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(54) **LIQUID-CRYSTAL DISPLAY**

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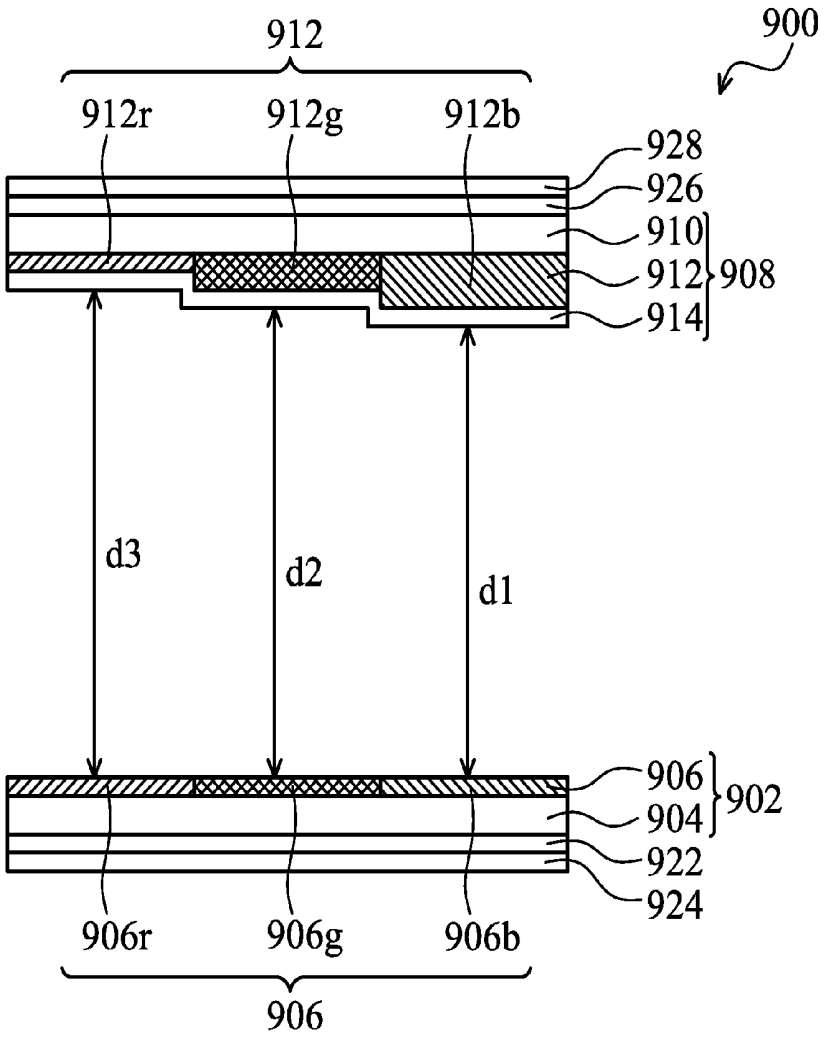
(57) **ABSTRACT**

An embodiment of a liquid-crystal display is provided which includes: a first substrate having a first pixel electrode, a second pixel electrode, and a third pixel electrode; a second substrate having an opposite electrode, wherein the first pixel electrode, the second pixel electrode and the third pixel electrode, respectively, have a first overlapping area, a second overlapping area and a third overlapping area overlapped with the opposite electrode, and wherein the first overlapping area is smaller than the second overlapping area and the third overlapping area; and a liquid-crystal layer interposed between the first substrate and the second substrate. In addition, another embodiment of a liquid-crystal display is also provided, in which the first pixel electrode, the second pixel electrode and the third pixel electrode have different gaps with the opposite electrode, respectively.



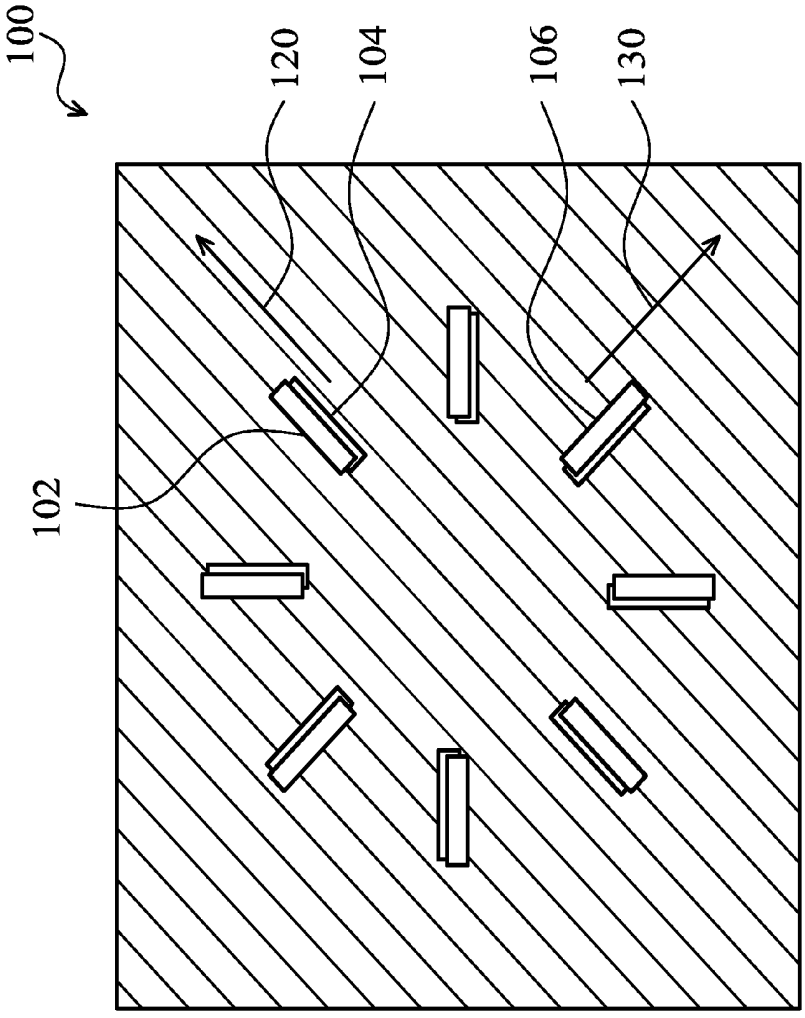


FIG. 1

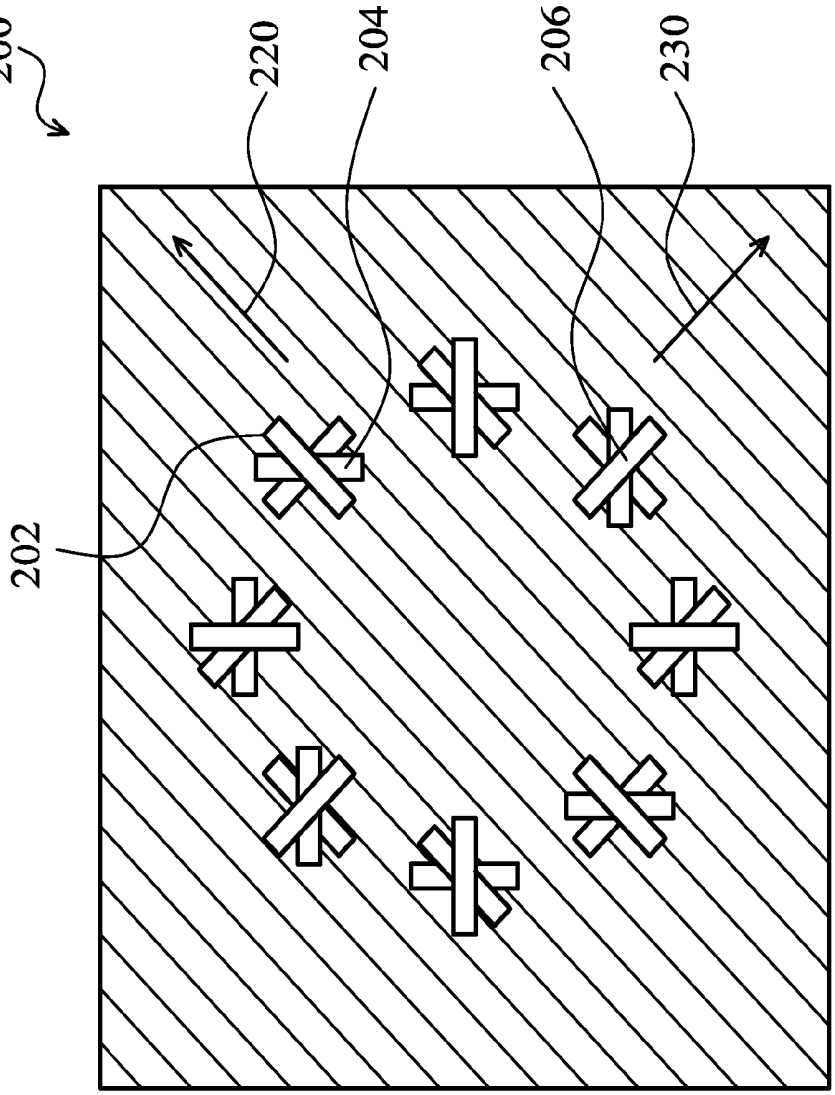
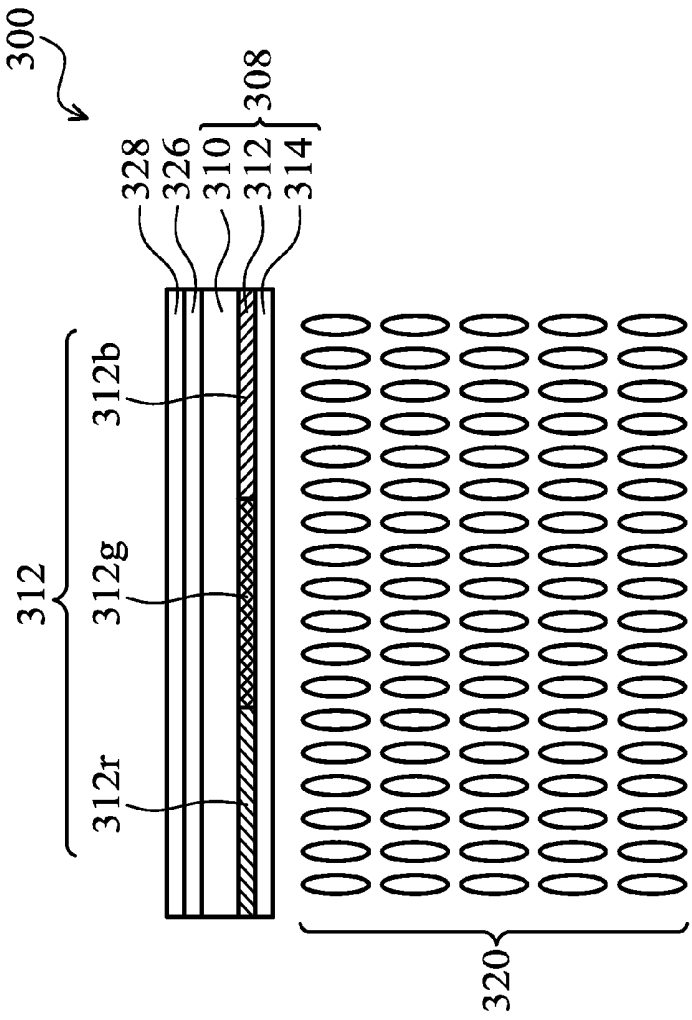


FIG. 2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308
328
326
310
312
314
302
306
304
322
324
312
312b
312g
312r
306b
306g
306r
306
320

FIG. 3

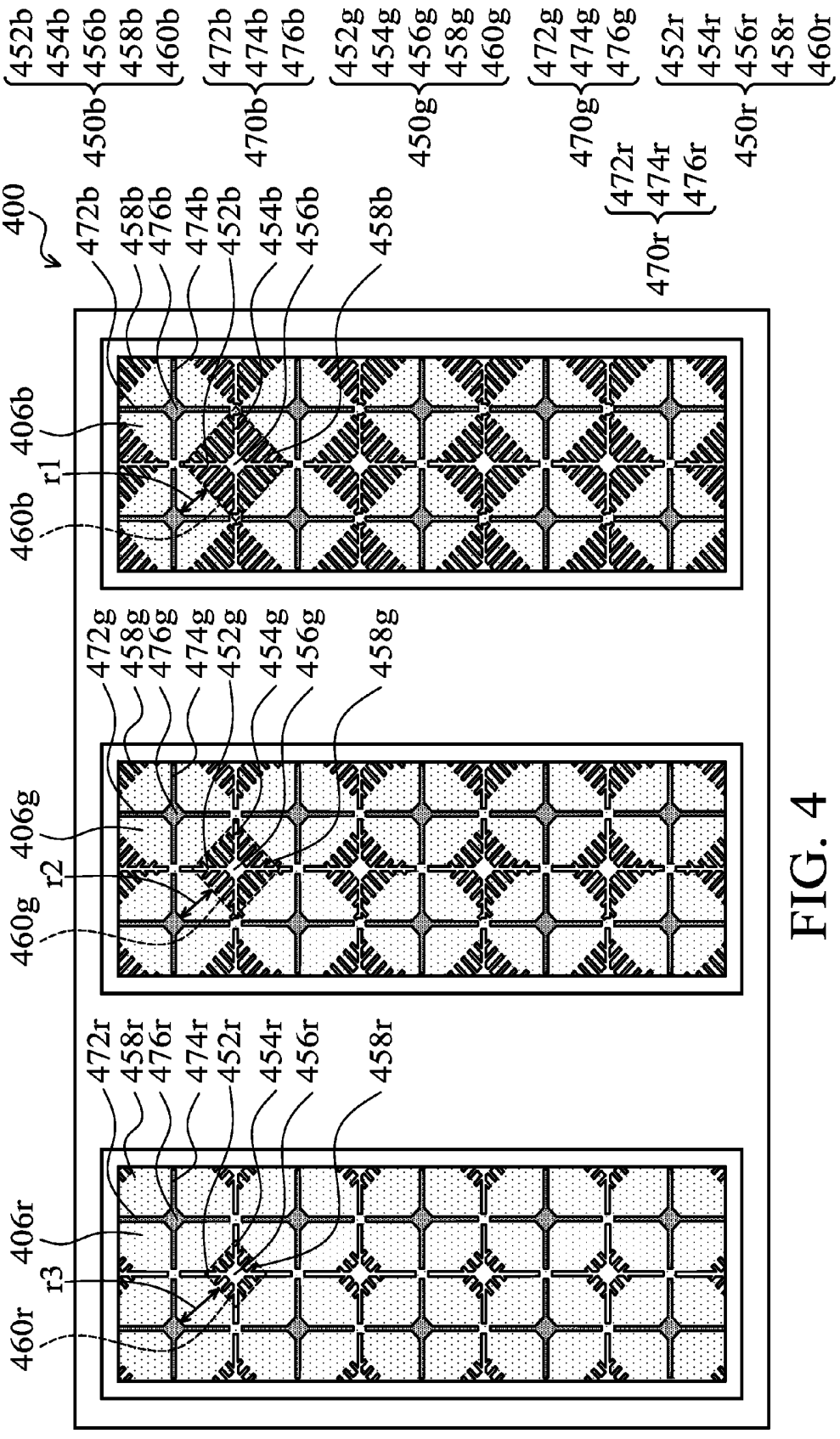
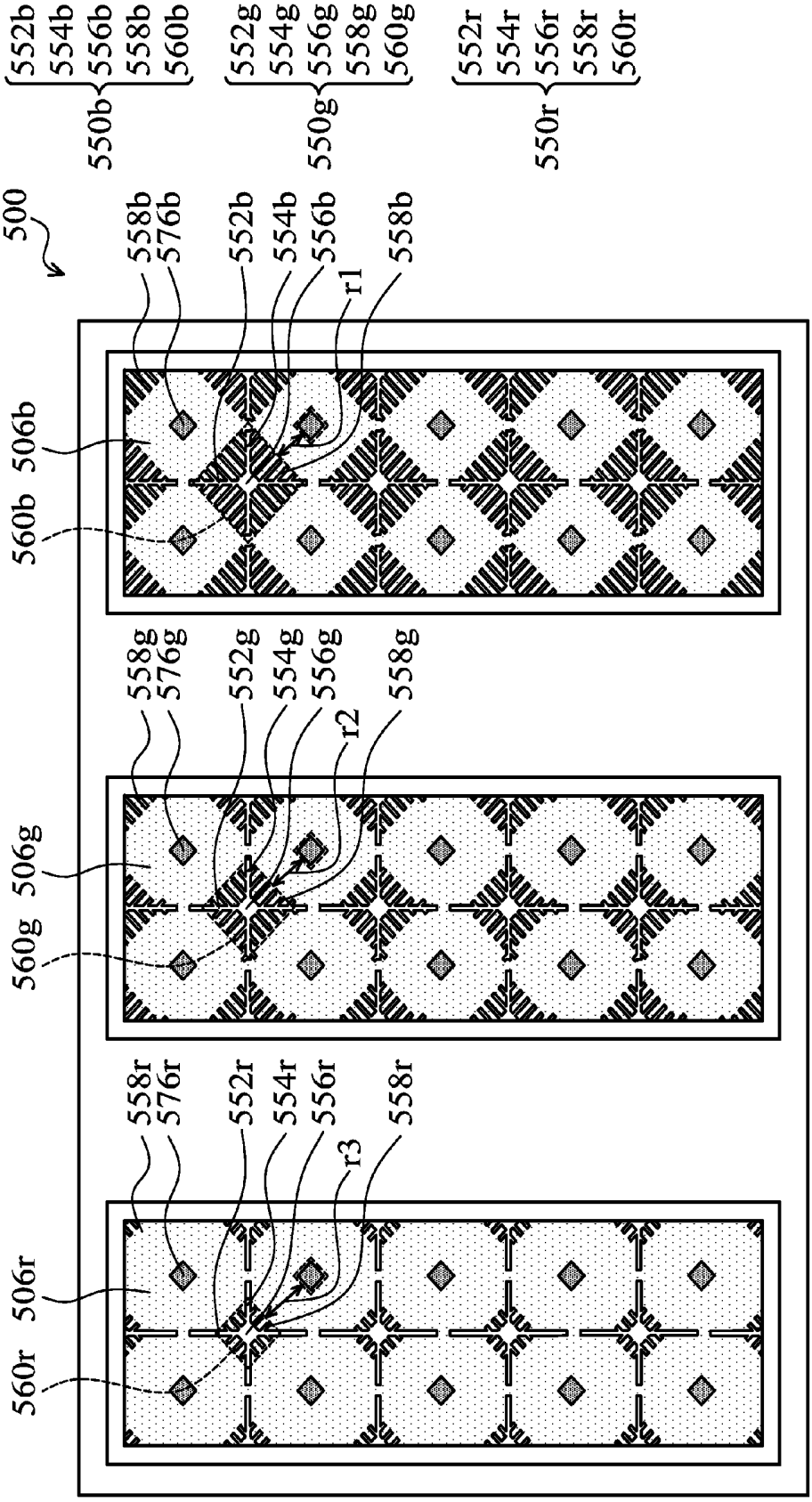

400
450b
452b
454b
456b
458b
460b
470b
472b
474b
476b
450g
452g
454g
456g
458g
460g
470g
472g
474g
476g
450r
452r
454r
456r
458r
460r
470r
472r
474r
476r
406b
r1
406g
r2
406r
r3

FIG. 4


500
552b
554b
556b
558b
560b
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552g
554g
556g
558g
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552r
554r
556r
558r
560r
550r
558b
576b
552b
554b
556b
r1
558b
506b
560b
558g
576g
552g
554g
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r2
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558r
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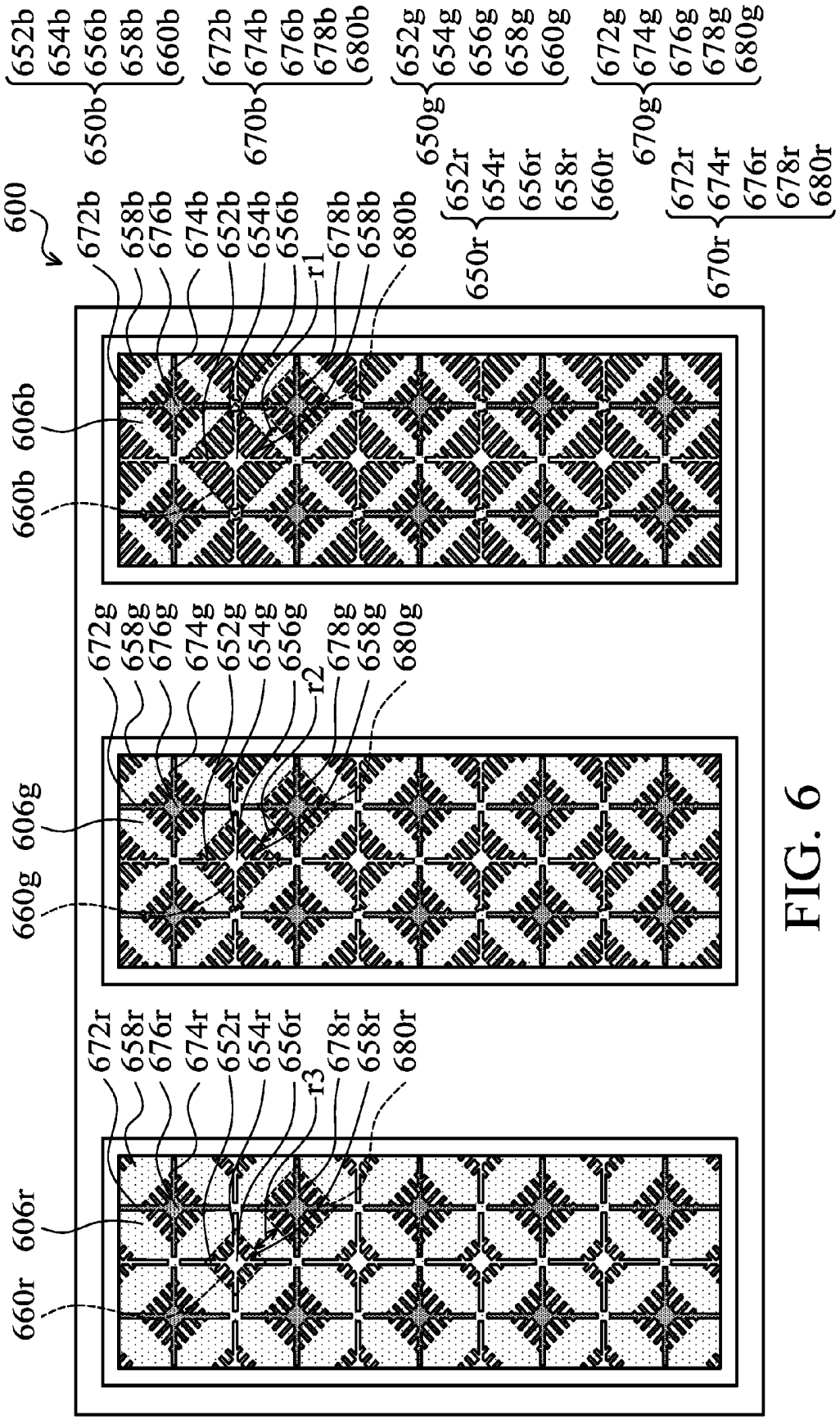
r3
558r
506r
560r

FIG. 5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674b
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678g
680g
650r
652r
654r
656r
658r
660r
670r
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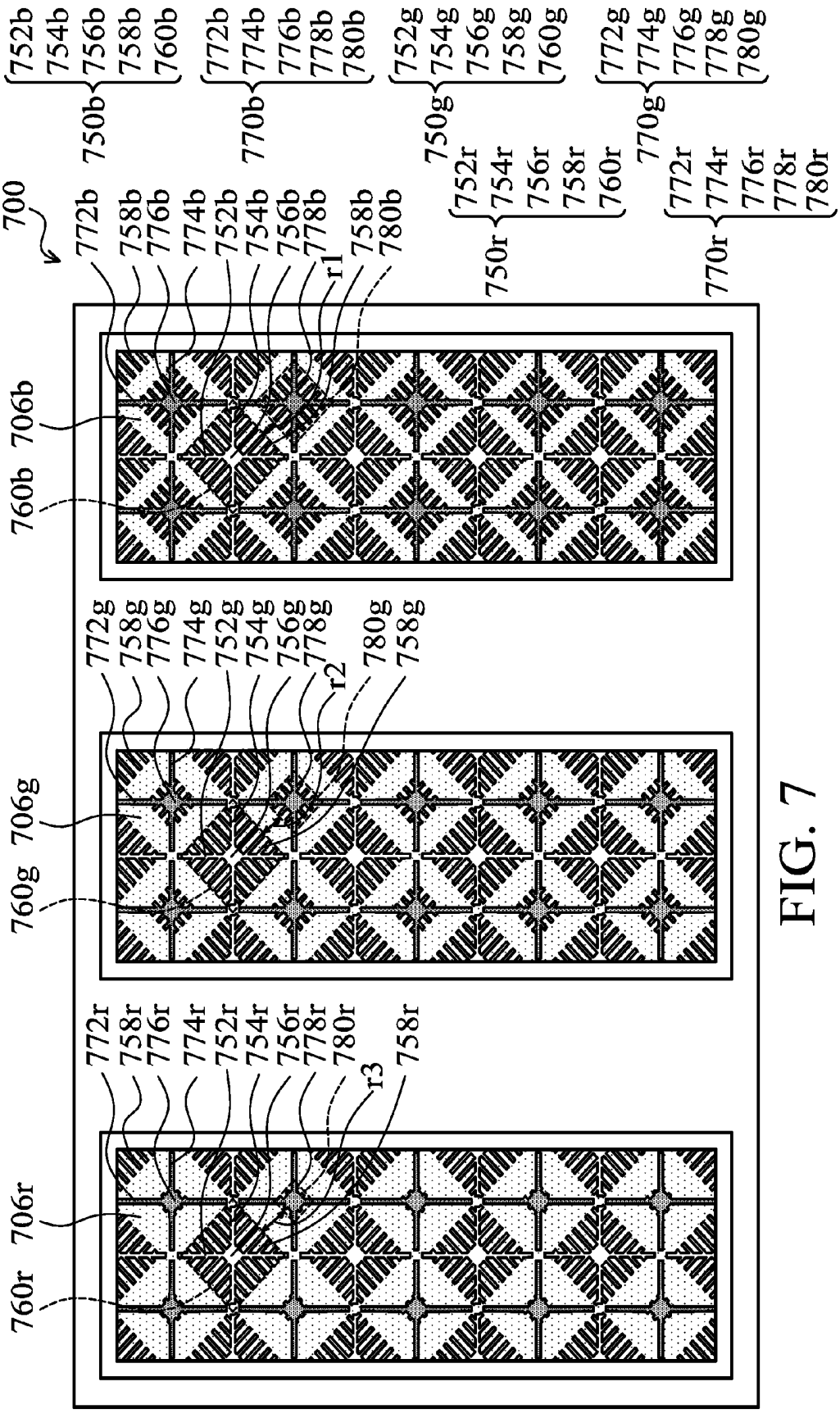
660r
r1
r2
r3

FIG. 6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756b
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756g
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760g
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774g
776g
778g
780g
750r
752r
754r
756r
758r
760r
770r
772r
774r
776r
778r
780r
706b
760b
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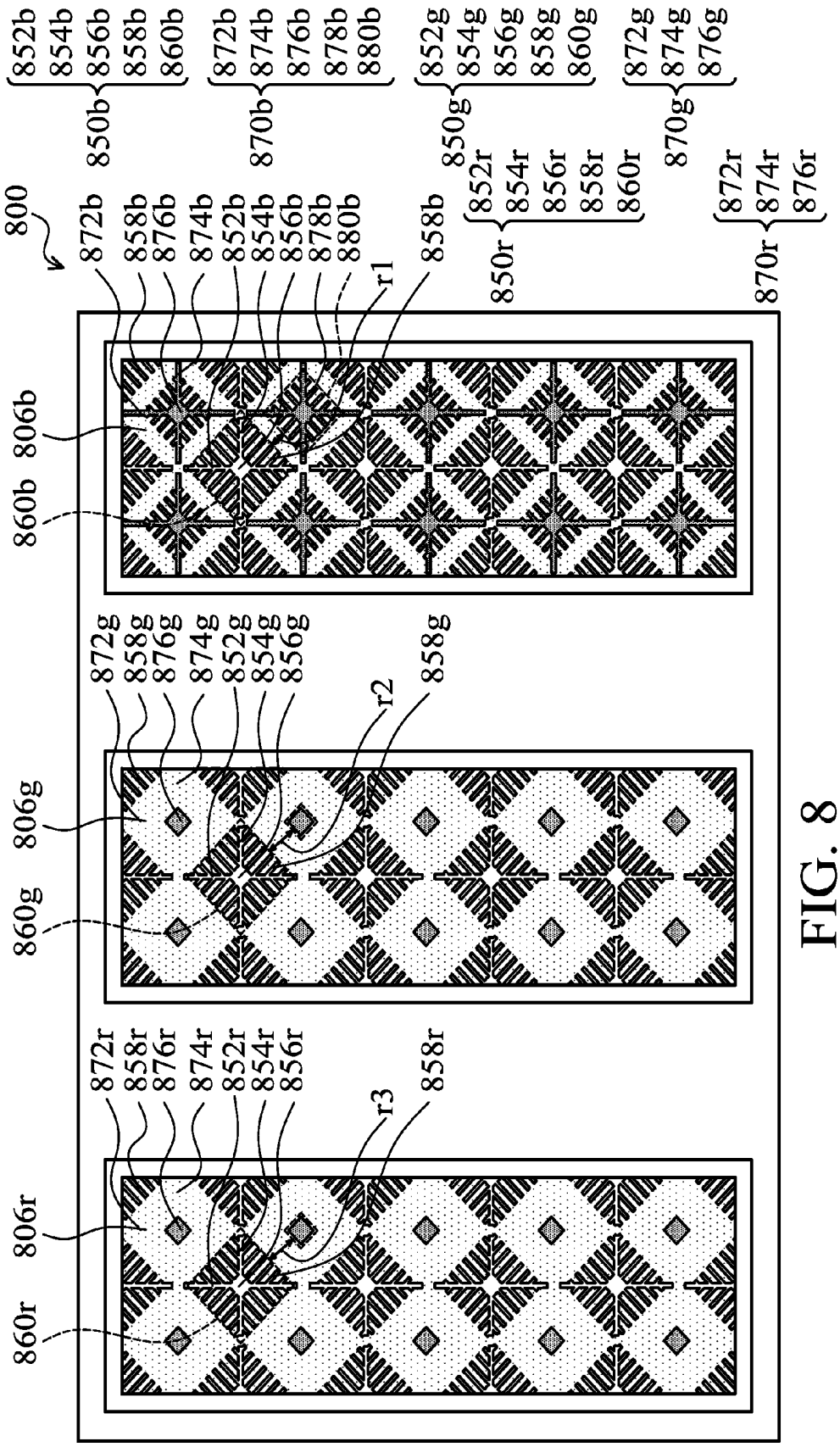
760g
706r
760r
r1
r2
r3

FIG. 7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870g
872g
874g
876g
850r
852r
854r
856r
858r
860r
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874r
876r
806b
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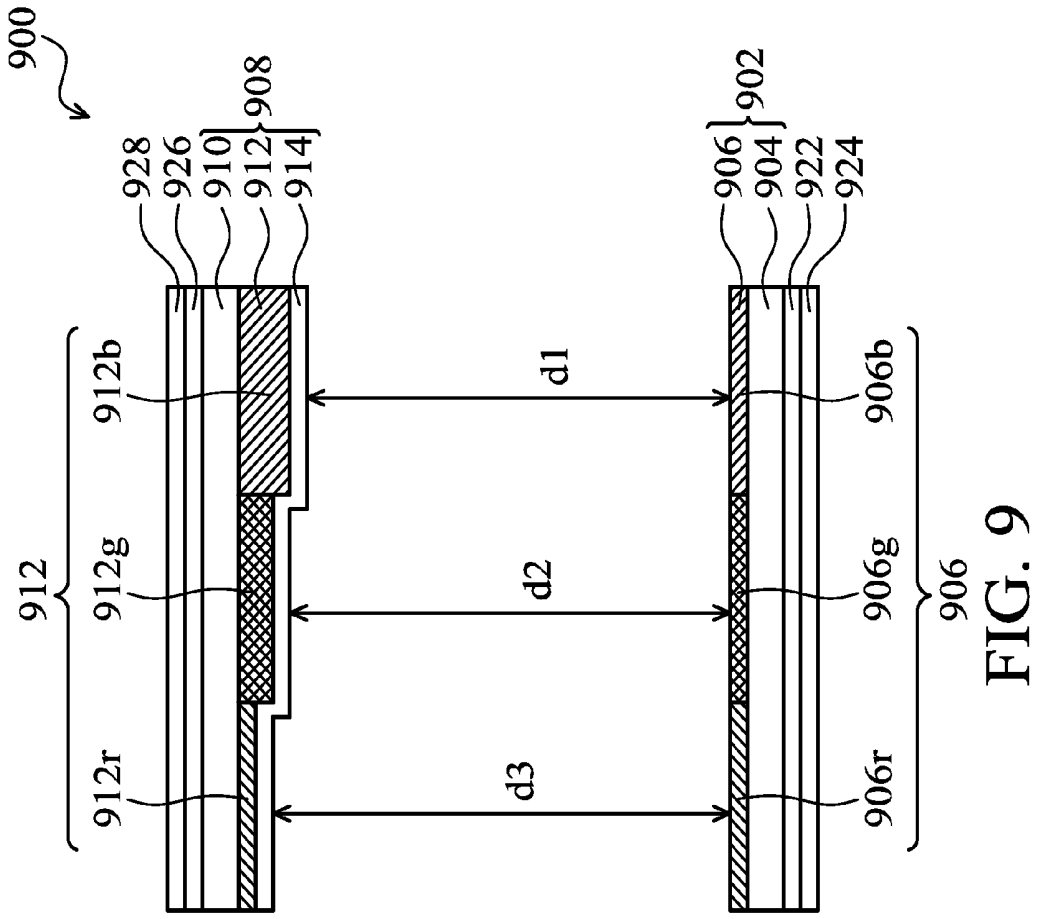
860r
r1
r2
r3

FIG. 8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928
926
910
912
914
908
906
904
922
924
902
912
912b
912g
912r
d1
d2
d3
906b
906g
906r
906

FIG. 9

LIQUID-CRYSTAL DISPLAY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of Taiwan Patent Application No. 101114644, filed on Apr. 25, 2012, the entirety of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present disclosure relates to a liquid-crystal display. More particularly, the present disclosure relates to a liquid-crystal display which may improve grey level inversion.

DESCRIPTION OF THE RELATED ART

[0003] A liquid-crystal display is an imaging device that displays images by controlling light flux because light has different polarization and refraction performances with respect to the arrangements of liquid-crystal molecules. A conventional twisted nematic (TN) liquid-crystal display has good transmittance performance, but it can only have a narrow viewing angle due to the structure and optical properties of the TN type liquid crystal. Thus, to develop a liquid-crystal display which has good transmittance and a wide viewing angle represents breakthrough progress.

[0004] A vertical alignment (VA) type wide-viewing-angle LCD has been developed to solve the aforementioned problems. The VA type LCD comprises a patterned vertical alignment (PVA) type LCD, a multi-domain vertical alignment (MVA) type LCD, and so on. The PVA type LCD achieves the goal of wide-viewing-angle characteristics by applying a fringing-field effect thereto and optical compensation films. The MVA type LCD widens the viewing-angle and improves transmittance of the liquid-crystal display by dividing a pixel area into multi domains and tilting liquid crystals in the multi domains in several different directions using protrusion features or specific patterns.

[0005] However, the current VA type LCD still has shortcomings that need to be addressed. Referring to FIG. **1**, a top view of a liquid-crystal layer of a VA type LCD **100** according to the known art is illustrated. When a voltage is applied to the electrodes, liquid-crystal molecules **102** and **106** tilt respectively in horizontal directions **120**, **130**, and the liquid-crystal molecules **102** and **104** which are arranged in a direction parallel to an electric field (such as parallel to the normal line of the paper) tilt in the same horizontal direction, such as the horizontal direction **120**, without a horizontal twist. Light cannot penetrate through the liquid-crystal molecules **102** and **104** since they are tilted in the same horizontal direction, and therefore the transmittance of the VA type LCD is reduced. In theory, the LCD has 255 grey levels, and higher grey levels should bring higher brightness. However, it is observed that higher grey levels bring lower brightness than lower grey levels when providing a large viewing angle. The black-white inversion phenomenon is called grey level inversion.

[0006] A technique which adds a chiral dopant to the liquid-crystal layer was developed to solve the aforementioned problems. For example, referring to FIG. **2**, a top view of a liquid-crystal layer of a VA type LCD that includes the chiral dopant is illustrated. When a voltage is applied to the electrodes, the liquid-crystal molecules **202** and **206** respectively tilt in horizontal directions **220** and **230**, and the liquid-crystal molecules **202** and **204** which are arranged in a direction parallel to the electric field (such as the direction through the paper) also have different horizontal twists. Accordingly, light can penetrate through the liquid-crystal layer by the birefringence of the liquid-crystal molecules **202** and **204**. In addition, optical dark fringes resulting from the liquid-crystal molecules which are not tilted or tilted in undesired directions can also be narrowed and faded, and therefore the grey level inversion is improved.

[0007] Although the grey level inversion can be improved by doping the chiral dopant to the liquid-crystal layer, the grey level inversion still remains, and it is particularly serious in the blue pixel and/or with an increased gap between the substrate (i.e. the thickness of the liquid-crystal layer). Accordingly, a new technique for improving the transmittance preventing the grey level inversion in the LCD is needed.

BRIEF SUMMARY OF THE INVENTION

[0008] One object of the present disclosure is to provide a liquid-crystal display, including: a first substrate having a first pixel electrode, a second pixel electrode and a third pixel electrode; a second substrate having an opposite electrode, wherein the first pixel electrode has a first overlapping area overlapped with the opposite electrode, the second pixel electrode has a second overlapping area overlapped with the opposite electrode, and the third pixel electrode has a third overlapping area overlapped with the opposite electrode; and a liquid-crystal layer interposed between the first substrate and the second substrate; wherein the first overlapping area is smaller than the second overlapping area, and the first overlapping area is smaller than the third overlapping area.

[0009] Another object of the present disclosure is to provide a vertical alignment liquid-crystal, including: a first substrate having a first pixel electrode, a second pixel electrode and a third pixel electrode; a second substrate having an opposite electrode; and a liquid-crystal layer interposed between the first substrate and the second substrate, wherein the liquid-crystal layer comprises a chiral dopant doped therein; wherein the gap between the first pixel electrode and the second substrate is smaller than the gap between the second pixel electrode and the second substrate, and the gap between the first pixel electrode and the second substrate is smaller than the gap between the third pixel electrode and the second substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

[0011] FIG. **1** shows a top view of a liquid-crystal layer of an LCD according to known art.

[0012] FIG. **2** shows a top view of a liquid-crystal layer of a VA type LCD according to known art.

[0013] FIG. **3** shows a cross-sectional view of an LCD according to an embodiment of the present disclosure.

[0014] FIGS. **4-8** show top views of LCDs according to some embodiments of the present disclosure.

[0015] FIG. **9** shows a cross-sectional view of an LCD according to another embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The following description is of the best-contemplated mode of carrying out the invention. This description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. For example, the formation of a first feature over, above, below, or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. The scope of the invention is best determined by reference to the appended claims.

[0017] It should be understood that although the terms first, second, third, etc., may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer, and/or section from another element, component, region, layer, and/or section. For example, a first element, component, region, layer, and/or section could be termed a second element, component, region, layer, and/or section without departing from the teachings of the example embodiments.

[0018] FIG. **3** shows a cross-sectional view of a liquid-crystal display (LCD) **300** according to an embodiment of the present disclosure. The LCD **300** may be a vertical alignment (VA) type LCD. As shown in FIG. **3**, the LCD **300** may comprise a first substrate **302** and a second substrate **308** opposite and parallel to each other. In an embodiment, the first substrate **302** may be a thin-film transistor (TFT) substrate including a base substrate **304** with at least one first pixel unit **306***b*, at least one second pixel unit **306***g*, and at least one third pixel unit **306***r* disposed thereon. In some embodiments, the first pixel unit **306***b*, the second pixel unit **306***g*, and the third pixel unit **306***r* may be a blue pixel unit **306***b*, a green pixel unit **306***g*, and a red pixel unit **306***r*, respectively. Each of the pixel units may comprise a pixel electrode **306** and a TFT (not shown) disposed on the base substrate **304**. For example, the first pixel unit **306***b*, the second pixel unit **306***g*, and the third pixel unit **306***r* may respectively comprise the first pixel electrode **306***b*, the second pixel electrode **306***g*, and the third pixel electrode **306***r*. A black matrix (not shown) may be disposed between each pixel. In the following sections of the present disclosure, for clarity and understanding, the pixel electrode in the first electrode unit **306***b* is referred as to the blue pixel electrode **306***b*, the pixel electrode in the second pixel **306***g* unit is referred as to the green pixel electrode **306***g*, and the pixel electrode in the third pixel unit **306***r* is referred as to the red pixel electrode **306***r*. However, it is not intended to limit the scope of these pixel electrodes.

[0019] The second substrate **308** may comprise a glass substrate with a color filter **312** and an opposite electrode **314** disposed thereon. The color filter **312** may comprise a blue filter **312***b* with respect to the blue pixel electrode **306***b*, a green filter **312***g* with respect to the green pixel electrode **306***g* and a red filter **312***r* with respect to the red pixel electrode **306***r*. In an embodiment, the blue filter **312***b*, the green filter **312***g*, and the red filter **312***r* may have the same thickness.

[0020] A liquid-crystal layer **320** may be interposed between the first substrate **302** and the second substrate **308**, such as between the pixel electrode **306** and the opposite electrode **314**. The liquid-crystal layer **320** may comprise a twisted nematic liquid-crystal material, for example a negative nematic liquid-crystal or a positive nematic liquid crystal. In an embodiment, chiral active substances, such as chiral dopants, are added in the liquid-crystal layer **320**. Thus, the liquid-crystal molecules of the liquid-crystal layer **320** may twist along an axis, thereby having optical activity, and the axis is parallel to a normal line of the first substrate **302**. In an optional embodiment, the LCD **300** may further comprise a first compensation film **322** and the first polarizer **324** disposed on the first substrate **302**, and may further comprise a second compensation film **326** and a second polarizer **328** disposed on the second substrate **308**.

[0021] FIG. **4** shows a top view of an electrode pattern of an LCD **400** according to an embodiment of the present disclosure. In FIG. **4**, a unit pattern of the pixel electrodes **406***b*, **406***g*, **406***r* on the first substrate **302** and the opposite electrode **314** on the second substrate **308** is illustrated. The cross-sectional view of the LCD **400** may be referred to in FIG. **3**.

[0022] Referring to FIG. **4**, the blue pixel electrode **406***b* may comprise a first hollow portion **450***b*; the green pixel electrode **406***g* may comprise a green hollow portion **450***g*; and the red pixel electrode **406***r* may comprise a red hollow portion **450***r*. The opposite electrode **314** may comprise a fourth hollow portion **470***b* with respect to the blue pixel electrode **406***b*, a fifth hollow portion **470***g* with respect to the green pixel electrode **406***g*, and a sixth hollow portion **470***r* with respect to the red pixel electrode **406***r*. The blue pixel electrode **406***b* and the opposite electrode **314** may have a first overlapping area. In other words, the first overlapping area is an overlapping area of the area of the blue pixel electrode **406***b* with the removal of the area of the first hollow portion **450***b* and the area of the opposite electrode **314** over the blue pixel electrode **406***b* with the removal of the fourth hollow portion **470***b*. Similarly, the green pixel electrode **406***g* and the opposite electrode **314** may have a second overlapping area. The second overlapping area is an overlapping area of the area of the green pixel electrode **406***g* with the removal of the area of the first hollow portion **450***g* and the area of the opposite electrode **314** over the green pixel electrode **406***g* with the removal of the fifth hollow portion **470***g*. The red pixel electrode **406***r* and the opposite electrode **314** may have a third overlapping area. The third overlapping area is an overlapping area of the area of the red pixel electrode **406***r* with the removal of the area of the first hollow portion **450***r* and the area of the opposite electrode **314** over the red pixel electrode **406***r* with the removal of the sixth hollow portion **470***r*.

[0023] The first hollow portion **450***b* may comprise at least one first longitudinal slit area **452***b*, at least one first transverse slit area **454***b* and at least one first cross area **456***b* located at the intersection of the first longitudinal slit area **452***b* and the first transverse slit area **454***b*. The second hollow portion **450***g* may comprise at least one second longitudinal slit area **452***g*, at least one second transverse slit area **454***g*, and at least one second cross area **456***g* located at the intersection of the second longitudinal slit area **452***g* and the second transverse slit area **454***g*. The third hollow portion **450***r* may comprise at least one third longitudinal slit area **452***r*, at least one third transverse slit area **454***r* and at least one third cross area **456***r* located at the intersection of the third longitudinal slit area **452***r* and the third transverse slit area **454***r*. The fourth hollow portion **470***b* may comprise at least one fourth longitudinal slit area **472***b*, at least one fourth

transverse slit area **474***b*, and at least one fourth cross area **476***b* located at the intersection of the fourth longitudinal slit area **472***b* and the fourth transverse slit area **474***b*. The fifth hollow portion **470***g* may comprise at least one fifth longitudinal slit area **472***g*, at least one fifth transverse slit area **474***g*, and at least one fifth cross area **476***g* located at the intersection of the fifth longitudinal slit area **472***g* and the fifth transverse slit area **474***g*. The sixth hollow portion **470***r* may comprise at least one sixth longitudinal slit area **472***r*, at least one sixth transverse slit area **474***r*, and at least one sixth cross area **476***r* located at the intersection of the sixth longitudinal slit area **472***r* and the sixth transverse slit area **474***r*. The first to sixth longitudinal slit areas **452***b*, **452***g*, **452***r*, **472***b*, **472***g*, **472***r* may be substantially perpendicular to the first to sixth transverse slit areas **454***b*, **454***g*, **454***r*, **474***b*, **474***g*, **474***r*. The first to sixth cross areas **456***b*, **456***g*, **456***r*, **476***b*, **476***g*, **476***r* may have various suitable shapes, such as a circle, rectangle or rhombus.

[0024] The first longitudinal slit area **452***b*, the first transverse slit area **454***b*, and the first cross area **456***b*, respectively, may be interleavely arranged with the fourth longitudinal slit area **472***b*, the fourth transverse slit area **474***b* and the fourth cross area **476***b*. The second longitudinal slit area **452***g*, the second transverse slit area **454***g* and the second cross area **456***g*, respectively, may be interleavely arranged with the fifth longitudinal slit area **472***g*, the fifth transverse slit area **474***g* and the fifth cross area **476***g*. The third longitudinal slit area **452***r*, the third transverse slit area **454***r* and the third cross area **456***r*, respectively, may be interleavely arranged with the sixth longitudinal slit area **472***r*, the sixth transverse slit area **474***r* and the sixth cross area **476***r*.

[0025] In an embodiment, each of the first to sixth cross areas **456***b*, **456***g*, **456***r*, **476***b*, **476***g*, **476***r* may have an area substantially greater than the overlapping area of one intersection of these longitudinal and transverse slit areas. In some embodiments, the fourth to sixth longitudinal slit areas **472***b*, **472***g*, **472***r* may respectively extend over the fourth to sixth cross areas **476***b*, **476***g*, **476***r*. Similarly, the fourth to sixth transverse slit areas **474***b*, **474***g*, **474***r* may respectively extend over the fourth to sixth cross areas **476***b*, **476***g*, **476***r*.

[0026] The first hollow portion **450***b* may further comprise at least one first finger-type extension area **458***b*. The first finger-type extension area **458***b* may comprise a plurality of separated finger-type electrodes extending around from the first longitudinal slit area **452***b*, the first transverse slit area **454***b* and the first cross section **456***b*, such that the first hollow portion **450***b* may comprise at least one first rhombus hollow portion **460***b* (shown as the dotted line) having a substantially rhombus shape with a center located at the first cross area **456***b*. The second hollow portion **450***g* may further comprise at least one second finger-type extension area **458***g*. The second finger-type extension area **458***g* may comprise a plurality of separated finger-type electrodes extending around from the second longitudinal slit area **452***g*, the second transverse slit area **454***g* and the second cross section **456***g*, such that the second hollow portion **450***g* may comprise at least one second rhombus hollow portion **460***g* (shown as the dotted line) which has a substantially rhombus shape with a center located at the second cross area **456***g*. The third hollow portion **450***r* may further comprise at least one third finger-type extension area **458***r*. The third finger-type extension area **458***r* may comprise a plurality of separated finger-type electrodes extending around from the third longitudinal slit area **452***r*, the third transverse slit area **454***r*, and the third cross section **456***r*, such that the third hollow portion **450***r* may comprise at least one third rhombus hollow portion **460***r* (shown as the dotted line) which has a substantially rhombus shape with a center located at the third cross area **456***r*.

[0027] In an embodiment, the pixel electrodes **406***b*, **406***g*, **406***r* may generate a fringing electric field due to the presence of the first to sixth hollow portions **450***b*, **450***g*, **450***r*, **470***b*, **470***g*, **470***r* (including the first to third rhombus hollow portions **460***b*, **460***g* **460***r*), and thus the pixel electrodes **406***b*, **406***g*, **406***r* and the opposite electrode **314** may control the liquid-crystal layer **320** more precisely.

[0028] Referring to FIG. **4** again, a distance from a side of the first rhombus hollow portion **460***b* to its adjacent fourth cross section area **456***b* is defined as the first distance **r1**. A distance from a side of the second rhombus hollow portion **460***g* to its adjacent fifth cross section area **456***g* is defined as the second distance **r2**. A distance from a side of the third rhombus hollow portion **460***r* to its adjacent sixth cross section area **456***r* is defined as the third distance **r3**. The first distance **r1** may be less than the second distance **r2** and the third distance **r3**. This is because the first rhombus hollow portion **460***b* has an area greater than that of the second and third rhombus hollow portions **460***g*, **460***r*.

[0029] In this embodiment, by defining the first distance **r1** as being less than the second distance **r2** and the third distance **r3**, the first overlapping area of the blue pixel electrode **406***b* and the opposite electrode **314** may be smaller than the second overlapping area and the third overlapping area. The grey level inversion in the blue pixel unit **406***b* can therefore be improved. In addition, since the grey level inversion in the green and red pixel units **406***g*, **406***r* is relatively minor compared to that in the blue pixel unit **406***b*, the green and red pixel electrodes **406***g*, **406***r* may have a relatively greater overlapping area with the opposite electrode **314** so as to achieve a better transmittance. In addition, although FIG. **4** only shows that the second overlapping area of the green pixel electrode **406***b* and opposite electrode **314** is smaller than the third overlapping area of the red pixel electrode **406***r* and opposite electrode **314**, in other embodiments, the second overlapping area can be substantially equal to the third overlapping area (i.e., the second distance **r2** being substantially equal to the third distance **r3**) for achieving much better transmittance.

[0030] FIG. **5** shows a top view of an electrode pattern of an LCD **500** according to an embodiment of the present disclosure. In FIG. **5**, a unit pattern of the pixel electrodes **506***b*, **506***g*, **506***r* on the first substrate **302** and the opposite electrode **314** on the second substrate **308** is illustrated. The cross-sectional view of the LCD **500** may be referred to in FIG. **3**. In this embodiment, like reference numerals are used to indicate elements substantially similar to the elements described in the above embodiments.

[0031] This embodiment is similar to the embodiment shown in FIG. **4**. For example, the first rhombus hollow portion **560***b* of the blue pixel electrode **506***b* may have a greater area than that of the second rhombus hollow portion **560***g* of the green pixel electrode **506***g* and the third rhombus hollow portion **560***r* of the red pixel electrode **506***r* (i.e., the first distance **r1** is less than the second distance **r2** and the third distance **r3**). However, it should be noted that, in this embodiment, the fourth to sixth hollow portions **560***b*, **560***g*, **560***r* on the opposite electrode **314** does not have the fourth to sixth longitudinal slit areas and the fourth to sixth transverse slit areas as shown in FIG. **4**. Thus, in this embodiment, the

fourth to sixth hollow portions are the fourth to sixth cross areas **576***b*, **576***g*, **576***r*. In addition, although FIG. **5** only shows that the fourth to sixth cross areas **576***b*, **576***g*, **576***r* have a rhombus shape, other shapes such as rectangles, circles or ovals can be used. In this embodiment, the fourth to sixth cross areas **576***b*, **576***g*, **576***r* may have the same size and area so as to have a first overlapping area smaller than the second overlapping area and the third overlapping area.

[0032] FIG. **6** shows a top view of an electrode pattern of an LCD **600** according to an embodiment of the present disclosure. A unit pattern of the pixel electrodes **606***b*, **606***g*, **606***r* on the first substrate **302** and the opposite electrode **314** on the second substrate **308** is illustrated in FIG. **6**. The cross-sectional view of the LCD **600** may be referred to in FIG. **3**. In this embodiment, like reference numerals are used to indicate elements substantially similar to the elements described in the above embodiments.

[0033] This embodiment is similar to the embodiment shown in FIG. **4**. For example, the first rhombus hollow portion **660***b* of the blue pixel electrode **606***b* may have a greater area than that of the second rhombus hollow portion **660***g* of the green pixel electrode **606***g* and the third rhombus hollow portion **660***r* of the red pixel electrode **606***r*. However, it should be noted that, in this embodiment, the fourth hollow portion **670***b* may further comprise at least one fourth finger-type extension area **678***b*. The fourth finger-type extension area **678***b* may comprise a plurality of separated finger-type electrodes extending around from the fourth longitudinal slit area **672***b*, the fourth transverse slit area **674***b*, and the fourth cross section **676***b*, such that the fourth hollow portion **670***b* may comprise at least one fourth rhombus hollow portion **680***b* having a substantially rhombus shape with a center located at the fourth cross area **676***b*. The fifth hollow portion **670***g* may further comprise at least one fifth finger-type extension area **678***g*. The fifth finger-type extension area **678***g* may comprise a plurality of separated finger-type electrodes extending around from the fifth longitudinal slit area **672***g*, the fifth transverse slit area **674***g*, and the fifth cross section **676***g*, such that the fifth hollow portion **670***g* may comprise at least one fifth rhombus hollow portion **680***g* which has a substantially rhombus shape with a center located at the fifth cross area **676***g*. The sixth hollow portion **670***r* may further comprise at least one sixth finger-type extension area **678***r*. The sixth finger-type extension area **678***r* may comprise a plurality of separated finger-type electrodes extending around from the sixth longitudinal slit area **672***r*, the sixth transverse slit area **674***r* and the sixth cross section **676***r*, such that the sixth hollow portion **670***r* may comprise at least one sixth rhombus hollow portion **680***r* which has a substantially rhombus shape with a center located at the sixth cross area **676***r*.

[0034] In this embodiment, the distance from a side of the first rhombus hollow portion **660***b* to its adjacent fourth cross section area **656***b* is defined as the first distance **r1**. The distance from a side of the second rhombus hollow portion **660***g* to its adjacent fifth cross section area **656***g* is defined as the second distance **r2**. The distance from a side of the third rhombus hollow portion **660***r* to its adjacent sixth cross section area **656***r* is defined as the third distance **r3**. The first distance **r1** may be less than the second distance **r2** and the third distance **r3**. This is because the first rhombus hollow portion **670***b* has an area larger than that of the second and third rhombus hollow portions **680***g*, **680***r*. In an embodiment, the second rhombus hollow portions **680***g* may have an area less than that of the third rhombus hollow portions **680***r* for improving the grey level inversion in the green pixel unit **606***g*. Moreover, in other embodiments, the second rhombus hollow portions **680***g* may have an area substantially equal to that of the third rhombus hollow portions **680***r* if better transmittance is needed.

[0035] In this embodiment, the fourth to sixth longitudinal slit areas **672***b*, **672***g*, **672***r* may respectively extend over the fourth to sixth cross areas **676***b*, **676***g*, **676***r*. Similarly, the fourth to sixth transverse slit areas **674***b*, **674***g*, **674***r* may extend over the fourth to sixth cross areas **676***b*, **676***g*, **676***r*, respectively. In an optional embodiment, each of the fourth to sixth longitudinal and transverse slit areas **6742**, **672***g*, **672***r*, **674***b*, **674***g*, **674***r* may be comprised in the fourth to sixth cross areas **676***b*, **676***g*, **676***r* and may not extend over them.

[0036] FIG. **7** shows a top view of an electrode pattern of an LCD **700** according to an embodiment of the present disclosure. In FIG. **6**, a unit pattern of the pixel electrodes **706***b*, **706***g*, **706***r* on the first substrate **302** and the opposite electrode **314** on the second substrate **308** is illustrated. The cross-sectional view of the LCD **600** may be referred to in FIG. **3**. In this embodiment, like reference numerals are used to indicate elements substantially similar to the elements described in the above embodiments.

[0037] This embodiment is similar to the embodiment shown in FIG. **6**. However, in this embodiment, the first rhombus hollow portion **760***b*, the second rhombus hollow portion **760***g*, and the third rhombus hollow portion **760***r* may have the same size and shape, and the fourth rhombus hollow portion **780***b* may have an area greater than that of the second rhombus hollow portion **780***b* and the third rhombus hollow portion **780***r*. Thus, the first distance **r1** may be less than the second distance **r2** and the third distance **r3**. The first overlapping area of the blue pixel electrode **706***b* and the opposite electrode **314** may be smaller than that of the second overlapping area of the green pixel electrode **706***g* and the opposite electrode **314** and the third overlapping area of red pixel electrode **760***r* and the opposite electrode **314**. In an embodiment, the fifth rhombus hollow portion **780***g* may have an area smaller than that of the sixth rhombus hollow portion for improving the grey level inversion in the green pixel unit **706***g*. In other embodiments, the fifth rhombus hollow portions **780***g* may have an area substantially equal to that of the sixth rhombus hollow portions **780***r* if better transmittance is needed.

[0038] FIG. **8** shows a top view of an electrode pattern of an LCD **800** according to an embodiment of the present disclosure. In FIG. **8**, a unit pattern of the pixel electrodes **806***b*, **806***g*, **806***r* on the first substrate **302** and the opposite electrode **314** on the second substrate **308** is illustrated. The cross-sectional view of the LCD **800** may be referred to in FIG. **3**. In this embodiment, like reference numerals are used to indicate elements substantially similar to the elements described in the above embodiments.

[0039] This embodiment is similar to the embodiment shown in FIG. **7**. However, in this embodiment, the fourth rhombus hollow portion **880***b*, the fifth rhombus hollow portion **880***g* and the sixth rhombus hollow portion **880***r* may have the same or different sizes and shapes. For example, referring to FIG. **8**, the fifth hollow portion may comprise the fifth longitudinal slit area **872***g*, the fifth transverse slit area **874***g*, and the fifth cross area **876***g*. The sixth hollow portion may comprise the sixth longitudinal slit area **872***r*, the fifth transverse slit area **874** and the fifth cross area **876***r*. Com-

pared to the fifth and six rhombus hollow portions **880***g*, **880***r*, the fourth rhombus hollow portion **880***b* may further comprise a fourth finger-type extension area **878***b*. For example, the fourth rhombus hollow portion **880***b* may comprise the fourth longitudinal slit area **872***b*, the fourth transverse slit area **874***b*, the fourth cross area **876***b* and the fourth finger-type extension area **878***b*. The fourth finger-type extension area **878***b* may comprise a plurality of separated finger-type electrodes. The fourth cross area **876***b*, the fifth cross area **876***g* and the sixth cross area **876***r* may have the same size and shape. Thus, the blue pixel electrode **806***b* and the opposite electrode **314** may have a first overlapping area smaller than the second overlapping area of the green pixel electrode **806***g* and the opposite electrode **314** and the third overlapping area of the red pixel electrode **806***r* and the opposite electrode **314**.

[0040] In an embodiment, the fifth and sixth hollow portions **870***g*, **870***r* may have a shape different from that of the fourth hollow portion **870***b*. Alternatively, the fifth and sixth hollow portions **870***g*, **870***r* may have different shapes from each other. In other embodiments, the fifth hollow portion **870***g* may have an area smaller than or equal to that of the sixth hollow portion **870***r*.

[0041] FIG. **9** shows a cross-sectional view of an LCD **900** according to an embodiment of the present disclosure. In an embodiment, the LCD **900** may be a VA type LCD. In some embodiments, the first substrate **902** may be a TFT substrate which comprises a base substrate **902** with at least one first pixel unit **906***b*, at least one second pixel unit **906***g*, and at least one pixel electrode **906***r* disposed thereon. In an embodiment, the first pixel unit **906***b*, the second pixel unit **906***g*, and the third pixel unit **906***r* may be the blue pixel unit **906***b*, the green pixel unit **906***g*, and the red pixel unit **906***r*, respectively. Each pixel unit may have a pixel electrode **906** and a thin-film transistor (not shown) disposed on the base substrate. For example, the first pixel unit **906***b*, the second pixel unit **906***g* and the third pixel unit **906***r* may respectively comprise the first pixel electrode **906***b*, the second pixel electrode **906***g*, and the third pixel electrode **906***r*. The pixel electrode **906** may be formed of any suitable transparent conductive material. A black matrix (not shown) may be disposed between each pixel. In the following sections of the present disclosure, for clarity and understanding, the pixel electrode in the first electrode unit **906***b* is referred as to the blue pixel electrode **906***b*, the pixel electrode in the second pixel unit is referred as to the green pixel electrode **906***g*, and the pixel electrode in the third pixel unit is referred as to the red pixel electrode **906***r*. However, this is not intended to limit the scope of these pixel electrodes.

[0042] The second substrate **908** may be a glass substrate with an opposite electrode **914** and a color filter **912** may be disposed thereon. A liquid-crystal layer (not shown) may be interposed between the first substrate **902** and the second substrate **908**, such as between the pixel electrode **906** and the opposite electrode **914**. The liquid-crystal layer may comprise a twisted nematic liquid-crystal material, for example, a negative nematic liquid-crystal or a positive nematic liquid crystal. In an embodiment, chiral active substances, such as chiral dopants, may be added to the liquid-crystal layer. Thus, the liquid-crystal molecules of the liquid-crystal layer may twist along an axis, thereby having optical activity, and the axis is parallel to a normal line of the first substrate **902**.

[0043] The color filter **912** may comprise a blue filter **912***b* with respect to the blue pixel electrode **906***b*, a green filter **912***g* with respect to the green pixel electrode **906***g*, and a red filter **912***r* with respect to the red pixel electrode **906***r*. The blue filter **912***b*, the green filter **912***g* and the red filter **912***r* may have different thicknesses. For example, the blue filter **912***b* may have a thickness greater than that of the green filter **912***g* and the red filter **912***r*. Since the opposite electrode **914** is conformally formed on the color filter **912**, the gap d**1** between the blue pixel electrode **906***b* and the opposite electrode **914** may be smaller than the gap d**2** between the green pixel electrode **906***g* and the gap d**3** between the red pixel electrode **906***r* and the opposite electrode **914**. Thus, the grey level inversion in the blue pixel unit **906***b* may be improved. It should be noted that the LCD **900** may also comprise any one of the electrode patterns shown in FIGS. **4-8**, for improving the grey level inversion in the blue pixel unit electrode without sacrificing transmittance.

[0044] While the preferred embodiments of the invention have been described above, it will be recognized and understood that various modifications can be made to the invention and the appended claims are intended to cover all such modifications which may fall within the spirit and scope of the invention.

What is claimed is:

1. A liquid-crystal display, comprising:

a first substrate having a first pixel electrode, a second pixel electrode and a third pixel electrode;

a second substrate having an opposite electrode, wherein the first pixel electrode has a first overlapping area overlapped with the opposite electrode, the second pixel electrode has a second overlapping area overlapped with the opposite electrode, and the third pixel electrode has a third overlapping area overlapped with the opposite electrode; and

a liquid-crystal layer interposed between the first substrate and the second substrate;

wherein the first overlapping area is smaller than the second overlapping area, and the first overlapping area is smaller than the third overlapping area.

2. The liquid-crystal display according to claim **1**, wherein the first pixel electrode comprises a first hollow portion, the second pixel electrode comprises a second hollow portion and the third pixel electrode comprises a third hollow portion, wherein the opposite electrode has a fourth hollow portion with respect to the first hollow portion, a fifth hollow portion with respect to the second hollow portion, and a sixth hollow portion with respect to the third hollow portion.

3. The liquid-crystal display according to claim **2**, wherein the area of the first hollow portion is greater than the area of the second hollow portion, and the area of the first hollow portion is greater than the area of the third hollow portion.

4. The liquid-crystal display according to claim **2**, wherein the area of the fourth hollow portion is greater than the area of the fifth hollow portion, and the area of the fourth hollow portion is greater than the area of the sixth hollow portion.

5. The liquid-crystal display according to claim **2**, wherein the first hollow portion comprises at least one first longitudinal slit area, at least one first transverse slit area, and at least one first cross area located at the intersection of the first longitudinal slit area and the first transverse slit area; the second hollow portion comprises at least one second longitudinal slit area, at least one second transverse slit area, and at least one second cross area located at the intersection of the second longitudinal slit area and the second transverse slit area; the third hollow portion comprises at least one third longitudinal slit area, at least one third transverse slit area and

at least one third cross area located at the intersection of the third longitudinal slit area and the third transverse slit area; the fourth hollow portion comprises at least one fourth longitudinal slit area, at least one fourth transverse slit area and at least one fourth cross area located at the intersection of the fourth longitudinal slit area and the fourth transverse slit area; the fifth hollow portion comprises at least one fifth longitudinal slit area, at least one fifth transverse slit area and at least one fifth cross area located at the intersection of the fifth longitudinal slit area and the fifth transverse slit area; and the sixth hollow portion comprises at least one sixth longitudinal slit area, at least one sixth transverse slit area and at least one sixth cross area located at the intersection of the sixth longitudinal slit area and the sixth transverse slit area.

6. The liquid crystal display according to claim **5**, wherein the first longitudinal slit area is interleavely arranged with the fourth longitudinal slit area, the first transverse slit area is interleavely arranged with the fourth transverse slit area, and the first cross area is interleavely arranged with the fourth cross area; the second longitudinal slit area is interleavely arranged with the fifth longitudinal slit area, the second transverse slit area is interleavely arranged with the fifth transverse slit area, and the second cross area is interleavely arranged with the fifth cross area; and the third longitudinal slit area is interleavely arranged with the sixth longitudinal slit area, the third transverse slit area is interleavely arranged with the sixth transverse slit area, and the third cross area is interleavely arranged with the sixth cross area.

7. The liquid-crystal display according to claim **6**, wherein the first hollow portion further comprises at least one first finger-type extension area extending around from the first longitudinal slit area, the first transverse slit area, and the first cross section such that the first hollow portion comprises at least one first rhombus hollow portion which has a substantially rhombus shape with a center located at the first cross area; the second hollow portion further comprises at least one second finger-type extension area extending around from the second longitudinal slit area, the second transverse slit area and the second cross section such that the second hollow portion comprises at least one second rhombus hollow portion which has a substantially rhombus shape with a center located at the second cross area; and the third hollow portion further comprises at least one third finger-type extension area extending around from the third longitudinal slit area, the third transverse slit area and the third cross section such that the third hollow portion comprises at least one third rhombus hollow portion which has a substantially rhombus shape with a center located at the third cross area, and wherein the first finger-type extension area, the second finger-type extension area and the third finger type extension area further comprise finger-type electrodes.

8. The liquid-crystal display according to claim **7**, wherein the distance from a side of the first rhombus hollow portion to its adjacent fourth cross section area is less than the distance from a side of the second rhombus hollow portion to its adjacent fifth cross section area, the distance from a side of the first rhombus hollow portion to its adjacent fourth cross section area is less than and the distance from a side of the third rhombus hollow portion to its adjacent sixth cross section area.

9. The liquid-crystal display according to claim **7**, wherein the fourth hollow portion further comprises at least one fourth finger-type extension area extending around from the fourth longitudinal slit area, the fourth transverse slit area, and the fourth cross section such that the fourth hollow portion comprises at least one fourth rhombus hollow portion which has a substantially rhombus shape with a center located at the fourth cross area; the fifth hollow portion further comprises at least one fifth finger-type extension area extending around from the fifth longitudinal slit area, the fifth transverse slit area and the fifth cross section such that the fifth hollow portion comprises at least one fifth rhombus hollow portion which has a substantially rhombus shape with a center located at the fifth cross area; and the sixth hollow portion further comprises at least one sixth finger-type extension area extending around from the sixth longitudinal slit area, the sixth transverse slit area, and the sixth cross section such that the sixth hollow portion comprises at least one sixth rhombus hollow portion which has a substantially rhombus shape with a center located at the sixth cross area, and wherein the fourth finger-type extension area, the fifth finger-type extension area, and the sixth finger type extension area further comprise finger-type electrodes.

10. The liquid-crystal display according to claim **9**, wherein the distance from a side of the first rhombus hollow portion to its adjacent fourth cross section area is less than the distance from a side of the second rhombus hollow portion to its adjacent fifth cross section area, the distance from a side of the first rhombus hollow portion to its adjacent fourth cross section area is less than and the distance from a side of the third rhombus hollow portion to its adjacent sixth cross section area.

11. The liquid-crystal display according to claim **10**, wherein the area of the first rhombus hollow portion is equal to the area of the second rhombus hollow portion, and the area of the first rhombus hollow portion is equal to the area of the third rhombus hollow portion.

12. The liquid-crystal display according to claim **10**, wherein the area of the fourth rhombus hollow portion is equal to the area of the fifth rhombus hollow portion, and the area of the fourth rhombus hollow portion is equal to the area of the fifth rhombus hollow portion the sixth rhombus hollow portion.

13. The liquid-crystal display according to claim **1**, wherein the liquid-crystal layer comprises a chiral dopant doped therein.

14. The liquid-crystal display according to claim **1**, wherein the second overlapping area is smaller than the third overlapping area.

15. The liquid-crystal display according to claim **1**, wherein the first pixel electrode locates at a blue pixel unit, the second pixel electrode locates at a green pixel unit, and the third pixel electrode locates at a red pixel unit.

16. The liquid-crystal display according to claim **1**, wherein the gap between the first pixel electrode and the second substrate is smaller than the gap between the second pixel electrode and the second substrate, and the gap between the second pixel electrode and the second substrate is smaller than the gap between the third pixel electrode and the second substrate.

17. A vertical alignment liquid-crystal, comprising:

a first substrate having a first pixel electrode, a second pixel electrode and a third pixel electrode;

a second substrate having an opposite electrode; and

a liquid-crystal layer interposed between the first substrate and the second substrate, wherein the liquid-crystal layer comprises a chiral dopant doped therein;

wherein the gap between the first pixel electrode and the second substrate is smaller than the gap between the second pixel electrode and the second substrate, and the gap between the first pixel electrode and the second substrate is smaller than the gap between the third pixel electrode and the second substrate.

18. The vertical alignment liquid-crystal according to claim **17**, wherein the second substrate further comprises a color filter which comprises a blue filter with respect to the first pixel electrode, a green filter with respect to the second pixel electrode and a red filter with respect to the third pixel electrode, and wherein the blue filter has a thickness greater than that of the green filter and the red filter.

19. The vertical alignment liquid-crystal according to claim **17**, wherein the gap between the second pixel electrode and the second substrate is smaller than the gap between the third pixel electrode and the second substrate.

* * * * *

专利名称(译)	液晶显示器		
公开(公告)号	US20130286328A1	公开(公告)日	2013-10-31
申请号	US13/794556	申请日	2013-03-11
[标]申请(专利权)人(译)	群创光电股份有限公司		
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摘要(译)

提供一种液晶显示器的实施例，包括：第一基板，具有第一像素电极，第二像素电极和第三像素电极;具有相对电极的第二基板，其中第一像素电极，第二像素电极和第三像素电极分别具有第一重叠区域，第二重叠区域和与相对电极重叠的第三重叠区域，并且其中第一重叠区域小于第二重叠区域和第三重叠区域;以及插入在第一基板和第二基板之间的液晶层。此外，还提供了液晶显示器的另一实施例，其中第一像素电极，第二像素电极和第三像素电极分别与相对电极具有不同的间隙。