

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|----|-----------------|---------|
| JP | 2015-500562 | 1/2015 |
| KR | 10-2006-0036131 | 4/2006 |
| KR | 10-2012-0075042 | 7/2012 |
| KR | 10-2013-0092896 | 8/2013 |
| KR | 10-2013-0137985 | 12/2013 |
| WO | 2015/193763 | 12/2015 |

* cited by examiner

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Primary Examiner — Roy Potter

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PLC

US 2017/0250164 A1 Aug. 31, 2017

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- (51) **Int. Cl.**
H01L 25/075 (2006.01)
H01L 27/12 (2006.01)
H01L 33/50 (2010.01)

- (52) **U.S. Cl.**
CPC *H01L 25/0753* (2013.01); *H01L 27/124*
(2013.01); *H01L 33/504* (2013.01); *H01L*
2933/0041 (2013.01)

- (58) **Field of Classification Search**
CPC . H01L 25/0753; H01L 27/124; H01L 33/504;

(57) **ABSTRACT**

A display apparatus including a light emitting diode part including a plurality of regularly arranged light emitting diodes, and a thin-film transistor (TFT) panel part including a plurality of TFTs configured to drive the light emitting diodes disposed on the TFT panel part. The light emitting diode part further includes a transparent substrate disposed on the light emitting diodes, and a phosphor layer disposed on the transparent substrate and configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes, in which a thickness of the transparent substrate is less than a thickness of the phosphor layer.

14 Claims, 5 Drawing Sheets

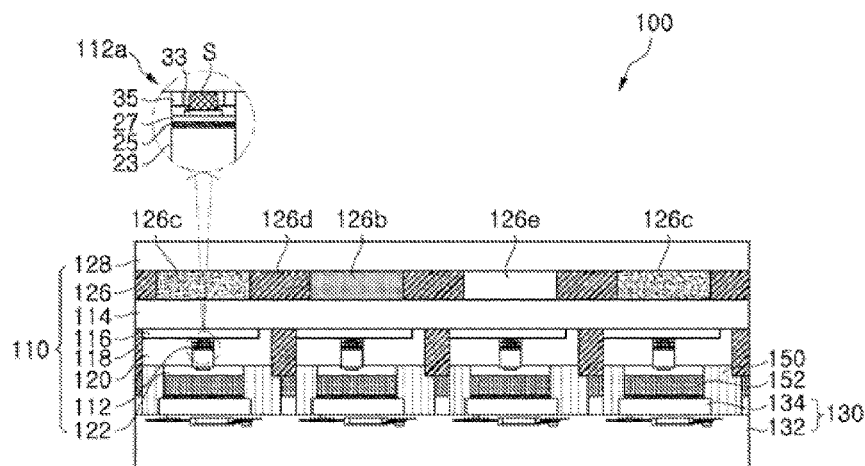


FIG. 1

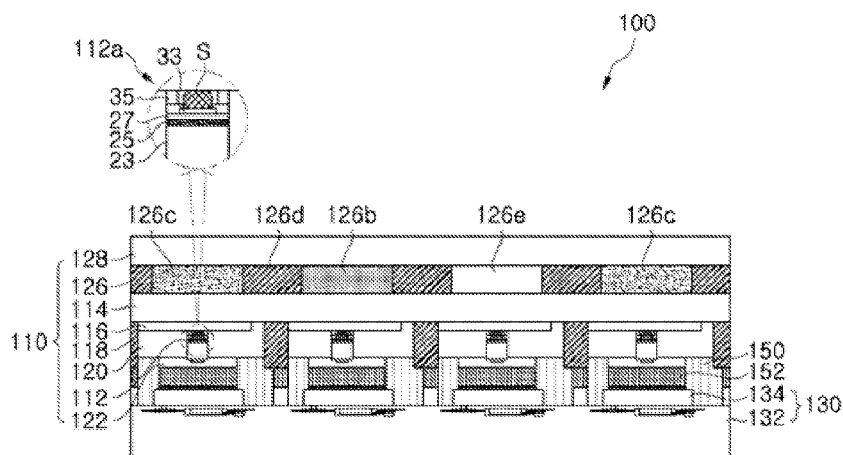


FIG. 2

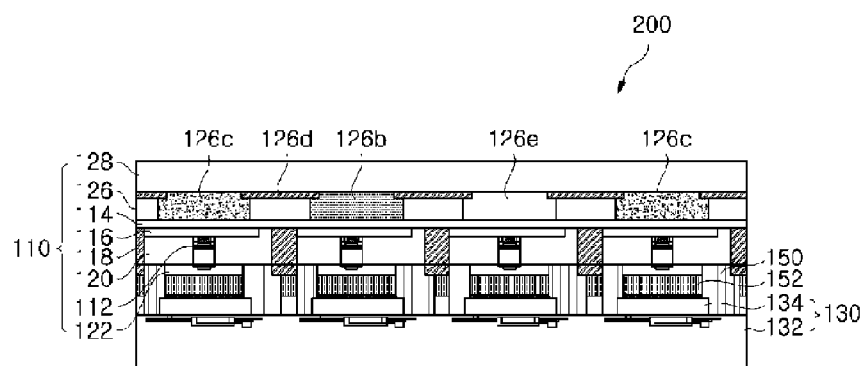


FIG. 3A

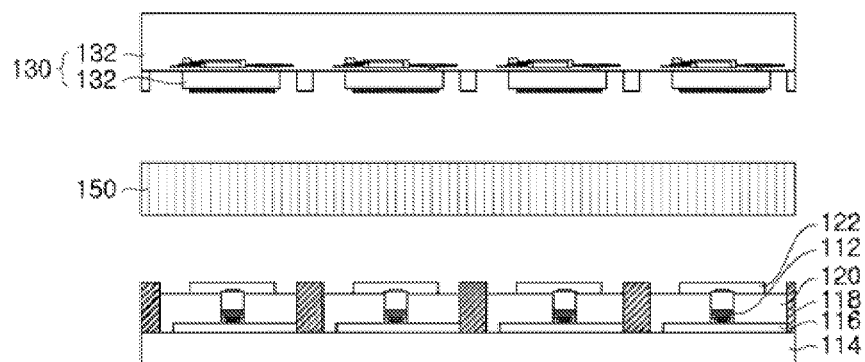


FIG. 3B

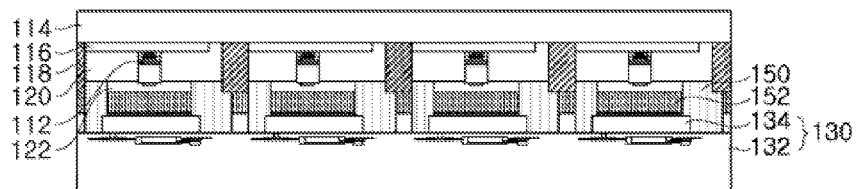


FIG. 3C

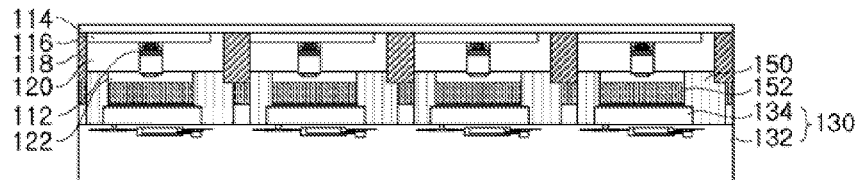


FIG. 3D

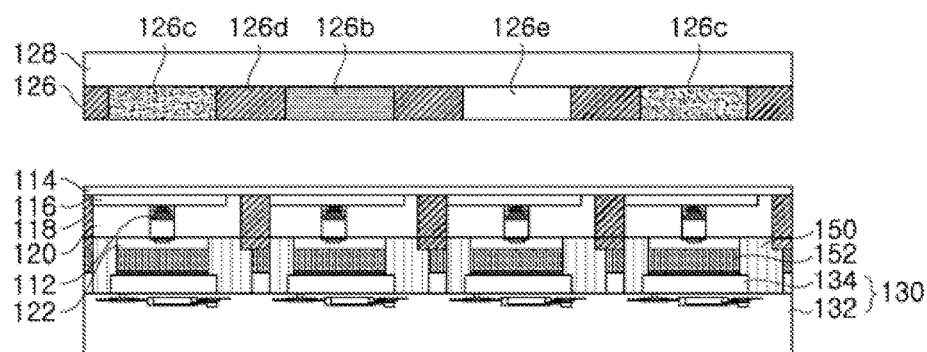


FIG. 4

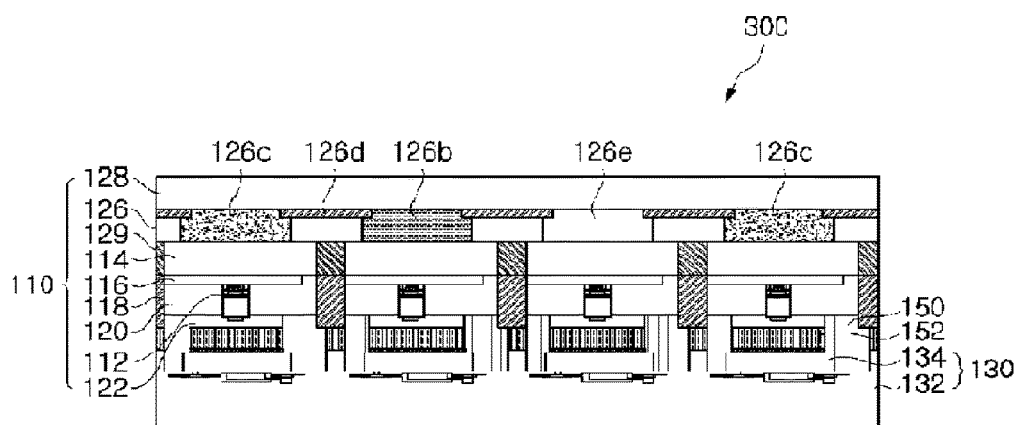


FIG. 5A

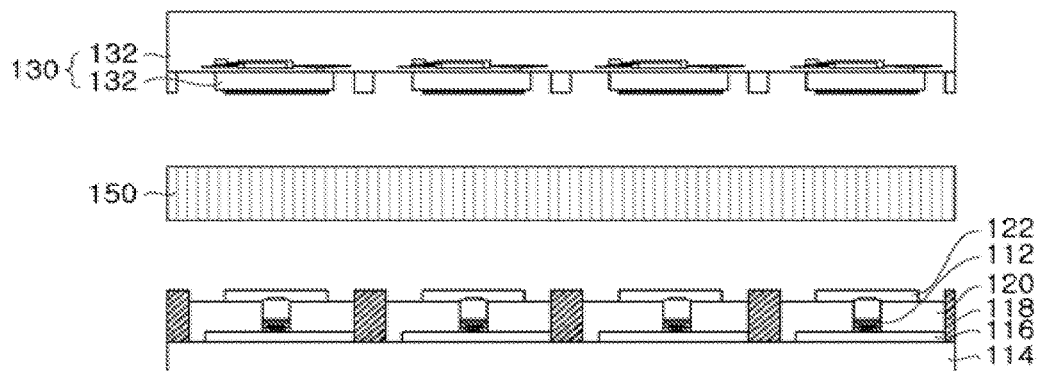


FIG. 5B

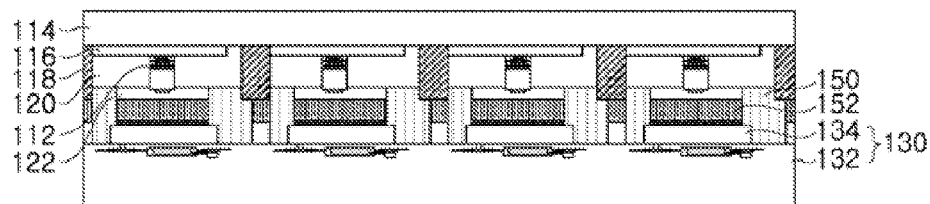


FIG. 5C

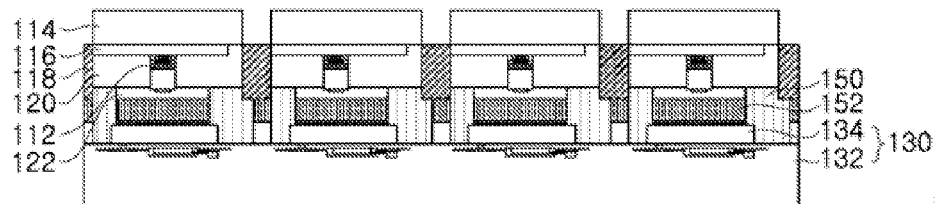


FIG. 5D

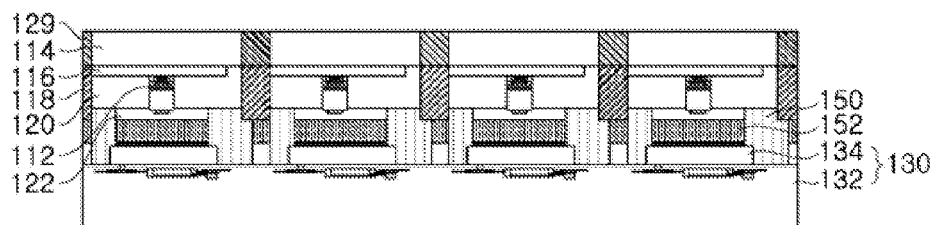


FIG. 5E

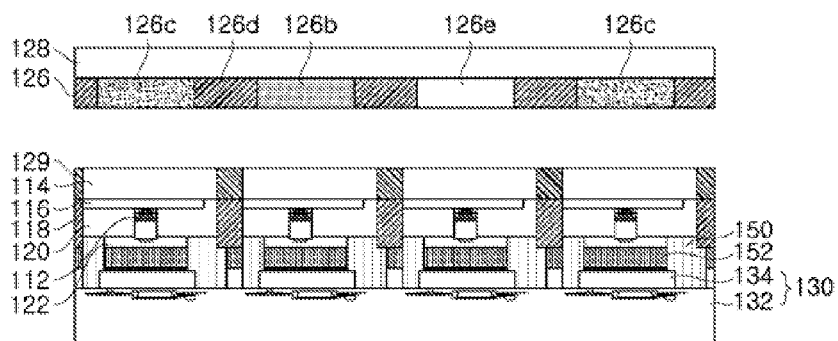


FIG. 6

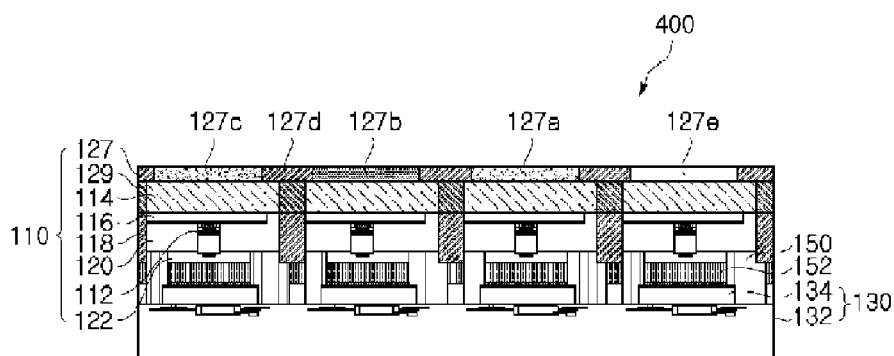
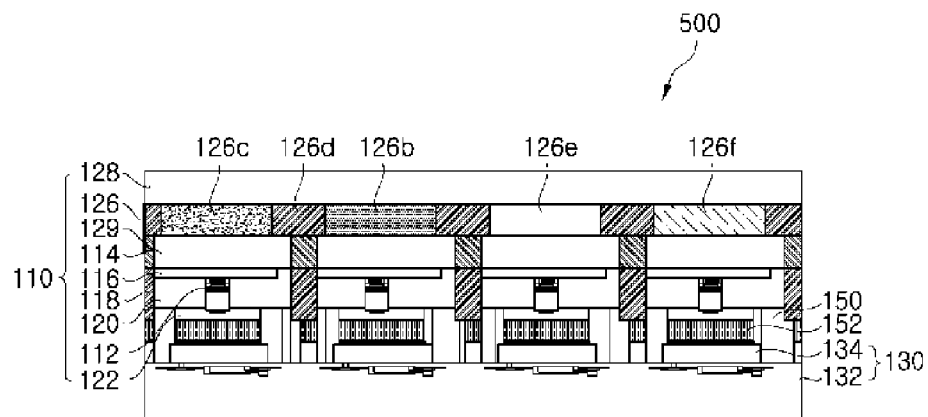


FIG. 7



1

DISPLAY APPARATUS AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from and the benefit of U.S. Provisional Patent Application No. 62/300,348, filed on Feb. 26, 2016, which is hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND

Field

Exemplary embodiments relate to a display apparatus and a method of manufacturing the same, and more particularly, to a display apparatus using micro-light emitting diodes and a method of manufacturing the same.

Discussion of the Background

A light emitting diode generally refers to an inorganic semiconductor device that emits light through recombination of electrons and holes. Light emitting diodes have been recently used in various fields including displays, automobile lamps, general lighting, and the like. A light emitting diode has various advantages, such as long lifespan, low power consumption, and rapid response. As such, a light emitting device using a light emitting diode is used as a light source in various fields.

Recently, smart TVs or monitors may realize colors using a thin-film transistor liquid crystal display (TFT LCD) panel and use light emitting diodes (LEDs) as a light source for a backlight unit to display a color. In addition, a display apparatus is often manufactured using organic light emitting diodes (OLEDs).

In a TFT-LCD, since one LED may be used as a light source for many pixels, a backlight light source must be kept in a turned-on state. As a result, the TFT-LCD may suffer from constant power consumption regardless of the brightness of a displayed screen. On the other hand, although power consumption of an OLED has been continuously reduced due to ongoing development of the technology, the OLED still has much higher power consumption than LEDs formed of inorganic semiconductors. Thus, OLEDs have a lower efficiency than LEDs.

Moreover, a passive matrix (PM) drive type OLED may suffer from deterioration in response speed from controlling pulse amplitude modulation (PAM) of the OLED having large capacitance, and may also suffer from deterioration in lifespan upon high current driving through pulse width modulation (PWM) for realizing a low duty ratio. Moreover, an active matrix (AM) driving type OLED may require connection of TFTs for each pixel, which may increase in manufacturing costs and cause non-uniform brightness according to the characteristics of the TFTs.

SUMMARY

Exemplary embodiments provide a display apparatus using micro-light emitting diodes having low power consumption that may be applicable to a wearable apparatus, a smartphone, or a TV, and a method of manufacturing the same.

According to an exemplary embodiment, a display apparatus includes a light emitting diode part including a plurality of regularly arranged light emitting diodes, and a thin-film transistor (TFT) panel part including a plurality of TFTs configured to drive the light emitting diodes disposed

2

on the TFT panel part. The light emitting diode part further includes a transparent substrate disposed on the light emitting diodes, and a phosphor layer disposed on the transparent substrate and configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes, in which a thickness of the transparent substrate is less than a thickness of the phosphor layer.

The transparent substrate may have a thickness equal to or less than 10 μm .

The phosphor layer may include a green phosphor layer configured to emit green light by converting a wavelength of light emitted from the light emitting diodes, and a red phosphor layer configured to emit red light by converting a wavelength of light emitted from the light emitting diodes.

The light emitting diodes may include blue light emitting diodes configured to emit blue light, and the phosphor layer may further include a transparent layer transmitting light emitted from the light emitting diodes without a wavelength conversion.

Each of the light emitting diodes may include an n-type semiconductor layer, a p-type semiconductor layer, an active layer interposed between the n-type semiconductor layer and the p-type semiconductor layer, an n-type electrode coupled to the n-type semiconductor layer, and a p-type electrode coupled to the p-type semiconductor layer.

The display apparatus may further include an anisotropic conductive film electrically connecting the light emitting diode part to the TFT panel part.

According to an exemplary embodiment, a display apparatus includes a light emitting diode part including a plurality of regularly arranged light emitting diodes, and a thin-film transistor (TFT) panel part including a plurality of TFTs configured to drive the light emitting diodes disposed on the TFT panel part. The light emitting diode part further includes a transparent substrate disposed on the light emitting diodes, and a phosphor layer disposed on the transparent substrate and configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes. The transparent substrate includes a plurality of sections each disposed on an upper surface of the light emitting diodes, respectively, and a blocking portion formed between the sections of the transparent substrate and blocking light emitted from the light emitting diodes.

The blocking portion may include a metal.

According to an exemplary embodiment, a display apparatus includes a light emitting diode part including a plurality of regularly arranged light emitting diodes, and a thin-film transistor (TFT) panel part including a plurality of TFTs configured to drive the light emitting diodes disposed on the TFT panel part. The light emitting diode part further includes a substrate disposed on the light emitting diodes and including a white phosphor configured to emit white light by converting a wavelength of light emitted from the light emitting diodes, and a color filter including a blue light portion, a green light portion, and a red light portion, each portion being configured to transmit blue light, green light, and red light, respectively, therethrough among white light emitted from the substrate. The substrate includes a plurality of sections each disposed on an upper surface of each light emitting diode, and a blocking portion formed between the sections and blocking light emitted from the light emitting diodes.

The color filter may further include a transparent portion configured to transmit white light emitted from the substrate therethrough without a wavelength conversion.

According to an exemplary embodiment, a method of manufacturing a display apparatus includes forming a substrate including a plurality of regularly arranged light emitting diodes, coupling the substrate to a thin-film transistor (TFT) panel part including a plurality of TFTs configured to drive the light emitting diodes, reducing a thickness of the substrate by etching or grinding the substrate, and forming a phosphor layer on an upper surface of the substrate, the phosphor layer being configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes, in which a thickness of the substrate is reduced to be less than a thickness of the phosphor layer.

The method may further include coupling the substrate to the TFT panel part by an anisotropic conductive film.

According to an exemplary embodiment, a method of manufacturing a display apparatus includes forming a substrate including a plurality of regularly arranged light emitting diodes, coupling the substrate to a thin-film transistor (TFT) panel part including a plurality of TFTs configured to drive the light emitting diodes, etching a portion of the substrate, such that light emitted from each of the light emitting diodes is prevented from being mixed with light emitted from adjacent light emitting diodes, and forming a phosphor layer on the substrate, the phosphor layer being configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes.

BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the disclosed technology, and are incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the disclosed technology, and together with the description serve to describe the principles of the disclosed technology.

FIG. 1 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

FIG. 2 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

FIG. 3A, FIG. 3B, FIG. 3C, and FIG. 3D are cross-sectional views illustrating a method of manufacturing the display apparatus of FIG. 2 according to an exemplary embodiment.

FIG. 4 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

FIG. 5A, FIG. 5B, FIG. 5C, FIG. 5D, and FIG. 5E are cross-sectional views illustrating a method of manufacturing the display apparatus of FIG. 4 according to an exemplary embodiment.

FIG. 6 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

FIG. 7 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of various exemplary embodiments. It is apparent, however, that various exemplary embodiments may be practiced without these specific details or with one or more equivalent arrangements. In other instances, well-known structures and devices are

shown in block diagram form in order to avoid unnecessarily obscuring various exemplary embodiments.

In the accompanying figures, the size and relative sizes of layers, films, panels, regions, etc., may be exaggerated for clarity and descriptive purposes. Also, like reference numerals denote like elements.

When an element or layer is referred to as being “on,” “connected to,” or “coupled to” another element or layer, it may be directly on, connected to, or coupled to the other element or layer or intervening elements or layers may be present. When, however, an element or layer is referred to as being “directly on,” “directly connected to,” or “directly coupled to” another element or layer, there are no intervening elements or layers present. For the purposes of this disclosure, “at least one of X, Y, and Z” and “at least one selected from the group consisting of X, Y, and Z” may be construed as X only, Y only, Z only, or any combination of two or more of X, Y, and Z, such as, for instance, XYZ, XYY, YZ, and ZZ. Like numbers refer to like elements throughout. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

Although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, layer, and/or section from another element, component, region, layer, and/or section. Thus, a first element, component, region, layer, and/or section discussed below could be termed a second element, component, region, layer, and/or section without departing from the teachings of the present disclosure.

Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for descriptive purposes, and, thereby, to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the drawings. Spatially relative terms are intended to encompass different orientations of an apparatus in use, operation, and/or manufacture in addition to the orientation depicted in the drawings. For example, if the apparatus in the drawings is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. Furthermore, the apparatus may be otherwise oriented (e.g., rotated 90 degrees or at other orientations), and, as such, the spatially relative descriptors used herein interpreted accordingly.

The terminology used herein is for the purpose of describing particular embodiments and is not intended to be limiting. As used herein, the singular forms, “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Moreover, the terms “comprises,” “comprising,” “includes,” and/or “including,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, components, and/or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Various exemplary embodiments are described herein with reference to sectional illustrations that are schematic illustrations of idealized exemplary embodiments and/or intermediate structures. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus,

5

exemplary embodiments disclosed herein should not be construed as limited to the particular illustrated shapes of regions, but are to include deviations in shapes that result from, for instance, manufacturing. The regions illustrated in the drawings are schematic in nature and their shapes are not intended to illustrate the actual shape of a region of a device and are not intended to be limiting.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure is a part. Terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense, unless expressly so defined herein.

Hereinafter, exemplary embodiments of the present disclosure will be described in detail with reference to the accompanying drawings.

FIG. 1 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

Referring to FIG. 1, the display apparatus 100 according to an exemplary embodiment includes a light emitting diode part 110, a TFT panel part 130, and an anisotropic conductive film 150.

The light emitting diode part 110 includes light emitting diodes 112, a support substrate 114, transparent electrodes 116, a first blocking portion 118, an insulation layer 120, first connection electrodes 122, a phosphor layer 126, and a protective substrate 128.

The light emitting diode part 110 includes a plurality of light emitting diodes 112, which are regularly arranged on the support substrate 114. For example, the plurality of light emitting diodes 112 may be arranged at constant intervals in a matrix form. The plurality of light emitting diodes 112 may include, for example, blue light emitting diodes emitting blue light, and may alternatively or additionally include UV light emitting diodes emitting UV light, as needed.

In the display apparatus 100, the light emitting diode part 110 may be driven by power applied from an exterior power source. More particularly, an image may be reproduced through on-off combination of the light emitting diodes 112 in the light emitting diode part 110, and red light, green light, and blue light may be emitted through the phosphor layer 126 without using a separate LCD. In FIG. 1, a region including a single light emitting diode 112 may be used as a subpixel in the display apparatus 100. In the light emitting diode part 110, one subpixel may have a larger size than the light emitting diode 112 disposed in the subpixel.

Each of the light emitting diodes 112 includes an n-type semiconductor layer 23, an active layer 25, a p-type semiconductor layer 27, an n-type electrode 31, a p-type electrode 33, and a wall 35.

The n-type semiconductor layer 23, the active layer 25, and the p-type semiconductor layer 27 may include Group III-V based compound semiconductors. For example, the n-type semiconductor layer 23, the active layer 25, and the p-type semiconductor layer 27 may include nitride semiconductors such as (Al, Ga, In)N. According to an exemplary embodiment, however, locations of the n-type semiconductor layer 23 and the p-type semiconductor layer 27 may be interchanged.

The n-type semiconductor layer 23 may include an n-type dopant (for example, Si) and the p-type semiconductor layer 27 may include a p-type dopant (for example, Mg). The active layer 25 is interposed between the n-type semiconductor layer 23 and the p-type semiconductor layer 27. The

6

active layer 25 may have a multi-quantum well (MQW) structure, and the composition of the active layer 25 may be varied to emit light having a desired peak wavelength.

The light emitting structure including the n-type semiconductor layer 23, the active layer 25, and the p-type semiconductor layer 27 may have a structure that is similar to a vertical-type light emitting diode 112. In this case, the n-type electrode 31 may be formed on an outer surface of the n-type semiconductor layer 23, and the p-type electrode 33 may be formed on an outer surface of the p-type semiconductor layer 27.

As shown in FIG. 1, referring to an enlarged portion of a light emitting diode 112a, a bonding portion S may be formed between the p-type electrode 33 and the transparent electrode 116 to couple the light emitting diode 112, which has a structure similar to that of the vertical-type light emitting diode, to the transparent electrode 116 formed on the support substrate 114. Here, the wall 35 may be formed on the light emitting diode 112 to prevent the bonding portion S from escaping from a space between the p-type electrode 33 and the transparent electrode 116.

The wall 35 may be formed to cover a portion of the p-type electrode 33, such that the p-type electrode 33 may be exposed on the p-type semiconductor layer 27. The wall 35 may include a plurality of layers. For example, the wall 35 may include a first layer and a second layer, and may be formed by forming the first layer including SiN on the p-type semiconductor layer 27 to cover a portion of the p-type electrode 33, and then forming the second layer including SiO₂ on the first layer. The second layer may have a greater thickness and a smaller width than those of the first layer.

The support substrate 114 is a substrate on which the plurality of light emitting diodes 112 may be mounted, and may be an insulation substrate, a conductive substrate, or a printed circuit board. For example, the support substrate 114 may be at least one of a sapphire substrate, a gallium nitride substrate, a glass substrate, a silicon carbide substrate, a silicon substrate, a metal substrate, and a ceramic substrate. According to an exemplary embodiment, the support substrate 114 may be a transparent substrate that may transmit light emitted from the light emitting diodes 112. For example, the support substrate 114 may be a flexible glass substrate having a thickness of, for example, 30 μm to 100 μm.

The transparent electrode 116 may be formed on the support substrate 114, and may be electrically connected to the p-type electrode 33 of the light emitting diode 112. In FIG. 1, a plurality of transparent electrodes 116 may be formed on the support substrate 114, and may be coupled to the plurality of light emitting diodes 112, respectively. Alternatively, the plurality of light emitting diodes 112 may be coupled to one transparent electrode 116, as needed. In addition, the transparent electrodes 116 may be separated from each other on the support substrate 114. For example, the transparent electrodes 116 may include indium tin oxide (ITO) and the like.

The first blocking portion 118 is formed on the support substrate 114 and may be provided in plural. The first blocking portion 118 prevents light emitted from a certain light emitting diode 112 from being directed towards other light emitting diodes 112 adjacent thereto, when light emitted from the light emitting diodes 112 is emitted to the outside through the transparent electrodes 116. Accordingly, each of the first blocking portions 118 may be formed between the transparent electrodes 116 separated from each other, and may be formed to cover a portion of each of the

transparent electrodes **116**, as needed. The first blocking portion **118** may include, for example, aluminum (Al) or chromium (Cr).

The insulation layer **120** may surround the light emitting diode **112**. The insulation layer **120** may cover an exposed surface of a connecting plane between the light emitting diode **112** and the transparent electrode **116**, while covering the transparent electrode **116**. When the insulation layer **120** surrounds the light emitting diode **112**, the n-type semiconductor layer **23** and the n-type electrode **31** of the light emitting diode **112** may be exposed through the insulation layer **120**.

The first connection electrode **122** covers the insulation layer **120**, and may also cover the n-type semiconductor layer **23** and the n-type electrode **31** not covered by the insulation layer **120**. Accordingly, the first connection electrode **122** may be electrically connected to the n-type semiconductor layer **23**.

The phosphor layer **126** may be formed on an upper surface of the support substrate **114**, and may include a green phosphor layer **126b**, a red phosphor layer **126c** and, a transparent layer **126e**. In addition, a blocking layer **126d** may be formed between the green phosphor layer **126b**, the red phosphor layer **126c**, and the transparent layer **126e**. The green phosphor layer **126b**, the red phosphor layer **126c**, and the transparent layer **126e** may be alternately arranged to be adjacent to one another or may be separated from one another by a predetermined distance.

The green phosphor layer **126b** converts the wavelength of blue light emitted from the light emitting diodes **112** to emit green light, and the red phosphor layer **126c** converts the wavelength of blue light emitted from the light emitting diode **112** to emit red light. In addition, the transparent layer **126e** is disposed near the green phosphor layer **126b** and the red phosphor layer **126c** to transmit blue light emitted from the light emitting diodes **112a** therethrough. Accordingly, red light, green light, and blue light may be emitted through the phosphor layer **126**.

The protective substrate **128** may be formed on an upper surface of the phosphor layer **126**. The protective substrate **128** may protect the phosphor layer **126** from an external environment by preventing the phosphor layer **126** from being directly exposed to the outside. The protective substrate **128** may include a transparent material, similarly to the support substrate **114**. For example, the protective substrate **128** may be a glass substrate having a thickness of 30 μm to 100 μm .

The TFT panel part **130** includes a panel substrate **132** and second connection electrodes **134**, and is coupled to the light emitting diode part **110** to supply power to the light emitting diode part **110**. The TFT panel part **130** may control power supply to the light emitting diode part **110** such that only a portion the light emitting diodes **112** in the light emitting diode part **110** may emit light.

The panel substrate **132** may include a TFT drive circuit therein. The TFT drive circuit may be a circuit for driving an active matrix (AM) or a passive matrix (PM).

The second connection electrodes **134** may be electrically connected to the TFT drive circuit of the panel substrate **132** and to the first connection electrodes **122** of the light emitting diode part **110**. In this manner, power supplied through the TFT drive circuit may be supplied to each of the light emitting diodes **112** through the first and second connection electrodes **122**, **134**. Although now shown, the second connection electrodes **134** may be covered by a separate protective layer, which may include, for example, SiN_x .

The anisotropic conductive film **150** may electrically connect the light emitting diode part **110** to the TFT panel part **130**. The anisotropic conductive film **150** may include an adhesive organic insulation material and conductive particles uniformly dispersed therein for electrical connection. The anisotropic conductive film **150** may be conductive in the thickness direction thereof, and has insulating properties in the plane direction thereof. In addition, the anisotropic conductive film **150** may have adhesive properties. Thus, the anisotropic conductive film **150** may bond the light emitting diode part **110** to the TFT panel part **130**, such that the light emitting diode part **110** may be electrically connected to the TFT panel part **130** therethrough. Particularly, the anisotropic conductive film **150** may connect ITO electrodes, which are known to be difficult to solder at high temperatures.

As such, when the light emitting diode part **110** is coupled to the TFT panel part **130** via the anisotropic conductive film **150**, the first connection electrodes **122** of the light emitting diode part **110** may be electrically connected to the second connection electrodes **134** of the TFT panel part **130** via an electrode connection portion **152**.

FIG. 2 is a cross-sectional view of a display apparatus according to an exemplary embodiment, and FIGS. 3A to 3D are cross-sectional views illustrating a method of manufacturing the display apparatus of FIG. 2 according to an exemplary embodiment.

Referring to FIG. 2, the display apparatus **200** according to an exemplary embodiment includes a light emitting diode part **110**, a TFT panel part **130**, and an anisotropic conductive film **150**. The light emitting diode part **110** includes light emitting diodes **112**, a support substrate **114**, transparent electrodes **116**, a first blocking portion **118**, an insulation layer **120**, first connection electrodes **122**, a phosphor layer **126**, and a protective substrate **128**. The TFT panel part **130** includes a panel substrate **132** and second connection electrodes **134**. The display apparatus **200** of FIG. 2 may include substantially the same components as those of the display apparatus **100** illustrated in FIG. 1. As such, repeated descriptions of substantially the same components will be omitted.

In FIG. 2, the support substrate **114** may include a transparent material such that light emitted from the plurality of light emitting diodes **112** is transmitted to the outside through the support substrate **114**. The phosphor layer **126** may be formed on the upper surface of the support substrate **114**. Here, light emitted from one of light emitting diodes **112** may need to be emitted to the outside only through the corresponding phosphor layer **126** disposed thereon after passing through the support substrate **114**. More particularly, when light emitted from one light emitting diode **112** is emitted through another phosphor layer, instead of the corresponding phosphor layer **126** disposed thereon, the display apparatus **200** may not realize a desired color.

That is, one light emitting diode **112** may function as one subpixel, which realizes one color among blue light, green light, and red light. When light emitted from one light emitting diode **112** is emitted through the green phosphor layer **126b** or the transparent layer **126e**, instead of the corresponding red phosphor layer **126c** disposed on the light emitting diode **112**, green light and/or blue light may be emitted together with red light.

Accordingly, the support substrate **114** according to an exemplary embodiment may have a thickness less than a thickness of the support substrate **114** of the display apparatus **100** illustrated in FIG. 1. In the display apparatus **100** illustrated in FIG. 1, the support substrate **114** may have a

thickness of 30 μm to 100 μm , whereas the support substrate **114** according to an exemplary embodiment illustrated with reference to FIG. **2** may have a thickness of 10 μm or less. In this manner, the display apparatus **200** according to an exemplary embodiment may allow light emitted from each of the light emitting diodes **112** to travel only towards one of the red phosphor layer **126c**, the green phosphor layer **126b**, and the transparent layer **126e** disposed on the corresponding light emitting diodes **112**. In addition, a thickness of the support substrate **114** may be less than a thickness of the phosphor layer **126**.

Hereinafter, a method of manufacturing the display apparatus **200** including the support substrate **114** having a small thickness will be described with reference to FIGS. **3A** to **3D**, on which light emitting diode part **110** is formed.

Referring to FIG. **3A**, a plurality of transparent electrodes **116**, a plurality of light emitting diodes **112**, a first blocking portion **118**, an insulation layer **120**, and first connection electrodes **122** are formed on the support substrate **114**. A TFT panel part **130** is coupled to the light emitting diode part via an anisotropic conductive film **150**.

Referring to FIG. **3B**, the display apparatus **200** including the TFT panel part **130** is rotated such that the support substrate **114** faces upward direction. Then, the upper surface of the support substrate **114** is subjected to etching or grinding to reduce the thickness of the support substrate **114**. For example, the support substrate **114** having a thickness of about 30 μm to 100 μm may be etched or grinded to a small thickness of 10 μm or less. FIG. **3C** shows the support substrate **114** after etching or grinding the support substrate **114** to reduce the thickness thereof.

Referring to FIG. **3D**, a phosphor layer **126** and a protective substrate **128** are bonded to an upper surface of the support substrate **114**, thereby providing a display apparatus **200**, as shown in FIG. **2**.

FIG. **4** is a cross-sectional view of a display apparatus according to an exemplary embodiment. FIGS. **5A** to **5E** are cross-sectional views illustrating a method of manufacturing the display apparatus of FIG. **4** according to an exemplary embodiment.

Referring to FIG. **4**, the display apparatus **300** according to an exemplary embodiment includes a light emitting diode part **110**, a TFT panel part **130**, and an anisotropic conductive film **150**, a support substrate **114**, transparent electrodes **116**, a first blocking portion **118**, an insulation layer **120**, first connection electrodes **122**, a phosphor layer **126**, a protective substrate **128**, and a second blocking portion **129**. The light emitting diode part **110** includes light emitting diodes **112**. The TFT panel part **130** includes a panel substrate **132** and second connection electrodes **134**. The display apparatus **300** of FIG. **4** may include substantially the same components as those of the display apparatus **100** illustrated in FIG. **1**. As such, repeated descriptions of substantially the same components will be omitted.

Referring to FIG. **4**, the support substrate **114** according to an exemplary embodiment may include a transparent material, such that light emitted from the plurality of light emitting diodes **112** may be emitted to the outside through the support substrate **114** and the phosphor layer **126** formed on the upper surface of the support substrate **114**. The support substrate **114** is divided into a plurality of support substrates (or sections) separated from each other, of which are disposed only on the corresponding light emitting diodes **112**, respectively. In particular, the second blocking portion **129** may be formed between the support substrates **114**.

The second blocking portion **129** may be provided in plural such that each of the second blocking portions **129** is

disposed between adjacent support substrates **114**. In this manner, the second blocking portion **129** may prevent light emitted from one light emitting diode from traveling towards another light emitting diode **112** adjacent thereto, when light emitted from the light emitting diodes travels towards the phosphor layer **126** through the support substrates **114**.

More particularly, when the second blocking portion **129** is formed between the support substrates **114**, light emitted from one light emitting diode **112** may be discharged to the outside through the support substrate **114** and the phosphor layer **126** disposed on the light emitting diode **112**.

Hereinafter, a method of manufacturing the display apparatus **300** including the support substrate **114** and the second blocking portion **129** will be described with reference to FIGS. **5A** to **5E**, on which the light emitting diode part **110** is formed.

Referring to FIG. **5A**, a plurality of transparent electrodes **116**, a plurality of light emitting diodes **112**, first blocking portions **118**, an insulation layer **120**, and first connection electrodes **122** are formed on the support substrate **114**. A TFT panel part **130** is coupled to the light emitting diode part via an anisotropic conductive film **150**.

Referring to FIG. **5B**, the display apparatus **300** including the TFT panel part **130** is rotated such that the support substrate **114** faces upward direction. Then, a portion of the support substrate **114** may be subjected to wet etching. The etching may be performed on a portion of the support substrate **114** overlapping the first blocking portion **118**. As such, the support substrate **114** may be divided into a plurality of support substrates, and each of the first blocking portions **118** may be exposed through a space between the support substrates **114**, as shown in FIG. **5C**.

Although not shown in the drawings, the transparent electrodes **116** may be formed on the first blocking portion **118**, which may also be etched together with the support substrate **114** during etching the support substrate **114**. In this manner, a portion of the support substrate **114** disposed on the first blocking portion **118** may be removed by etching, such that the support substrate **114** may be formed to overlap each of the light emitting diodes **112**.

Then, as shown in FIG. **5D**, the second blocking portion **129** may be formed on grooves, which are formed by partially etching the support substrate **114** described above. The second blocking portion **129** may include aluminum (Al) or chromium (Cr), similarly to the first blocking portion **118**. In this manner, the second blocking portion **129** may be electrically connected to the first blocking portion **118**, and the first and second blocking portions **118**, **129** may function as common electrodes electrically connected to the transparent electrodes **116**.

Then, as shown in FIG. **5E**, after the support substrate **114** and the second blocking portion **129** are formed, a phosphor layer **126** and a protective substrate **128** may be attached to an upper surface of the support substrate **114**, thereby fabricating the display apparatus **300** of FIG. **4**.

FIG. **6** is a cross-sectional view of a display apparatus according to an exemplary embodiment.

Referring to FIG. **6**, the display apparatus **400** according to an exemplary embodiment includes a light emitting diode part **110**, a TFT panel part **130**, and an anisotropic conductive film **150**. The light emitting diode part **110** includes light emitting diodes **112**, a support substrate **114**, transparent electrodes **116**, a first blocking portion **118**, an insulation layer **120**, first connection electrodes **122**, a second blocking portion **129**, and a color filter **127**. The display apparatus **400** of FIG. **6** may include substantially the same components as

11

those of the display apparatus **100** illustrated in FIG. 1. As such, repeated descriptions of substantially the same components will be omitted.

The support substrate **114** according to an exemplary embodiment may include a transparent material and white phosphors therein. More particularly, the support substrate **114** may include a plurality of white phosphors and a receiving portion that receives the plurality of white phosphors therein. The receiving portion may be formed of a polymer resin, glass, or a ceramic material. Herein, the receiving portion will be described as being formed of a glass. That is, the support substrate **114** includes the plurality of phosphors dispersed in the receiving portion formed of a transparent glass.

The transparent electrodes **116**, the plurality of light emitting diodes **112**, the first blocking portion **118**, the insulation layer **120**, and the first connection electrodes **122** may be formed on the support substrate **114**, as similar to the support substrate **114** of the display apparatus **100** of FIG. 1. In addition, the support substrate **114** including the white phosphors is divided into a plurality of support substrates **114** (or sections) by partially etching the support substrate **114**. The second blocking portion **129** may be formed between the support substrates **114**, as similar to the support substrate **114** of the display apparatus **200** of FIG. 4.

As a result, light emitted from the light emitting diodes **112** may be subjected to wavelength conversion into white light through the support substrates **114** formed on the light emitting diodes **112**.

In addition, the color filter **127** may be formed on the upper surface of the support substrate **114**. The color filter **127** may have a film shape, and filters white light emitted through the support substrate **114** including the white phosphors, such that one of blue light, green light, and red light may be emitted through the color filter **127**. To this end, the color filter **127** includes a blue light portion **127a** that filters white light to allow blue light to pass therethrough, a green light portion **127b** that filters white light to allow green light to pass therethrough, and a red light portion **127c** that filters white light to allow red light to pass therethrough. The color filter **127** may further include a transparent portion **127e** that allows white light to pass therethrough, as needed.

The blue light portion **127a**, the green light portion **127b**, the red light portion **127c**, and the transparent portion **127e** may be disposed adjacent to one another, and a light blocking portion **127d** may be further formed between the blue light portion **127a**, the green light portion **127b**, the red light portion **127c**, and the transparent portion **127e**.

FIG. 7 is a cross-sectional view of a display apparatus according to an exemplary embodiment.

Referring to FIG. 7, the display apparatus **500** according to an exemplary embodiment includes a light emitting diode part **110**, a TFT panel part **130**, and an anisotropic conductive film **150**. The light emitting diode part **110** includes light emitting diodes **112**, a support substrate **114**, transparent electrodes **116**, a first blocking portion **118**, an insulation layer **120**, first connection electrodes **122**, a phosphor layer **126**, a protective substrate **128**, and a second blocking portion **129**. The TFT panel part **130** includes a panel substrate **132** and second connection electrodes **134**. The display apparatus **500** of FIG. 7 may include substantially the same components as those of the display apparatus **100** and **300** illustrated in FIGS. 1 and 4. As such, repeated descriptions of substantially the same components will be omitted.

In FIG. 7, the light emitting diodes **112** may be blue light emitting diodes, and the phosphor layer **126** includes a green

12

phosphor layer **126b**, a red phosphor layer **126c**, a blocking layer **126d**, a transparent layer **126e**, and a white phosphor layer **126f**. Accordingly, the phosphor layer **126** may emit green light, red light, blue light, and white light through wavelength conversion of blue light emitted from the light emitting diodes **112**.

In FIG. 7, yttrium aluminum garnet (YAG) phosphors may be used to convert the wavelength of the blue light emitted from the light emitting diodes **112** into white light, and the white phosphor layer **126f** may be disposed adjacent to the green phosphor layer **126b**, the red phosphor layer **126c**, and the transparent layer **126e**. In addition, the blocking layer **126d** may be further disposed between the green phosphor layer **126b**, the red phosphor layer **126c**, the transparent layer **126e**, and the white phosphor layer **126f**.

According to exemplary embodiments, the display apparatus may include micro-light emitting diodes formed of nitride semiconductors, and thus, may have high efficiency and high resolution that may be applicable to a wearable apparatus, while reducing power consumption.

In addition, according to exemplary embodiments, the display apparatus may include a blocking portion that prevents light emitted from one light emitting diode and passed through a phosphor layer from being mixed with light emitted from other light emitting diodes on a transparent support substrate, so as to prevent light emitted from one light emitting diode from being transferred to other subpixels, thereby realizing a desired color.

Although certain exemplary embodiments have been described herein, it should be understood by those skilled in the art that these embodiments are given by way of illustration only, and that various modifications, variations, and alterations can be made without departing from the spirit and scope of the invention. Therefore, the scope of the invention should be limited only by the accompanying claims and equivalents thereof.

What is claimed is:

1. A display apparatus comprising:

a light emitting diode part comprising a plurality of regularly arranged light emitting diodes; and
a thin-film transistor (TFT) panel part comprising a plurality of TFTs configured to drive the light emitting diodes disposed on the TFT panel part,

wherein the light emitting diode part further comprises:
a transparent substrate disposed on the light emitting diodes; and

a phosphor layer disposed on the transparent substrate and configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes, and

wherein a thickness of the transparent substrate is less than a thickness of the phosphor layer.

2. The display apparatus of claim 1, wherein the transparent substrate has a thickness equal to or less than 10 μm .

3. The display apparatus of claim 1, wherein the phosphor layer comprises:

a green phosphor layer configured to emit green light by converting a wavelength of light emitted from the light emitting diodes; and

a red phosphor layer configured to emit red light by converting a wavelength of light emitted from the light emitting diodes.

4. The display apparatus of claim 3, wherein:
the light emitting diodes comprises blue light emitting diodes configured to emit blue light; and

13

the phosphor layer further comprises a transparent layer transmitting light emitted from the light emitting diodes without a wavelength conversion.

5. The display apparatus of claim 1, wherein each of the light emitting diodes comprises:

- an n-type semiconductor layer;
- a p-type semiconductor layer;
- an active layer interposed between the n-type semiconductor layer and the p-type semiconductor layer;
- an n-type electrode coupled to the n-type semiconductor layer; and
- a p-type electrode coupled to the p-type semiconductor layer.

6. The display apparatus of claim 1, further comprising an anisotropic conductive film electrically connecting the light emitting diode part to the TFT panel part.

7. A display apparatus comprising:

- a light emitting diode part comprising a plurality of regularly arranged light emitting diodes; and
- a thin-film transistor (TFT) panel part comprising a plurality of TFTs configured to drive the light emitting diodes disposed on the TFT panel part,

wherein the light emitting diode part further comprises:

- a transparent substrate disposed on the light emitting diodes; and
- a phosphor layer disposed on the transparent substrate and configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes, and

wherein the transparent substrate comprises:

- a plurality of sections each disposed on an upper surface of the light emitting diodes, respectively; and
- a blocking portion formed between the sections of the transparent substrate and blocking light emitted from the light emitting diodes.

8. The display apparatus of claim 7, wherein the blocking portion comprises a metal.

9. A display apparatus comprising:

- a light emitting diode part comprising a plurality of regularly arranged light emitting diodes; and
- a thin-film transistor (TFT) panel part comprising a plurality of TFTs configured to drive the light emitting diodes disposed on the TFT panel part,

wherein the light emitting diode part further comprises: a substrate disposed on the light emitting diodes and comprising a white phosphor configured to emit white light by converting a wavelength of light emitted from the light emitting diodes; and

a color filter comprising a blue light portion, a green light portion, and a red light portion, each portion being configured to transmit blue light, green light, and red

14

light, respectively, therethrough among white light emitted from the substrate, and

wherein the substrate comprises:

- a plurality of sections each disposed on an upper surface of each light emitting diode; and
- a blocking portion formed between the sections and blocking light emitted from the light emitting diodes.

10. The display apparatus of claim 9, wherein the color filter further comprises a transparent portion configured to transmit white light emitted from the substrate therethrough without a wavelength conversion.

11. A method of manufacturing a display apparatus, the method comprising:

- forming a substrate comprising a plurality of regularly arranged light emitting diodes;
- coupling the substrate to a thin-film transistor (TFT) panel part comprising a plurality of TFTs configured to drive the light emitting diodes;
- reducing a thickness of the substrate by etching or grinding the substrate; and

forming a phosphor layer on an upper surface of the substrate, the phosphor layer being configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes,

wherein a thickness of the substrate is reduced to be less than a thickness of the phosphor layer.

12. The method of claim 11, further comprising coupling the substrate to the TFT panel part by an anisotropic conductive film.

13. A method of manufacturing a display apparatus, the method comprising:

- forming a substrate having a plurality of regularly arranged light emitting diodes;
- coupling the substrate to a thin-film transistor (TFT) panel part comprising a plurality of TFTs configured to drive the light emitting diodes;

etching a portion of the substrate;

forming a blocking portion on the etched substrate, such that light emitted from each of the light emitting diodes is prevented from being mixed with light emitted from adjacent light emitting diodes; and

forming a phosphor layer on the substrate, the phosphor layer being configured to emit at least one of blue light, green light, and red light by converting at least a portion of a wavelength of light emitted from the light emitting diodes.

14. The method of claim 13, further comprising coupling the substrate to the TFT panel part by an anisotropic conductive film.

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