



(12) **United States Patent**  
**Takeya et al.**

(10) **Patent No.:** **US 10,050,026 B2**  
(45) **Date of Patent:** **Aug. 14, 2018**

(54) **DISPLAY APPARATUS**

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(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **15/395,490**

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(22) Filed: **Dec. 30, 2016**

International Search Report dated Apr. 4, 2017, for PCT Application  
No. PCT/KR2016/015390.

(65) **Prior Publication Data**

US 2017/0194304 A1 Jul. 6, 2017

(Continued)

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**Related U.S. Application Data**

(60) Provisional application No. 62/273,656, filed on Dec.  
31, 2015.

(51) **Int. Cl.**  
**H01L 29/20** (2006.01)  
**H01L 25/16** (2006.01)

(Continued)

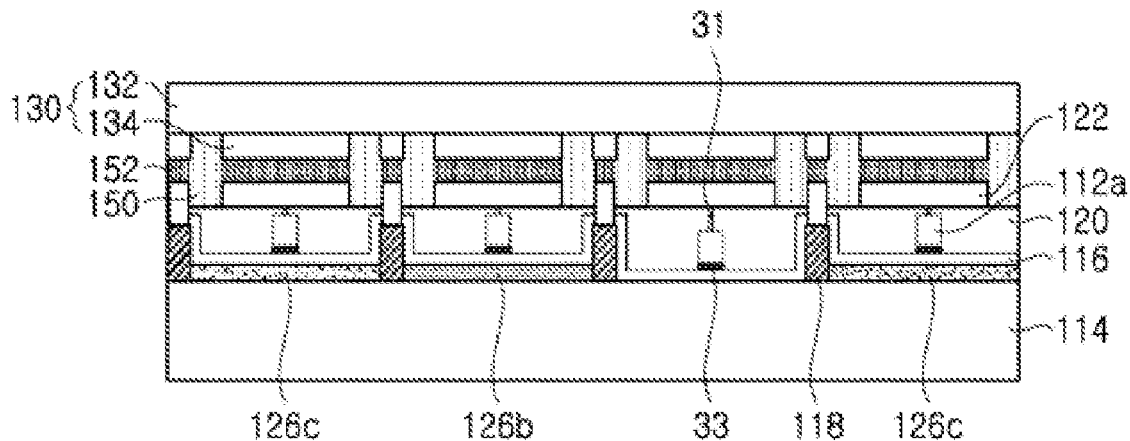
(52) **U.S. Cl.**  
CPC ..... **H01L 25/167** (2013.01); **H01L 25/162**  
(2013.01); **H01L 27/1218** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC . H01L 25/167; H01L 25/162; H01L 27/1218;  
H01L 33/504; H01L 33/505; H01L 33/62  
See application file for complete search history.

(57) **ABSTRACT**

A display apparatus includes a light emitting diode part and a thin film (TFT) panel configured to drive the light emitting diode part. The light emitting diode part includes a transparent support substrate, a plurality of light emitting diodes, a plurality of phosphor layers disposed on the support substrate covering at a first portion of the plurality of light emitting diodes and configured to emit light through a conversion of introduced light. Another display apparatus includes a light emitting diode part including a plurality of light emitting diodes and a TFT panel configured to drive the light emitting diode part. The TFT panel includes a panel substrate including a TFT driving circuit and a plurality of grooves formed on the panel substrate. The TFT panel also includes a plurality of phosphor layers the plurality of grooves and configured to emit light through wavelength conversion of introduced light.

**8 Claims, 13 Drawing Sheets**



(51) **Int. Cl.***H01L 33/50* (2010.01)*H01L 33/62* (2010.01)*H01L 27/12* (2006.01)(52) **U.S. Cl.**CPC ..... *H01L 33/504* (2013.01); *H01L 33/505*  
(2013.01); *H01L 33/62* (2013.01)(56) **References Cited**

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FIG. 1

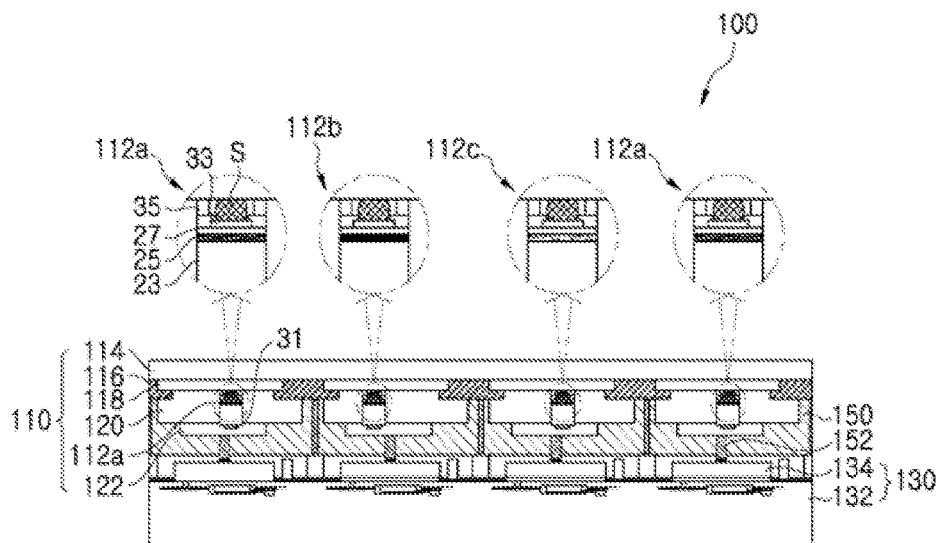


FIG. 2

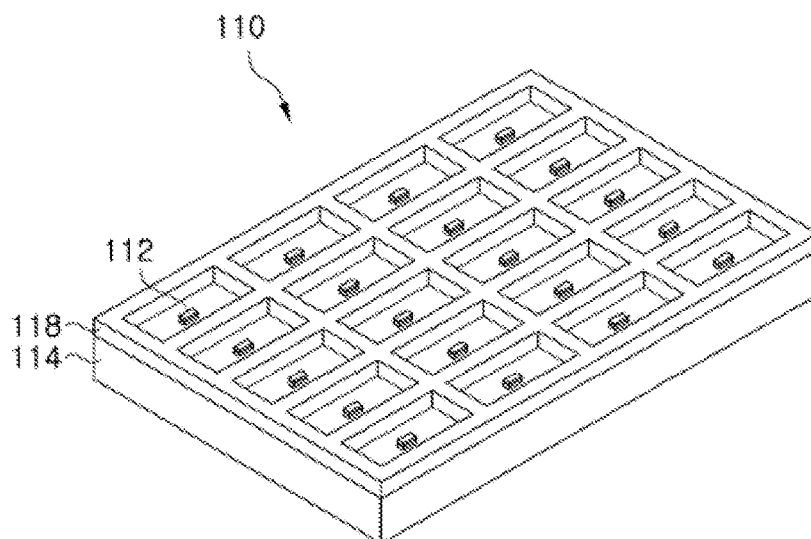


FIG. 3A

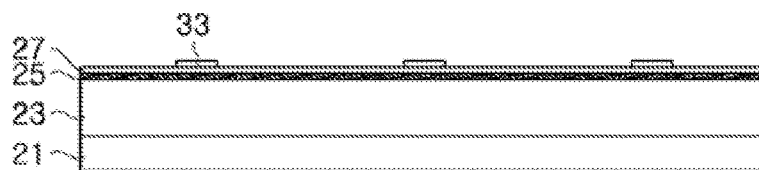


FIG. 3B

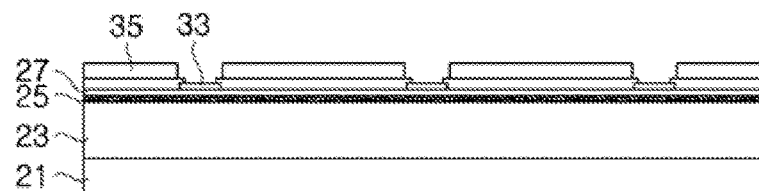


FIG. 3C

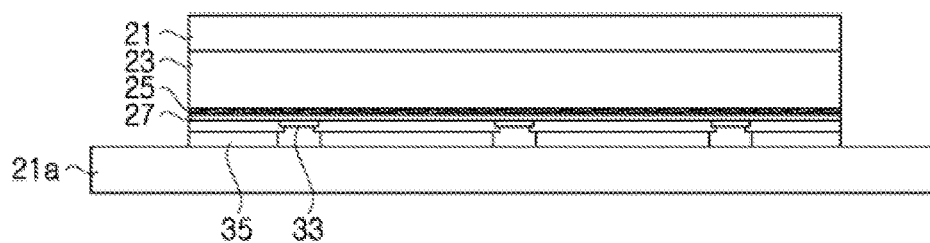


FIG. 3D

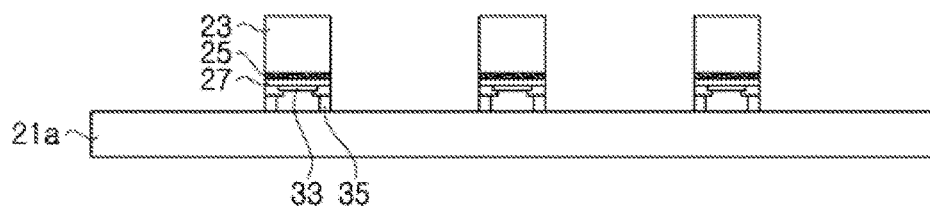


FIG. 3E

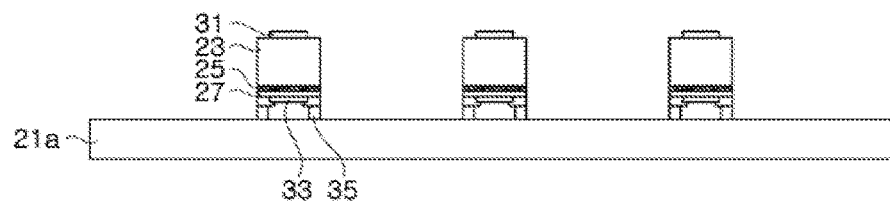


FIG. 3F

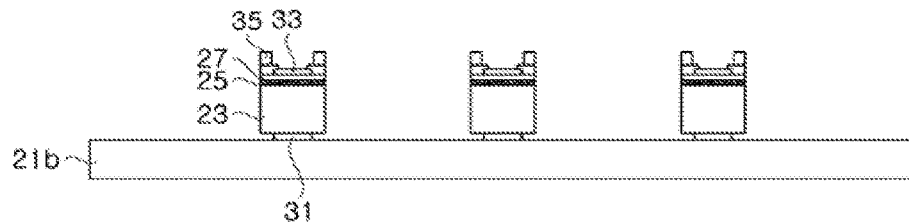


FIG. 3G

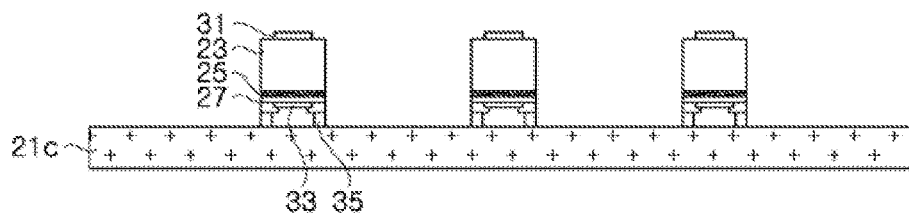


FIG. 3H

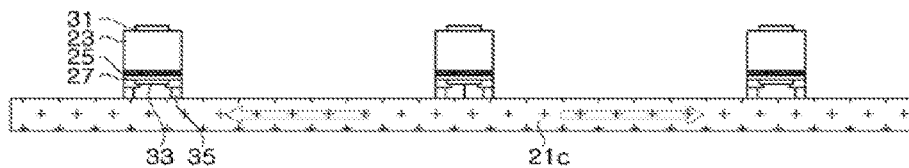


FIG. 3I

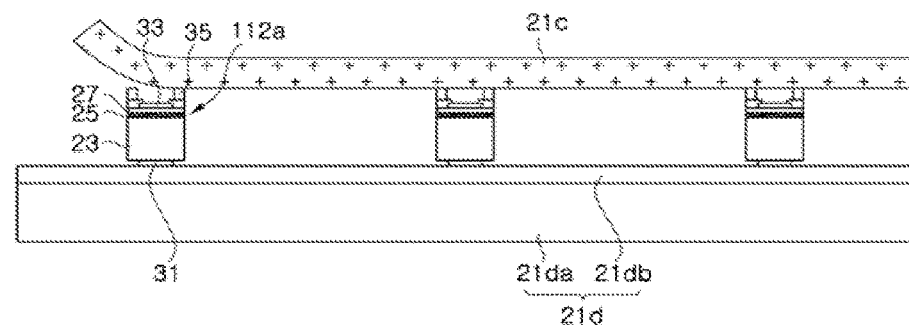


FIG. 3J

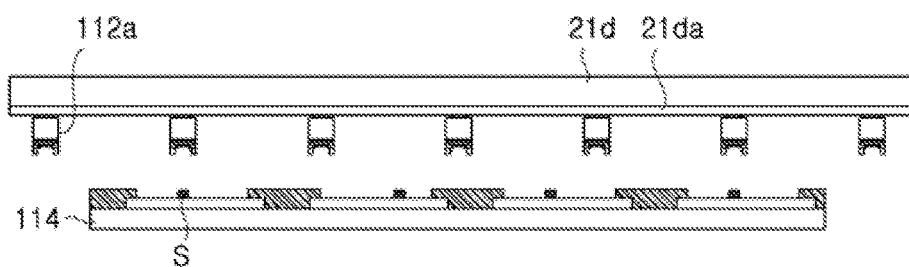


FIG. 3K

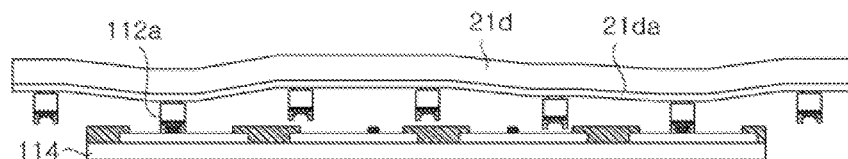


FIG. 3L

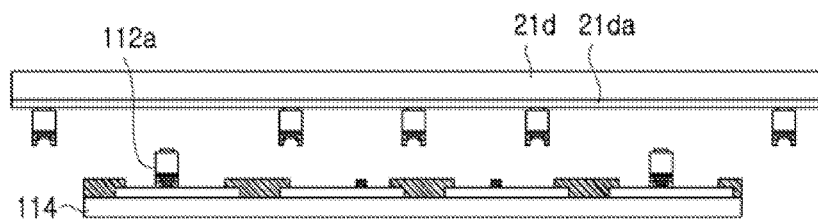


FIG. 3M

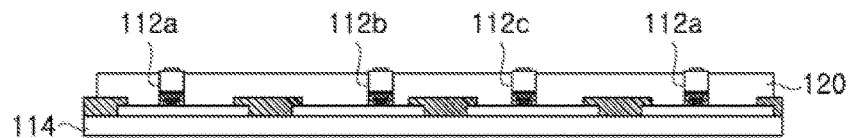


FIG. 3N

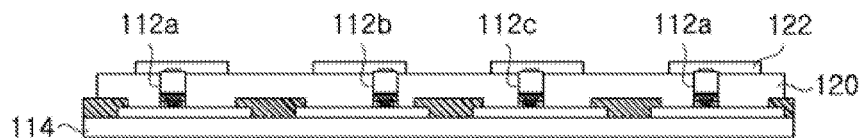


FIG. 3O

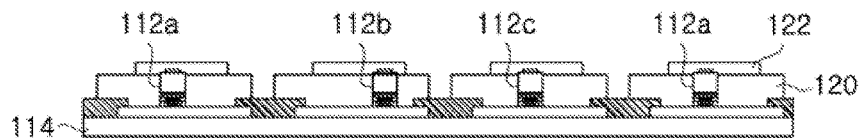


FIG. 3P

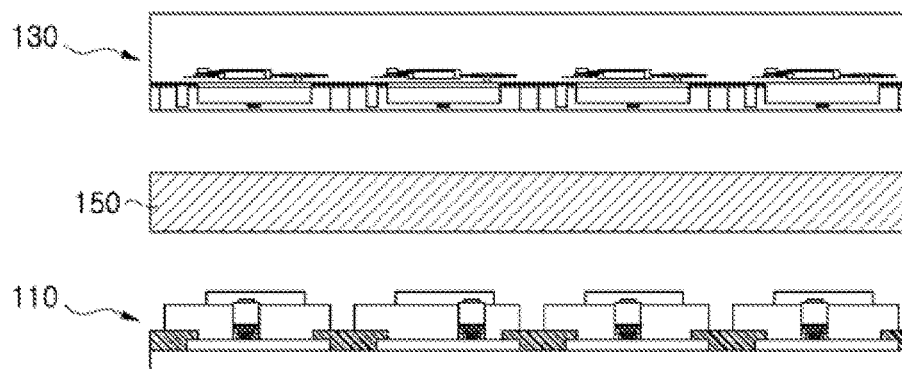


FIG. 4A

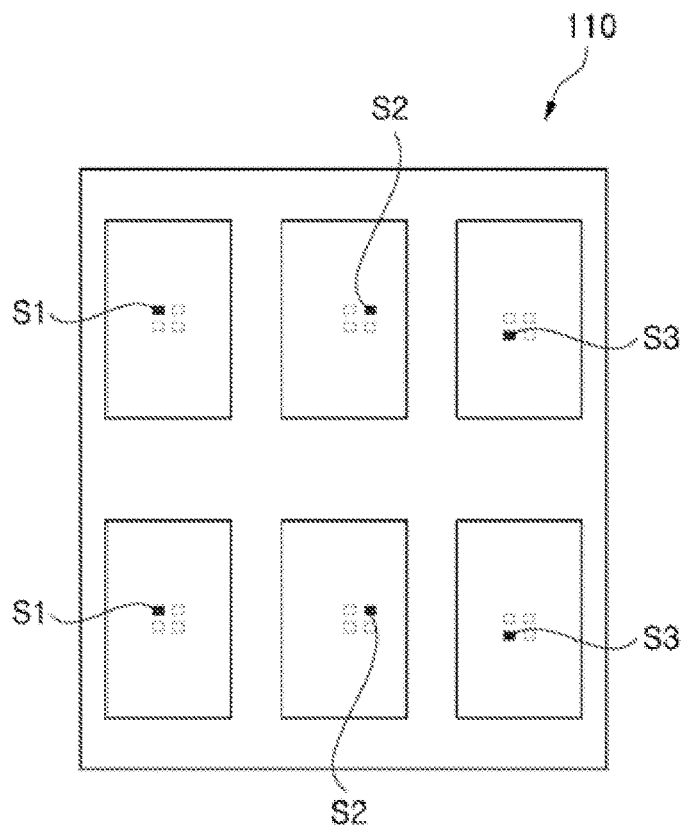


FIG. 4B

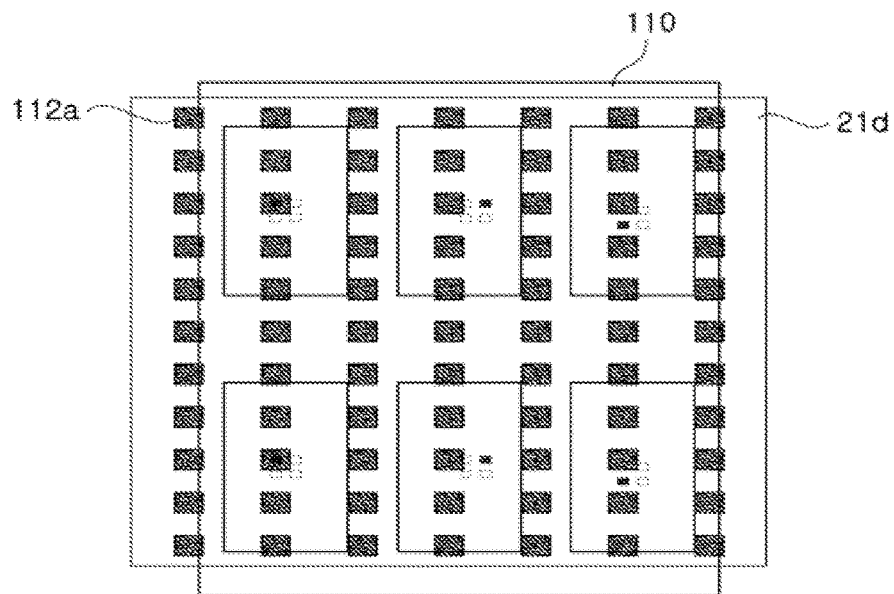


FIG. 4C

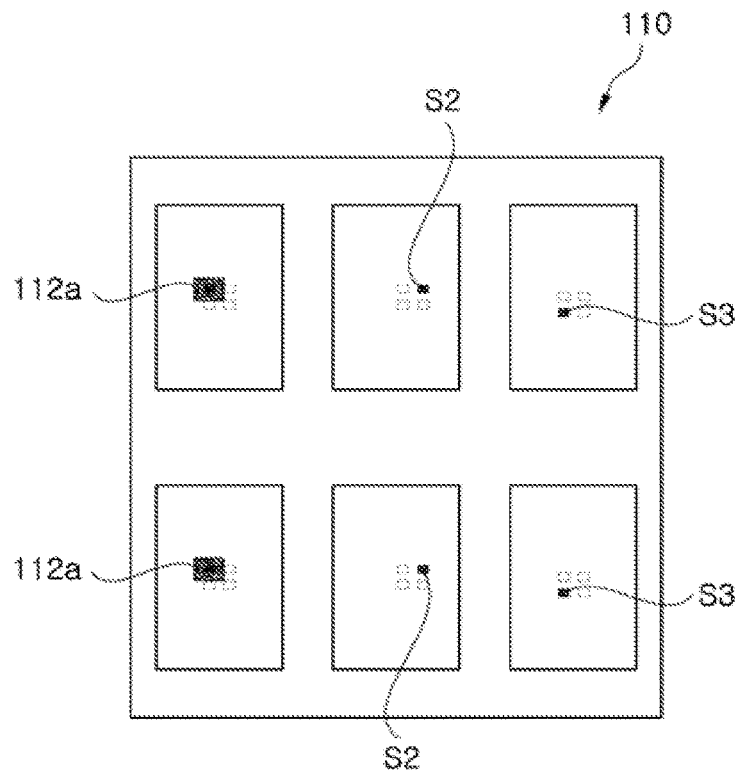




FIG. 4D

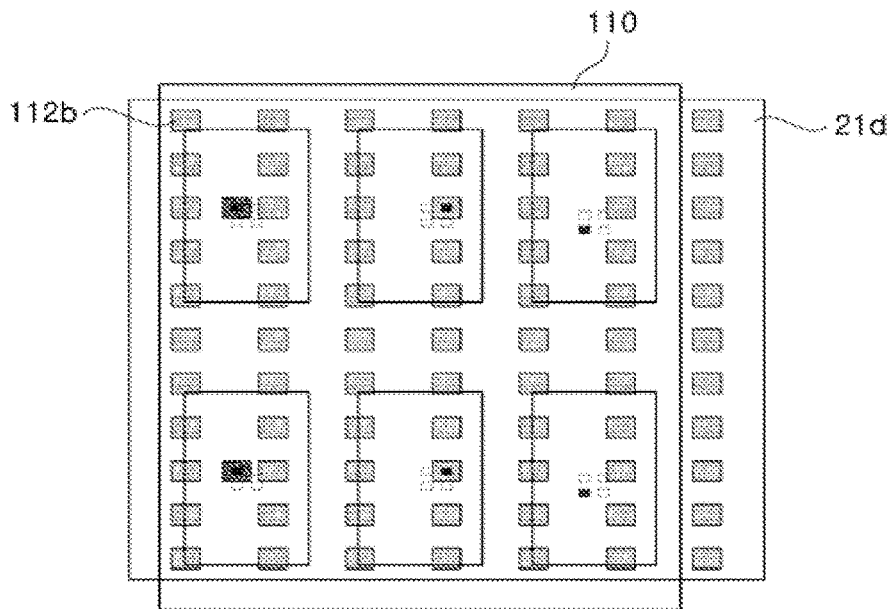


FIG. 4E

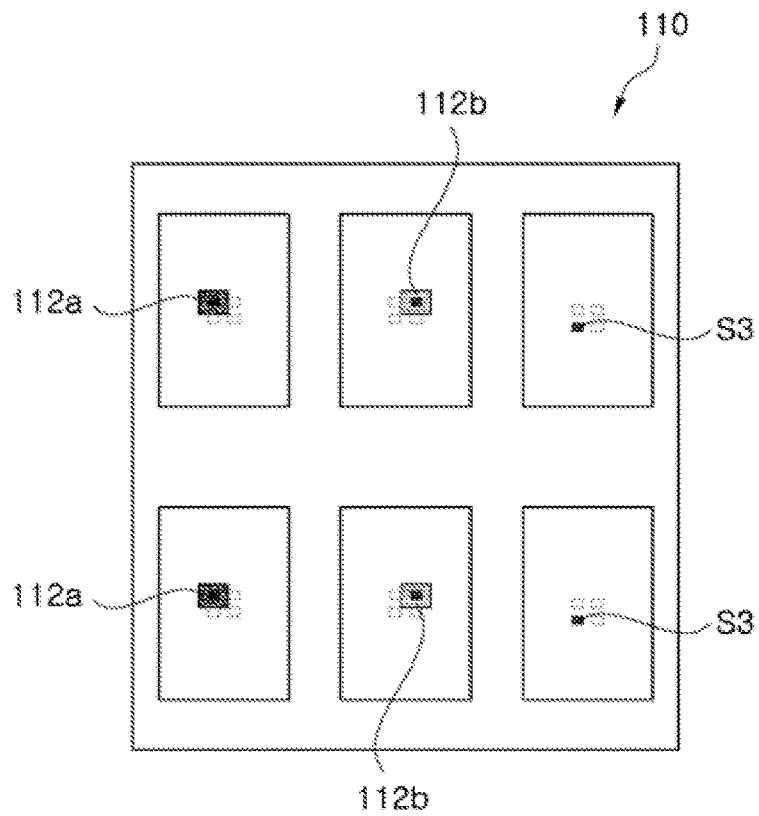


FIG. 4F

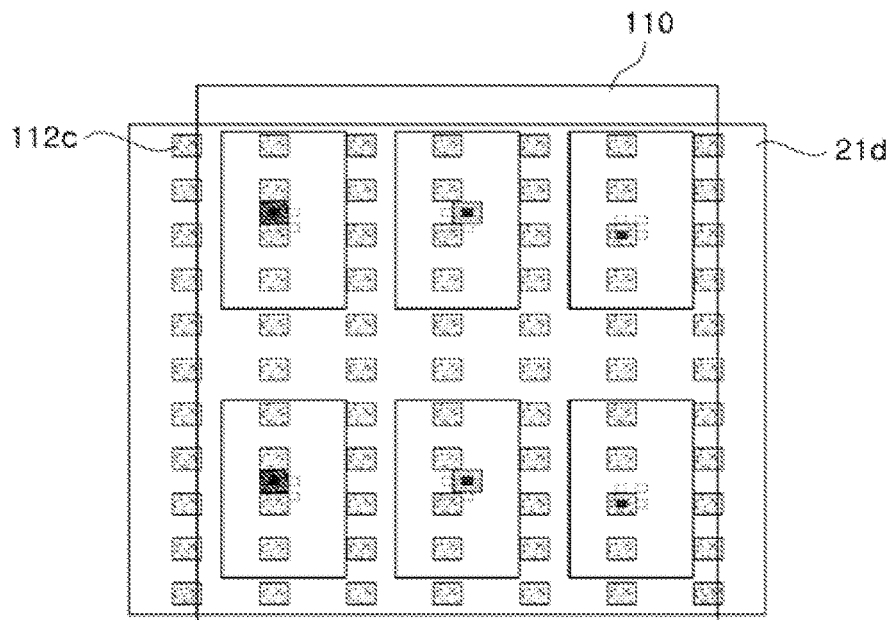


FIG. 4G

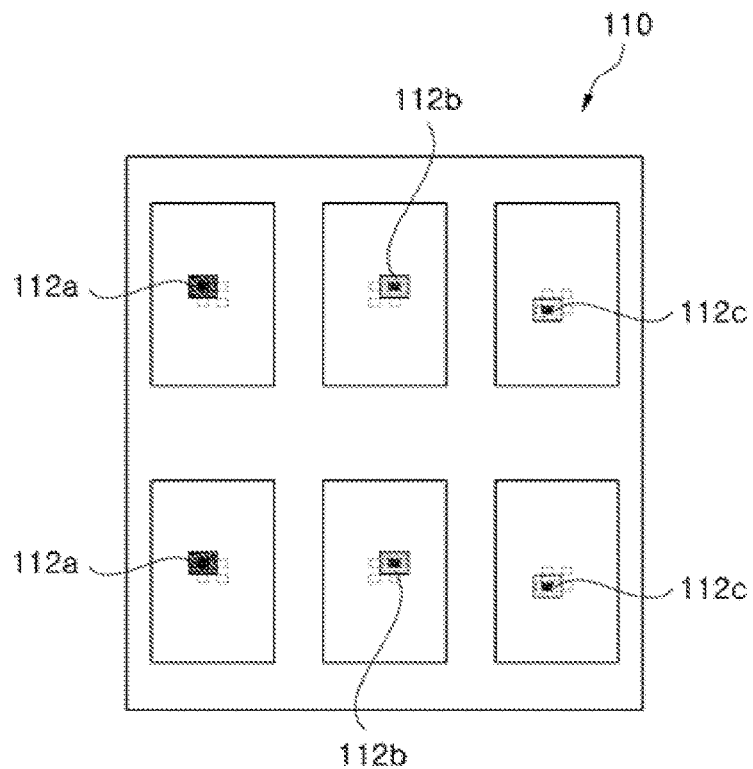


FIG. 5

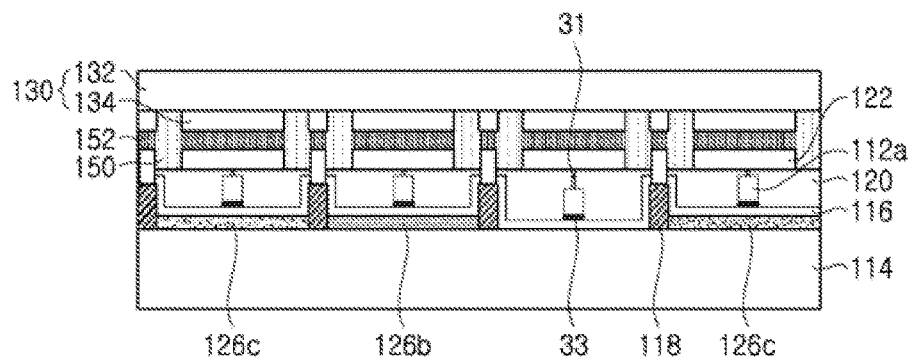


FIG. 6A

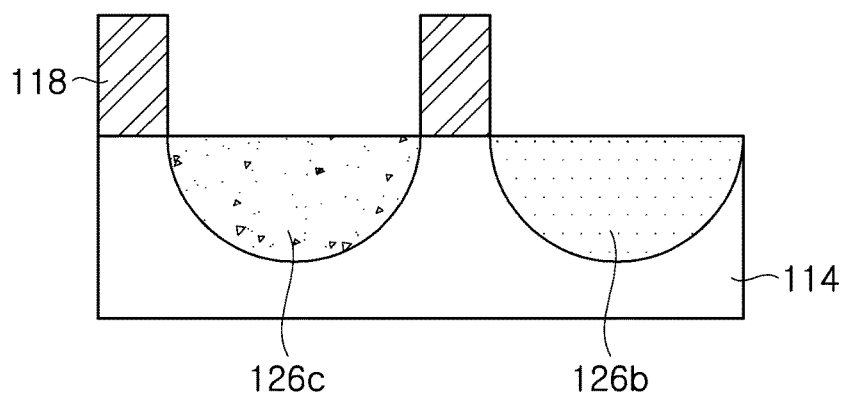


FIG. 6B

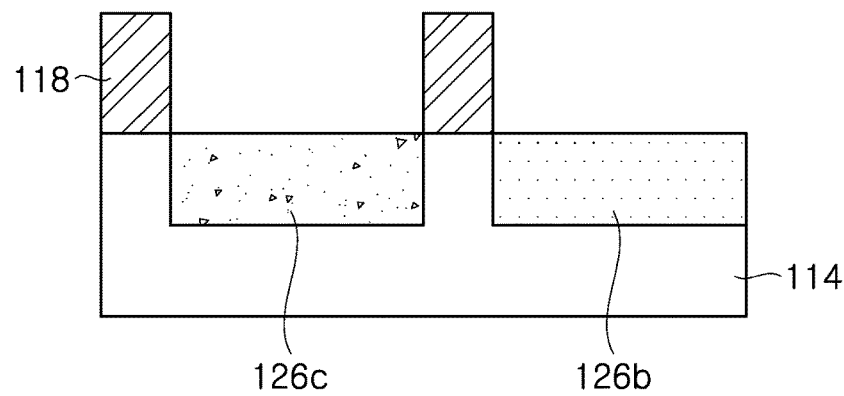


FIG. 7

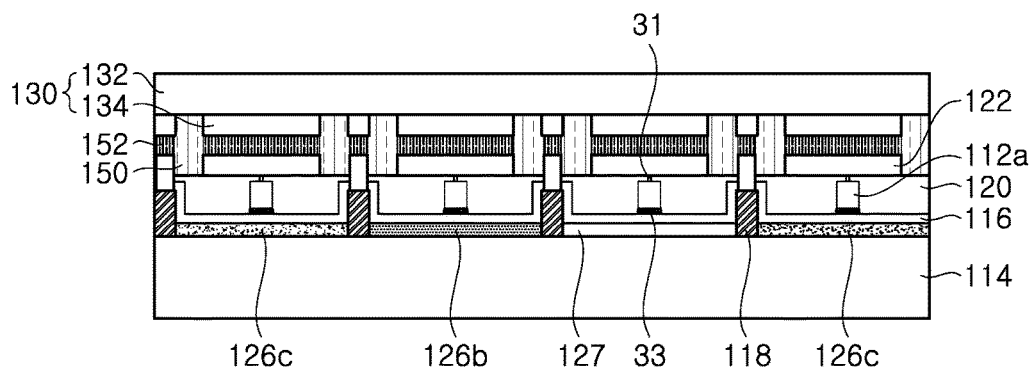


FIG. 8

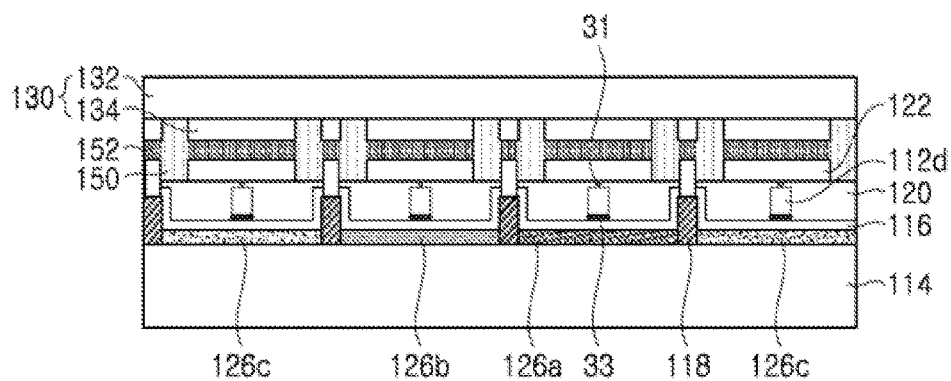


FIG. 9

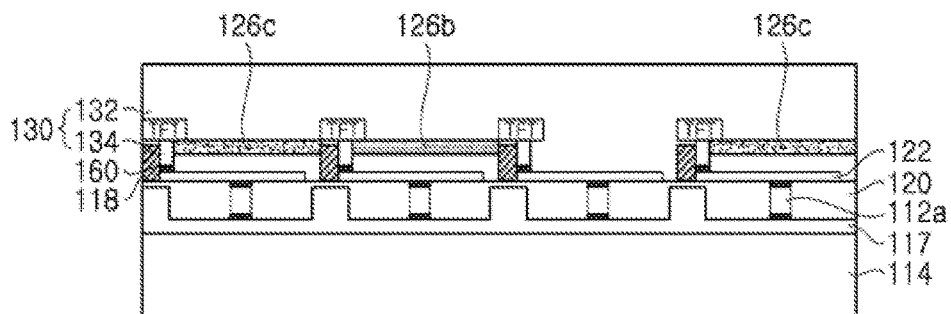


FIG. 10A

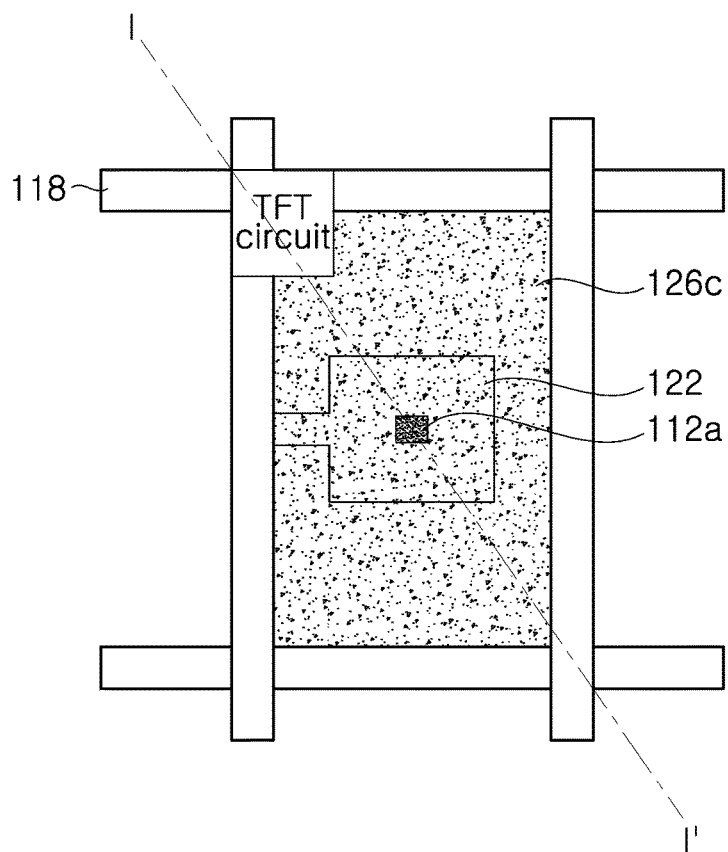


FIG. 10B

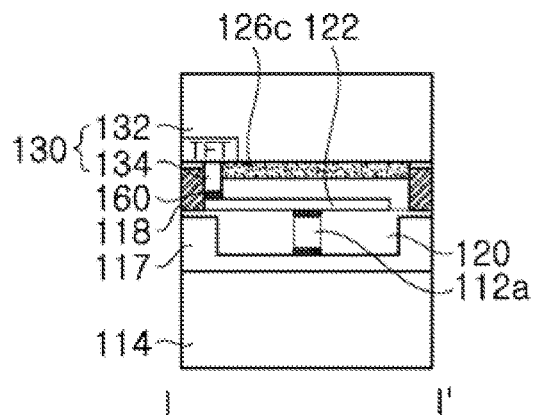


FIG. 11

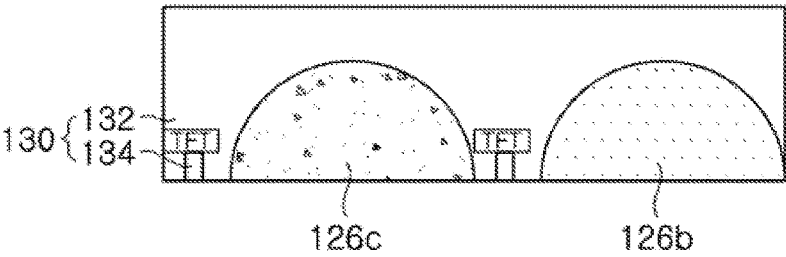


FIG. 12A

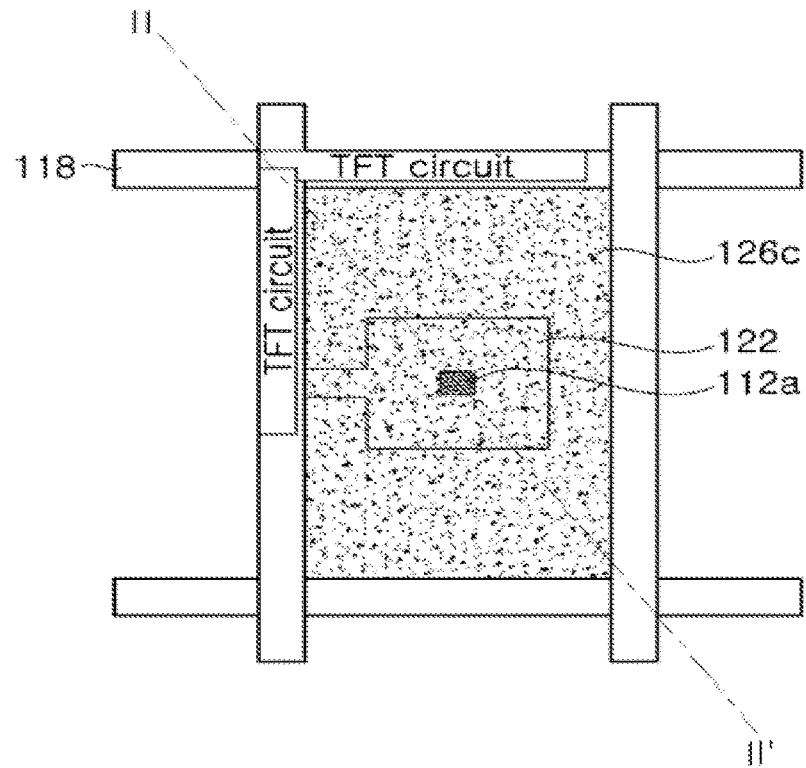
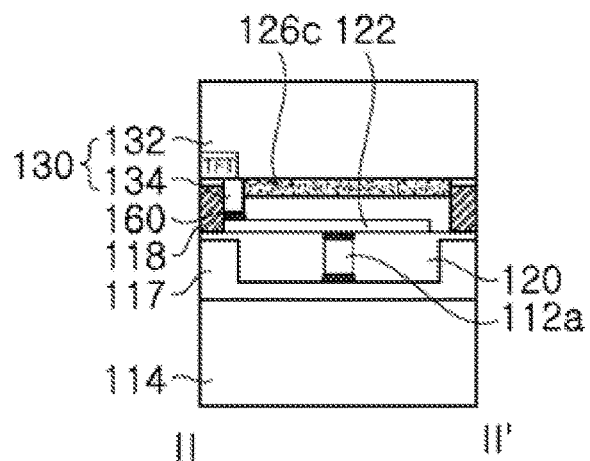


FIG. 12B



1

**DISPLAY APPARATUS****CROSS REFERENCE TO RELATED APPLICATION**

This application claims the benefit of U.S. Provisional Patent Application No. 62/273,656, filed on Dec. 31, 2015, which is hereby incorporated by reference for all purposes as if fully set forth herein.

**BACKGROUND****Field**

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

**Discussion of the Background**

Consumer demand has been trending toward display that consume less power to extend the battery life of their electronic devices or reduce the amount of power a particular apparatus display apparatus requires from the grid. However, conventional display devices such as a liquid crystal display or organic light emitting diode (OLED) require high power consumption to drive these conventional display. In addition, these conventional displays often suffer from inaccurate color contrast, low response time for generating images, high production cost, short lifespan, or uneven brightness of various sub-pixels. Therefore, there is a need for an efficient display apparatus with accurate color contrast, high response time, low production cost, long lifespan, and even brightness levels of the various sub-pixels or pixels.

The above information disclosed in this Background section is only for enhancement of understanding of the background of the inventive concept, and therefore, it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

**SUMMARY**

Exemplary embodiments of the present disclosure provide a display apparatus employing micro-light emitting diodes having low power consumption high resolution and applicable to a wearable apparatus, smartphone, television, or monitor.

In one or more exemplary embodiments, a display apparatus includes a light emitting diode part including a transparent support substrate, a plurality of light emitting diodes regularly arranged on the support substrate, a plurality of phosphor layers disposed on the support substrate covering at a first portion of the plurality of light emitting diodes and configured to emit light through a conversion of introduced light. The display apparatus also includes a TFT panel configured to drive the light emitting diode part.

In one or more exemplary embodiments, a display apparatus includes a light emitting diode part including a plurality of light emitting diodes regularly arranged and a thin film transistor (TFT) panel configured to drive the light emitting diode part. The TFT panel includes a panel substrate including a TFT driving circuit and comprises a plurality of grooves formed on the panel substrate. The TFT pane includes a plurality of phosphor layers filling the plurality of grooves formed on the panel substrate and configured to emit light through wavelength conversion of introduced light.

2

According to exemplary embodiments, the display apparatus employs micro-light emitting diodes comprising nitride semiconductors, thereby realizing high efficiency and high resolution.

The foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the claimed subject matter.

**BRIEF DESCRIPTION OF DRAWINGS**

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and together with the description serve to explain the principles of the inventive concept.

FIG. 1 is a sectional view of a display apparatus according to a first exemplary embodiment of the present disclosure.

FIG. 2 is a perspective view of a light emitting diode part of the display apparatus according to the first exemplary embodiment of the present disclosure.

FIGS. 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3I, 3J, 3K, 3L, 3M, 3N, 3O, 3P are sectional views illustrating a method of manufacturing the light emitting diode part of the display apparatus according to the first exemplary embodiment of the present disclosure.

FIGS. 4A, 4B, 4C, 4D, 4E, 4F, and 4G are plan views illustrating a method of manufacturing the light emitting diode part of the display apparatus according to the first exemplary embodiment of the present disclosure.

FIG. 5 is a schematic sectional view of a display apparatus according to a second exemplary embodiment of the present disclosure.

FIGS. 6A and 6B are schematic sectional views of a phosphor layer of a display apparatus according to a third exemplary embodiment of the present disclosure.

FIG. 7 is a schematic sectional view of a display apparatus according to a fourth exemplary embodiment of the present disclosure.

FIG. 8 is a schematic sectional view of a display apparatus according to a fifth exemplary embodiment of the present disclosure.

FIG. 9 is a schematic sectional view of a display apparatus according to a sixth exemplary embodiment of the present disclosure.

FIG. 10A is a schematic plan view of the display apparatus according to the sixth exemplary embodiment of the present disclosure.

FIG. 10B is a schematic sectional view along sectional line I-I' of FIG. 10A.

FIG. 11 is a schematic sectional view of a modified phosphor layer of the display apparatus according to the sixth exemplary embodiment of the present disclosure.

FIG. 12A is a schematic plan view of a display apparatus according to a seventh exemplary embodiment of the present disclosure.

FIG. 12B is a schematic sectional view along sectional line II-II' of FIG. 12A.

**DETAILED DESCRIPTION OF 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 exem-



plary 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 pixels, panels, regions, area, portions, etc., may be exaggerated for clarity and descriptive purposes. Also, like reference numerals denote like elements.

Unless otherwise specified, the illustrated exemplary embodiments are to be understood as providing exemplary features of varying detail of various exemplary embodiments. Therefore, unless otherwise specified, the features, blocks, components, elements, and/or aspects of the various illustrations may be otherwise combined, separated, interchanged, and/or rearranged without departing from the disclosed exemplary embodiments. Further, in the accompanying figures, the size and relative sizes of blocks, components, elements, etc., may be exaggerated for clarity and descriptive purposes.

When an element is referred to as being “on,” “connected to,” or “coupled to” another element, it may be directly on, connected to, or coupled to the other element or intervening elements may be present. When, however, an element is referred to as being “directly on,” “directly connected to,” or “directly coupled to” another element, there are no intervening elements 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. 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, portions, areas, and/or sections, these elements, components, regions, portions, areas, and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, portion, area, and/or section from another element, component, region, portion, area, and/or section. Thus, a first element, component, region, and/or section discussed below could be termed a second element, component, region, portion, area, and/or section without departing from the teachings of the present disclosure.

Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper,” “end,” “inside,” “left,” “right,” 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.

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.

A light emitting diode (LED) refers to an inorganic semiconductor device that emits light through recombination of electrons and holes, and has been used in various fields including displays, car lamps, general lighting, and the like. The light emitting diode has many advantages such as a long lifespan, low power consumption, and rapid response time. A light emitting device using such a light emitting diode is used as a light source in various fields.

Recently, television or monitors tend to reproduce colors using thin film transistor liquid crystal display (TFT-LCD) panels and employ light emitting diodes as backlight sources for color reproduction. However, since one LED is used as a light source for multiple pixels and sub-pixels, a backlight source is always turned on. Therefore, power consumption is constant regardless of whether a displayed screen is bright or dark. In order to compensate for this problem, there is a display apparatus which divides the screen into several zones and controls contrast thereof. However, since the screen is divided into units consisting of thousands to tens of thousands of pixels, it is difficult to achieve accurate control of contrast while reducing power consumption.

Even more recently, display devices have begun using organic light emitting diode (OLED) to directly emitting light for each sub-pixel. Although power consumption of OLEDs has been continuously reduced over time, power consumption of OLEDs is still much larger than that of inorganic semiconductor based-devices or LEDs. Thus, OLEDs have low efficiency.

In addition, pulse modulation-driven (PM-driven) OLEDs can suffer from a low response time in generating images due to Pulse Amplifier Modulation (PAM) control of a large capacity OLED. PM-driven OLED also suffer from short lifespan due to the high current driving required for pulse width modulation (PWM) control for realizing low duty of the OLEDs. When an OLED device is driven by an AM driving method, it is necessary to connect TFTs to each pixel, thereby causing increase in production costs and uneven brightness depending upon TFT characteristics.

According to one or more exemplary embodiments described below, the display apparatus employs micro-light emitting diodes including nitride semiconductors, thereby realizing high efficiency and high resolution suitable for wearable apparatus, smartphone, television, or monitor.

One or more exemplary embodiments described below are configured such that 1000 or less pixels correspond to one light emitting diode, whereby a light emitting diode corresponding to pixels not requiring light can be turned off, thereby enabling accurate control of contrast while reducing power consumption.

Furthermore, according to one or more exemplary embodiments, the display apparatus is manufactured using a

stretchable substrate and thus can be more conveniently manufactured in manufacture of the display apparatus using micro-light emitting diodes.

Accordingly, energy efficiency display apparatuses with accurate color contrast, high response time, low production cost, long lifespan, and even brightness levels compared to conventional LCD or OLED display devices and manufacturing methods of these energy efficient display apparatuses are described below with respect to various exemplary embodiments and accompanying drawings.

FIG. 1 is a sectional view of a display apparatus according to a first exemplary embodiment of the present disclosure and FIG. 2 is a perspective view of a light emitting diode part of the display apparatus according to the first exemplary embodiment of the present disclosure.

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

Referring to FIG. 1 and FIG. 2, the light emitting diode part 110 includes light emitting diodes 112, a support substrate 114, a transparent electrode 116, a blocking portion 118, an insulation layer 120, and a first connection electrode 122. FIG. 1 is flipped upside down (e.g., rotated 180 degrees) when compared to FIG. 2.

A plurality of light emitting diodes 112 are regularly arranged on the support substrate 114. For example, the plurality of light emitting diodes 112 may be arranged in a matrix, as shown in FIG. 2. In this exemplary embodiment, the plurality of light emitting diodes 112 includes a plurality of blue light emitting diodes 112a, a plurality of green light emitting diodes 112b, and a plurality of red light emitting diodes 112c. The plurality of blue light emitting diodes 112a, the plurality of green light emitting diodes 112b and the plurality of red light emitting diodes 112c are alternately arranged such that the blue light emitting diode 112a, the green light emitting diode 112b, and the red light emitting diode 112c are adjacent one another. For example, a red LED 112c is adjacent to a first blue LED 112a on first side of the first blue LED 112a and a green LED 112b is adjacent to the first blue LED 112a on a second side of the first blue LED 112a.

In this exemplary embodiment, as shown in FIG. 2, the light emitting diode part 110 may be driven in the display apparatus 100 by an external power source. Put another way, a display apparatus 100 may generate an image by turning the plurality of light emitting diodes 112 of the light emitting diode part 110 on or off in various combinations without a separate LCD acting as a shutter or polarizer of light. The display apparatus 100 may also generate images without the use of color filters. Accordingly, a region including one light emitting diode 112 may be used as one sub-pixel in the display apparatus 100. As shown in FIG. 2, the size of one sub-pixel in the light emitting diode part 110 may be larger than the size of the light emitting diode 112 disposed in the sub-pixel.

Referring again to FIG. 1, each of the light emitting diodes 112 may include 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 portion 35. The n-type semiconductor layer 23, the active layer 25, and the p-type semiconductor layer 27 may include a group III-V compound semiconductor. For example, a nitride semiconductor may be used as the n-type semiconductor layer 23, the active layer 25, and the p-type semiconductor layer 27. The nitride semiconductor layer may include aluminum (Al), gallium (Ga), indium (In), or some combi-

nation thereof in varying concentrations with nitrogen (N) for the n-type semiconductor layer 23, the active layer 25, and the p-type semiconductor layer 27. Some combinations of include AlN, AlGaIn, GaN, InN, InGaIn, or InGaAlN. Although the p-type semiconductor layer 27 is arranged closer to the support substrate 114 than the n-type semiconductor layer 23 in FIG. 1, the relative position of semiconductor layers 27 and 23 may be interchanged along with their associated n-type electrode 31 and p-type electrode 33.

The n-type semiconductor layer 23 may include an n-type dopant (e.g., Si) and the p-type semiconductor layer 27 may include a p-type dopant (e.g., Mg). The active layer 25 may have a multi-quantum well (MQW) structure and the composition of the active layer may be determined so as 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 be formed similar to a vertical light emitting diode. In this structure, the n-type electrode 31 is formed on an outer surface of the n-type semiconductor layer 23 and the p-type electrode 33 is formed on an outer surface of the p-type semiconductor layer 27. The outer surface of the n-type semiconductor layer 23 and the p-type semiconductor layer 27 is a surface that faces away from the active layer 25.

In addition, as shown in FIG. 1, a bonding portion S may be formed between the p-type electrode 33 and the transparent electrode 116 in order to bond the light emitting diode 112 to the transparent electrode 116 of the support substrate 114, and the wall portion 35 may be formed in order to prevent the bonding portion S from deviating between the p-type electrode 33 and the transparent electrode 116. In other words, the wall portion 35 helps retain the bonding portion S between the p-type electrode and the transparent electrode 116.

Here, the bonding portion S may include a pure metal or a metal alloy and provides a site for bonding through a process of metal diffusion bonding or eutectic bonding. The bonding portion S for metal diffusion bonding may include at least one of Cu-to-Cu, Au-to-Au, Ti-to-Ti/Si, and Al-to-Al. The bonding portion S for eutectic bonding may include at least one of Au/In, Cu/Sn, Au/Sn, Au/Si, Au/Ge, and Al/Ge.

The wall portion 35 may be formed to cover a portion of the p-type electrode 33 to expose the p-type electrode 33 on the p-type semiconductor layer 27. The wall portion 35 may be composed of a plurality of layers as shown in FIG. 1. The wall portion 35 may include a first layer including silicon nitride (SiN) is formed to cover a portion of the p-type electrode 33 on the p-type semiconductor layer 27 and a second layer including silicon dioxide (SiO<sub>2</sub>) is then formed on the first layer. The second layer may be thicker than the first layer. The second layer may cover less surface area of the p-type semiconductor layer 27 than the first layer. Put another way, the second layer may have a narrow horizontal width when compared to a horizontal width of the first layer in the cross-sectional view of FIG. 1.

The display apparatus includes the support substrate 114. The plurality of light emitting diodes 112 are mounted on the support substrate 114. The support substrate 114 may be an insulating 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. In addition, a plurality of conductive patterns, which may be electrically connected to the plurality of light emitting diodes 112, may be formed on the support substrate 114 or

a circuit pattern may be formed therein, as needed. Further, the support substrate **114** may be a flexible substrate.

The transparent electrode **116** is formed on the support substrate **114** and may be electrically connected to the p-type electrode **33** of the light emitting diode **112**. In this embodiment, a plurality of transparent electrodes **116** may be formed on the support substrate **114**. Here, one light emitting diode **112** may be coupled to one transparent electrode **116** and a plurality of light emitting diodes **112** may be coupled to the a plurality of transparent electrodes **116**. Further, the plurality of transparent electrodes **116** may be spaced apart from one another on the support substrate **114**. For example, the plurality of transparent electrodes **116** may be formed of ITO.

The blocking portion **118** is formed on the support substrate **114**. A plurality of blocking portions **118** may be formed on the support substrate. The blocking portion **118** serves to prevent light emitted from the light emitting diode **112** from being emitted to undesired locations. For example, the blocking portion **118** is selectively located to block light from one light emitting diode **112** from being mixed with light emitted from an adjacent light emitting diode **112**. As another example, the blocking portion **118** is not located directly over the light emitting diode **112** to allow the light emitted from the light emitting diode **112** to travel through the transparent electrode **116**. Accordingly, the blocking portion **118** may be formed between adjacent transparent electrodes **116**. A plurality of blocking portions **118** may be spaced apart from each other and may be formed to cover a portion of the transparent electrode **116**. In this exemplary embodiment, the blocking portion **118** may be formed of chromium (Cr).

The insulation layer **120** is formed to surround the light emitting diode **112** and cover an exposed region of a surface to which the light emitting diode **112** is coupled (e.g., a surface of the transparent electrode **116** or a surface of the first connection electrode **122**). Accordingly, the insulation layer **120** may be formed to cover a portion of the blocking portion **118**. As the insulation layer **120** is formed to surround the light emitting diode **112**, the n-type semiconductor layer **23** and the n-type electrode **31** of the light emitting diode **112** can be exposed through the insulation layer **120**.

The first connection electrode **122** is formed to cover the insulation layer **120** and may be formed to 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 TFT panel **130** includes a panel substrate **132** and a second connection electrode **134**. The TFT panel **130** is coupled to the light emitting diode part **110** and serves to supply electric power to the light emitting diode part **110**. In addition, the TFT panel **130** controls the electric power supplied to the light emitting diode part **110** to allow only some of the plurality of the light emitting diodes **112** in the light emitting diode part **110** to emit light. For example, the TFT panel **130** may control the electrical power to supply light to only one, two, three, or more light emitting diodes **112** of the light emitting diode part **110**.

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

The second connection electrode **134** may be electrically connected to the TFT driving circuit of the panel substrate

**132** and may be electrically connected to the first connection electrode **122** of the light emitting diode part **110**. Accordingly, electric power supplied through the TFT driving circuit can be supplied to each light emitting diode **112** through the first and second connection electrodes **122**, **134**. At this time, the second connection electrode **134** may be covered by a separate protective layer and the protective layer may include silicon nitride (SiN<sub>x</sub>).

The anisotropic conductive film **150** serves to electrically connect the light emitting diode part **110** and the TFT panel **130** to each other. The anisotropic conductive film **150** includes an adhesive organic material having an insulating property and conductive particles for electrical connection uniformly dispersed therein. The anisotropic conductive film **150** is conductive in a first direction (e.g., the vertical direction in FIG. 1) and in a second direction (e.g., the horizontal direction in FIG. 1). In addition, the anisotropic conductive film **150** has bonding properties to bond the TFT panel **130** to the light emitting diode part **110** which needs to be electrically connected. In particular, the anisotropic conductive film **150** can be useful for connecting electrodes, which are difficult to solder at high temperature, such as ITO.

As such, when the light emitting diode part **110** and the TFT panel **130** are coupled via the anisotropic conductive film **150**, the first connection electrode **122** of the light emitting diode part **110** and the second connection electrode **134** of the TFT panel **130** are electrically connected to each other to form an electrode connection portion **152**.

FIGS. 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3I, 3J, 3K, 3L, 3M, 3N, 3O, and 3P are sectional views illustrating a method of manufacturing the light emitting diode part **110** of the display apparatus **100** according to the first exemplary embodiment of the present disclosure. FIGS. 4A, 4B, 4C, 4D, 4E, 4F, and 4G are plan views illustrating a method of manufacturing the light emitting diode part **110** of the display apparatus **100** according to the first exemplary embodiment of the present disclosure.

Referring to FIG. 3A-3P and FIGS. 4A-4G, a process of manufacturing the light emitting diode part **110** will be described. As shown in FIG. 3A, an n-type semiconductor layer **23**, an active layer **25**, and a p-type semiconductor layer **27** are sequentially grown on a growth substrate **21**. Then, a plurality of p-type electrodes **33** are formed on the p-type semiconductor layer **27**. The plurality of p-type electrodes **33** may be separated a predetermined distance from each other such that one p-type electrode **33** can be provided to one light emitting diode **112**.

Referring to FIG. 3B, a wall portion **35** is formed on the p-type semiconductor layer **27** on which the p-type electrodes **33** are formed. The wall portion **35** may be composed of two layers. The first layer of the wall portion **35** is formed to cover the entirety of the p-type semiconductor layer **27** while covering a portion of the p-type electrode **33**. The first layer of the wall portion **35** contains silicon nitride (SiN). In addition, a second layer of the wall portion **35** contains silicon dioxide (SiO<sub>2</sub>) and is formed on the first layer. In this exemplary embodiment, the second layer may be formed thicker than the first layer and may be formed on the first layer in a region in which the p-type electrodes **33** are not formed.

Referring to FIG. 3C, with the wall portion **35** formed as described above, the semiconductor layers **23**, **25**, and **27** are bonded to a first substrate. In this exemplary embodiment, the second layer of the wall portion **35** is coupled to the first substrate **21a**. The first substrate **21a** may be a substrate such

as the support substrate **114**. The first substrate **21a** and the support substrate **114** may be a sapphire substrate.

Referring to FIG. 3D, with the semiconductor layers coupled to the first substrate, the growth substrate **21** is removed from the semiconductor layers by laser lift-off (LLO) and the semiconductor layers **23**, **25**, and **27** are subjected to etching to isolate light emitting diodes **112** from each other. Here, etching for isolation of the individual light emitting diodes **112** may be performed by dry etching.

Referring to FIG. 3E, after isolation of the light emitting diodes **112** from each other, n-type electrodes **31** are formed on the n-type semiconductor layer **23**. Here, the plurality of n-type electrodes **31** may be formed before or after the isolation of the light emitting diodes **112**. Then, as shown in FIG. 3F, each of the light emitting diodes **112** is coupled to a second substrate **21b** such that the n-type electrodes **31** can be coupled to the second substrate **21b**, and then the first substrate **21a** is removed. The second substrate **21b** may be the same kind of substrate (e.g., a sapphire substrate) as the first substrate **21a**.

Referring to FIG. 3G, each of the light emitting diodes **112** is coupled to a third substrate **21c** such that the wall portion **35** can be coupled to the third substrate **21c**, and then the second substrate **21b** is removed. The third substrate **21c** may be a stretchable sheet which can be stretched or shrunk in a horizontal direction in cross-sectional view or any direction in plan view. Accordingly, as shown in FIG. 3H, it is possible to extend the distance between the respective light emitting diodes **112** by increasing the stretchable third substrate **21c** or change the alignment of the light emitting diodes **112** in respective rows or columns.

Then, with the distance between the respective light emitting diodes **112** extended or reduced, each of the light emitting diodes **112** is coupled to a fourth substrate **21d** such that the n-type electrode **31** can be coupled to the fourth substrate **21d**, as shown in FIG. 3I. Accordingly, the distance between the respective light emitting diodes **112** set by adjusting the stretchable third substrate **21c** may be maintained by coupling the n-type electrode **31** to the fourth substrate **21d**. The fourth substrate **21d** may include a base **21da** having flexibility and an adhesive layer **21db** formed on the base **21da**.

In this way, a plurality of light emitting diodes **112** arranged on the fourth substrate **21d** is coupled to a support substrate **114**, as shown in FIG. 3J, in which the support substrate **114** may be formed with a bonding portion S at locations where the light emitting diodes **112** are disposed. With transparent electrodes **116** and a blocking portion **118** formed on the support substrate **114**, the bonding portion S is formed at the locations of the support substrate where the light emitting diodes **112** will be mounted. Accordingly, even when the plural light emitting diodes **112** coupled to the fourth substrate **21d** are entirely transferred to the support substrate **114**, the light emitting diodes **112** can be transferred only to the locations where the bonding portion S is formed on the support substrate **114**.

Referring to FIG. 3K, among the light emitting diodes **112** coupled to the fourth substrate, only the light emitting diodes **112** corresponding to the locations where the bonding portion S is formed on the support substrate **114** can be coupled to the support substrate **114** by application of external force. Accordingly, as shown in FIG. 3L, the light emitting diodes **112** can be coupled only to the locations where the bonding portion S is formed.

Further, although not illustrated in this exemplary embodiment, when external force is selectively applied only to desired light emitting diodes **112** on the fourth substrate

**21d**, on which the plurality of light emitting diodes **112** is arranged, so as to be bonded to the support substrate **114**, as shown in FIG. 3K, the stretchable third substrate **3c** having flexibility can be omitted. That is, when a flexible fourth substrate **21d** is used instead of the second substrate **21b** as shown in FIG. 3F, the light emitting diodes **112** can be selectively coupled to the support substrate **114** by application of external force, as shown in FIG. 3K.

In this exemplary embodiment, a process of mounting the light emitting diodes **112** on the support substrate **114** as shown in FIG. 3L will be described with reference to FIGS. 4A-4G, in which a blue light emitting diode **112a**, a green light emitting diode **112b**, and a red light emitting diode **112c** are mounted on the support substrate **114**. The processes of manufacturing the blue light emitting diode **112a**, the green light emitting diode **112b**, and the red light emitting diode **112c** are the same as those shown in FIGS. 3A to 3I.

Like FIG. 3J, FIG. 4A shows the bonding portion S formed on the support substrate **114**, in which the bonding portion S is formed at all locations at which the blue light emitting diode **112a**, the green light emitting diode **112b**, and the red light emitting diode **112c** are coupled. The bonding portion S may be divided into a first bonding portion S1, a second bonding portion S2, and a third bonding portion S3. The first bonding portion S1 is provided to couple the blue light emitting diode **112a** to the support substrate and the second bonding portion S2 is provided to couple the green light emitting diode **112b** thereto. Further, the third bonding portion S3 is provided to couple the red light emitting diode **112c**.

The temperatures at which the first to third bonding portions S1, S2, S3 are bonded may be different from each other. The temperature at which the first bonding portion S1 is bonded is the highest temperature, and the temperature at which the third bonding portion S3 is bonded is the lowest temperature. For example, the bonding temperature of the first bonding portion S1 using silver-tin (AgSn) is about 230° C., and the bonding temperature of the second bonding portion S2 using zinc-tin (ZnSn) is about 198° C. The bonding temperature of the third bonding portion S3 using indium (In) is about 157° C. In this way, the bonding temperatures of the first to third bonding portions S1, S2, and S3 are different since the light emitting diodes **112** are bonded to the bonding portion S according to a predetermined sequence.

Since the blue light emitting diode **112a** is first bonded to the support substrate **114**, the bonding temperature of the first bonding portion S1 is the highest. Thus, since the bonding temperature of the bonding portion S2 is higher than that of the second bonding portion S2 or the third bonding portion S3, the first bonding portion S1 can be kept in a bonded state during bonding of the green light emitting diode **112b** or the red light emitting diode **112c**.

With the first to third bonding portions S1, S2, S3 formed on the support substrate **114**, as shown in FIG. 4A, a fourth substrate **21d** on which the blue light emitting diodes **112a** are formed is disposed at a corresponding location on the support substrate **114** and the blue light emitting diodes **112a** are bonded to the support substrate **114**, as shown in FIG. 4B. At this time, the blue light emitting diodes **112a** formed on the fourth substrate **21d** are spaced farther apart from each other by a stretching substrate corresponding to a third substrate **21c** than the blue light emitting diodes **112a** formed on the growth substrate **21**. Accordingly, the blue light emitting diodes **112a** are not disposed at a location corresponding to the location of the second bonding portion

11

S2 or the third bonding portion S3. Then, with the blue light emitting diodes 112a brought into contact with the first bonding portion S1, the first bonding portion S1 is heated to about 230° C., followed by lowering the temperature to bond the first bonding portion S1 to the blue light emitting diodes 112a such that the blue light emitting diodes 112a can be bonded to the support substrate 114.

The state that the blue light emitting diodes 112a are bonded to the support substrate 114 is shown in FIG. 4C. As shown in FIG. 4D, a fourth substrate 4d on which the green light emitting diodes 112b are formed is disposed at a corresponding location on the support substrate 114 and the green light emitting diodes 112b are bonded to the support substrate 114. At this time, as described above, the green light emitting diodes 112b formed on the fourth substrate 21d are spaced farther apart from each other than the green light emitting diodes 112b formed on the growth substrate 21. Accordingly, even when the green light emitting diodes 112b are disposed at a location corresponding to the second bonding portion S2 formed on the support substrate 114, there can be no interference between the green light emitting diodes 112b and the blue light emitting diodes 112a previously bonded to the support substrate 114. Then, with the green light emitting diodes 112b brought into contact with the second bonding portion S2, the second bonding portion S2 is heated to about 198° C., followed by lowering the temperature to bond the second bonding portion S2 to the green light emitting diodes 112b. As a result, the green light emitting diodes 112b can be bonded to the support substrate 114.

The state that the blue light emitting diodes 112a and the green light emitting diodes 112b are bonded to the support substrate 114 is shown in FIG. 4E. In this state, as shown in FIG. 4F, a fourth substrate 21d on which the red light emitting diodes 112c are formed disposed at a corresponding location on the support substrate 114 and the red light emitting diodes 112c are bonded to the support substrate 114. At this time, the distance between red light emitting diodes 112c formed on the support substrate 114 is also wide, thereby causing no interference between the blue light emitting diodes 112a or the green light emitting diodes 112b previously bonded to the support substrate 114. Then, with the red light emitting diodes 112c brought into contact with the third contact portion S3, the third bonding portion S3 is heated to about 157° C., followed by lowering the temperature to bond the third bonding portion S3 to the red light emitting diodes 112c such that the red light emitting diodes 112c can be bonded to the support substrate 114. The state that the blue light emitting diodes 112a, the green light emitting diodes 112b, and the red light emitting diodes 112c are bonded to the support substrate 114 is shown in FIG. 4G.

Here, each of the distances between the blue light emitting diodes 112a, the green light emitting diodes 112b, and the red light emitting diodes 112c formed on the different fourth substrates 21d may be at least two times the width of each of the light emitting diodes 112. In this way, the light emitting diodes 112 are bonded to the support substrate 114 in the state that the light emitting diodes 112 are separated from each other by a distance of at least two times the width of each light emitting diode 112, thereby preventing interference with other light emitting diodes 112.

FIG. 3M is a sectional view corresponding to the plan view of FIG. 4G. That is, as shown in FIG. 3M, the blue light emitting diodes 112a, the green light emitting diodes 112b, and the red light emitting diodes 112c may be bonded to the support substrate 114. Then, as shown in FIG. 3M, an insulation layer 120 may be formed to cover substantially

12

the entirety of each of the light emitting diodes 112 excluding a portion thereof. The insulation layer 120 is formed to cover both the transparent electrode 116 and the blocking portion 118 while surrounding each of the light emitting diodes 112. As a result, it is possible to prevent the transparent electrode 116 electrically connected to each of the light emitting diodes 112 from being exposed to the outside. In addition, an upper portion of the n-type semiconductor layer 23 and the n-type electrode 31 of each light emitting diode 112 may be exposed through an upper surface of the insulation layer 120.

Then, as shown in FIG. 3N, with the n-type semiconductor layer 23 and the n-type electrode 31 exposed through the upper surface of the insulation layer 120, a first connection electrode 122 may be formed on the insulation layer 120 to cover the n-type semiconductor layer 23 and the n-type electrode 31.

Then as shown in FIG. 3O, the insulation layer 120 is etched to expose an upper surface of the blocking portion 118. As a result, the light emitting diode part 110 according to the exemplary embodiment can be manufactured.

Next, as shown in FIG. 3P, the manufactured light emitting diode part 110 is bonded to a TFT panel 130 via an anisotropic conductive film 150, thereby providing the display apparatus 100 according to this exemplary embodiment, as shown in FIG. 1.

FIG. 5 is a schematic sectional view of a display apparatus according to a second exemplary embodiment of the present disclosure.

Referring to FIG. 5, a display apparatus 100 according to the second exemplary embodiment includes a light emitting diode part 110, a TFT panel unit 130, and an anisotropic conductive film 150. In description of the second exemplary embodiment, the same or similar descriptions as in the first exemplary embodiment will be omitted.

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

Although the support substrate 114 may be formed in the same manner as in the first embodiment, the support substrate 114 may be formed as a transparent substrate so as to allow light emitted from blue light emitting diodes 112a to pass therethrough while supporting the blue light emitting diodes 112a in this exemplary embodiment.

In this exemplary embodiment, the blocking portion 118 may be formed on the support substrate 114 and an upper surface of the support substrate 114 may be divided into a plurality of zones by the blocking portion 118. The plurality of zones may be sub-pixel regions. A plurality of phosphor layers 126 may be formed on the support substrate 114 to cover the sub-pixels formed on the upper surface of the support substrate 114.

The phosphor layers 126 may include a green phosphor layer 126b and a red phosphor layer 126c, in which the green phosphor layer 126b may be formed on one of three sub-pixels, the red phosphor layer 126c may be formed on another sub-pixel, and no phosphor layer may be formed on the third sub-pixel with reference to three sub-pixels. In this structure, the green phosphor layer 126b converts blue light emitted from the blue light emitting diodes 112a into green light and the red phosphor layer 126c converts blue light emitted from the blue light emitting diodes 112a into red light. In the sub-pixel on which the phosphor layer is not formed, blue

13

light emitted from the blue light emitting diodes **112a** may be emitted as is (i.e., without being converted by a phosphor layer).

Then, with the phosphor layers **126** disposed on the support substrate, the plurality of transparent electrodes **116** may be formed on the plurality of phosphor layers **126**. The plurality of transparent electrodes **116** are formed on the overall upper surface of the support substrate **114** so as to cover the blocking portion **118**, the plurality of phosphor layers **126**, and regions of the support substrate **114** in which the phosphor layers **126** are not formed.

The plurality of transparent electrodes **116** may include indium-tin-oxide (ITO) and indium-zinc-oxide (IZO). The plurality of transparent electrodes **116** may be a carbon nanotube film, a graphene film, a transparent conductive polymer film such as poly(ethylenedioxythiophene) (PEDOT), and the like. The plurality of transparent electrodes **116** may include any one of polyaniline, polyacetylene, polypyrrole, and polythiophene.

In addition, the plurality of blue light emitting diodes **112a** are mounted on the plurality of transparent electrodes **116**. Each of the plurality of blue light emitting diodes **112a** is mounted such that a p-type electrode **33** is electrically connected to a transparent electrode **116**, and an n-type electrode **31** is disposed on the surface of the blue light emitting diode **112a** opposite the surface of the blue light emitting diode **112a** on which the p-type electrode **33** is disposed.

The insulation layer **120** is formed to cover the entirety of the blue light emitting diode **112a** and the transparent electrode **116** such that only the n-type electrode **31** is exposed through the insulation layer **120**. The first connection electrode **122** is formed so as to electrically contact the n-type electrode **31** exposed on the insulation layer **120**. Here, the first connection electrode **122** may include a reflective surface to reflect blue light emitted from the blue light emitting diode **112a** toward the support substrate **114**.

Then, the TFT panel **130** having a plurality of second connection electrodes **134** formed on one surface thereof is coupled to the light emitting diode part **110** by the anisotropic conductive film **150** after formation of the light emitting diode part **110** as described above. Accordingly, the anisotropic conductive film **150** electrically connects the plurality of first connection electrodes **122** to the plurality of second connection electrodes **134** via the electrode connection portion **152**.

FIGS. **6A** and **6B** are a schematic sectional view of a phosphor layer of a display apparatus according to a third exemplary embodiment of the present disclosure.

Referring to FIGS. **6A** and **6B**, the display apparatus **100** according to this embodiment has the same structure as that of the second embodiment except that the phosphor layer is formed in grooves of the support substrate **114** instead of being formed on the upper surface of the support substrate **114**. Accordingly, descriptions of the same or similar features as those of the first and second exemplary embodiments will be omitted.

In this exemplary embodiment, the support substrate **114** may have a plurality of grooves formed on one surface thereof. The plurality of grooves may be regularly formed in a predetermined pattern and the plurality of blocking portions **118** may be formed in a region in which the grooves are not formed. Accordingly, the plurality of sub-pixels can be divided into a plurality of zones by the blocking portion **118** and the width of the grooves can be formed equal to the width of the sub-pixels.

14

In addition, the grooves may be formed in a concave or convex shape to have a non-polygonal shape such as the lens shape as shown in FIG. **6A**, or may have polygonal shape such as the rectangular shape in a longitudinal cross-sectional view, as shown in FIG. **6A**.

The plurality of grooves may be filled with the green phosphor layer **126b** or the red phosphor layer **126c** such that the upper surface of the support substrate **114** becomes coplanar.

Of course, as shown in FIG. **5**, since the groove is not formed in a region in which the green phosphor layer **126b** or the red phosphor layer **126c** is not formed, blue light emitted from the blue light emitting diode **112a** disposed in this region can be emitted to the outside through the support substrate **114** without a corresponding phosphor layer.

FIG. **7** is a schematic sectional view of a display apparatus according to a fourth exemplary embodiment of the present disclosure.

Referring to FIG. **7**, a display apparatus **100** according to the fourth exemplary embodiment includes a light emitting diode part **110**, a TFT panel **130**, and an anisotropic conductive film **150**. In the following description of the fourth exemplary embodiment, descriptions of the same or similar features as those of the first and second exemplary embodiments will be omitted.

The light emitting diode part **110** includes a plurality of blue light emitting diodes **112a**, a support substrate **114**, a transparent electrode **116**, a blocking portion **118**, an insulation layer **120**, a plurality of first connection electrodes **122**, and a plurality of phosphor layers **126**.

In this exemplary embodiment, the light emitting diode part **110** may further include a transparent layer **127** in a region of the support substrate **114** of a sub-pixel, in which the green phosphor layer **126b** or the red phosphor layer **126c** is not formed. The transparent layer **127** may be formed to the same thickness as the green phosphor layer **126b** and the red phosphor layer **126c** and allow blue light emitted from the blue light emitting diode **112a** to be directly transmitted towards the support substrate **114**.

Accordingly, the plurality of transparent electrodes **116** formed on the green phosphor layer **126b**, the red phosphor layer **126c**, and the transparent layer **127** may be formed to have the same height in the respective sub-pixels, and the blue light emitting diodes **112a** may also be mounted at the same height. That is, in this exemplary embodiment, since the blue light emitting diodes **112a** are disposed at the same distance from the support substrate **114**, it is possible to prevent a problem caused by a height difference of the various bonding portions **S** in a subsequent process, such as a transfer process.

FIG. **8** is a schematic sectional view of a display apparatus according to a fifth exemplary embodiment of the present disclosure.

Referring to FIG. **8**, a display apparatus **100** according to the fifth exemplary embodiment includes a light emitting diode part **110**, a TFT panel **130**, and an anisotropic conductive film **150**. In the following description of the fifth exemplary embodiment, descriptions of the same or similar features as those of the first and second exemplary embodiments will be omitted.

The light emitting diode part **110** includes ultra violet (UV) light emitting diodes **112d**, a support substrate **114**, a plurality of transparent electrodes **116**, a blocking portion **118**, an insulation layer **120**, a plurality of first connection electrodes **122**, and a plurality of phosphor layers **126**.

The display apparatus **100** according to this exemplary embodiment includes the UV light emitting diodes **112d**.

15

Thus, a green phosphor layer **126b** converts ultraviolet light emitted from the UV light emitting diodes **112d** into green light and a red phosphor layer **126c** converts UV light emitted from the UV light emitting diodes **112d** into red light. Furthermore, the blue phosphor layer **126a** converts UV light emitted from the UV light emitting diodes **112d** into blue light.

In the above exemplary embodiment, since three sub-pixels form one pixel, one pixel emits blue light, green light, and red light.

Thus, in the light emitting diode part **110** according to this exemplary embodiment, a blue phosphor layer **126a**, a green phosphor layer **126b**, and a red phosphor layer **126c** are formed together with the blocking portion **118** on the support substrate **114** and have the same thickness. The transparent electrodes **116** may be formed on the blue phosphor layer **126a**, the green phosphor layer **126b**, and the red phosphor layer **126c**, respectively. Other features of this exemplary embodiment are the same as or similar to those of the fourth exemplary embodiment, and detailed descriptions thereof will be omitted.

FIG. 9 is a schematic sectional view of a display apparatus according to a sixth exemplary embodiment of the present disclosure. FIG. 10A is a schematic plan view of the display apparatus according to the sixth exemplary embodiment of the present disclosure. FIG. 10B is a schematic sectional view along sectional line I-I' of FIG. 10A. FIG. 11 is a schematic sectional view of a modified phosphor layer of the display apparatus according to the sixth exemplary embodiment of the present disclosure.

Referring to FIG. 9, a display apparatus **100** according to the sixth exemplary embodiment includes a light emitting diode part **110** and a TFT panel **130**. In the following description of the sixth exemplary embodiment, descriptions of the same or similar features as those of the first and second exemplary embodiments will be omitted.

The light emitting diode part **110** includes a plurality of light emitting diodes **112**, a support substrate **114**, an electrode **117**, a blocking portion **118**, an insulation layer **120**, a plurality of first connection electrodes **122**, and a plurality of phosphor layers **126**.

A bottom electrode **117** may be formed on the support substrate **114**. The bottom electrode **117** may be formed to cover the entirety of the support substrate **114** and may have a plurality of grooves open at an upper side thereof. The plurality of light emitting diodes **112** may be mounted within the plurality of grooves of the bottom electrode, and one groove may correspond to one sub-pixel. Further, in this exemplary embodiment, the bottom electrode **117** may be opaque and have a reflective surface may to reflect light emitted from the light emitting diodes **112** in an upward direction.

The bottom electrode **117** may include a stack structure of ITO-Ag-ITO, whereby diffusion and/or oxidation of the bottom electrode **117** can be prevented by ITO. In addition, the bottom electrode **117** may have a stack structure of Ti—Al—Ti, or a stack structure of Mo—Al—Mo-ITO.

As described above, one or more light emitting diodes **112** may be mounted within the plurality of grooves formed on the bottom electrode **117** such that the p-type electrode **33** of each of the light emitting diodes **112** can be electrically connected to the bottom electrode **117**. Each of the light emitting diodes **112** may include an n-type electrode **31** formed on a surface opposite to a surface on which the p-type electrode **33** is formed. Here, the plurality of light emitting diodes **112** may be blue light emitting diodes that

16

emit blue light or a plurality of UV light emitting diodes that emit UV light, or some combination thereof.

The insulation layer **120** may be formed on an upper surface of the bottom electrode **117** to cover the entirety of the light emitting diode **112**. At this time, the n-type electrode **31** of each light emitting diode may be exposed through the insulation layer **120** instead of being covered by the insulation layer **120**. The blocking portion **118** and the first connection electrodes **122** may be formed on an upper surface of the insulation layer **120**. The blocking portion **118** is formed on the upper surface of the insulation layer **120** in a region that does not overlap the plurality of grooves of the bottom electrode **117**. Thus, as in the second exemplary embodiment, the insulation layer **120** can be divided into plurality of zones by the blocking portion **118**, and each of the zones may be a sub-pixel.

The first connection electrodes **122** may be formed to cover the insulation layer **120** in a plurality of zones divided by the blocking portion **118** such that each of the first connection electrode **122** is placed in a zone between the blocking portions **118**, as shown in FIGS. 10A and 10B. At this time, each of the first connection electrodes **122** may be formed on an upper side of the light emitting diode **112** to be electrically connected to the n-type electrode **31** of the light emitting diode **112**. Accordingly, the first connection electrodes **122** may be transparent so as to allow light emitted from the light emitting diodes **112** to pass through the first connection electrodes **122**. Of course, the first connection electrodes **122** may be formed to cover the entirety of the sub-pixels.

Further, in this exemplary embodiment, a connection portion **160** may be formed near the blocking portion **118**. The connection portion **160** bonds second connection electrodes **134** of the TFT panel **130** to the first connection electrodes **122** such that the first connection electrodes **122** are electrically connected to the second connection electrodes **134**, respectively.

The TFT panel **130** includes a panel substrate **132** and the second connection electrodes **134**, and may further include a TFT driving circuit formed therein and phosphor layers **126**. The TFT driving circuit may be formed inside the panel substrate **132** and may be regularly arranged at constant intervals inside the panel substrate **132**. In addition, as shown in FIG. 11, the TFT driving circuit may not overlap a groove of panel substrate.

The second connection electrodes **134** are electrically connected to the TFT driving circuit and may be formed under the TFT driving circuit, as shown in FIG. 9. As described above, the second connection electrodes **134** may be electrically connected to the first connection electrodes **122** by the connection portion **160**, respectively.

In this exemplary embodiment, the plurality of light emitting diodes **112** may include blue light emitting diodes, and the plurality of phosphor layers may include a green phosphor layer **126b** and a red phosphor layer **126c**. In addition, a plurality of grooves formed on the panel substrate **132** may be filled with the green phosphor layer **126b** or the red phosphor layer **126c**. That is, the panel substrate **132** may have a plurality of grooves regularly formed on a surface corresponding to the light emitting diode part **110**. The plurality of grooves may be formed in regions corresponding to sub-pixels of the light emitting diode part **110** at a location where the second connection electrodes **134** are not formed. The plurality of grooves thus formed may be filled with the green phosphor layer **126b** or the red phosphor layer **126c**.

17

The plurality of grooves formed on the panel substrate **132** are not formed at all locations corresponding to the sub-pixels and, since three sub-pixels form one pixel, the groove is not formed in a region corresponding to one of the three sub-pixels (e.g., the blue sub-pixel region). Accordingly, blue light emitted from the light emitting diodes **112** is converted into green light in one sub-pixel and is converted into red light in another sub-pixel. In the third sub-pixel, the blue light may be emitted to the panel substrate **132** without being subjected to wavelength conversion.

The plurality of grooves formed on the panel substrate **132** may have a rectangular shape in a longitudinal cross-sectional view, as shown in FIG. **9**, or may have a concave shape as shown in FIG. **11**.

On the other hand, the plurality of grooves may be formed on the panel substrate **132** so as to correspond to all of the sub-pixels, as needed, and, as in the fourth exemplary embodiment, the green phosphor layer **126b**, the red phosphor layer **126c** and the transparent layer **127** may be formed at locations corresponding to three sub-pixels, respectively.

Further, when the plurality of light emitting diodes **112** include UV light emitting diodes, the plurality of phosphor layers include a blue phosphor layer **126a**, a green phosphor layer **126b**, and a red phosphor layer **126c**, and a plurality of grooves may be formed on the panel substrate **132** so as to correspond to all of the sub-pixels. As in the fifth exemplary embodiment, the blue phosphor layer **126a**, the green phosphor layer **126b**, and the red phosphor layer **126c** may be formed at locations corresponding to three sub-pixels, respectively.

FIG. **12** is a schematic plan view of a display apparatus according to a seventh exemplary embodiment of the present disclosure.

Referring to FIG. **12**, a display apparatus **100** according to the seventh exemplary embodiment includes a light emitting diode part **110** and a TFT panel **130**. In the following description of the seventh exemplary embodiment, descriptions of the same features as those of the first and sixth exemplary embodiments will be omitted.

The TFT panel **130** includes a panel substrate **132**, a plurality of second connection electrodes **134**, a TFT driving circuit, and a plurality of phosphor layers **126**. The TFT driving circuit may be formed inside the panel substrate **132** and may be formed along a region outside of the sub-pixel regions of on the light emitting diode part **110**. That is, the TFT driving circuit may be formed in a line shape along a region in which the groove of the bottom electrode **117** is not formed on the support substrate **114** of the light emitting diode part **110**. Accordingly, the TFT driving circuit may not cover part of light emitted from the light emitting diodes **112** and the display apparatus **100** according to this exemplary embodiment may allow light to be emitted from the entirety of the sub-pixels.

Various exemplary embodiments described above employ a plurality of micro-light emitting diodes including nitride semiconductors. Using micro-light emitting diodes including nitride semiconductors for each sub-pixel region for a display apparatus results in a high efficiency and high resolution display apparatus compared to conventional display apparatus. For example, exemplary embodiments described herein are suitable in reducing the power consumption of any type of display apparatus (e.g., a wearable apparatus that requires low power consumption).

Although some exemplary embodiments have been described with reference to the accompanying drawings, it should be understood that these embodiments are given by

18

way of illustration only and various modifications, variations and alterations can be made by those skilled in the art without departing from the spirit and scope of the present disclosure. Therefore, the scope of the present disclosure should be interpreted according to the appended claims and equivalents thereof.

What is claimed is:

1. A display apparatus, comprising:

a light emitting diode part comprising:

a transparent support substrate;

a plurality of light emitting diodes regularly arranged on the support substrate; and

a plurality of phosphor layers disposed on the support substrate covering at a first portion of the plurality of light emitting diodes and configured to emit light through a conversion of introduced light;

a blocking portion disposed on the support substrate and interposed between the plurality of phosphor layers;

a plurality of transparent electrodes covering the plurality of phosphor layers and comprising portions disposed on each side surface of the blocking portion laterally adjacent to the plurality of light emitting diodes, the plurality of transparent electrodes electrically connected to the plurality of light emitting diodes; and

a TFT panel configured to drive the light emitting diode part.

2. The display apparatus according to claim 1, wherein: the support substrate comprises a plurality of regions corresponding to a plurality of pixels, and each light emitting diode is configured to emit light for 1000 pixels or less.

3. The display apparatus according to claim 1, wherein: the plurality of light emitting diodes is a plurality of blue light emitting diodes configured to emit blue light, and the plurality of phosphor layers comprises at least one of a green phosphor layer configured to emit green light through wavelength conversion of the blue light into green light and a red phosphor layer configured to emit red light through wavelength conversion of the blue light into red light.

4. The display apparatus according to claim 3, further comprising a transparent layer disposed on the support substrate covering a second portion of the plurality of light emitting diodes not covered by the plurality of phosphor layers.

5. The display apparatus according to claim 1, wherein: the plurality of light emitting diodes is a plurality of ultra violet (UV) light emitting diodes configured to emit UV light, and

the plurality of phosphor layers comprises at least one of a blue phosphor layer configured to emit blue light through wavelength conversion of the UV light into blue light, a green phosphor layer configured to emit green light through wavelength conversion of the UV light into green light, and a red phosphor layer configured to emit red light through wavelength conversion of the UV light into red light.

6. The display apparatus according to claim 1, wherein the support substrate comprises a plurality of grooves formed on an upper surface thereof and the plurality of phosphor layers are disposed within the plurality of grooves, respectively.

7. The display apparatus according to claim 6, wherein each of the plurality of grooves has a polygonal cross-section.



8. The display apparatus according to claim 6, wherein each of the plurality of grooves has a non-polygonal cross-section.

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