US010636349B2

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

(10) **Patent No.: US 10,636,349 B2**
(45) **Date of Patent: Apr. 28, 2020**

(54) **MICRO LED DISPLAY DEVICE AND METHOD OF FABRICATING THE SAME**

(71) Applicant: **LUMENS CO., LTD.**, Yongin-si, Gyeonggi-do (KR)

(72) Inventors: **Eun Sung Shin**, Yongin-si (KR); **Dong Hee Cho**, Yongin-si (KR); **Yong Pil Kim**, Yongin-si (KR); **Myung Ji Moon**, Yongin-si (KR); **Han Beet Chang**, Yongin-si (KR); **Jae Soon Park**, Yongin-si (KR)

(73) Assignee: **LUMENS CO., LTD.**, Yongin-si (KR)

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

(21) Appl. No.: **15/888,943**

(22) Filed: **Feb. 5, 2018**

(65) **Prior Publication Data**

US 2018/0308420 A1 Oct. 25, 2018

(30) **Foreign Application Priority Data**

Apr. 21, 2017 (KR) 10-2017-0051892

(51) **Int. Cl.**

G09G 3/32	(2016.01)
H04N 5/374	(2011.01)
G09G 3/14	(2006.01)

(52) **U.S. Cl.**

CPC ***G09G 3/32*** (2013.01); ***G09G 3/14*** (2013.01); ***H04N 5/374*** (2013.01); *G09G 2310/0264* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0299044 A1* 12/2011 Yeh H04N 9/315 353/52

2012/0187389 A1* 7/2012 Shoda H01L 27/3246 257/40

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2009-509326 A 3/2000

JP 2003-031858 A 1/2003

(Continued)

OTHER PUBLICATIONS

PCT International Search Report for International Application PCT/KR2018/000391, filed Jan. 9, 2018.

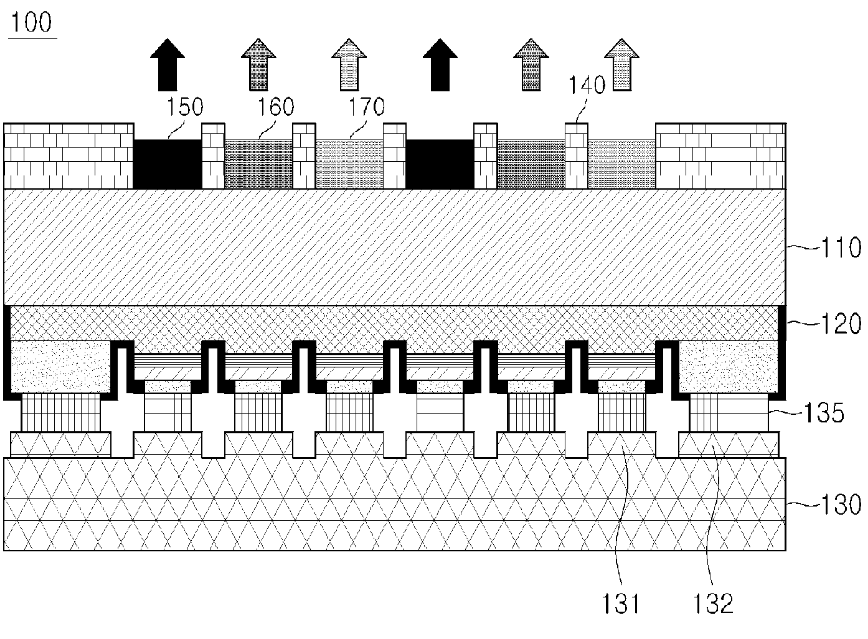
Primary Examiner — Stephen T. Reed

(74) *Attorney, Agent, or Firm* — Mei & Mark LLP

(57) **ABSTRACT**

Disclosed is a micro light emitting diode (LED) display device which is capable of implementing a full color of high resolution, the micro LED display device including: a micro LED driving substrate (backplane) in which a plurality of CMOS cells is arranged in rows and columns; and a micro LED panel which is flip-chip bonded onto the micro LED driving substrate, and includes a plurality of micro LED pixels electrically connected with the plurality of CMOS cells, in which the micro LED panel includes the plurality of micro LED pixels formed by etching a first surface of an emission structure along a unit pixel region, and a plurality of separators formed on a second surface of the emission structure corresponding to positions of portions formed by etching the emission structure in a vertical direction.

20 Claims, 18 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0223875	A1*	9/2012	Lau	H01L 27/156 345/83
2014/0008667	A1	1/2014	Lau et al.	
2014/0111408	A1*	4/2014	Lau	G09G 3/3241 345/83
2014/0319470	A1	10/2014	Kim et al.	
2017/0162091	A1*	6/2017	Wu	G09G 3/006

FOREIGN PATENT DOCUMENTS

JP	2007-109792	A	4/2007
JP	2008-124500	A	5/2008
JP	2008-262993	A	10/2008
JP	2009-009711	A	1/2009
JP	2016-102211	A	6/2016
JP	2017-510843	A	4/2017
KR	10-2008-00622921	A	7/2008
KR	10-1411689	B1	6/2014
KR	10-2014-0129852	A	11/2014
WO	2011-040237	A1	4/2011
WO	2015/135839	A1	9/2015

* cited by examiner

FIG. 1

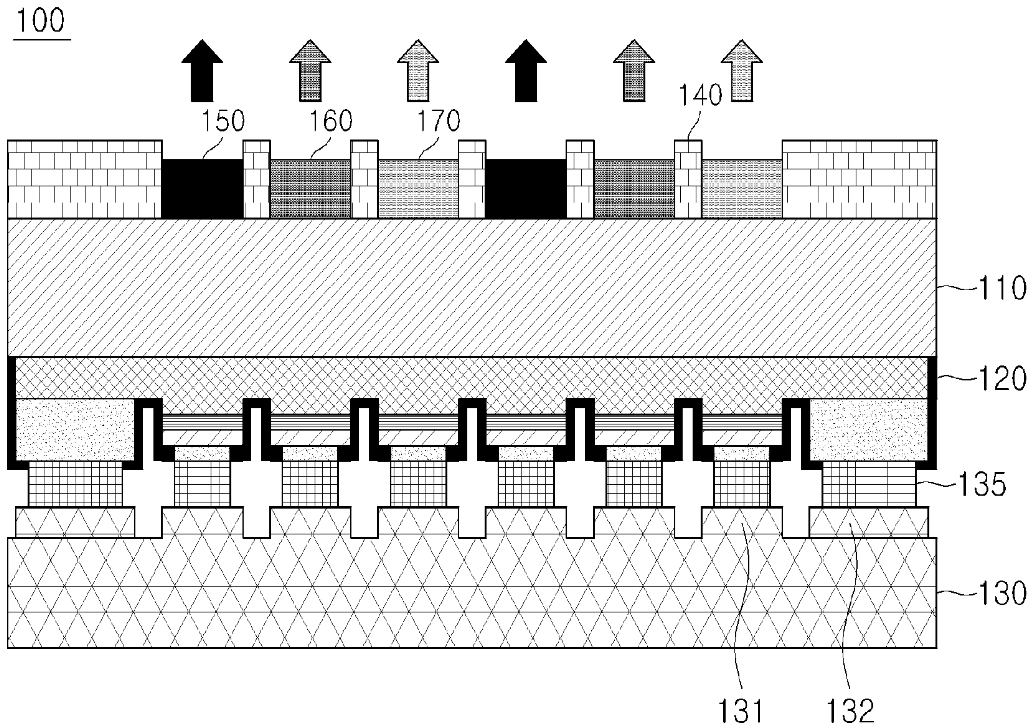


FIG. 2

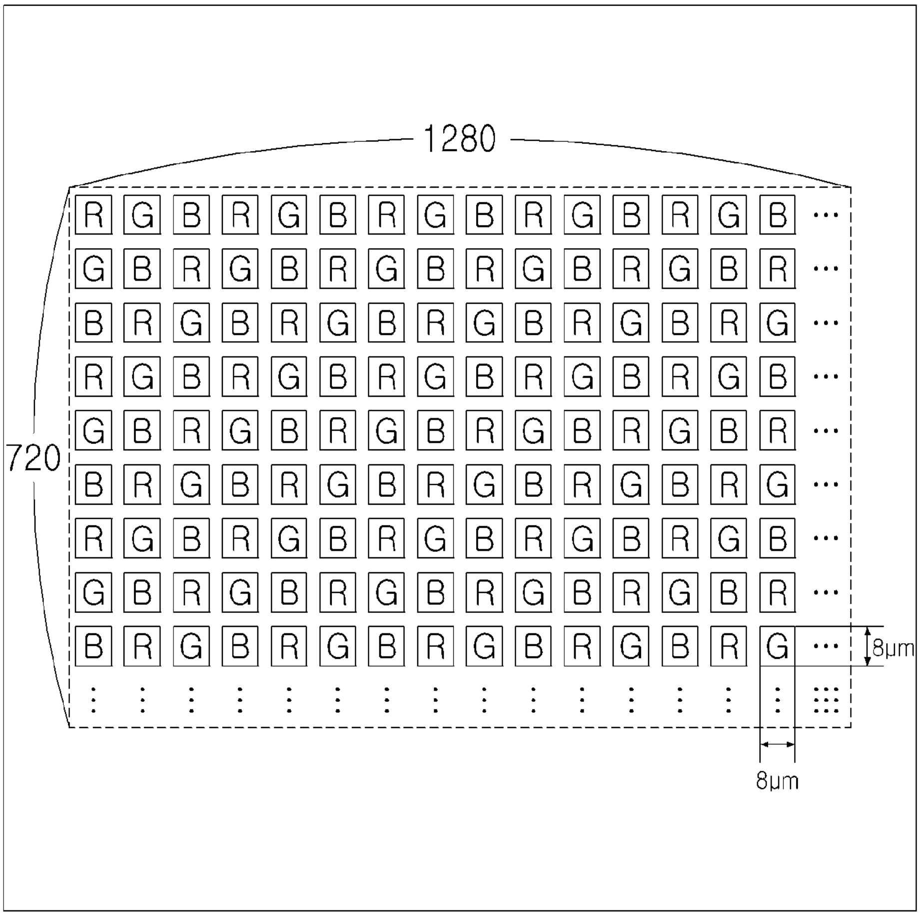

1280
720
R G B R G B R G B R G B R G B
G B R G B R G B R G B R G B R
B R G B R G B R G B R G B R G
8μm
8μm

FIG. 3

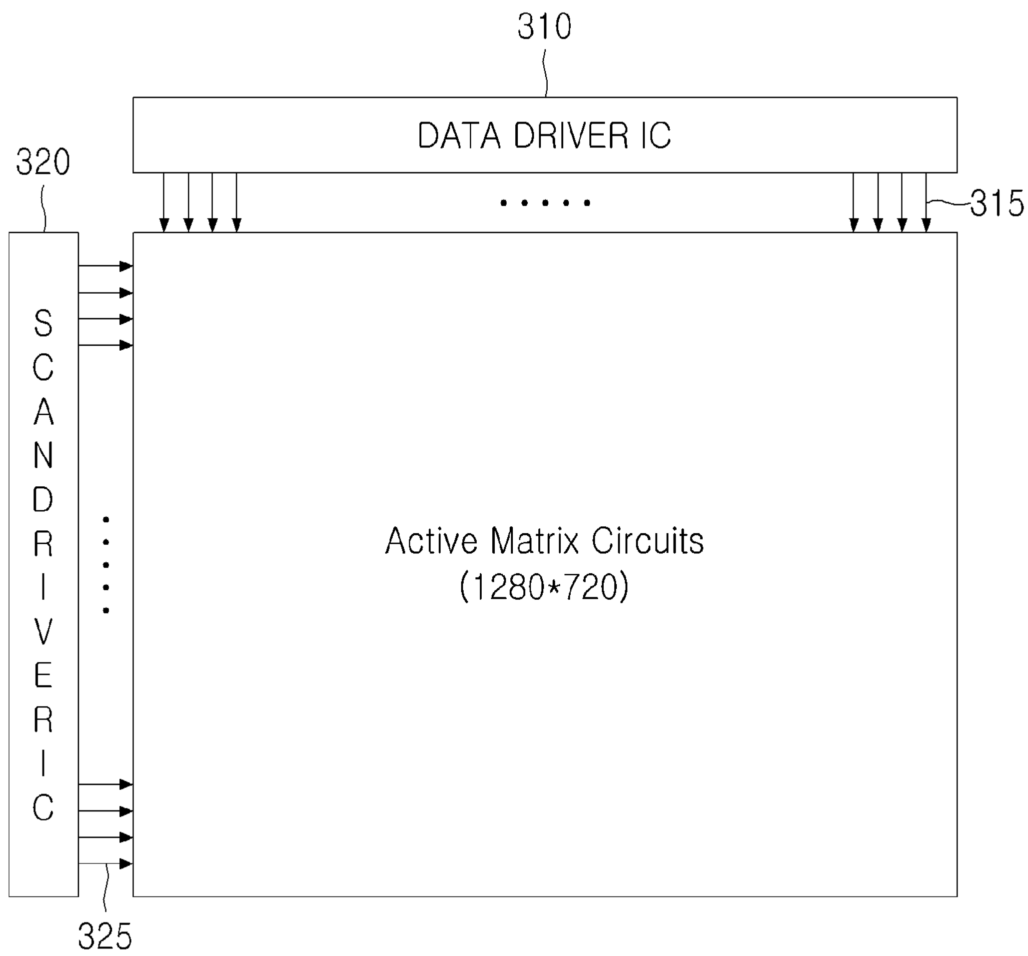
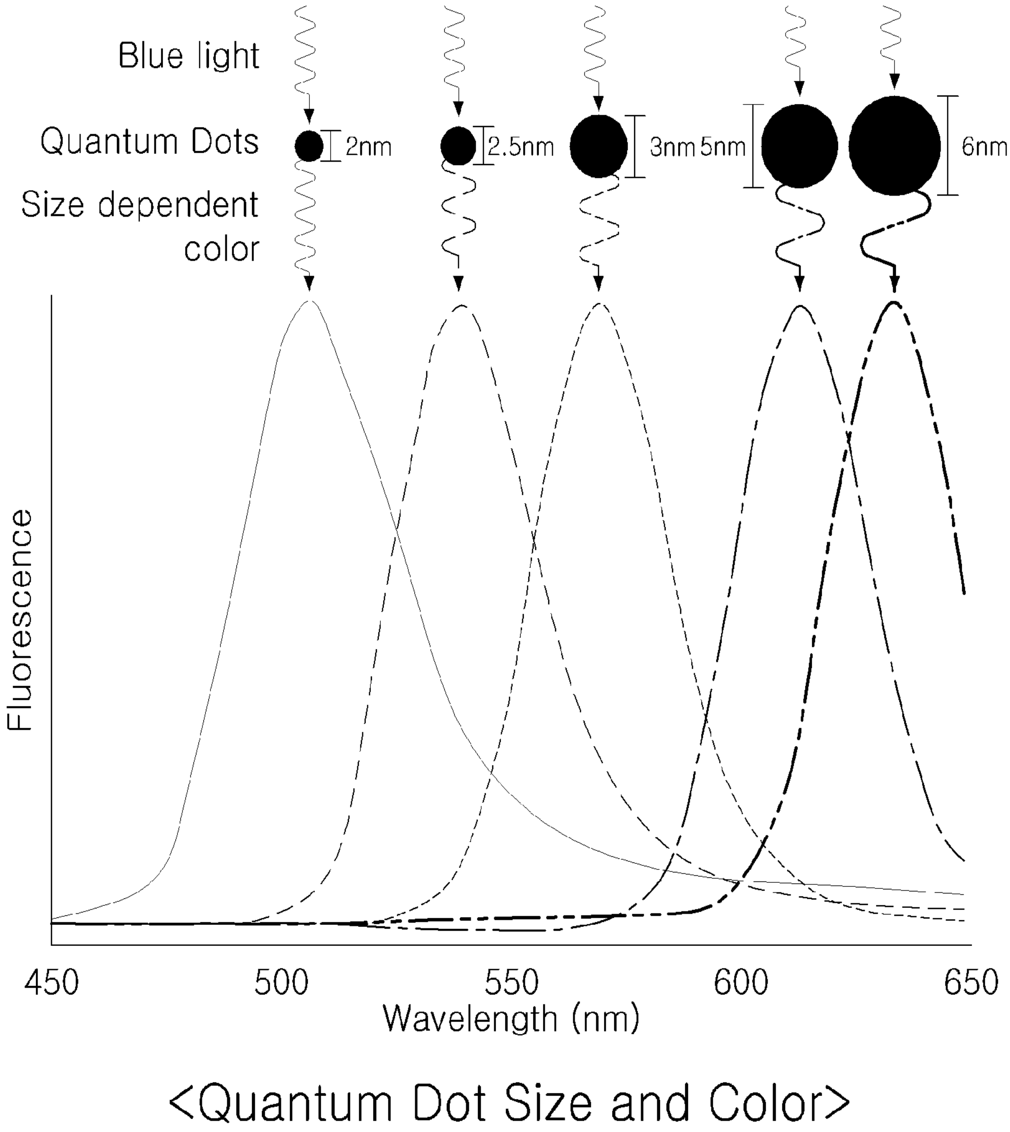

310
DATA DRIVER IC
320
315
SCAN DRIVER IC
Active Matrix Circuits
(1280*720)
325

FIG. 4



<Quantum Dot Size and Color>

FIG. 5A

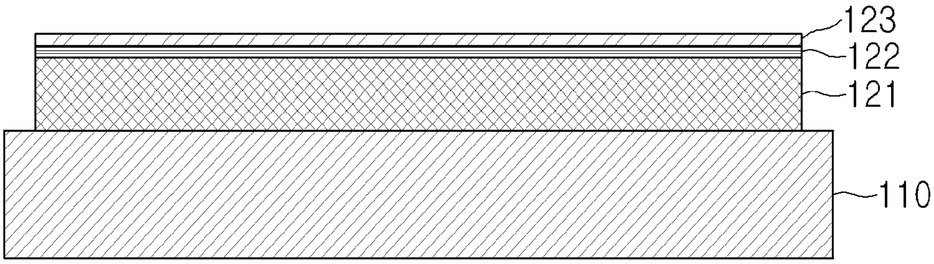


FIG. 5B

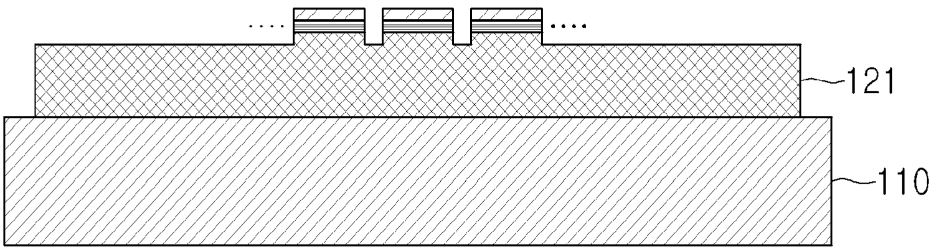


FIG. 5C

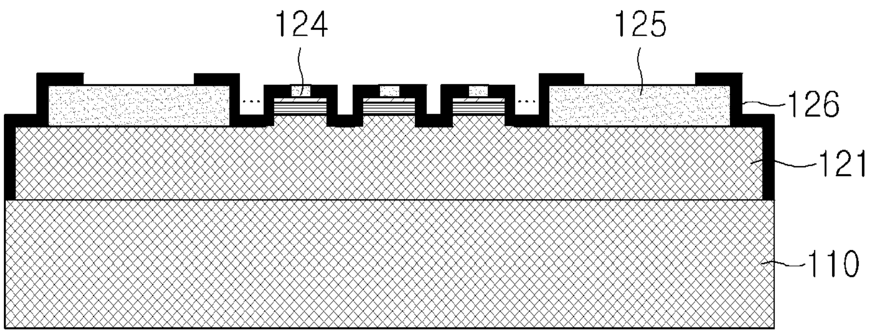


FIG. 5D

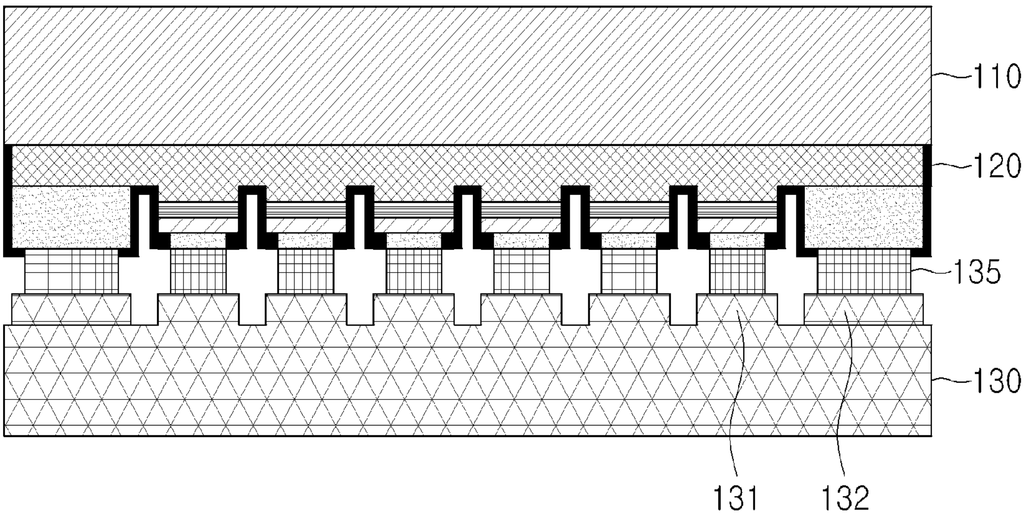


FIG. 5E

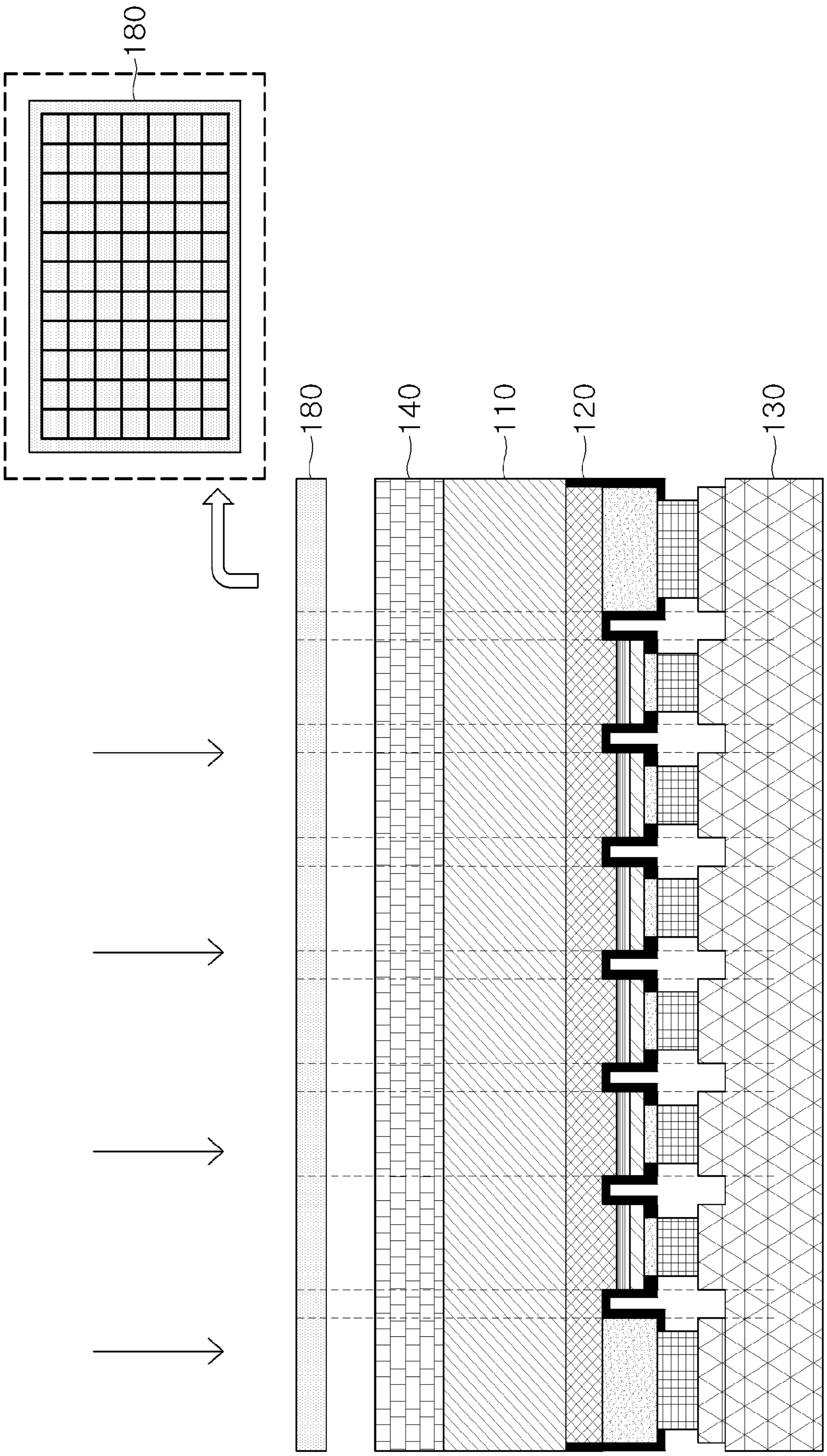


FIG. 5F

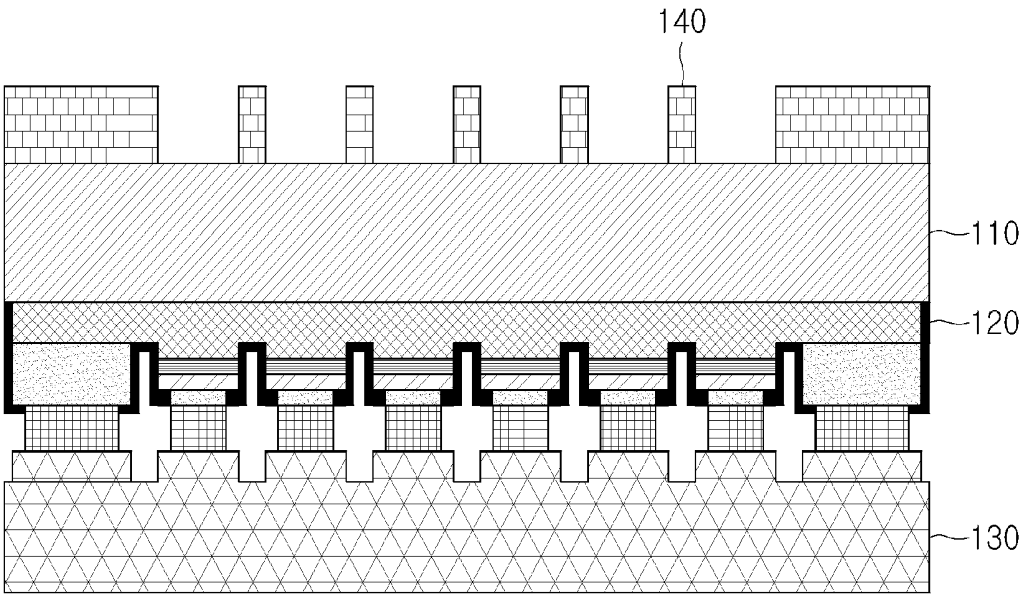


FIG. 5G

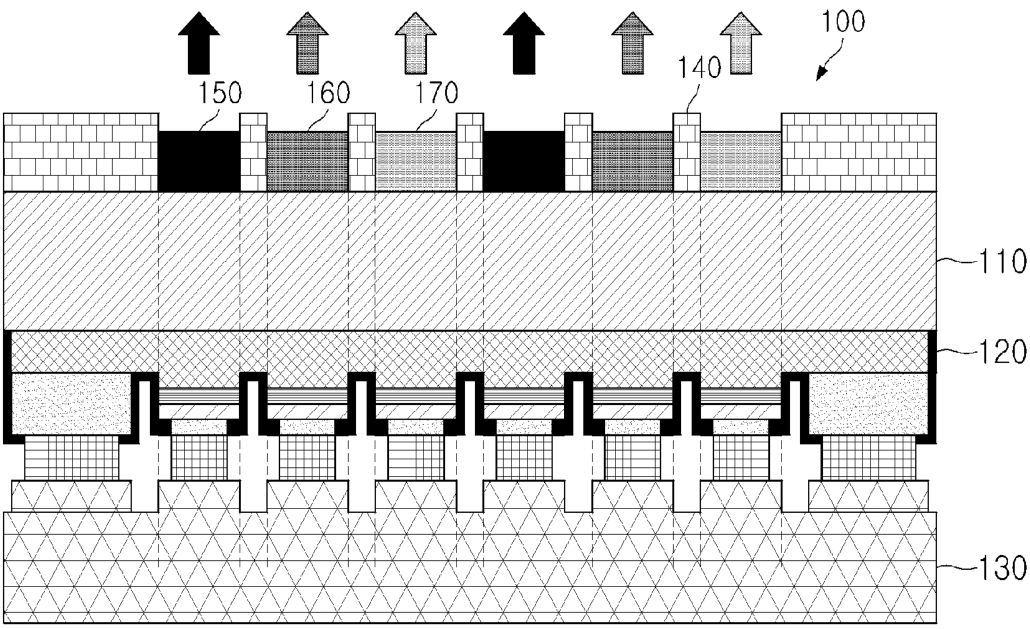


FIG. 6

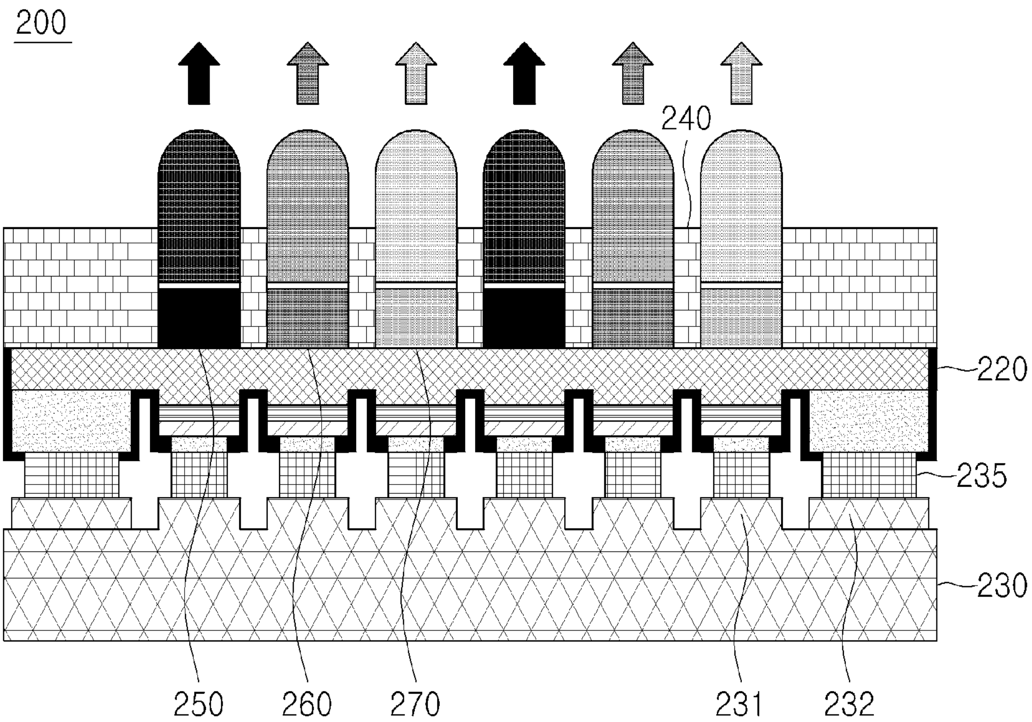


FIG. 7A

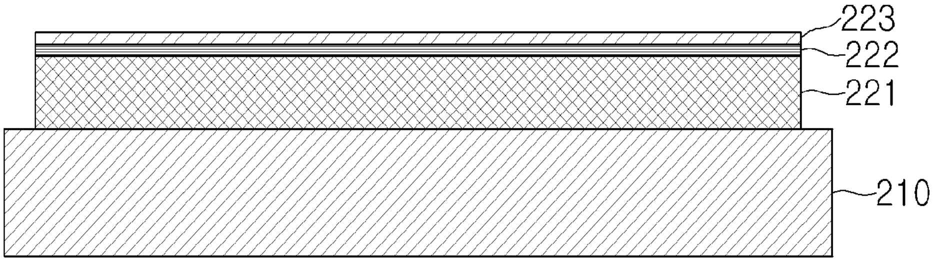


FIG. 7B

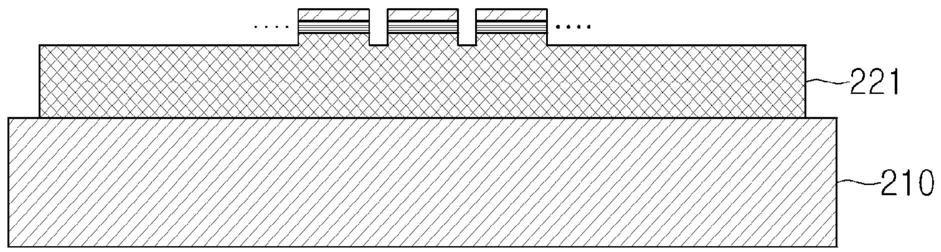


FIG. 7C

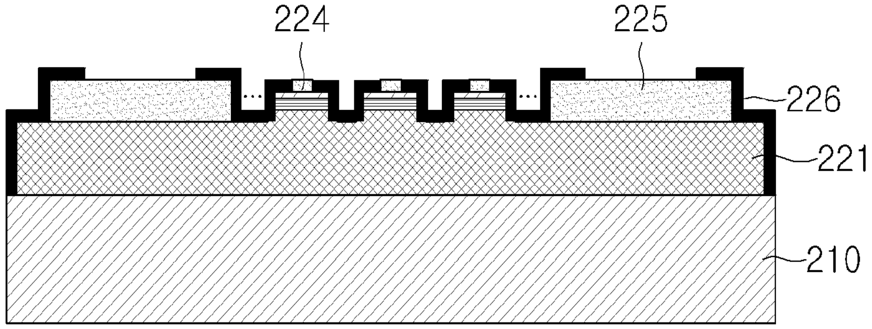


FIG. 7D

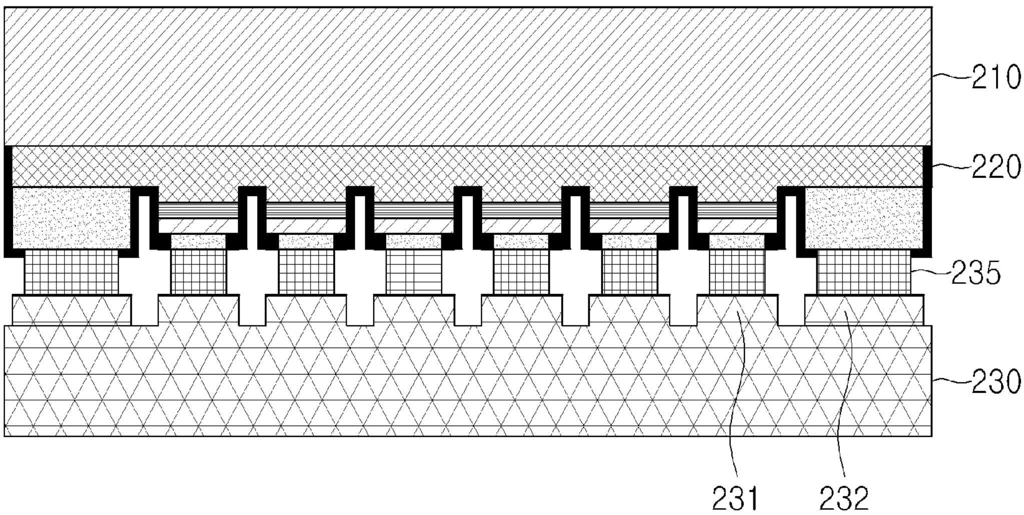


FIG. 7E

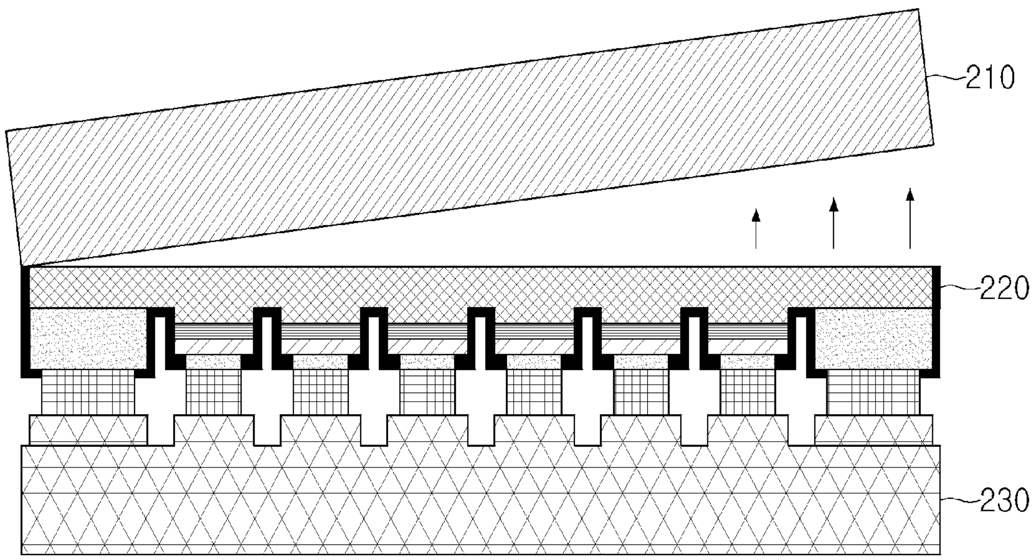


FIG. 7F

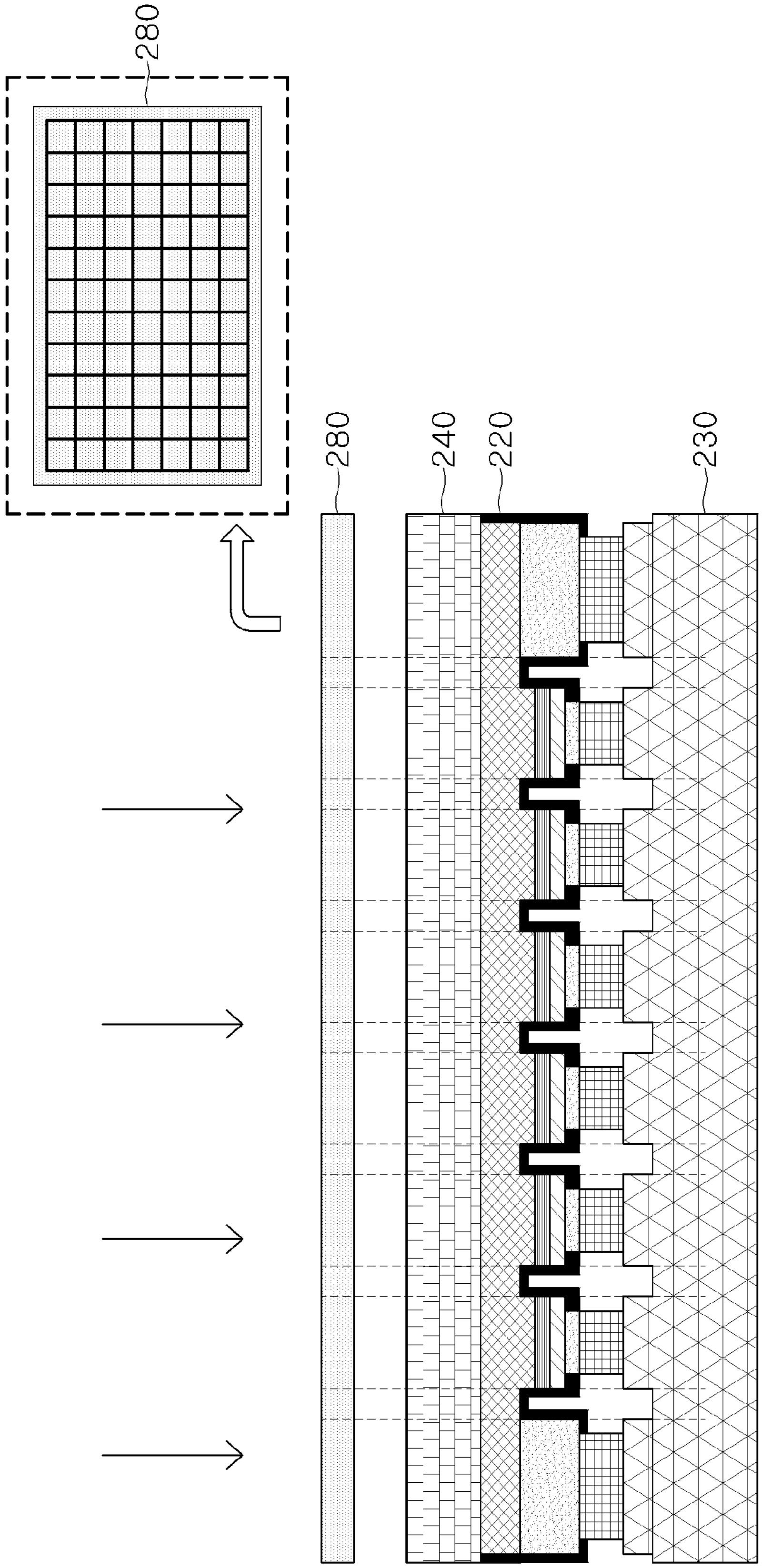


FIG. 7G

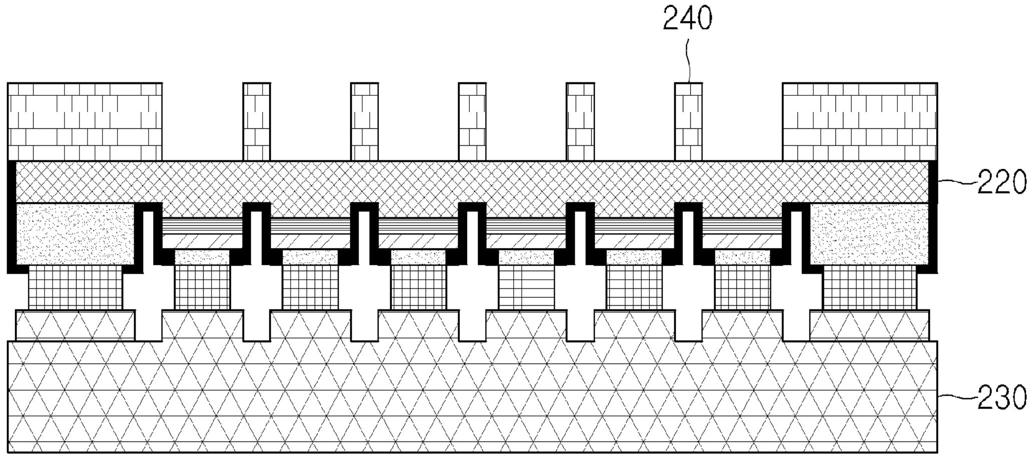


FIG. 7H

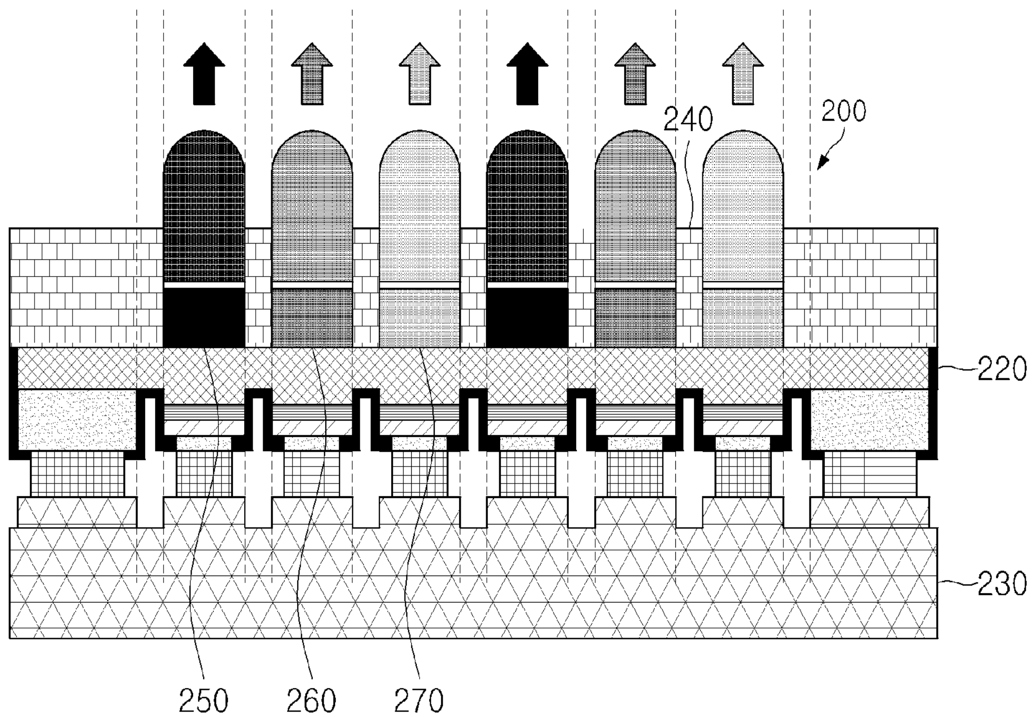


FIG. 8

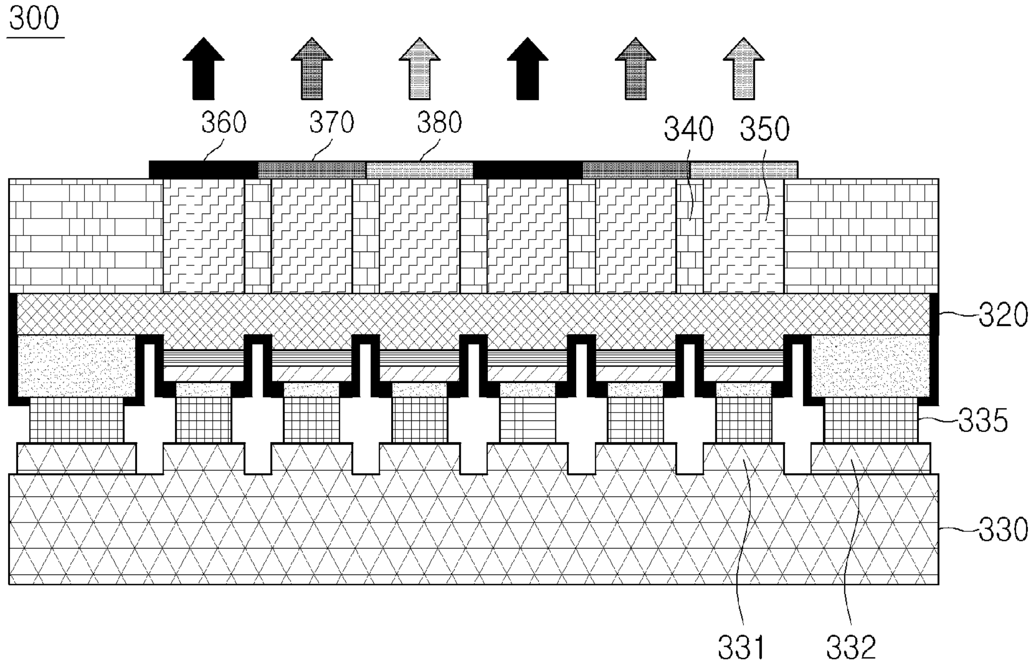

300
360
370
380
340
350
320
335
330
331
332

FIG. 9

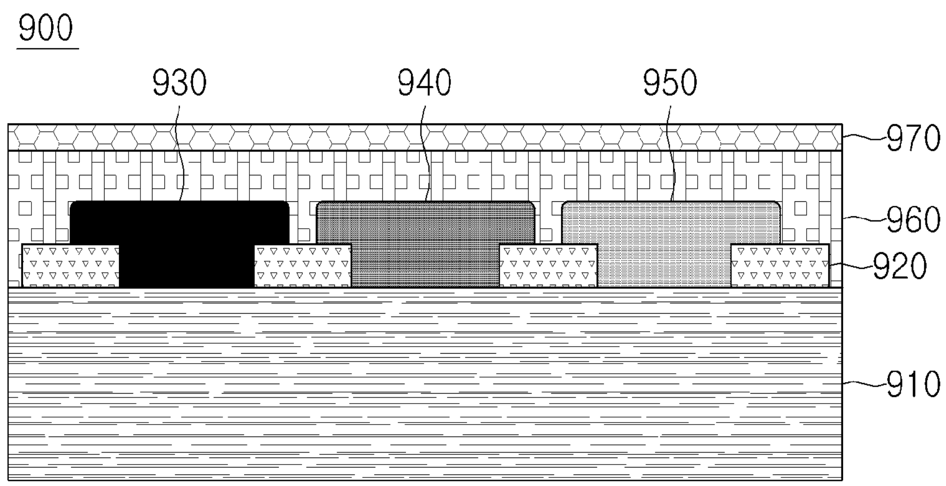

900
930
940
950
970
960
920
910

FIG. 10A

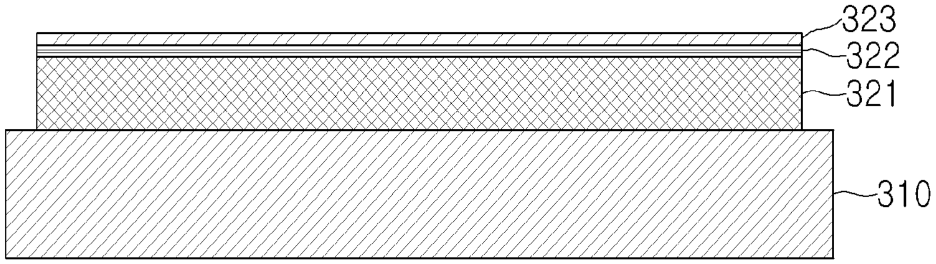


FIG. 10B

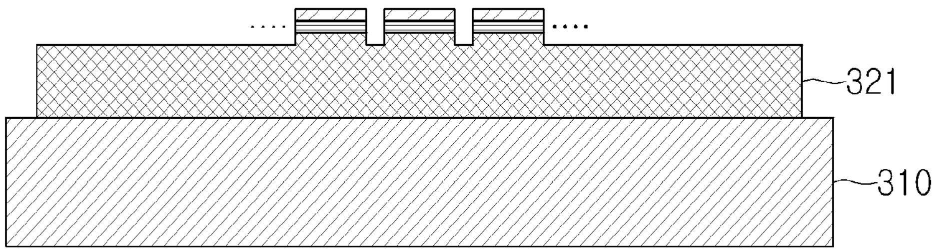


FIG. 10C

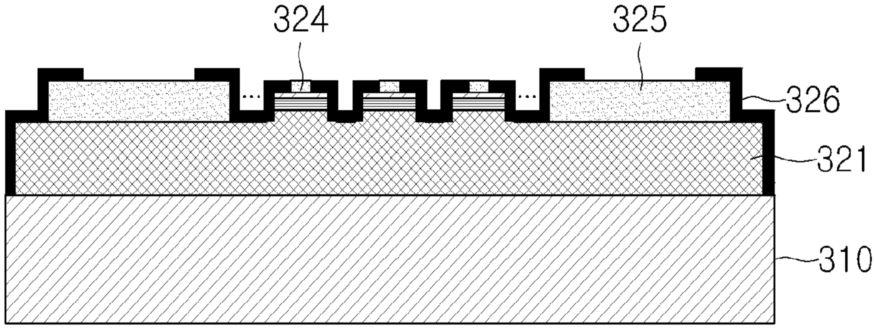


FIG. 10D

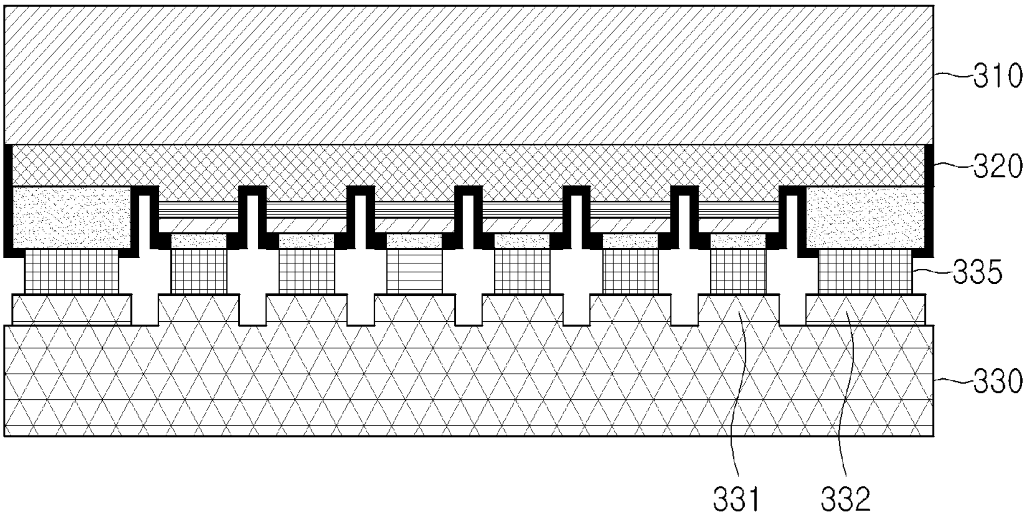


FIG. 10E

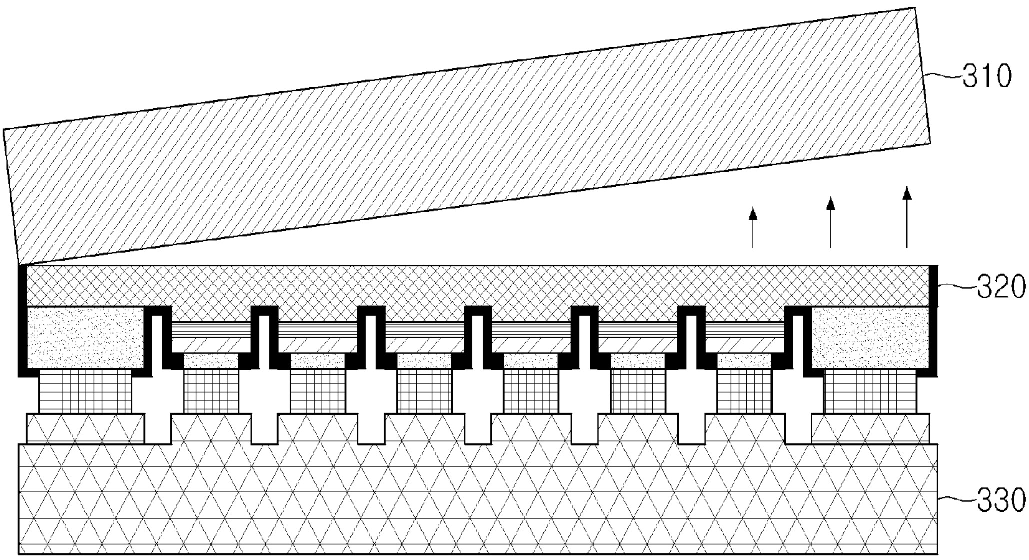


FIG. 10F

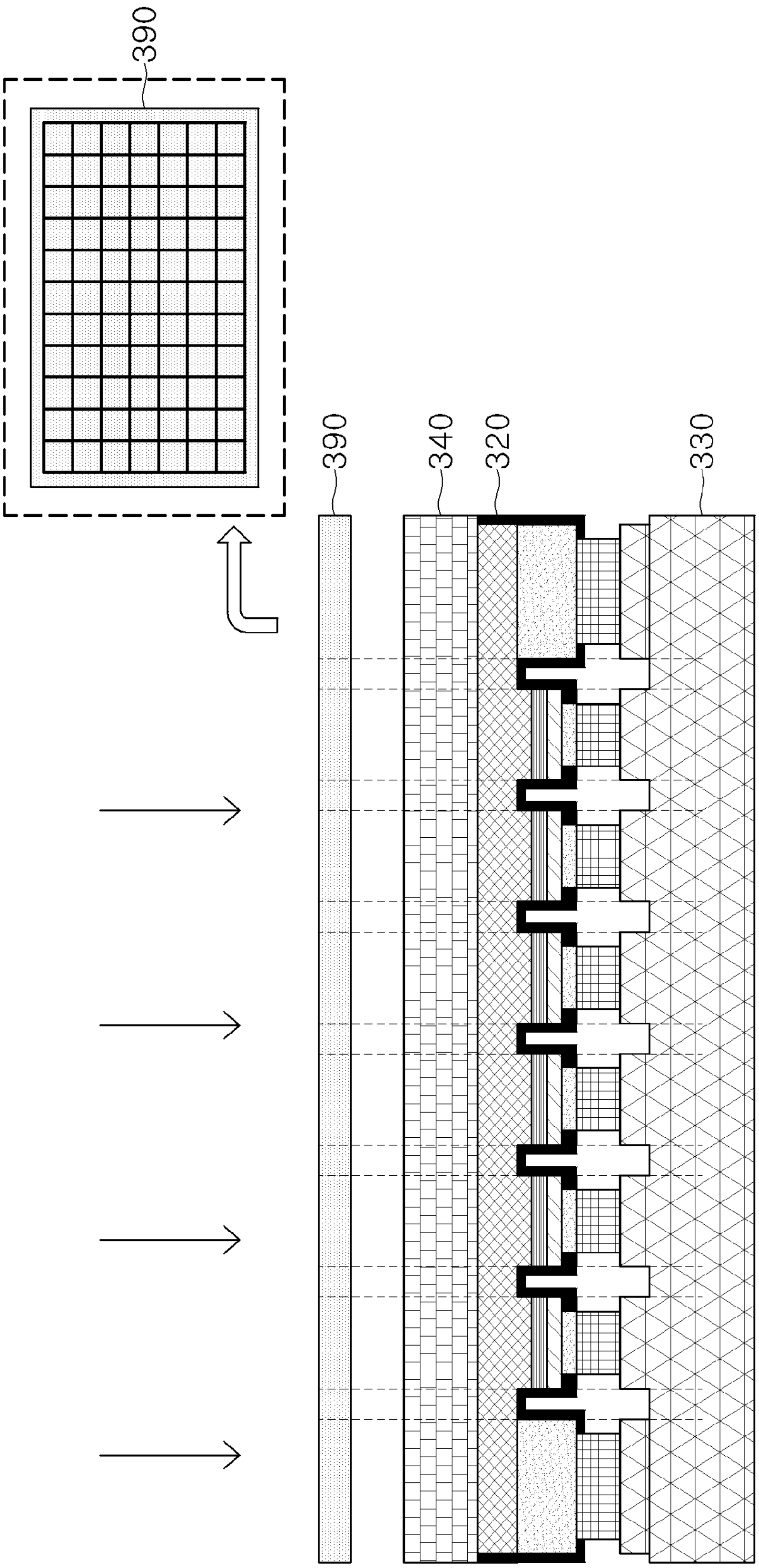


FIG. 10G

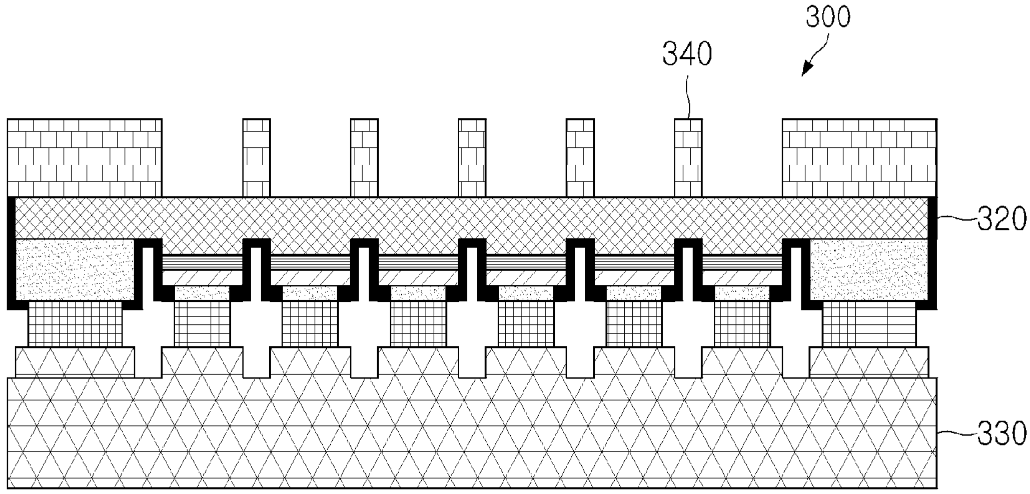
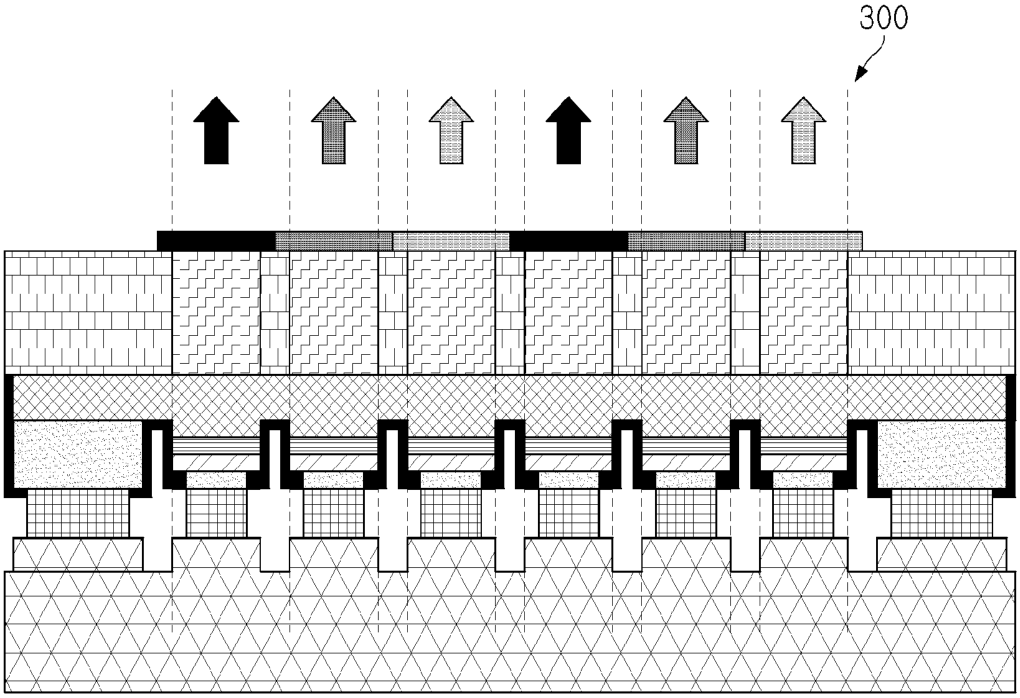


FIG. 10H



MICRO LED DISPLAY DEVICE AND METHOD OF FABRICATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0051892 filed in the Korean Intellectual Property Office on Apr. 21, 2017, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

The present invention relates to a micro light emitting diode (LED) display device and a method of fabricating the same, and more particularly, to a micro LED display device which has a separator structure between micro LED pixels, and a method of fabricating the same.

2. Background of the Disclosure

A light emitting diode (LED) is a sort of semiconductor device which converts electric energy to light energy. The LED has advantages in low power consumption, semi-permanent life, high response speed, safety, and eco friendliness, compared to an existing light source, such as fluorescent light and incandescent light.

In this respect, a lot of research on replacement of the existing light source with the LED has been conducted, and there increases the case in which the LED is used as a light source of a lighting device, such as various lamps used in indoor and outdoor places, a liquid crystal display device, an electronic display, and a streetlamp.

Recently, an LED industry makes a new attempt to be applied to various industries beyond an existing traditional lighting range, and particularly, research is actively conducted in a low power driven flexible display field, an attachment-type information display device field for monitoring a human body, a vital reaction and deoxyribonucleic acid (DNA) sensing field, a bio convergence field for verifying effectiveness of optogenetics, and a photonics textile field in which a conductive fiber is combined with an LED light source.

In general, when an LED chip is fabricated in a size of several to several tens of micros which is small, it is possible to overcome a disadvantage in that the LED chip is broken when an inorganic material is bent according to a characteristic of the inorganic material, and it is possible to broadly apply the LED chip to various application fields up to a wearable device and a medical device for body insertion, as well as the foregoing flexible display, by giving flexibility by transferring the LED chip to a flexible substrate. However, when the LED light source is applied to the foregoing application fields, it is necessary to develop a light source which is thin and flexible, and has a size in a micro level, and in order to give flexibility to the LED, there is a demand for a process of transferring a separated thin film GaN layer to a flexible substrate in an individual or desired arrangement.

According to the research and development on the micro LED technology field, there currently exists a micro LED panel fabricating technology which is capable of implementing one color (that is, red, green, and blue), but a micro LED panel fabricating technology which is capable of implementing a full color has not been reported in the academic world or the industrial world as yet. Accordingly, it is necessary to develop a micro LED panel which is capable of implementing a full color.

SUMMARY OF THE DISCLOSURE

An object of the present invention is to solve the foregoing problems and other problems. Another object of the present invention is to provide a micro light emitting diode (LED) display device having a structure in which a plurality of separators is repeatedly formed on a growth substrate corresponding to locations between micro LED pixels, and a method of fabricating the same.

Another object of the present invention is to provide a micro light emitting diode (LED) display device having a structure in which a plurality of separators is repeatedly formed on a first conductive semiconductor layer corresponding to locations between micro LED pixels, and a method of fabricating the same.

Another object of the present invention is to provide a micro light emitting diode (LED) display device which is capable of implementing a full color by injecting an R/G/B color light changing material between separators, and a method of fabricating the same.

Another object of the present invention is to provide a micro light emitting diode (LED) display device which is capable of implementing a full color by injecting a fluorescent substance for emitting a white color between separators and disposing a color filter on the fluorescent substance, and a method of fabricating the same.

An exemplary embodiment of the present invention provides a micro light emitting diode (LED) display device, including: a micro LED driving substrate (backplane) in which a plurality of CMOS cells is arranged in rows and columns; and a micro LED panel which is flip-chip bonded onto the micro LED driving substrate, and includes a plurality of micro LED pixels electrically connected with the plurality of CMOS cells, in which the micro LED panel includes the plurality of micro LED pixels formed by etching a first surface of an emission structure along a unit pixel region, and a plurality of separators formed on a second surface of the emission structure corresponding to positions of (dent) portions formed by etching the emission structure in a vertical direction.

Another exemplary embodiment of the present invention provides a method of fabricating a micro light emitting diode (LED) display device, the method including: fabricating a micro LED driving substrate (backplane) in which a plurality of CMOS cells is arranged in rows and columns; fabricating a micro LED panel including a plurality of micro LED pixels formed by etching a first surface of an emission structure along a unit pixel region, and corresponding to the plurality of CMOS cells; disposing a plurality of bumps on the micro LED driving substrate, and flip-chip bonding the micro LED panel on the micro LED driving substrate on which the plurality of bumps is disposed; coating a second surface of the emission structure with a photo resist, disposing mask patterns on the photo resist, and performing an exposure process of emitting light; and forming a plurality of separators on the second surface of the emission structure by performing a developing process on the photo resist which passes through the exposure process.

The effects of the micro LED display device and the method of fabricating the same according to the exemplary embodiments of the present invention will be described below.

According to at least one of the exemplary embodiments of the present invention, the plurality of separators is periodically disposed on the growth substrate corresponding to the locations between the pixels, thereby effectively removing color interference between the pixels and easily applying the R/G/B color light changing materials onto the growth substrate.

According to at least one of the exemplary embodiments of the present invention, the plurality of separators is periodically disposed on the emission structure corresponding to the locations between the pixels, thereby effectively removing color interference between the pixels, minimizing light scattering due to the growth substrate, and easily applying the R/G/B color light changing materials onto the emission structure.

According to at least one of the exemplary embodiments of the present invention, the plurality of separators is periodically disposed on the emission structure corresponding to locations between the pixels, thereby effectively removing color interference between the pixels, minimizing light scattering due to the growth substrate, and easily applying the white light emitting fluorescent substance onto the emission structure.

However, the effects achieved by the micro LED display device and the method of fabricating the same according to the exemplary embodiments of the present invention are not limited to the foregoing matters, and non-mentioned other effects may be clearly appreciated to those skilled in the art on the basis of the descriptions below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view illustrating a micro LED display device according to a first exemplary embodiment of the present invention.

FIG. **2** is a diagram referred for illustrating the number of pixels and a size of a micro LED panel.

FIG. **3** is a diagram illustrating an operation of driving a micro LED panel through a CMOS backplane.

FIG. **4** is a diagram referred for describing a relationship between a size of a quantum dot and a luminous color.

FIGS. **5**A to **5**G are diagrams illustrating a method of fabricating the micro LED display device according to the first exemplary embodiment of the present invention.

FIG. **6** is a cross-sectional view illustrating a micro LED display device according to a second exemplary embodiment of the present invention.

FIGS. **7**A to **7**H are diagrams illustrating a method of fabricating the micro LED display device according to the second exemplary embodiment of the present invention.

FIG. **8** is a cross-sectional view illustrating a micro LED display device according to a third exemplary embodiment of the present invention.

FIG. **9** is a diagram illustrating an example of a structure of a color filter related to the present invention.

FIGS. **10**A to **10**H are diagrams illustrating a method of fabricating the micro LED display device according to the third exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, exemplary embodiments disclosed in the present specification will be described in detail with reference to the accompanying drawings, and the same or similar constituent elements are denoted by the same reference numerals regardless of a sign of the drawing, and repeated description thereof will be omitted. Hereinafter, in the description of the exemplary embodiments of the present invention, a case where each layer (film), a region, a pattern, or structures are formed "on" or "under" a substrate, each layer (film), a region, a pad, or patterns includes all of the cases in which each layer (film), the region, the pattern, or the structures are directly formed "on" or "under" the substrate, each layer (film), the region, the pad, or the patterns, or intervening constituent elements are present. Further, a reference of "on" or "under" each layer is described with reference to the drawings. In the drawings, for convenience and clearness of description, a thickness or a size of each layer is exaggerated, omitted, or schematically illustrated. Further, a size of each constituent element does not totally reflect an actual size.

In describing the exemplary embodiments disclosed in the present specification, a detailed explanation of known related technology may be omitted so as to avoid unnecessarily obscuring the subject matter of the exemplary embodiments disclosed in the present specification. Further, the accompanying drawings are provided for helping easy understanding of the exemplary embodiments disclosed in the present specification, and the technical spirit disclosed in the present specification is not limited by the accompanying drawings, and it will be appreciated that the present invention includes all of the modifications, equivalent matters, and substitutes included in the spirit and the technical scope of the present invention.

The present invention proposes a micro light emitting diode (LED) display device which includes a separator structure formed on a growth substrate or an emission structure corresponding to locations between pixels to implement a full color, and a method of fabricating the same. Hereinafter, in the present exemplary embodiment, the micro LED display device may be formed by flip-chip bonding a micro LED panel including a plurality of micro LED pixels and a CMOS backplane including a plurality of CMOS cells for independently driving the plurality of micro LED pixels through bumps.

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

First Exemplary Embodiment

FIG. **1** is a cross-sectional view illustrating a micro LED display device according to a first exemplary embodiment of the present invention.

Referring to FIG. **1**, the micro LED display device **100** according to the first exemplary embodiment of the present invention may include a micro LED driving substrate (or a CMOS backplane) **130**, a micro LED panel, and a plurality of bumps **135**.

The micro LED panel is an LED panel including an array structure in which a plurality of micro LED pixels stacked on a wafer is arranged in a matrix form, and may serve to output R/G/B light corresponding to image signals of an image display device. In this case, the plurality of micro LED pixels may be formed by any one of a blue LED, a green LED, a red LED, and a UV LED, but is not limited thereto.

For example, as illustrated in FIG. **2**, the micro LED panel may include micro LED pixels arranged in a plurality of rows **720** and a plurality of columns **1280**. Further, each of the plurality of micro LED pixels configuring the micro LED panel may be formed in a size of 8 μm×8 μm. However, the micro LED display device **100** may be fabricated by changing the number of pixels and a pixel size of the micro

LED panel and the like according to a usage and the kind of an image display device, which is apparent to those skilled in the art.

The micro LED panel may include an emission structure (or the plurality of micro LED pixels **120**), a growth substrate **110** on the emission structure **120**, a plurality of separators **140** on the growth substrate **110**, R/G/B color light changing materials **150**, **160**, and **170** positioned between the separators, and the like.

The emission structure **120** may include a first conductive semiconductor layer, an active layer under the first conductive semiconductor layer, a second conductive semiconductor layer under the active layer, a second conductive metal layer under the second conductive semiconductor layer, and a first conductive metal layer under the first conductive semiconductor layer, and a passivation layer. The emission structure **120** may emit light of different wavelengths according to a composition ratio of a compound semiconductor.

The first conductive semiconductor layer may include a compound semiconductor of III-V group elements in which an n-type dopant is doped. The first conductive semiconductor layer may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, AlInN, InGaN, AlN, and InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and an n-type dopant, such as Si, Ge, and Sn, may be doped.

The active layer is a layer in which electrons (or holes) injected through the first conductive semiconductor layer and holes (or electrons) injected through the second conductive semiconductor layer meet to emit light by a difference in a band gap of an energy band according to a forming material of the active layer. The active layer may be formed in any one of a single quantum well structure, a multi-quantum well (MQW) structure, a quantum dot structure, or a quantum wire structure, but is not limited thereto. The active layer may be formed of a semiconductor material having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). When the active layer is formed in the MQW structure, the active layer may be formed by alternately stacking a plurality of well layers and a plurality of barrier layers.

The second conductive semiconductor layer may include a compound semiconductor of III-V group elements in which a p-type dopant is doped. The second conductive semiconductor layer may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, InGaN, AlInN, AlN, InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and a p-type dopant, such as Mg, Zn, Ca, Sr, and Ba, may be doped.

The second conductive metal layer (that is, a p electrode) may be formed on the second conductive semiconductor layer, and the first conductive metal layer (that is, an n electrode) may be formed on the first conductive semiconductor layer. The first and second conductive metal layers provide power to the plurality of micro LED pixels formed in the micro LED panel.

The second conductive metal layer may be disposed on the second conductive semiconductor layer corresponding to each of the micro LED pixels, and may be electrically connected with each CMOS cell **131** provided in a micro LED driving substrate **130** through a bump **135**, respectively. In the meantime, as another exemplary embodiment, when a reflective layer (not illustrated), such as a distributed Bragg reflector (DBR) is present on the second conductive semiconductor layer, the second conductive metal layer may be disposed on the reflective layer.

The first conductive metal layer may be formed on a mesa-etched region of the first conductive semiconductor layer, and may be formed while being spaced apart from the plurality of micro LED pixels by a predetermined distance. The first conductive metal layer may be formed on the first conductive semiconductor layer so as to have a predetermined width along an outer region of the micro LED panel. A height of the first conductive metal layer may be formed to be substantially the same as a height of the plurality of micro LED pixels. The first conductive metal layer is electrically connected with a common cell **132** of the micro LED driving substrate **130** by the bump **135** to serve as a common electrode of the micro LED pixels. For example, the first conductive metal layer may be a common ground.

The passivation layer may be formed on at least one lateral surface of the first conductive semiconductor layer, the active layer, the second conductive semiconductor layer, and the first and second conductive metal layers. The passivation layer may be formed to electrically protect the first conductive semiconductor layer, the active layer, and the second conductive semiconductor layer, and may be formed of, for example, SiO_2, SiO_x, Si_xN_y, Si_3N_4, Al_2O_3, but is not limited thereto.

The growth substrate **110** may be formed of at least one of materials having transparency, for example, sapphire (Al_2O_3), a single crystal substrate, SiC, GaAs, GaN, ZnO, AlN, Si, GaP, InP, and Ge, but is not limited thereto.

The plurality of separators (or partitions or barrier ribs) **140** may be formed on a flat surface, on which the emission structure **120** is not stacked, between two surfaces of the growth substrate **110**. The plurality of separators **140** may be disposed on the growth substrate **110** corresponding to locations (that is, regions in which the active layer and the second conductive semiconductor layer are etched) between pixels to minimize color mixing between the pixels. The plurality of separators **140** may be fabricated by a photolithography process. Accordingly, the plurality of separators **140** may be formed of a photo resist (PR). The PR refers to a material which is selectively removing a portion which receives light and a portion which does not receive light during a subsequent development processing process by using a characteristic in which the PR receives light at a specific wavelength, so that solubility of the PR in a developer is changed. As the PR, a polymer compound may be used, but the PR is not limited thereto. In the meantime, as another exemplary embodiment, the plurality of separators **140** may also be formed of a ceramic material, not the polymer compound. In this case, the wet or dry etching process may be added to the photolithography process.

Heights of the separators **140** may be formed to be almost the same, and a gap between the separators **140** may be formed to be the same as a size of the pixel.

The R/G/B color light changing materials (or the R/G/B fluorescent substances) **150**, **160**, and **170** may be disposed between the separators to change wavelengths of light emitted from the LEDs (that is, the pixels), respectively. The R/G/B color light changing materials **150**, **160**, and **170** used in the micro LED panel **100** may be changed according to the kind of wavelength emitted by the LED.

As the red emitting fluorescent substance **150**, GaAlAs, (Y, Gd)BO_3:Eu^{3+}, Y_2O_2:Eu, and the like may be used, but the red emitting fluorescent substance **150** is not limited thereto. As the green emitting fluorescent substance **160**, GaP:N, Zn_2SiO_4:Mn, ZnS:Cu, Al, and the like may be used, but the green emitting fluorescent substance **160** is not limited thereto. As the blue emitting fluorescent substance

170, GaN, $BaMgAl_{14}O_{23}:Eu^{2+}$, ZnS:Ag, and the like may be used, but the blue emitting fluorescent substance **170** is not limited thereto.

As the R/G/B color light changing materials **150**, **160**, and **170**, a quantum dot may be used. The quantum dot is a semiconductor nano particle of which a diameter has a size of several nanometers (nm), and has a quantum mechanics characteristic, such as a quantum confinement effect. Herein, the quantum confinement effect means a phenomenon in which as a size of a semiconductor nano particle is decreased, a band gap energy is increased (inversely, a wavelength is decreased). The quantum dot fabricated by a chemical synthesis process may implement a desired color only by adjusting a particle size without changing a material thereof. For example, as illustrated in FIG. **4**, according to the quantum confinement effect, as a size of a nano particle is small, a quantum dot may emit blue light having a short wavelength, and as a size of a nano particle is large, a quantum dot may emit red light having a long wavelength.

The quantum dot may be a II-VI, III-V, or IV group material, and particularly, may be CdSe, CdTe, CdS, ZnSe, ZnTe, ZnS, InP, GaP, $GaInP_2$, PbS, ZnO, TiO_2, AgI, AgBr, Hg_{12}, PbSe, In_2S_3, In_2Se_3, Cd_3P_2, Cd_3As_2, or GaAs. Further, the quantum dot may have a core-shell structure. Herein, a core may include any one material selected from the group consisting of CdSe, CdTe, CdS, ZnSe, ZnTe, ZnS, HgTe, and HgS, and a shell may include any one material selected from the group consisting of CdSe, CdTe, CdS, ZnSe, ZnTe, ZnS, HgTe, and HgS.

The micro LED driving substrate **130** may be disposed so as to face the micro LED panel, and may serve to drive the plurality of micro LED pixels provided in the micro LED panel in response to an input image signal.

The micro LED driving substrate **130** may include an active matrix circuit unit including the plurality of CMOS cells **131** for individually driving the plurality of micro LED pixels, and a common cell **132** disposed in an outer region of the active matrix circuit unit. Examples of the micro LED driving substrate **130** may include a silicon (Si) substrate or a PCB substrate, but the micro LED driving substrate **130** is not limited thereto.

Each of the plurality of CMOs cells **131** provided in the active matrix circuit unit is electrically connected to the corresponding micro LED pixel through the bump **135**. Each of the plurality of CMOs cells **131** is an integrated circuit (IC) for individually driving the corresponding micro LED pixel. Accordingly, each of the plurality of CMOS cells **131** may be a pixel driving circuit including two transistors and one capacitor, and when the micro LED panel is flip-chip bonded to the micro LED driving substrate **130** by using the bumps **135**, each of the plurality of CMOS cells **131** may be configured in a form in which the individual micro LED pixel is disposed between a drain terminal and a common ground terminal of the transistor of the pixel driving circuit according to the equivalent circuit.

The common cell **132** disposed in the outer region of the active matrix circuit unit may include a data driver IC and a scan driver IC. For example, as illustrated in FIG. **3**, the plurality of micro LED pixels (not illustrated) configuring the micro LED panel may be positioned at crossing points of a plurality of scanning lines **325** and a plurality of data lines **315**. The plurality of scanning lines **325** input to the plurality of micro LED pixels are controlled by the scan driver IC **320**, and the plurality of data lines **315** input to the plurality of micro LED pixels are controlled by the data driver IC **310**.

A control operation of the micro LED panel through the micro LED driving substrate **130** will be simply described. The scan driver IC **320** turns on the pixel by inputting a high (H) signal to any one or more of the plurality of scanning lines **325** while scanning all of the plurality of scanning lines **325** when providing image data. In the meantime, when the data driver IC **310** provides image data to the plurality of data lines **315**, the pixels which are in a turn-on state in the scanning lines allow the image data to pass through and the corresponding image data is displayed through the micro LED panel. By this manner, a display for one frame is completed while all of the scanning lines are sequentially scanned.

As described above, in the micro LED display device according to the first exemplary embodiment of the present invention, the plurality of separators is periodically disposed on the growth substrate corresponding to the locations between the pixels, thereby effectively removing color interference between the pixels and easily applying the R/G/B color light changing materials onto the growth substrate.

FIGS. **5**A to **5**G are diagrams illustrating a method of fabricating the micro LED display device according to the first exemplary embodiment of the present invention.

Referring to FIG. **5**A, the emission structure **120** may be formed by sequentially growing the first conductive semiconductor layer **121**, the active layer **122**, and the second conductive semiconductor layer **123** on the growth substrate **110**.

The growth substrate **110** may be formed of at least one of materials having transparency, for example, sapphire (Al_2O_3), a single crystal substrate, SiC, GaAs, GaN, ZnO, AlN, Si, GaP, InP, and Ge, but is not limited thereto.

The first conductive semiconductor layer **121** may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, AlInN, InGaN, AlN, and InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and an n-type dopant, such as Si, Ge, and Sn, may be doped. The first conductive semiconductor layer **121** may be formed by injecting trimethyl gallium (TMGa) gas, ammonia (NH_3) gas, and xylene (SiH_4) gas to a chamber together with hydrogen gas. An undoped semiconductor layer (not illustrated) and/or a buffer layer (not illustrated) may be further included between the growth substrate **110** and the first conductive semiconductor layer **121**, but the present invention is not limited thereto.

The active layer **122** may be formed of a semiconductor material having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). The active layer **122** may be formed by injecting trimethyl gallium (TMGa) gas, trimethyl indium (TMIn) gas, and ammonia (NH_3) gas to a chamber together with hydrogen gas.

The second conductive semiconductor layer **123** may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, InGaN, AlInN, AlN, InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and a p-type dopant, such as Mg, Zn, Ca, Sr, and Ba, may be doped. The second conductive semiconductor layer **123** may be formed by injecting trimethyl gallium (TMGa) gas, ammonia (NH_3) gas, and biacetyl cyclopentadienyl magnesium ($EtCp_2Mg$)$\{Mg(C_2H_5C_5H_4)_2\}$ gas to a chamber together with hydrogen gas.

Referring to FIG. **5**B, a plurality of LEDs (that is, the plurality of micro LED pixels) may be formed by performing isolation etching on the emission structure **120** according to a unit pixel region. For example, the isolation etching may be performed by a dry etching method, such as inductively coupled plasma (ICP). One upper surface of the first conductive semiconductor layer **121** is exposed through the isolation etching. In this case, in order to form the common electrode (that is, the n electrode) **125**, the emission structure **120** may be etched so as that a border region of the first conductive semiconductor layer **121** has a predetermined width.

Referring to FIG. **5**C, the second conductive metal layer **124** may be formed on one upper surface of the second conductive semiconductor layer **123**, and the first conductive metal layer **125** may be formed on one upper surface of the mesa etched first conductive semiconductor layer **121**. In this case, the first and second conductive metal layers **125** and **124** may be formed by a deposition process or a plating process, but are not limited thereto.

Then, a passivation layer **126** may be formed on the growth substrate **110**, the compound semiconductor layers **121**, **122**, and **123**, the first conductive metal layer **125**, and the second conductive metal layer **124**, and the passivation layer **126** may be selectively removed so that one upper surface of each of the first and second conductive metal layers **125** and **124** is exposed to the outside.

Referring to FIG. **5**D, the plurality of bumps **135** is disposed on the CMOS cells **131** and the common cell **132** of the micro LED driving substrate **130**. The first and second conductive metal layers **125** and **124** are made to head downwardly by inversing up and down the micro LED panel. The CMOS cells **131** are in contact with the micro LED pixels by making the micro LED driving substrate **130** in the state in which the plurality of bumps **135** is disposed face the micro LED panel and corresponding one-to-one the CMOS cells **131** and the micro LED pixels, and then the CMOS cells **131** and the micro LED pixels are heated. Then, the plurality of bumps **135** is melted, and as a result, the CMOS cells **131** and the corresponding micro LED pixels are electrically connected, and the common cell **132** of the micro LED driving substrate **130** and the common electrode **125** of the micro LED panel corresponding to the common cell **132** are electrically connected.

Referring to FIG. **5**E, the PR **140** may be coated on the growth substrate **110** by using a spin coating method. In the meantime, as another exemplary embodiment, bonding force between the growth substrate **110** and the PR **140** may be improved by chemically processing (for example, hexamethyldisilazane processing) the surface of the growth substrate **110** before the coating process.

Then, mask patterns **180** may be precisely arranged on the PR **140**, and then an exposure process of emitting ultraviolet rays and the like may be performed. In this case, the mask patterns **180** may be arranged in a matrix form, and an interval between the mask patterns **180** may correspond to a distance between the pixels.

Referring to FIG. **5**F, the plurality of separators **140** may be formed on the growth substrate **110** by performing a developing process on the PR **140** which passes the exposure process. In this case, the plurality of separators **140** may be disposed on the growth substrate **110** corresponding to the locations between the pixels (that is, the regions in which the active layer and the second conductive semiconductor layer are etched). In the developing process, as a developer for the PR **140**, a water-soluble alkali solution may be used.

In the meantime, in the present exemplary embodiment, the case where the plurality of separators is formed through the PR is exemplified, but the present invention is not limited thereto. For example, as another exemplary embodiment, the plurality of separators may also be formed on the growth substrate by forming a material for forming the separator on the growth substrate, stacking the PR on the material, sequentially performing exposure and developing processes by using a mask pattern, and wet or dry etching a region exposed by the PR.

Referring to FIG. **5**G, the R fluorescent substance **150** may be injected between a first separator and a second separator formed on the growth substrate **110**, the G fluorescent substance **160** may be injected between the second separator and a third separator formed on the growth substrate **110**, and the B fluorescent substance **170** may be injected between the third separator and a fourth separator formed on the growth substrate **110**. Accordingly, the pixel in which the R fluorescent substance **150** is present between the separators may emit red light, the pixel in which the G fluorescent substance **160** is present between the separators may emit green light, and the pixel in which the B fluorescent substance **170** is present between the separators may emit blue light.

The micro LED display device **100** formed through the foregoing processes may implement a full color of high resolution (an HD level). The micro LED display device **100** may be applied to various display devices, such as a head-up display (HUD) for a vehicle and a head mounted display (HMD).

Second Exemplary Embodiment

FIG. **6** is a cross-sectional view illustrating a micro LED display device according to a second exemplary embodiment of the present invention. Unlike the micro LED display device **100** of FIG. **1**, the exemplary embodiment of the present invention may provide a micro LED display device which is capable of minimizing light scattering by removing a growth substrate. Herein, in the present exemplary embodiment, a micro LED driving substrate **230**, an emission structure **220**, a plurality of separators **240**, and R/G/B color light changing materials **250**, **260**, and **270** are the same as the micro LED driving substrate **130**, the emission structure **120**, the plurality of separators **140**, and the R/G/B color light changing materials **150**, **160**, and **170** of FIG. **1**, so that detailed descriptions thereof will be omitted.

Referring to FIG. **6**, the micro LED display device **200** according to the second exemplary embodiment of the present invention may include the micro LED driving substrate **230**, a micro LED panel, and a plurality of bumps **235**.

The micro LED panel is an LED panel including an array structure in which a plurality of micro LED pixels stacked on a wafer is arranged in a matrix form, and may serve to output R/G/B light corresponding to image signals of an image display device. In this case, the plurality of micro LED pixels may be formed by any one of a blue LED, a green LED, a red LED, and a UV LED, but is not limited thereto.

The micro LED panel may include the emission structure (or the plurality of micro LED pixels) **220**, the plurality of separators **240** on the emission structure **220**, and the R/G/B color light changing materials **250**, **260**, and **270** positioned between the separators, and the like.

The emission structure **220** may include a first conductive semiconductor layer, an active layer, a second conductive semiconductor layer, a first conductive metal layer, a second conductive metal layer, and a passivation layer. The emission structure **220** may emit light of different wavelengths according to a composition ratio of a compound semiconductor.

The second conductive metal layer (that is, a p electrode) may be formed on the second conductive semiconductor layer of the emission structure **220**, and the first conductive metal layer (that is, an n electrode) may be formed on the first conductive semiconductor layer. A passivation layer may be formed on at least one lateral surface of the first conductive semiconductor layer, the active layer, the second conductive semiconductor layer, and the first and second conductive metal layers. The passivation layer may be formed to electrically protect the first conductive semiconductor layer, the active layer, and the second conductive semiconductor layer, and may be formed of, for example, SiO_2, SiO_x, SiO_xN_y, Si_3N_4, Al_2O_3, but is not limited thereto.

The plurality of separators **240** may be formed on a flat surface which is not etched between two surfaces of the emission structure **220**. The plurality of separators **240** may be disposed on the emission structure **220** corresponding to locations (that is, the regions in which the active layer and the second conductive semiconductor layer are etched) between the pixels to serve to minimize color mixing between the pixels. The plurality of separators **240** may be fabricated by a photolithography process.

Heights of the separators **240** may be formed to be almost the same, and a gap between the separators **240** may be formed to be the same as a size of the pixel.

The R/G/B color light changing materials (or the R/G/B fluorescent substances) **250**, **260**, and **270** may be disposed between the separators to change wavelengths of light emitted from the LEDs (that is, the pixels), respectively. As the red emitting fluorescent substance **250**, GaAlAs, (Y, Gd)BO_3:Eu^{3+}, Y_2O_2:Eu, a quantum dot, and the like may be used, but the red emitting fluorescent substance **250** is not limited thereto. As the green emitting fluorescent substance **260**, GaP:N, Zn_2SiO_4:Mn, ZnS:Cu, Al, a quantum dot, and the like may be used, but the green emitting fluorescent substance **260** is not limited thereto. As the blue emitting fluorescent substance **270**, GaN, $BaMgAl_{14}O_{23}$:Eu^{2+}, ZnS:Ag, a quantum dot, and the like may be used, but the blue emitting fluorescent substance **270** is not limited thereto.

The micro LED driving substrate **230** may be disposed so as to face the micro LED panel, and may serve to drive the plurality of micro LED pixels provided in the micro LED panel in response to an input image signal. The micro LED driving substrate **230** may include an active matrix circuit unit including a plurality of CMOS cells **231** for individually driving the plurality of micro LED pixels, and a common cell **232** disposed in an outer region of the active matrix circuit unit.

As described above, in the micro LED display device according to the second exemplary embodiment of the present invention, the plurality of separators is periodically disposed on the emission structure corresponding to the locations between the pixels, thereby effectively removing color interference between the pixels, minimizing light scattering due to the growth substrate, and easily applying the R/G/B color light changing materials onto the emission structure.

FIGS. **7**A to **7**G are diagrams illustrating a method of fabricating the micro LED display device according to the second exemplary embodiment of the present invention.

Referring to FIG. **7**A, the emission structure **220** may be formed by sequentially growing a first conductive semiconductor layer **221**, an active layer **222**, and a second conductive semiconductor layer **223** on a growth substrate **210**.

The growth substrate **210** may be formed of at least one of the materials having transparency, for example, sapphire (Al_2O_3), a single crystal substrate, SiC, GaAs, GaN, ZnO, AlN, Si, GaP, InP, and Ge, but is not limited thereto.

The first conductive semiconductor layer **221** may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, AlInN, InGaN, AlN, and InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and an n-type dopant, such as Si, Ge, and Sn, may be doped. The first conductive semiconductor layer **221** may be formed by injecting trimethyl gallium (TMGa) gas, ammonia (NH_3) gas, and xylene (SiH_4) gas to a chamber together with hydrogen gas.

The active layer **222** may be formed of a semiconductor material having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). The active layer **222** may be formed by injecting trimethyl gallium (TMGa) gas, trimethyl indium (TMIn) gas, and ammonia (NH_3) gas to a chamber together with hydrogen gas.

The second conductive semiconductor layer **223** may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, InGaN, AlInN, AlN, InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and a p-type dopant, such as Mg, Zn, Ca, Sr, and Ba, may be doped. The second conductive semiconductor layer **223** may be formed by injecting trimethyl gallium (TMGa) gas, ammonia (NH_3) gas, and biacetyl cyclopentadienyl magnesium ($EtCp_2Mg$){$Mg(C_2H_5C_5H_4)_2$} gas to a chamber together with hydrogen gas.

Referring to FIG. **7**B, a plurality of LEDs (that is, the plurality of micro LED pixels) may be formed by performing isolation etching on the emission structure **220** according to a unit pixel region. For example, the isolation etching may be performed by a dry etching method, such as inductively coupled plasma (ICP). One upper surface of the first conductive semiconductor layer **221** is exposed through the isolation etching. Referring to FIG. **7**C, the second conductive metal layer **224** may be formed on one upper surface of the second conductive semiconductor layer **223**, and the first conductive metal layer **225** may be formed on one upper surface of the mesa-etched first conductive semiconductor layer **221**. In this case, the first and second conductive metal layers **225** and **224** may be formed by a deposition process or a plating process, but are not limited thereto.

Then, a passivation layer **226** may be formed on the growth substrate **210**, the compound semiconductor layers **221**, **222**, and **223**, the first conductive metal layer **225**, and the second conductive metal layer **224**, and the passivation layer **226** may be selectively removed so that one upper surface of each of the first and second conductive metal layers **225** and **224** is exposed to the outside.

Referring to FIG. **7**D, the plurality of bumps **235** is disposed on the CMOS cells **231** and the common cell **232** of the micro LED driving substrate **230**. The first and second conductive metal layers **225** and **224** are made to head downwardly by inversing up and down the micro LED panel. The CMOS cells **231** are in contact with the micro LED pixels by making the micro LED driving substrate **230** in the state in which the plurality of bumps **235** is disposed face the micro LED panel and corresponding one-to-one the CMOS cells **231** and the micro LED pixels, and then the CMOS cells **231** and the micro LED pixels are heated. Then, the plurality of bumps **235** is melted, and as a result, the CMOS cells **231** and the corresponding micro LED pixels are electrically connected, and the common cell **232** of the micro LED driving substrate **230** and the common electrode **225** of the micro LED panel corresponding to the common cell **232** are electrically connected.

Referring to FIG. **7**E, the growth substrate **210** attached to the emission structure **220** may be separated by a laser lift off (LLO) method, a chemical lift off (CLO) method, an electrical lift off (ELO), an etching method, or the like. As another exemplary embodiment, the growth substrate **210** attached to the emission structure **220** may be ground to be flat and at least a part of the growth substrate **210** may be removed.

Referring to FIG. **7**F, an upper portion of the emission structure **220** may be coated with a photo resist (PR) **240** by using a spin coating method. In the meantime, as another exemplary embodiment, bonding force between the emission structure **220** and the PR **240** may be improved by chemically processing (for example, hexamethyldisilazane processing) the surface of the emission structure **220** before the coating process. Further, a passivation layer (not illustrated) for protecting the emission structure **220** may be formed between the emission structure **220** and the PR **240** before the coating process. Then, mask patterns **280** may be precisely arranged on the PR **240** and then an exposure process of emitting ultraviolet rays and the like may be performed.

Referring to FIG. **7**G, the plurality of separators **240** may be formed on the emission structure **220** by performing a developing process on the PR **240** which passes the exposure process. In this case, the plurality of separators **240** may be disposed on the emission structure **220** corresponding to the locations between the pixels (that is, the regions in which the active layer and the second conductive semiconductor layer are etched).

In the meantime, in the present exemplary embodiment, the case where the plurality of separators is formed through the PR is exemplified, but the present invention is not limited thereto. For example, as another exemplary embodiment, the plurality of separators may also be formed on the growth substrate by forming a material for forming the separator on the growth substrate, stacking the PR on the material, sequentially performing exposure and developing processes by using a mask pattern, and wet or dry etching a region exposed by the PR.

Referring to FIG. **7**H, the R fluorescent substance **250** may be injected between a first separator and a second separator formed on the emission structure **220**, the G fluorescent substance **260** may be injected between the second separator and a third separator formed on the emission structure **220**, and the B fluorescent substance **270** may be injected between the third separator and a fourth separator formed on the emission structure **220**. Accordingly, the pixel in which the R fluorescent substance **250** is present between the separators may emit red light, the pixel in which the G fluorescent substance **260** is present between the separators may emit green light, and the pixel in which the B fluorescent substance **270** is present between the separators may emit blue light.

The micro LED display device **200** formed through the foregoing processes may minimize light scattering due to the growth substrate and implement a full color of high resolution (an HD level).

Third Exemplary Embodiment

FIG. **8** is a cross-sectional view illustrating a micro LED display device according to a third exemplary embodiment of the present invention. Unlike the micro LED display device **200** of FIG. **6**, the exemplary embodiment of the present invention may provide a micro LED display device which is capable of implementing a full color by disposing fluorescent substances and color filters between separators. Hereinafter, in the present exemplary embodiment, a micro LED driving substrate **330**, an emission structure **320**, and a plurality of separators **340** are the same as the micro LED driving substrate **230**, the emission structure **220**, and the plurality of separators **240** of FIG. **6**, so that detailed descriptions thereof will be omitted.

Referring to FIG. **8**, the micro LED display device **300** according to the third exemplary embodiment of the present invention may include the micro LED driving substrate **330**, a micro LED panel, and a plurality of bumps **335**.

The micro LED panel is an LED panel including an array structure in which a plurality of micro LED pixels stacked on a wafer is arranged in a matrix form, and may serve to output R/G/B light corresponding to image signals of an image display device. In this case, the plurality of micro LED pixels may be formed by any one of a blue LED, a green LED, a red LED, and a UV LED, but is not limited thereto.

The micro LED panel may include an emission structure (or a plurality of micro LED pixels) **320**, the plurality of separators **340** on the emission structure **320**, a fluorescent substance **350** positioned between the separators, and color filters **360**, **370**, and **380** on the fluorescent substance **350**.

The plurality of separators **340** may be formed on a flat surface which is not etched between two surfaces of the emission structure **320**. The plurality of separators **340** may be disposed on the emission structure **320** corresponding to locations (that is, the regions in which an active layer and a second conductive semiconductor layer are etched) between the pixels to serve to minimize color mixing between the pixels. The plurality of separators **340** may be fabricated by a photolithography process.

Heights of the separators **340** may be formed to be almost the same, and a gap between the separators **340** may be formed to be the same as a size of the pixel.

The fluorescent substance **350** may be disposed between the separators **340** on the emission structure **320** to change a wavelength of light emitted from the plurality of micro LED pixels to a wavelength of white light. For example, when the emission structure **320** is a blue LED, a yellow fluorescent substance (a material based on Y3Al5O12:Ce (YAG:Ce)) may be used as the fluorescent substance. Further, when the emission structure **320** is a blue LED, a fluorescent substance obtained by mixing a green fluorescent substance and a red fluorescent substance may be used as the fluorescent substance. Further, when the emission structure **320** is a UV LED, a fluorescent substance obtained by mixing a blue fluorescent substance, a green fluorescent substance, and a red fluorescent substance may be used as the fluorescent substance.

The color filters **360**, **370**, and **380** may be attached on the fluorescent substance **350** in the unit of a pixel to transmit only light of a specific wavelength in white light emitted from the fluorescent substance **350**. That is, the R filter **360** may transmit only a wavelength of red light in white light emitted from the fluorescent substance **350**, the G filter **370** may transmit only a wavelength of green light in white light emitted from the fluorescent substance **350**, and the B filter **380** may transmit only a wavelength of blue light in white light emitted from the fluorescent substance **350**. Accordingly, the pixel in which the fluorescent substance **350** and the R filter **360** are present between the separators may emit red light, the pixel in which the fluorescent substance **350** and the G filter **370** are present between the separators may emit green light, and the pixel in which the fluorescent substance **350** and the B filter **380** are present between the separators may emit blue light.

As the exemplary embodiment, as illustrated in FIG. **9**, a color filter **900** according to the present invention may include a transparent substrate **910**, a black matrix **920**, color filter layers **930**, **940**, and **950**, an over coat layer **960**, and an ITO layer **970**.

The transparent substrate **910** may be formed of thin glass or plastic. The black matrix **920** is disposed on the transparent substrate **910** to make light be positioned in an optically inactive region of the transparent substrate **910** to protect light from being leaked. The black matrix **920** needs to have low reflectance for an optimum contrast. The black matrix **920** may be formed of an inorganic material or an organic material, and chrome Cr may be used.

The color filter layers **930**, **940**, and **950** may be disposed on the transparent substrate **910** and include R/G/B dyes or pigments. The over coat layer **960** protects the color filter layers **930**, **940**, and **950** from impurities and flattens a surface of the color filter **900**. The over coat layer **960** may be formed of a transparent acryl resin, a polyimide resin, a polyurethane resin, or the like. The ITO layer **970** may be formed on the over coat layer **960**.

The micro LED driving substrate **330** may be disposed so as to face the micro LED panel, and may serve to drive the plurality of micro LED pixels provided in the micro LED panel in response to an input image signal. The micro LED driving substrate **330** may include an active matrix circuit unit including a plurality of CMOS cells **331** for individually driving the plurality of micro LED pixels, and a common cell **332** disposed in an outer region of the active matrix circuit unit.

As described above, in the micro LED display device according to the third exemplary embodiment of the present invention, the plurality of separators is periodically disposed on the emission structure corresponding to the locations between the pixels, thereby effectively removing color interference between the pixels, minimizing light scattering due to the growth substrate, and easily applying the fluorescent substance for emitting white light onto the emission structure.

FIGS. **10**A to **10**G are diagrams illustrating a method of fabricating the micro LED display device according to the third exemplary embodiment of the present invention.

Referring to FIG. **10**A, the emission structure **320** may be formed by sequentially growing a first conductive semiconductor layer **321**, an active layer **322**, and a second conductive semiconductor layer **323** on a growth substrate **310**.

The growth substrate **310** may be formed of at least one of materials having transparency, for example, sapphire (Al_2O_3), a single crystal substrate, SiC, GaAs, GaN, ZnO, AlN, Si, GaP, InP, and Ge, but is not limited thereto.

The first conductive semiconductor layer **321** may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, AlInN, InGaN, AlN, and InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and an n-type dopant, such as Si, Ge, and Sn, may be doped. The first conductive semiconductor layer **321** may be formed by injecting trimethyl gallium (TMGa) gas, ammonia (NH_3) gas, and xylene (SiH_4) gas to a chamber together with hydrogen gas.

The active layer **322** may be formed of a semiconductor material having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). The active layer **322** may be formed by injecting trimethyl gallium (TMGa) gas, trimethyl indium (TMIn) gas, and ammonia (NH_3) gas to a chamber together with hydrogen gas.

The second conductive semiconductor layer **323** may be selected from semiconductor materials, for example, InAlGaN, GaN, AlGaN, InGaN, AlInN, AlN, InN, having an empirical formula of $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$), and a p-type dopant, such as Mg, Zn, Ca, Sr, and Ba, may be doped. The second conductive semiconductor layer **323** may be formed by injecting trimethyl gallium (TMGa) gas, ammonia (NH_3) gas, and biacetyl cyclopentadienyl magnesium ($EtCp_2Mg$){$Mg(C_2H_5C_5H_4)_2$} gas to a chamber together with hydrogen gas.

Referring to FIG. **10**B, a plurality of LEDs (that is, the plurality of micro LED pixels) may be formed by performing isolation etching on the emission structure **320** according to a unit pixel region. For example, the isolation etching may be performed by a dry etching method, such as inductively coupled plasma (ICP). One upper surface of the first conductive semiconductor layer **321** is exposed through the isolation etching.

Referring to FIG. **10**C, the second conductive metal layer **324** may be formed on one upper surface of the second conductive semiconductor layer **323**, and the first conductive metal layer **325** may be formed on one upper surface of the mesa-etched first conductive semiconductor layer **321**. In this case, the first and second conductive metal layers **324** and **325** may be formed by a deposition process or a plating process, but are not limited thereto. Then, a passivation layer **326** may be formed on the growth substrate **310**, the compound semiconductor layers **321**, **322**, and **323**, and the first and second conductive metal layer **325** and **324**, and the passivation layer **326** may be selectively removed so that one upper surface of each of the first and second conductive metal layers **325** and **324** are exposed to the outside.

Referring to FIG. **10**D, a plurality of bumps **335** is disposed on the CMOS cells **331** and the common cell **332** of the micro LED driving substrate **330**. The first and second conductive metal layers **325** and **324** are made to head downwardly by inversing up and down the micro LED panel. The CMOS cells **331** are in contact with the micro LED pixels by making the micro LED driving substrate **330** in the state in which the plurality of bumps **335** is disposed face the micro LED panel and corresponding one-to-one the CMOS cells **331** and the micro LED pixels, and then the CMOS cells **331** and the micro LED pixels are heated. Then, the plurality of bumps **335** is melted, and as a result, the CMOS cells **331** and the corresponding micro LED pixels are electrically connected, and the common cell **332** of the micro LED driving substrate **330** and the common electrode **325** of the micro LED panel corresponding to the common cell **332** are electrically connected.

Referring to FIG. **10**E, the growth substrate **310** attached to the emission structure **320** may be separated by a laser lift off (LLO) method, a chemical lift off (CLO) method, an electrical lift off (ELO), an etching method, or the like.

Referring to FIG. **10**F, an upper surface of the emission structure **320** may be coated with a photo resist (PR) **340** by using a spin coating method. In the meantime, as another exemplary embodiment, bonding force between the emission structure **320** and the PR **340** may be improved by chemically processing (for example, hexamethyldisilazane processing) the surface of the emission structure **320** before the coating process. Further, a passivation layer (not illustrated) for protecting the emission structure **320** may be formed between the emission structure **320** and the PR **340** before the coating process. Then, mask patterns **380** may be precisely arranged on the PR **340** and then an exposure process of emitting ultraviolet rays and the like may be performed.

Referring to FIG. **10**G, the plurality of separators **340** may be formed on the emission structure **320** by performing a developing process on the PR **340** which passes the exposure process. In this case, the plurality of separators **340** may be disposed on the emission structure **320** corresponding to the locations between the pixels (that is, the regions in which the active layer and the second conductive semiconductor layer are etched).

In the meantime, in the present exemplary embodiment, the case where the plurality of separators is formed through the PR is exemplified, but the present invention is not limited thereto. For example, as another exemplary embodiment, the plurality of separators may also be formed on the growth substrate by forming a material for forming the separator on the growth substrate, stacking the PR on the material, sequentially performing exposure and developing processes by using a mask pattern, and wet or dry etching a region exposed by the PR.

Referring to FIG. **10**H, the fluorescent substance **350** may be injected between the separators **340** formed on the emission structure **320**. Accordingly, the fluorescent substance **350** may change a wavelength of light emitted from the micro LED pixel to a wavelength of white light.

Then, the color filters **360**, **370**, and **380** may be formed (or attached) on the plurality of separators **340** and the fluorescent substance **350**. Accordingly, the R filter **360** among the color filters may transmit only a wavelength of red light in white light emitted from the fluorescent substance **350**, the G filter **370** may transmit only a wavelength of green light in white light emitted from the fluorescent substance **350**, and the B filter **380** may transmit only a wavelength of blue light in white light emitted from the fluorescent substance **350**.

The micro LED display device **300** formed through the foregoing processes may minimize light scattering due to the growth substrate and implement a full color of high resolution (an HD level).

In the meantime, in the foregoing, the particular exemplary embodiments of the present invention have been described, but may be variously modified without departing from the scope of the invention as a matter of course. Accordingly, the scope of the present invention is not limited to the exemplary embodiment, and should be defined in equivalents of the claims, as well as the claims to be described below.

What is claimed is:

1. A micro light emitting diode (LED) display device, comprising:

a micro LED driving substrate in which a plurality of CMOS cells are arranged in rows and columns;

a micro LED panel which is flip-chip bonded onto the micro LED driving substrate and includes a plurality of micro LED pixels electrically connected with the plurality of CMOS cells, the micro LED panel defining an inner region in which the plurality of micro LED pixels are arranged and an outer region in which none of the plurality of micro LED pixels is arranged, each of the micro LED pixels defining a unit pixel region;

wherein the plurality of micro LED pixels are formed by etching a first surface of an emission structure comprising a first conductive semiconductor layer, an active layer and a second conductive semiconductor layer in etch portions defining the unit pixel regions, such that each of the plurality of micro LED pixels comprises:

a first conductive semiconductor layer having a first surface facing the micro LED driving substrate and a second surface opposite to the first surface;

an active layer on the first surface of the first conductive semiconductor layer; and

a second conductive semiconductor layer on the active layer,

wherein the micro LED panel further comprises a plurality of separators formed on a second surface, opposite to the first surface, of the emission structure in positions vertically corresponding to the etch portions, such that the plurality of separators extend from the first conductive semiconductor layer in a direction opposite to the micro LED driving substrate, and

wherein the micro LED panel further comprises a first conductive metal layer formed in the outer region of the micro LED panel.

2. The micro LED display device of claim **1**, wherein the micro LED panel includes a first color light changing material between a first separator and a second separator on the second surface of the emission structure, a second color light changing material between the second separator and a third separator, and a third color light changing material between the third separator and a fourth separator.

3. The micro LED display device of claim **1**, wherein the micro LED panel includes a white light emitting fluorescent substance between the separators on the second surface of the emission structure and a color filter disposed on the white light emitting fluorescent substance.

4. The micro LED display device of claim **3**, wherein the white light emitting fluorescent substance has the same height as a height of the separator, and the color filter includes a first filter configured to pass a first wavelength among wavelengths emitted from the white light emitting fluorescent substance, a second filter configured to a second wavelength among the wavelengths emitted from the white light emitting fluorescent substance, and a third filter configured to pass a third wavelength among wavelengths emitted from the white light emitting fluorescent substance.

5. The micro LED display device of claim **1**, wherein the plurality of separators are formed of a polymer compound or a ceramic material.

6. The micro LED display device of claim **1**, wherein the plurality of separators have the same height, and a gap between the separators corresponds to a pixel size.

7. The micro LED display device of claim **1**, wherein the emission structure includes a growth substrate located between the second surface of the first conductive semiconductor layer and the plurality of separators.

8. The micro LED display device of claim **1**, wherein the plurality of separators are formed directly on the second surface of the first conductive semiconductor layer.

9. The micro LED display device of claim **1**, wherein portions in which the plurality of micro LED pixels are not formed correspond to portions in which the first conductive semiconductor layer is exposed by selectively removing the active layer and the second conductive semiconductor layer using an etching process, and the first conductive metal layer is formed in the outer region spaced from the plurality of micro LED pixels in the inner region.

10. The micro LED display device of claim **1**, wherein a height of the first conductive metal layer is the same with the plurality of micro LED pixels.

11. The micro LED display device of claim **1**, wherein the first conductive metal layer serves as a common electrode of the plurality of micro LED pixels.

12. The micro LED display device of claim **1**, wherein the micro LED driving substrate includes a common cell formed to face the first conductive metal layer, and the first conductive metal layer and the common cell are electrically connected by bumps.

13. A method of fabricating a micro light emitting diode (LED) display device, the method comprising:

depositing a first conductive semiconductor layer, an active layer, and a second conductive semiconductor layer on a growth substrate;

etching the first conductive semiconductor layer, the active layer, and the second conductive semiconductor layer in predetermined etch portions of an inner region to form a plurality of micro LED pixels in the inner region;

etching the active layer and the second conductive semiconductor layer in an outer region to expose a first surface of the first conductive semiconductor layer without forming any micro LED pixel;

forming a first conductive metal layer on the first surface of the first conductive semiconductor layer in the outer region;

forming a second conductive metal layer on the second conductive semiconductor layer of each of the plurality of micro LED pixels;

flip-chip bonding the plurality of micro LED pixels to a driving substrate;

coating a photo resist over a second surface of the first conductive semiconductor layer; and

performing a developing process on the photo resist to form a plurality of separators over the second surface of the first conductive semiconductor layer,

wherein the locations of the plurality of separators vertically correspond to the predetermined etch portions.

14. The method of claim **13**, further comprising:

injecting a first color light changing material between a first separator and a second separator, a second color light changing material injected between the second separator and a third separator, and a third color light changing material injected between the third separator and a fourth separator.

15. The method of claim **13**, further comprising:

injecting a white light emitting florescent substance between the separators; and

disposing a color filter on the white light emitting florescent substance.

16. The method of claim **13**, further comprising removing the growth substrate before coating the photo resist over the second surface of the first conductive semiconductor layer, so that the plurality of separators are formed directly on the second surface of the first conductive semiconductor layer.

17. A micro LED display device comprising:

a driving substrate; and

a micro LED panel flip-chip bonded to the driving substrate, the micro LED panel comprising:

an inner region in which a plurality of micro LED pixels are formed by depositing a first conductive semiconductor layer, an active layer, and a second conductive semiconductor layer on a growth substrate and etching the first conductive semiconductor layer, the active layer, and the second conductive semiconductor layer in predetermined etch portions, such that each of the plurality of micro LED pixels comprises:

the first conductive semiconductor layer having a first surface facing the driving substrate and a second surface opposite to the first surface;

the active layer on the first surface of the first conductive semiconductor layer; and

the second conductive semiconductor layer on the active layer;

an outer region formed by etching the active layer and the second conductive semiconductor layer in a periphery of the inner region to expose the first surface of the first conductive semiconductor layer without forming any micro LED pixel;

a plurality of separators formed on the second surface of the first conductive semiconductor layer in positions vertically corresponding to the predetermined etch portions, such that the plurality of separators extend from the second surface of the first conductive semiconductor layer in a direction opposite to the driving substrate;

a first conductive metal layer disposed in the outer region to serve as a common electrode of the plurality of the micro LED pixels; and

a plurality of second conductive metal layers formed on the respective plurality of micro LED pixels.

18. The micro LED display device of claim **17**, wherein the plurality of separators are formed directly on the second surface of the first conductive semiconductor layer.

19. The micro LED display device of claim **17**, wherein the plurality of separators are formed on the growth substrate.

20. The micro LED display device of claim **17**, further comprising a color changing material disposed between the plurality of separators.

* * * * *

专利名称(译)	微型LED显示装置及其制造方法		
公开(公告)号	US10636349	公开(公告)日	2020-04-28
申请号	US15/888943	申请日	2018-02-05
申请(专利权)人(译)	LUMENS CO. , LTD.		
当前申请(专利权)人(译)	LUMENS CO. , LTD.		
[标]发明人	SHIN EUN SUNG CHO DONG HEE KIM YONG PIL MOON MYUNG JI CHANG HAN BEET PARK JAE SOON		
发明人	SHIN, EUN SUNG CHO, DONG HEE KIM, YONG PIL MOON, MYUNG JI CHANG, HAN BEET PARK, JAE SOON		
IPC分类号	G09G3/32 H04N5/374 G09G3/14		
CPC分类号	H04N5/374 G09G3/32 G09G3/14 G09G2310/0264		
优先权	1020170051892 2017-04-21 KR		
其他公开文献	US20180308420A1		
外部链接	Espacenet		

摘要(译)

公开了一种能够实现高分辨率的全色的微型发光二极管（LED）显示装置，该微型LED显示装置包括：微型CMOS驱动基板（底板），其中，多个CMOS单元排成一行。 和列； 微型LED面板，其被倒装芯片接合到微型LED驱动基板上，并且包括与多个CMOS单元电连接的多个微型LED像素，其中，微型LED面板包括由形成的多个微型LED像素。 沿着单位像素区域蚀刻发射结构的第一表面，并在发射结构的第二表面上形成多个隔板，所述多个隔板对应于通过蚀刻发射结构在垂直方向上形成的部分的位置。