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Display device and method of manufacturing the same

Abstract

Disclosed is a display device including: a substrate including a plurality of first pads transmitting a gate signal, a plurality of second pads transmitting a data signal, a plurality of third pads transmitting a first power voltage, and a plurality of fourth pads transmitting a second power voltage different from the first power voltage within a display area; and a plurality of display modules, each of which includes a light emitting diode connected to first to fourth electrodes attached to the first to fourth pads, a first transistor connected to the first electrode and the second electrode, a second transistor connected to the third electrode, and a light emitting diode connected to the second transistor and the fourth electrode.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims priority to and the benefit of Korean Patent Application No. 10-2021-0167506 filed in the Korean Intellectual Property Office on Nov. 29, 2021, the entire contents of which are incorporated herein by reference.

BACKGROUND

(a) Field

(2) An exemplary embodiment relates to a display device and a method of manufacturing the display device.

(b) Description of the Related Art

(3) Recently, a Light Emitting Diode (LED) display device using an LED as a light emitting element has been developed. In the LED display device, a small LED (mini LED and micro LED) may be used. The LED display device has a large advantage in terms of power consumption reduction and miniaturization.

(4) In the meantime, a transparent display device using the LED display device may be applied in various fields because an object or an image located at the rear of the display device can pass the display device and be recognized by a user located in front of the display device.

(5) The above information disclosed in this Background section is only for enhancement of understanding of the background, 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

(6) The present invention has been made in an effort to provide a display device with higher transmittance.

(7) The present invention has also been made in an effort to provide a display device in which a display module is easily bonded with a substrate.

(8) An exemplary embodiment of the present invention provides a display device including: a substrate including a plurality of first pads transmitting a gate signal, a plurality of second pads transmitting a data signal, a plurality of third pads transmitting a first power voltage, and a plurality of fourth pads transmitting a second power voltage different from the first power voltage within a display area; and a plurality of display modules, each of which includes first to fourth bonding electrodes attached to the first to fourth pads, a first transistor connected to the first bonding electrode and the second bonding electrode, a second transistor connected to the third bonding electrode, and a light emitting diode connected to the second transistor and the fourth bonding electrode.

(9) The substrate further includes a plurality of gate lines and a plurality of second power voltage lines extended in a first direction and arranged in a second direction crossing the first direction, and a plurality of data lines and a plurality of first power voltage lines extended in the second direction and arranged in the first direction, and the plurality of first pads is connected to the plurality of gate lines, the plurality of second pads is connected to the plurality of data lines, the plurality of third pads is connected to the plurality of first power voltage lines, and the plurality of fourth pads is connected to the plurality of second power voltage lines.

(10) The plurality of display modules is arranged in a matrix form in the first direction and the second direction, and at least one of the plurality of display modules is arranged to be shifted in a column direction or a row direction.

(11) At least one of the plurality of display modules connected to the first data line among the plurality of data lines is connected to a first power voltage line different from first power voltage lines of other display modules.

(12) At least one of the plurality of display modules connected to a first gate line among the plurality of gate lines is connected to a second power voltage line different from second power voltage lines of other display modules.

(13) The plurality of display modules includes a plurality of first display modules each of which includes a plurality of light emitting diodes, and a plurality of second display modules each of which includes one light emitting diode.

(14) In the plurality of first display modules, the plurality of light emitting diodes is arranged in different forms.

(15) The plurality of gate lines and the plurality of second power voltage lines, and the plurality of data lines and the plurality of first power voltage lines are located on different layers.

(16) The display area has a non-quadrangular form.

(17) The substrate has a curved form.

(18) The substrate includes at least one of a front glass, a rear glass, and side mirrors of a vehicle.

- (19) The display device further includes a curved glass substrate, and the substrate is flexible and is attached to the glass substrate.
- (20) The glass substrate may include at least one of a front glass, a rear glass, and side mirrors of a vehicle.
- (21) The display device may further include a gate driving unit supplying the gate signal and a source driving unit supplying the data signal, the gate driving unit and the source driving unit being disposed in a bezel area.
- (22) Each of the plurality of display modules further includes: a display element including a substrate, a first conductive semiconductor layer on the substrate, a first electrode on the first conductive semiconductor layer, a first activation layer on the first conductive semiconductor layer, a second conductive semiconductor layer on the first activation layer, a reflective layer on the second conductive semiconductor layer, a first passivation layer covering the reflective layer, a first electrode connected to the first conductive semiconductor layer and located on the first passivation layer, and a second electrode connected to the reflective layer and located on the passivation layer, in which the light emitting diode includes the first conductive semiconductor layer, the first activation layer, and the second conductive semiconductor layer; and a transistor including a first gate electrode on the first passivation layer, a gate insulating layer on the first gate electrode, a second activation layer on the gate insulating layer, a source electrode and a drain electrode on the second activation layer, a second passivation layer covering the source electrode and the drain electrode, and a second gate electrode on the second passivation layer, and the first bonding electrode is connected to the first electrode, the second bonding electrode is connected to the drain electrode, and the second electrode is connected to the source electrode.
- (23) Another exemplary embodiment of the present invention provides a display device including: a display element including a substrate, a first conductive semiconductor layer on the substrate, a first electrode on the first conductive semiconductor layer, a first activation layer on the first conductive semiconductor layer, a second conductive semiconductor layer on the first activation layer, a reflective layer on the second conductive semiconductor layer, a first passivation layer covering the reflective layer, a first electrode connected to the first conductive semiconductor layer and located on the first passivation layer, and a second electrode connected to the reflective layer and located on the passivation layer, a transistor including a first gate electrode on the first passivation layer, a gate insulating layer on the first gate electrode, a second activation layer on the gate insulating layer, a source electrode and a drain electrode on the second activation layer, a second passivation layer covering the source electrode and the drain electrode, and a second gate electrode on the second passivation layer; and a first bonding electrode connected to the first electrode and a second bonding electrode connected to the drain electrode, in which the second electrode is connected to the source electrode.
- (24) The first conductive semiconductor layer and the second conductive semiconductor layer may be formed of an III-V group material.
- (25) The first activation layer may be formed of an III-V group material.
- (26) At least one of the first electrode, the second electrode, the first gate electrode, the source electrode, the drain electrode, the second gate electrode, the first bonding electrode, and the second bonding electrode may include at least one transparent material of an indium tin oxide (ITO), an indium zinc oxide (IZO), and an Ag nanowire.
- (27) Another exemplary embodiment of the present invention provides a method of manufacturing a display device, the method including: forming a first conductive semiconductor layer on a substrate; forming a first activation layer on the first conductive semiconductor layer; forming a second conductive semiconductor layer on the first activation layer; forming a light emitting diode by forming a reflective layer on the second conductive semiconductor layer; forming a first passivation layer covering the reflective layer; forming a first electrode connected to the first conductive semiconductor layer on the first passivation layer and a second electrode and a first gate

electrode connected to the reflective layer; forming a gate insulating layer on the first gate electrode; forming a second activation layer on the gate insulating layer; forming a drain electrode and a source electrode connected to the second electrode on the second activation layer; forming a second passivation layer covering the source electrode and the drain electrode; forming a transistor by forming a second gate electrode on the second passivation layer; forming a third passivation layer on the second gate electrode; forming a first bonding electrode connected to the first electrode and a second bonding electrode connected to the drain electrode on the third passivation layer; cutting the substrate on which the light emitting diode and the transistor are formed into a plurality of display modules; and attaching the display module to the substrate including a plurality of pads to which a signal used for the light emitting diode to emit light is applied.

(28) According to the exemplary embodiments, the effects of the display device and the method of manufacturing the display device are as follows.

(29) According to at least one of the exemplary embodiments, there is an advantage in that it is possible to provide a more transparent display device.

(30) Further, according to at least one of the exemplary embodiments, there is an advantage in that it is possible to decrease a possibility of damage of a bonding portion between a substrate and a display module of a display device.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a block diagram schematically illustrating a display device according to an exemplary embodiment.

(2) FIG. 2 is a circuit diagram illustrating an example of a display element of the display device according to an exemplary embodiment.

(3) FIG. 3 is a top plan view illustrating a substrate of the display device according to the exemplary embodiment.

(4) FIG. 4 is a cross-sectional view of a partial region of the display device in which a display module is bonded to the substrate of FIG. 3.

(5) FIGS. 5 to 7 are cross-sectional views of the display module manufactured according to a method of manufacturing a display device according to an exemplary embodiment.

(6) FIGS. 8 to 10 are top plan views illustrating the display device according to various aspects of the exemplary embodiment.

(7) FIG. 11 is a schematic diagram illustrating an example in which a display device according to an embodiment is applied to the front and rear glasses of a vehicle.

DETAILED DESCRIPTION OF THE EMBODIMENTS

(8) Hereinafter, exemplary embodiments of the present invention will be described with reference to accompanying drawings so as to be easily understood by a person ordinary skilled in the art.

However, the present invention can be variously implemented and is not limited to the following exemplary embodiments.

(9) In addition, the size and thickness of each configuration shown in the drawings are arbitrarily shown for understanding and ease of description, but the present invention is not limited thereto.

(10) Further in the drawings, the thickness of layers, films, panels, regions, etc., are exaggerated for clarity. In the drawings, for understanding and ease of description, the thickness of some layers and areas is exaggerated. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being “on” another element, it can be directly on the other element or intervening elements may also be present.

(11) In addition, unless explicitly described to the contrary, the word “comprise”, and variations such as “comprises” or “comprising”, will be understood to imply the inclusion of stated elements

but not the exclusion of any other elements. Further, in the specification, the word “on” means positioning on or below the object portion, but does not essentially mean positioning on the upper side of the object portion based on a gravity direction.

(12) Hereinafter, a display device according to an exemplary embodiment will be described with reference to FIG. 1.

(13) FIG. 1 is a block diagram schematically illustrating a display device according to an exemplary embodiment. As illustrated in FIG. 1, the display device **10** includes a plurality of display modules **100a**, **100b**, **100c**, . . . , and **100z**, a substrate **200** on which the plurality of display modules **100a**, **100b**, **100c**, . . . , and **100z** are located, and driving units **300** and **400** providing signals corresponding to the plurality of display modules **100a**, **100b**, **100c**, . . . , and **100z**.

(14) Each display module **100** includes a display element emitting light according to the signals of the driving units **300** and **400**. One display module **100** may have one display element or a plurality of display elements emitting light of one color wavelength.

(15) The signals from the driving units **300** and **400** may be transmitted to each display module **100** through a plurality of bonding electrodes **110a**, **111a**, **112a**, and **113a** of each display module **100**. The plurality of bonding electrodes **110a**, **111a**, **112a**, and **113a** is electrically connected with a bonding pad on the substrate **200**.

(16) The number of plurality of bonding electrodes **110a**, **111a**, **112a**, and **113a** is different depending on the number of display elements included in each display module **100**. For example, four types of signals (for example, a gate signal, a data signal, a first power voltage, and a second power voltage) are applied to one display element, the display module **100** including one display element may have fourth bonding electrodes, and the display module **100** including four display elements may have 16 bonding electrodes. The plurality of bonding electrodes **110a**, **111a**, **112a**, and **113a** may be formed of a transparent material.

(17) The display module **100** including the plurality of display elements may also include a common bonding electrode receiving a signal commonly applied to each display element. For example, the display module **100** including four display elements in the form of 1×4 may include seven bonding electrodes (four data signal bonding electrodes, one gate signal bonding electrode, one first power voltage bonding electrode, and one second power voltage bonding electrode).

(18) The substrate **200** includes a plurality of signal lines. For example, the substrate **200** includes a plurality of gate lines **G1**, **G2**, . . . , and **Gn**, and a plurality of data lines **D1**, **D2**, . . . , and **Dm**. Further, the substrate **200** includes power voltage lines **VDD** and **VSS** providing the power voltage. The plurality of signals lines may be located on different layers or located on the same layer on the substrate **200**.

(19) The plurality of data lines **D1**, **D2**, . . . , and **Dm** is extended in a substantially column direction and is almost parallel to each other. The plurality of gate lines **G1**, **G2**, . . . , and **Gn** is extended in a substantially row direction and is almost parallel to each other.

(20) A bonding pad on the substrate **200** may be located on a surface of the substrate **200**. The disposition forms of the bonding pads connected to one display element on the substrate **200** are the same. The bonding pad on the substrate **200** is electrically connected with the plurality of signal lines.

(21) A gate driving unit **300** is connected with each display module **100** through the plurality of gate lines **G1**, **G2**, . . . , and **Gn**. The gate driving unit **300** generates the plurality of gate signals according to the control signal and transmits the generated gate signal to the corresponding gate line among the plurality of gate lines.

(22) A source driving unit **400** is connected with each display module **100** through the plurality of data lines **D1**, **D2**, . . . , and **Dm**. The source driving unit **400** receives an image data signal, a control signal, and the like and transmits a data signal to the corresponding data line among the plurality of data lines **D1**, **D2**, . . . , and **Dm**. The source driving unit **400** selects a grayscale voltage according to the image data signal and transmits the selected grayscale signal to the plurality of

data lines as the data signal.

(23) The source driving unit **400** samples and holds the image data signal, and transmits the plurality of data signals to the plurality of data lines **D1**, **D2**, . . . , and **Dm**, respectively. For example, the source driving unit **400** may apply a data signal having a predetermined voltage range to the plurality of data lines **D1**, **D2**, . . . , and **Dm** in response to the gate signal of an enable level.

(24) In addition to this, the gate driving unit **300** and/or the source driving unit **400** apply the first power voltage and the second power voltage to the power voltage lines **VDD** and **VSS**. The first power voltage applied to a power voltage line **VDD** and the second power voltage applied to the power voltage line **VSS** may have different values.

(25) The substrate **200**, the signal lines **G1**, **G2**, . . . , **Gn**, **D1**, **D2**, . . . , **Dm**, **VDD**, and **VSS**, and the pads **110a**, **111a**, **112a**, and **113a** on the substrate are formed of the transparent material and the transparent electrode is also used in the display module **100**, thereby implementing the display device **100** with high transmittance.

(26) In the meantime, when the substrate **200** has stretchable, flexible, bendable, and foldable properties, a curved display with high transmittance may be implemented by mounting the display module **100** to the substrate **200**. Otherwise, a curved display with high transmittance may also be implemented by mounting the display module **100** to the substrate **200** and then attaching the substrate **200** to a curved glass substrate and the like in a specific form. The curved display may be used as a front glass, a rear glass, and a side mirror of a vehicle, glass of a building, and a mirror.

(27) Next, the display element included in the display module **100** will be described with reference to FIG. 2.

(28) FIG. 2 is a circuit diagram illustrating an example of a display device of the display element according to an exemplary embodiment. The display element will be described based on a display module **100a** as an example.

(29) Referring to FIG. 2, the display element includes a first transistor **T1**, a second transistor **T2**, a storage capacitor **C1**, and a light emitting diode **LED**.

(30) A gate of the first transistor **T1** is connected with the first gate line **G1** through the bonding electrode **110a**, one end of the first transistor **T1** is connected with the data line **D1** through the bonding electrode **111a**, and the other end of the first transistor **T1** is connected to a gate of the first transistor **T1** at a first node **N1**.

(31) The first transistor **T1** is turned on according to the gate signal received through the gate line **G1** and performs a switching operation of transmitting the data signal transmitted to the data line **D1** to the first node **N1**.

(32) A gate of the second transistor **T2** is connected to one electrode of a storage capacitor **C1** at the first node **N1**, one end of the second transistor **T2** is connected with the power voltage line **VDD** supplying the first power voltage through the bonding electrode **112a**, and the other end of the second transistor **T2** is electrically connected with an anode of the light emitting diode **LED**. The second transistor **T2** receives a data signal according to a switching operation of the first transistor **T1** and supplies a driving current to the light emitting diode **LED**.

(33) The other electrode of the storage capacitor **C1** is connected with the power voltage line **VDD** through a bonding electrode **113a**.

(34) A cathode of the light emitting diode **LED** is connected with the power voltage line **VSS**. The light emitting diode **LED** receives a driving current from the second transistor **T2** and emits light.

(35) Next, the substrate **200** on which the display module **100** is disposed will be described with reference to FIG. 3.

(36) FIG. 3 is a top plan view illustrating the substrate of the display device according to the exemplary embodiment.

(37) On the substrate **200**, a gate line **210** and a power voltage line **213** extended in a first direction (x-axis direction) are arranged in a second direction (y-axis direction), and a data line **211** and a power voltage line **212** extended in the second direction (y-axis direction) are arranged in the first

direction (x-axis direction).

(38) The gate line **210** and the power voltage line **213** may be located on the different layer from that of the data line **211** and the power voltage line **212**.

(39) The form of the disposition of the pads **210c**, **211c**, **212c**, and **213c** corresponding to one display element may be the same on the substrate **200**. Each of the pads **210c**, **211c**, **212c**, and **213c** is connected to a signal line corresponding to the plurality of signal lines **210a**, **211a**, **212a**, and **213a** through corresponding one among connection wires **210b**, **211b**, **212b**, and **213b**.

(40) Next, a structure of the display device will be described with reference to FIG. 4.

(41) FIG. 4 is a cross-sectional view of a partial region of the display device in which the display module is bonded to the substrate of FIG. 3.

(42) Referring to FIG. 4, the display module **100** is located on the substrate **200**. The bonding electrodes **112a** and **113a** of the display module **100** are electrically connected to the pads **212c** and **213c** of the substrate **200**.

(43) The display element **120** may be located on a module substrate **101**. In this case, the module substrate **101** may be selected from the group consisting of sapphire, silicon carbide, zinc oxide, gallium nitride, aluminum nitride, zirconium diboride, gallium arsenide, and silicon, but is not limited thereto.

(44) In particular, other than sapphire, other heterogeneous substrates, such as glass, silicon carbide, silicon, GaAs, GaP, AlGaNP, Ge, SiSe, GaN, AlInGaNP, and InGaNP, may be used.

(45) A transistor **130** is located on the module substrate **101**. The display element **120** is connected with the transistor **130** (the second transistor T2 of FIG. 2). For example, an electrode **126** of the display element **120** is connected with an electrode **135** of the transistor **130**.

(46) The transistor **130** according to the exemplary embodiment of the present invention may be configured with any one of a coplanar structure, a staggered structure, an inverted coplanar structure, and an inverted staggered structure.

(47) The display element **120** includes a first conductive semiconductor layer **121**, a first electrode **125**, a first activation layer **122**, a second conductive semiconductor layer **123**, a second electrode **126**, and a first passivation layer **127**.

(48) More particularly, the first conductive semiconductor layer **121** is located on the module substrate **101**. The first activation layer **122** is located on the first conductive semiconductor layer **121**, and the second conductive semiconductor layer **123** is located on the first activation layer **122**.

(49) In this case, the first activation layer **122** may have a quantum well structure, such as GaN, InGaNP, AlGaNP, GaP, AlGaInP, AlInP, InP, GaAs, InGaAs, and AlGaAs, and may be formed of a III-V group material.

(50) The first conductive semiconductor layer **121** and the second conductive semiconductor layer **123** may include a p-GaN-based semiconductor material or an n-GaN-based semiconductor material, but the materials of the first activation layer **122** and the semiconductor layers **121** and **123** are not limited thereto. The n-GaN-based semiconductor material may include a III-V group material, such as GaN, n-GaN, n-InGaNP, n-AlGaNP, n-GaP, n-AlGaInP, n-AlInP, n-InP, n-GaAs, n-InGaAs, and n-AlGaAs. When the first conductive semiconductor layer **121** includes an n-GaN-based semiconductor material, impurities used for doping the first conductive semiconductor layer **121** include Si, Ge, Se, Te, or C. The p-GaN-based semiconductor material may include an III-V group material, such as GaN, p-GaN, p-InGaNP, p-AlGaNP, p-GaP, p-AlGaInP, p-AlInP, p-InP, p-GaAs, p-InGaAs, and p-AlGaAs. Herein when the second conductive semiconductor layer **123** includes the p-GaN-based semiconductor material, impurities used for doping the second conductive semiconductor layer **123** include Mg, Zn, or Be.

(51) A reflective layer **124** is located on the second conductive semiconductor layer **123**. Therefore, the display module **100** emits light in direction A1.

(52) A first passivation layer **127** is located on the reflective layer **124**. The first electrode **125** is connected to the first conductive semiconductor layer **121** through a contact hole, and the second

electrode **126** is connected to the reflective layer **124** through a contact hole. The first electrode **125** and the second electrode **126** may include a transparent material including at least one of an indium tin oxide (ITO), an indium zinc oxide (IZO), and an Ag nanowire.

(53) In the meantime, the transistor **130** is formed of a first gate electrode **131**, a gate insulating layer **132**, a second activation layer **133**, a source electrode **134**, a drain electrode **135**, a second passivation layer **136**, and a second gate electrode **137**. The transistor **130** is a dual gate transistor, and may decrease a leakage current flowing through the transistor **130**.

(54) In particular, the first gate electrode **131** is located on the first passivation layer **127**. The gate insulating layer **132** is located on the first gate electrode **131**, the second activation layer **133** is located on the gate insulating layer **132**, and the drain electrode **135** and the source electrode **134** are located on the second activation layer **133**. The first gate electrode **131**, the drain electrode **135**, and the source electrode **134** may be formed of a transparent material including at least one of an ITO, an IZO, and an Ag nanowire.

(55) The second activation layer **133** may include at least one of amorphous silicon, polycrystalline silicon, and a semiconductor oxide.

(56) Further, the second electrode **126** of the display element **120** and the drain electrode **135** of the transistor **130** are electrically connected, and may be formed of the same material.

(57) The second passivation layer **136** is located on the second activation layer **133**, the source electrode **134**, and the drain electrode **135**, and the second gate electrode **137** is located on the second passivation layer **136**. The second gate electrode **137** may be formed of a transparent material including at least one of an ITO, an IZO, and an Ag nanowire.

(58) A third passivation layer **102** is formed on the transistor **130** configured as described above, to protect the transistor **130**.

(59) The bonding electrode **113a** and the bonding electrode **112a** are located on the third passivation layer **102**. The bonding electrode **113a** is connected to the first electrode **125** through the contact hole, and the bonding electrode **112a** is connected to the source electrode **134** of the transistor **130** through the contact hole. The bonding electrodes **112a** and **113a** may be formed of a transparent material including at least one of an ITO or an IZO and an Ag nanowire.

(60) The substrate **200** includes a first substrate layer **201**, the data line **211** and the power voltage line **212** located on the first substrate layer **201**, a second substrate layer **202** located on the data line **211** and the power voltage line **212**, the gate line (not illustrated) and the power voltage line **213** located on the second substrate layer **202**, a third substrate layer **203** located on the gate line (not illustrated) and the power voltage line **213**, and pads **212c** and **213c** located on the third substrate layer **203** and connected to the corresponding signal line through the contact hole.

(61) Next, a method of manufacturing the display module **100** will be described with reference to FIGS. 5 to 7.

(62) FIGS. 5 to 7 are cross-sectional views of the display module manufactured according to a method of manufacturing a display device according to an exemplary embodiment.

(63) As illustrated in FIG. 5, a first conductive semiconductor layer **121**, a first activation layer **122**, a second conductive semiconductor layer **123**, and a reflective layer **124** are formed on a module substrate **101**.

(64) Thereafter, a first passivation layer **127** is formed on the first conductive semiconductor layer **121**, the first activation layer **122**, the second conductive semiconductor layer **123**, and the reflective layer **124**. Then, an individual display element is formed by etching the layers **121**, **122**, **123**, and **124** formed on the module substrate **101**.

(65) Then, a first electrode **125** and a second electrode **126** are formed on the first passivation layer **127**. The first electrode **125** is connected to the first conductive semiconductor layer **121** through a contact hole. The second electrode **126** is connected to the reflective layer **124** through the contact hole.

(66) Next, as illustrated in FIG. 6, a transistor **130** is formed on a display element **120**.

(67) A first gate electrode **131** is formed on the first passivation layer **127**. The first gate electrode **131** may be formed together with the first electrode **125** and the second electrode **126**. A gate insulating layer **132** is formed on the first gate electrode **131**, the first electrode **125**, and the second electrode **126**.

(68) A second activation layer **133** is formed on the gate insulating layer **132**, and a drain electrode **135** and a source electrode **134** are formed in a drain region and a source region of the second activation layer **133**, respectively. The drain electrode **135** of the transistor **130** is connected with the second electrode **126** of the display element **120** through the contact hole.

(69) A second passivation layer **136** is formed on the second activation layer **133**, the source electrode **134**, and the drain electrode **135**. A second gate electrode **137** is formed on the second passivation layer **136**.

(70) A third passivation layer **102** is formed on the second passivation layer **136** and the second gate electrode **137**. The first to third passivation layers **127**, **136**, and **102** may be formed of a single layer or multiple layers of a silicon oxide (SiO_x) or a silicon nitride (SiN_x), but are not limited thereto.

(71) A bonding electrode **113a** and a bonding electrode **112a** are formed on the third passivation layer **120**. The bonding electrode **113a** is connected to the first electrode **125** through the contact hole, and the bonding electrode **112a** is connected to the source electrode **134** of the transistor **130** through the contact hole.

(72) Referring to FIG. 7, the transistor **130** is separated to display modules **100-1** and **100-2** having at least one display element **120** by cutting the display element **120** and the transistor **130** formed on the module substrate **101** along a cutting line **140**.

(73) Next, a display device in which various forms of display modules are disposed will be described with reference to FIGS. 8 to 10.

(74) FIGS. 8 to 10 are top plan views illustrating the display device according to various aspects of the exemplary embodiment.

(75) As illustrated in FIG. 8, a plurality of display modules **100** is located within a non-quadrangular display area DA. The display modules **100** are arranged in a matrix form. For example, the display modules **1000**, **1001**, and **1002** connected to the same gate line Gi are connected to the same power voltage line VSS1. Similarly, the display modules **1002**, **1004**, and **1005** connected to the same data line Dj+2 are connected to the same power voltage line VDD3.

(76) As illustrated in FIG. 9, a plurality of display modules **100** is located within a non-quadrangular display area DA. The display modules **100** are arranged to be shifted in a column direction. For example, the display modules **1002**, **1004**, and **1005** connected to the same data line Dj+2 are connected to the different power voltage line VDD2 or VDD3.

(77) In addition to this, the display module **100** may also be arranged to be shifted in a row direction along the form of the display area DA. That is, the display module **100** may be freely attached to a pad located on the substrate **200**.

(78) Comparing the dispositions of the display modules **100** of FIGS. 8 and 9, areas of the regions BA1 and BA2 in which the display modules **100** are not disposed in FIG. 8 are larger than areas of the regions BA3 and BA4 in which the display modules **100** are not disposed in FIG. 9. Therefore, a bezel area in the non-quadrangular display area DA is viewed more widely.

(79) The display device according to the exemplary embodiment may provide a bezelless display device by freely disposing the display modules **100**.

(80) Referring to FIG. 10, the display modules **1000a** and **1000b** may include a plurality of display elements **120a**, . . . , and **120k**. For example, the display module **1000a** may have display elements **120a**, **120b**, and **120c** arranged in series. The display module **1000b** may have display elements **120h**, **120i**, **120j**, and **120k** arranged in a 2×2 form.

(81) The display module **100** may be configured in various forms while including various number of display elements, so that the display module **100** may correspond to various forms and/or

various sizes of the display area DA.

(82) In the meantime, in FIG. 10, it is described that one display module **1000a** or **1000b** includes the plurality of display elements **120a**, . . . , and **120k**, but various display modules may be coupled as one display module so that one module includes the plurality of display elements.

(83) The display device according to the exemplary embodiment uses an individual display module chip, so that it is possible to implement a large display with a size of several tens of meters, which cannot be currently implemented in display devices using OLED display elements.

(84) Further, it was possible to implement a flexible display device using a subminiature LED only in a passive matrix display form, but when the display module chip according to the present disclosure is used, it is possible to implement a flexible active matrix display using a subminiature LED. By disposing the gate driving unit **300** and the source driving unit **400** for driving the display device **10** in the bezel around the display area DA, the display device **10** according to the exemplary embodiment may also be used in a front glass, a rear glass, and side mirrors of a vehicle as shown in FIG. 11, a glass of a building, a mirror, and the like.

(85) While this invention has been described in connection with what is presently considered to be practical exemplary embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

Claims

1. A display device, comprising: a substrate including a plurality of first pads transmitting a gate signal, a plurality of second pads transmitting a data signal, a plurality of third pads transmitting a first power voltage, and a plurality of fourth pads transmitting a second power voltage different from the first power voltage, within a display area; and a plurality of display modules, each of which includes first to fourth bonding electrodes directly attached to the first to fourth pads, a first transistor directly connected to the first bonding electrode and the second bonding electrode, a second transistor directly connected to the third bonding electrode, and a light emitting diode directly connected to the second transistor and the fourth bonding electrode.
2. The display device of claim 1, wherein: the substrate further includes a plurality of gate lines and a plurality of second power voltage lines extended in a first direction and arranged in a second direction crossing the first direction, and a plurality of data lines and a plurality of first power voltage lines extended in the second direction and arranged in the first direction, and the plurality of first pads is connected to the plurality of gate lines, the plurality of second pads is connected to the plurality of data lines, the plurality of third pads is connected to the plurality of first power voltage lines, and the plurality of fourth pads is connected to the plurality of second power voltage lines.
3. The display device of claim 2, wherein: the plurality of display modules is arranged in a matrix form in the first direction and the second direction, and at least one of the plurality of display modules is arranged to be shifted in a column direction or a row direction.
4. The display device of claim 3, wherein: at least one of the plurality of display modules connected to the first data line among the plurality of data lines is connected to a first power voltage line different from first power voltage lines of other display modules.
5. The display device of claim 3, wherein: at least one of the plurality of display modules connected to a first gate line among the plurality of gate lines is connected to a second power voltage line different from second power voltage lines of other display modules.
6. The display device of claim 2, wherein: the plurality of display modules includes a plurality of first display modules each of which includes a plurality of light emitting diodes, and a plurality of second display modules each of which includes one light emitting diode.
7. The display device of claim 6, wherein: one of the plurality of first display modules includes a

plurality of light emitting diodes arranged in a first configuration, and another of the plurality of first display modules includes a plurality of light emitting diodes arranged in a second configuration different from the first configuration.

8. The display device of claim 2, wherein: the plurality of gate lines and the plurality of second power voltage lines, and the plurality of data lines and the plurality of first power voltage lines are located on different layers.

9. The display device of claim 1, wherein: the display area has a non-quadrangular form.

10. The display device of claim 1, wherein: the substrate has a curved form.

11. The display device of claim 10, wherein: the substrate includes at least one of a front glass of a vehicle, a rear glass of a vehicle, or a side mirrors of a vehicle.

12. The display device of claim 1, further comprising: a curved glass substrate, wherein the substrate is flexible, and the substrate is attached to the glass substrate.

13. The display device of claim 12, wherein: the substrate includes at least one of a front glass of a vehicle, a rear glass of a vehicle, or a side mirrors of a vehicle.

14. The display device of claim 1, further comprising: a gate driving unit supplying the gate signal and a source driving unit supplying the data signal, the gate driving unit and the source driving unit being disposed in a bezel area.

15. The display device of claim 1, wherein each of the plurality of display modules further includes: a display element including a substrate, a first conductive semiconductor layer on the substrate, a first electrode on the first conductive semiconductor layer, a first activation layer on the first conductive semiconductor layer, a second conductive semiconductor layer on the first activation layer, a reflective layer on the second conductive semiconductor layer, a first passivation layer covering the reflective layer, a first electrode connected to the first conductive semiconductor layer and located on the first passivation layer, and a second electrode connected to the reflective layer and located on the passivation layer, in which the light emitting diode includes the first conductive semiconductor layer, the first activation layer, and the second conductive semiconductor layer; and a transistor including a first gate electrode on the first passivation layer, a gate insulating layer on the first gate electrode, a second activation layer on the gate insulating layer, a source electrode and a drain electrode on the second activation layer, a second passivation layer covering the source electrode and the drain electrode, and a second gate electrode on the second passivation layer, and wherein the first bonding electrode is connected to the first electrode, the second bonding electrode is connected to the drain electrode, and the second electrode is connected to the source electrode.
