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Yoshida et al.

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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

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G02F 1/139 (2006.01)

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(2013.01); **G02F 1/134309** (2013.01); **G02F**
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G02F 1/136227 (2013.01)

USPC **349/129**; **349/139**

(58) **Field of Classification Search**

USPC **349/129**

See application file for complete search history.

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Primary Examiner — Richard Kim

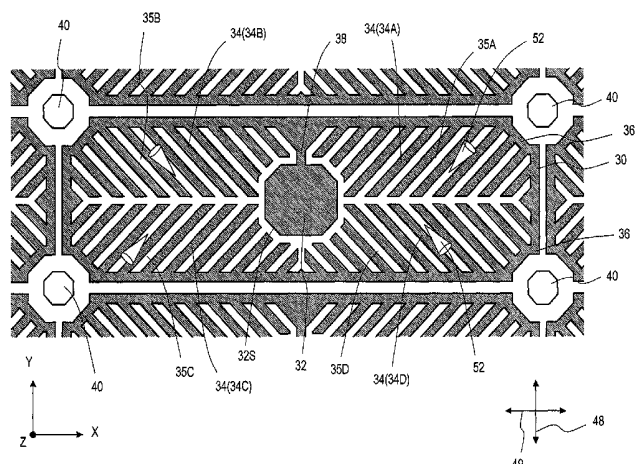
Assistant Examiner — Kendrick Hsu

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(57) **ABSTRACT**

The present invention has an object of providing a liquid crystal display device having a high transmittance or a high viewing angle characteristic. A liquid crystal display device according to the present invention includes a pixel electrode (30) including a peripheral portion (36), an island portion (32) and a plurality of branch portions (34). The plurality of branch portions (34) are formed of a plurality of first through fourth branch portions (34A through 34D) respectively extending in first through fourth directions. By these branch portions, first through fourth regions (35A through 35D) in which liquid crystal molecules are aligned in different directions from each other at the time of voltage application are formed. The island portion (32) is surrounded by the first through fourth regions (35A through 35D), and is connected to the peripheral portion (36) by a connection portion (38) but not by any of the plurality of branch portions (34) or connected to the peripheral portion (36) by one of the first through fourth branch portions (34A through 34D).

28 Claims, 32 Drawing Sheets



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FIG. 1

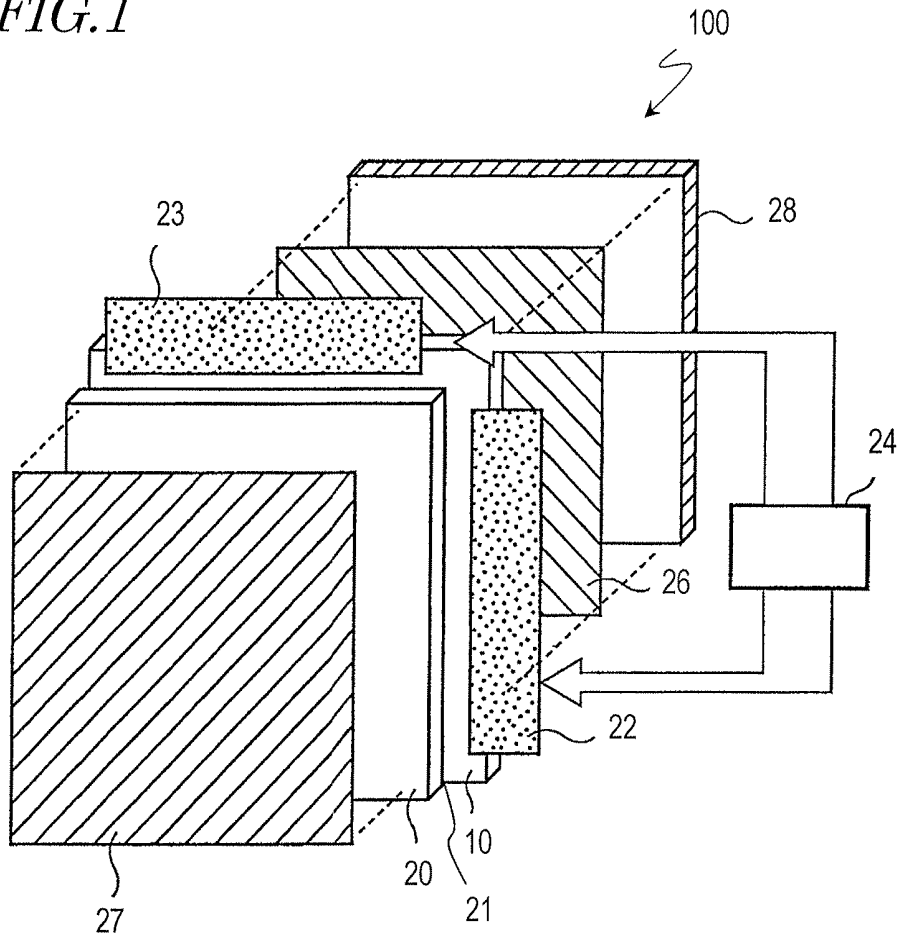


FIG. 2

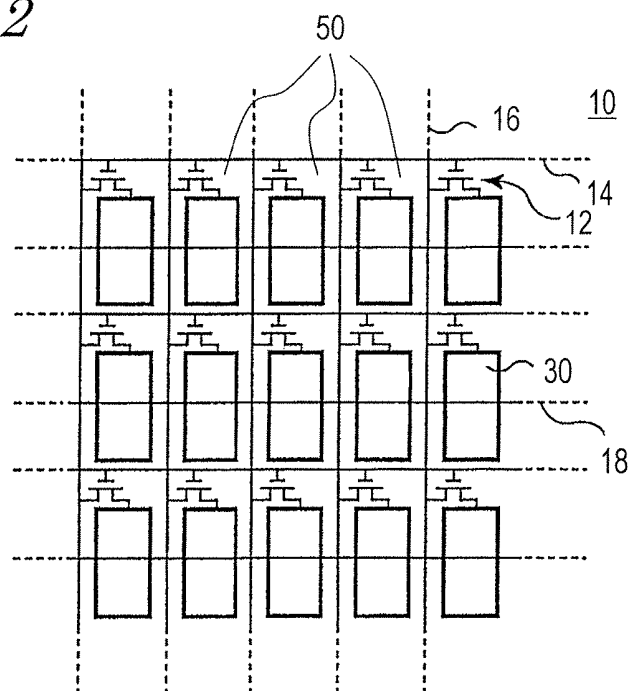


FIG. 3

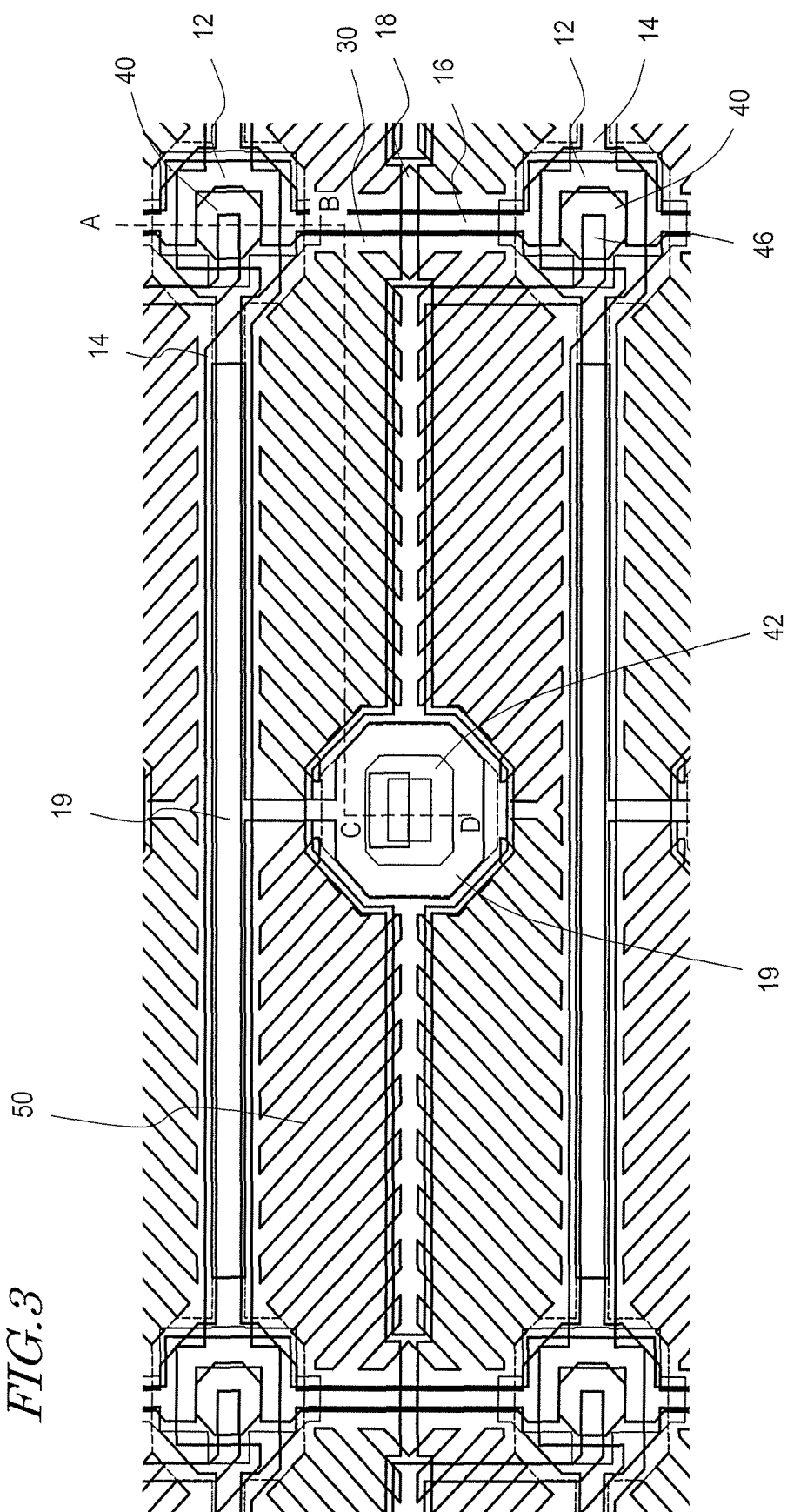
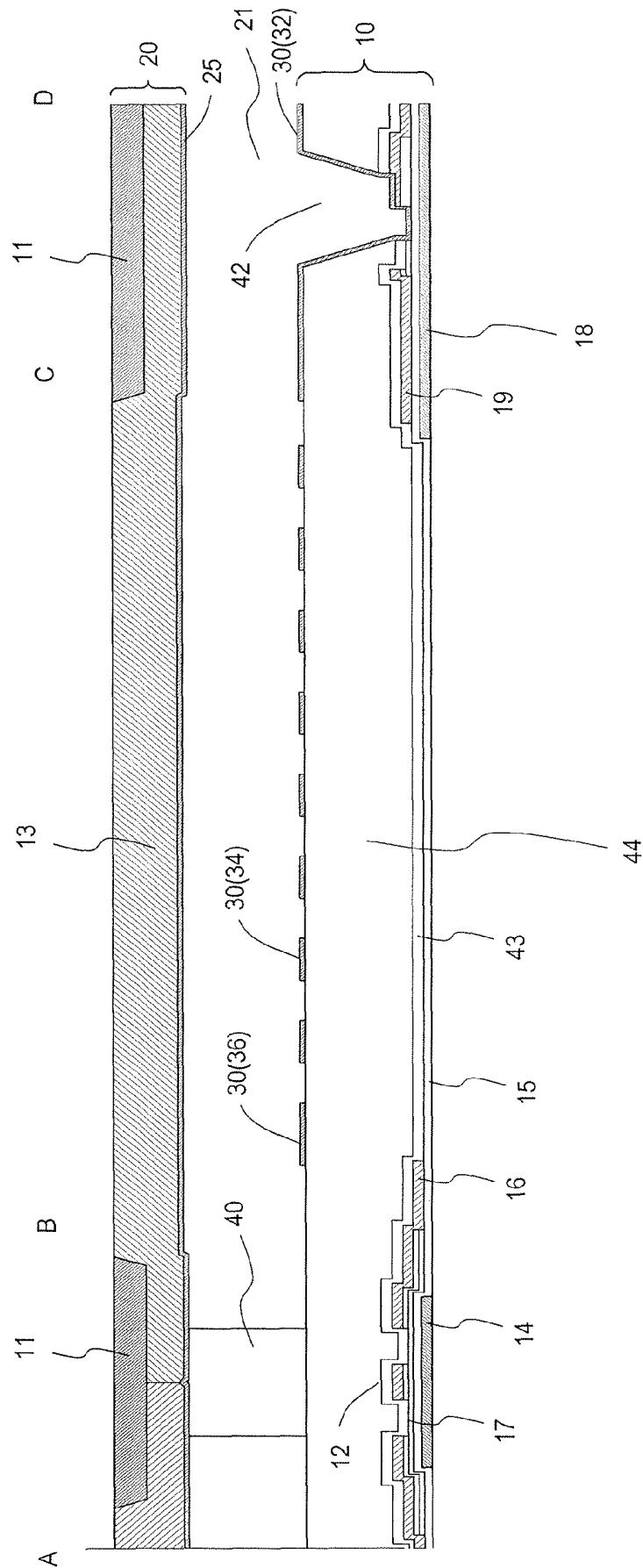


FIG. 4



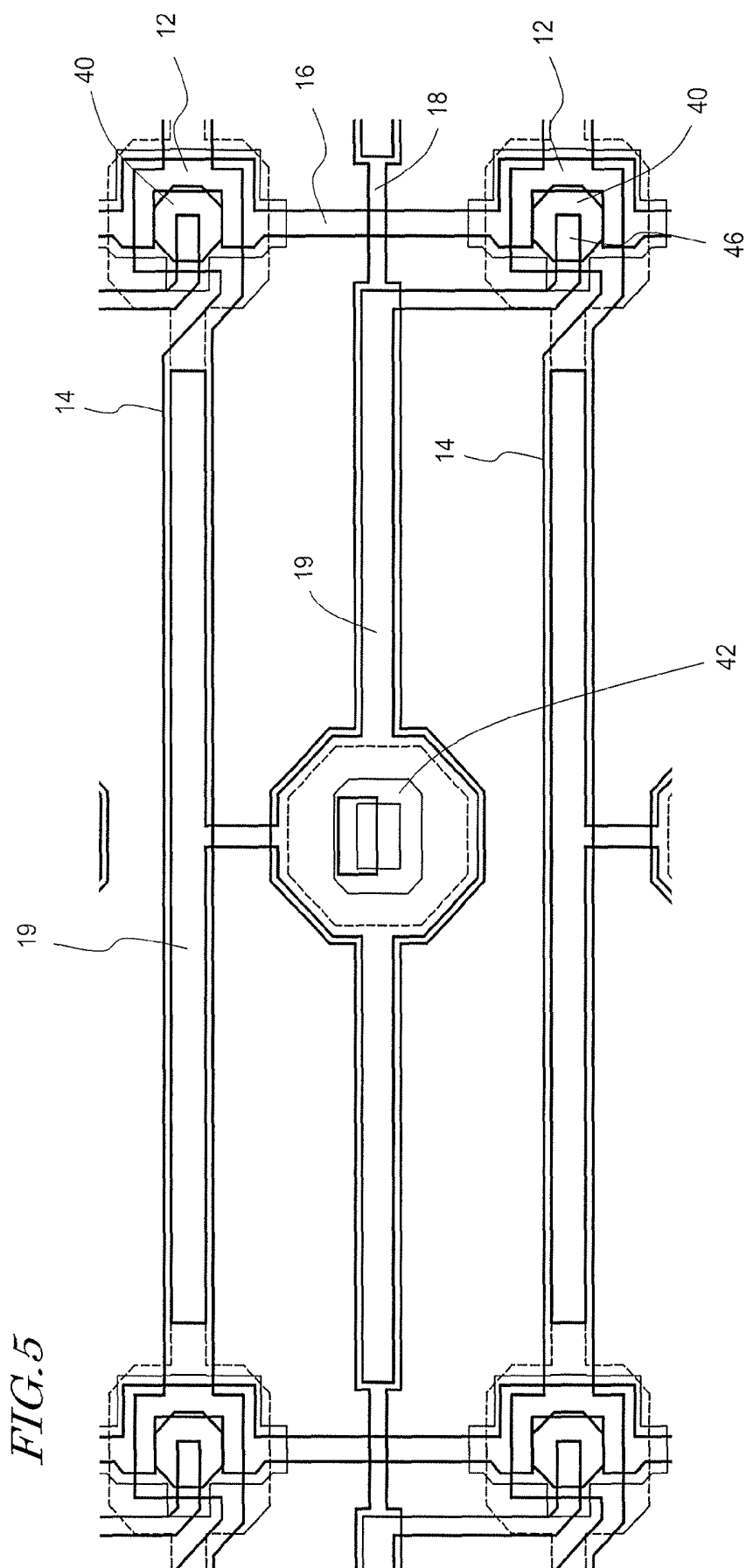


FIG. 6

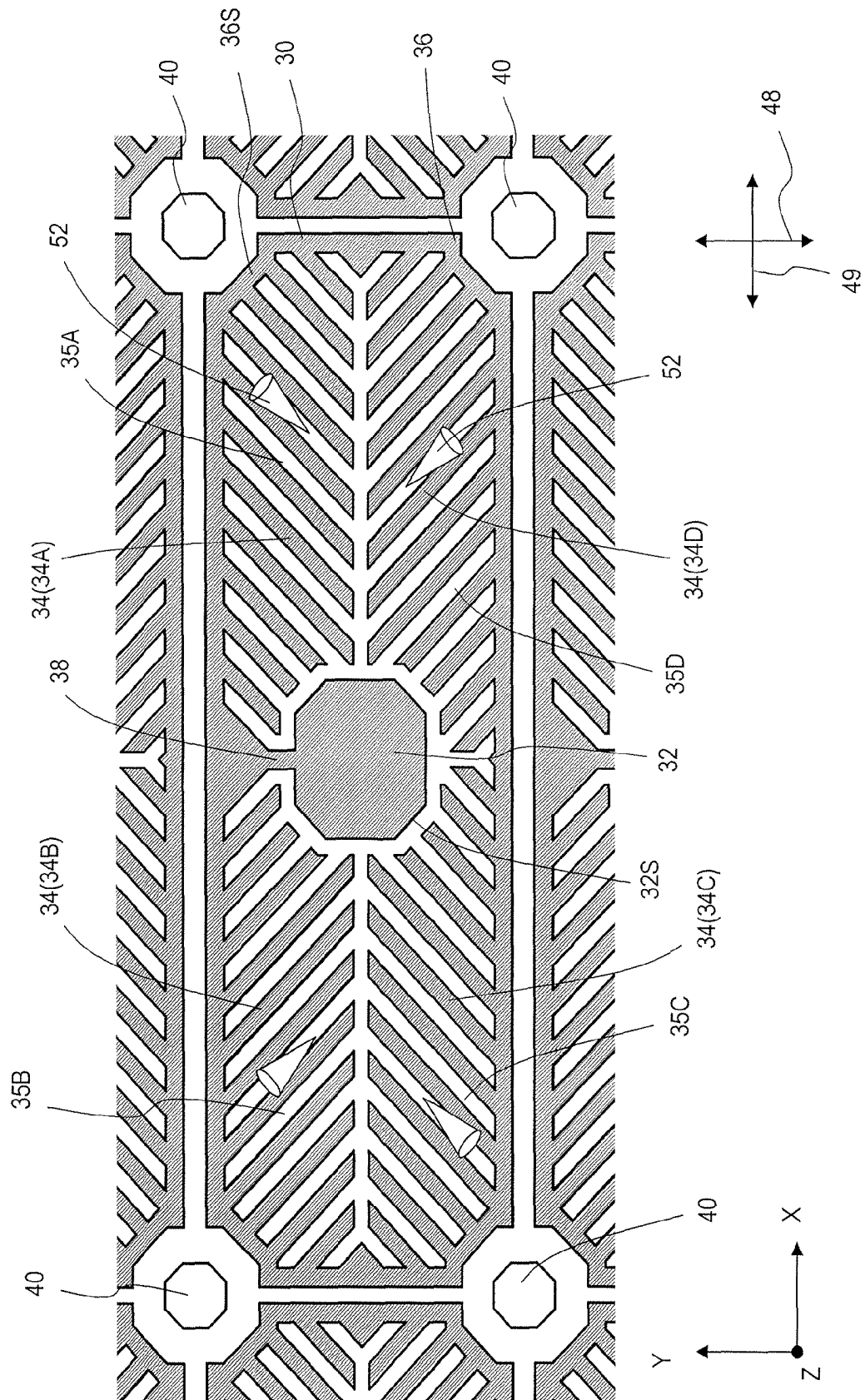


FIG. 7

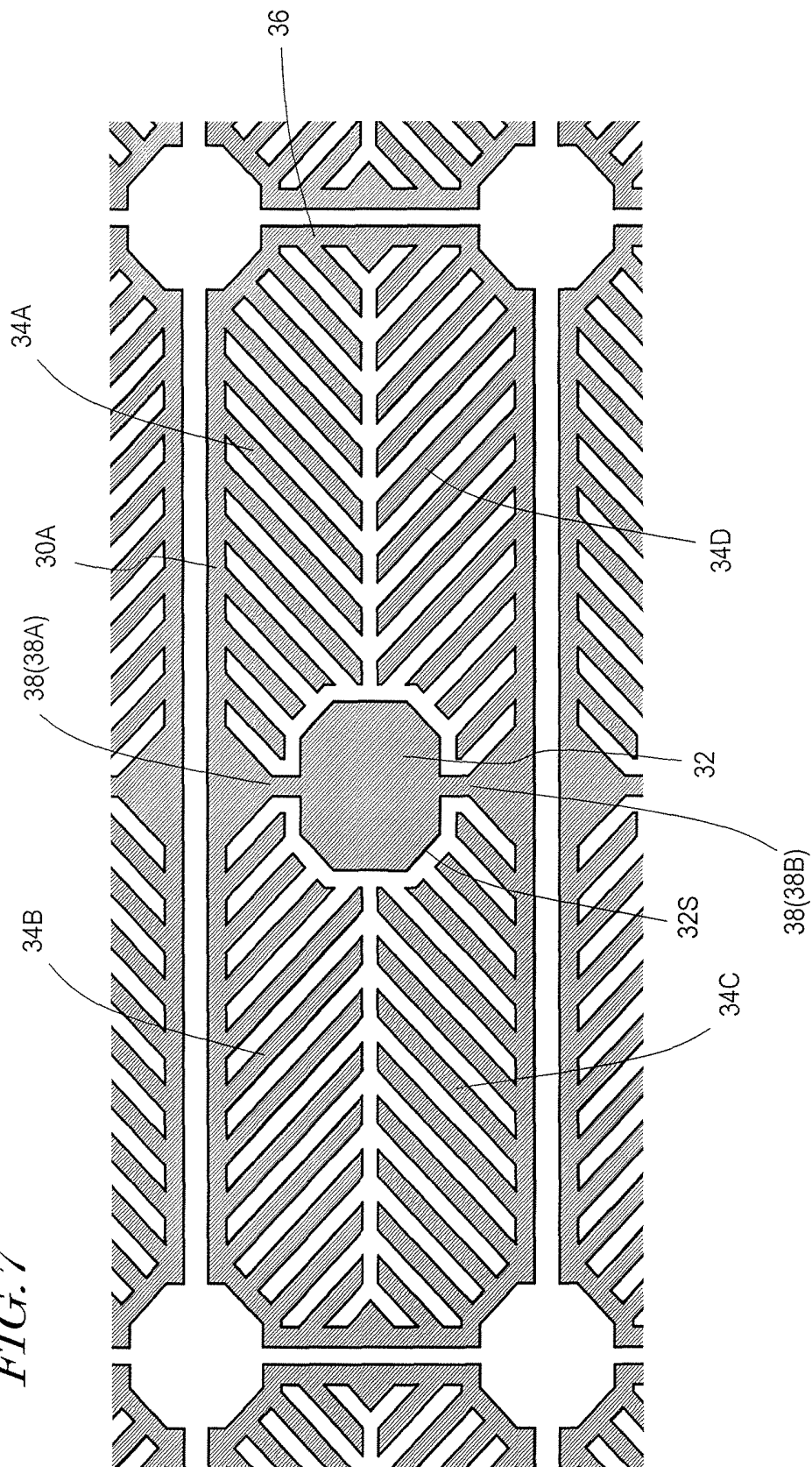


FIG. 8

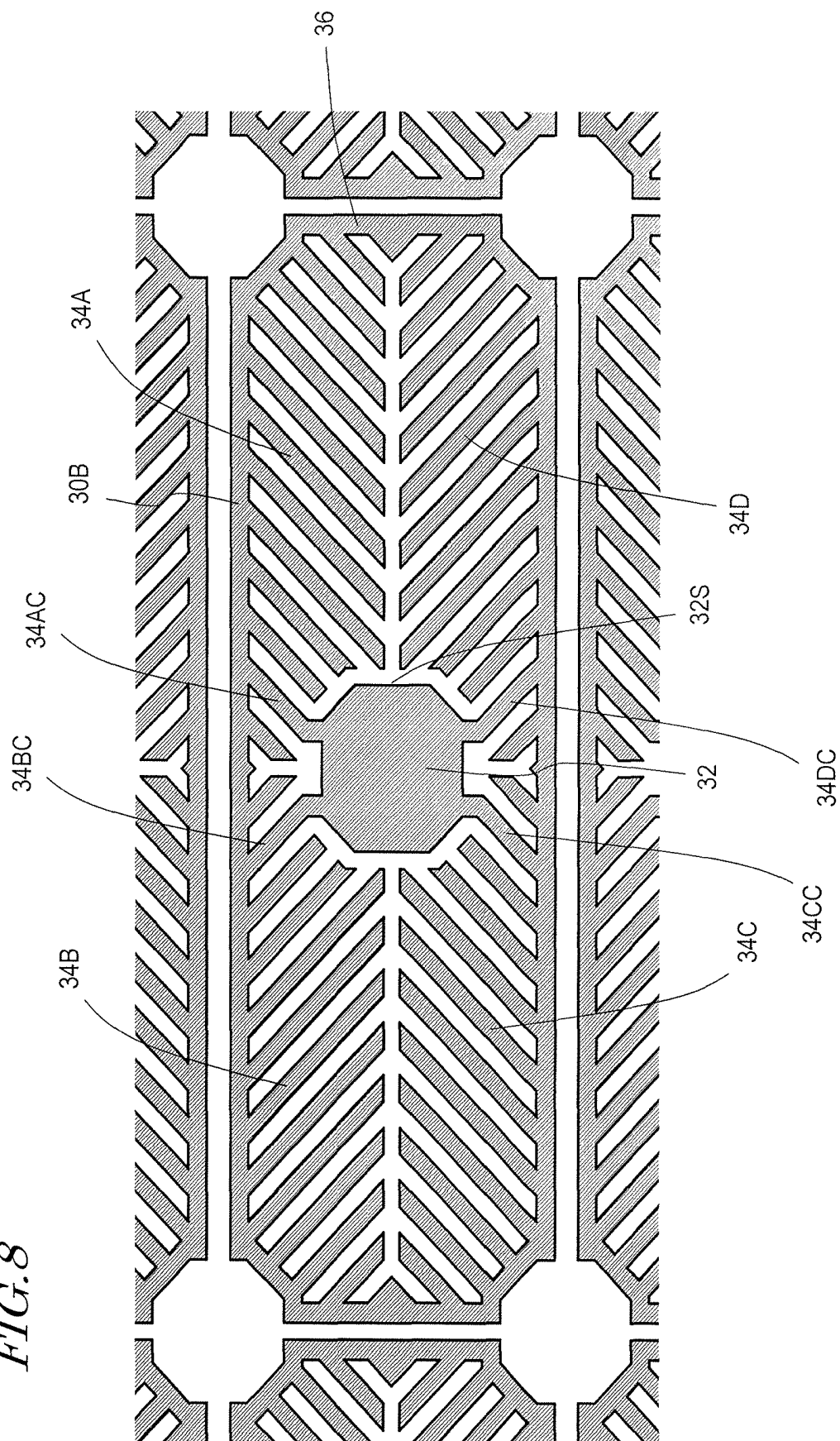


FIG. 9

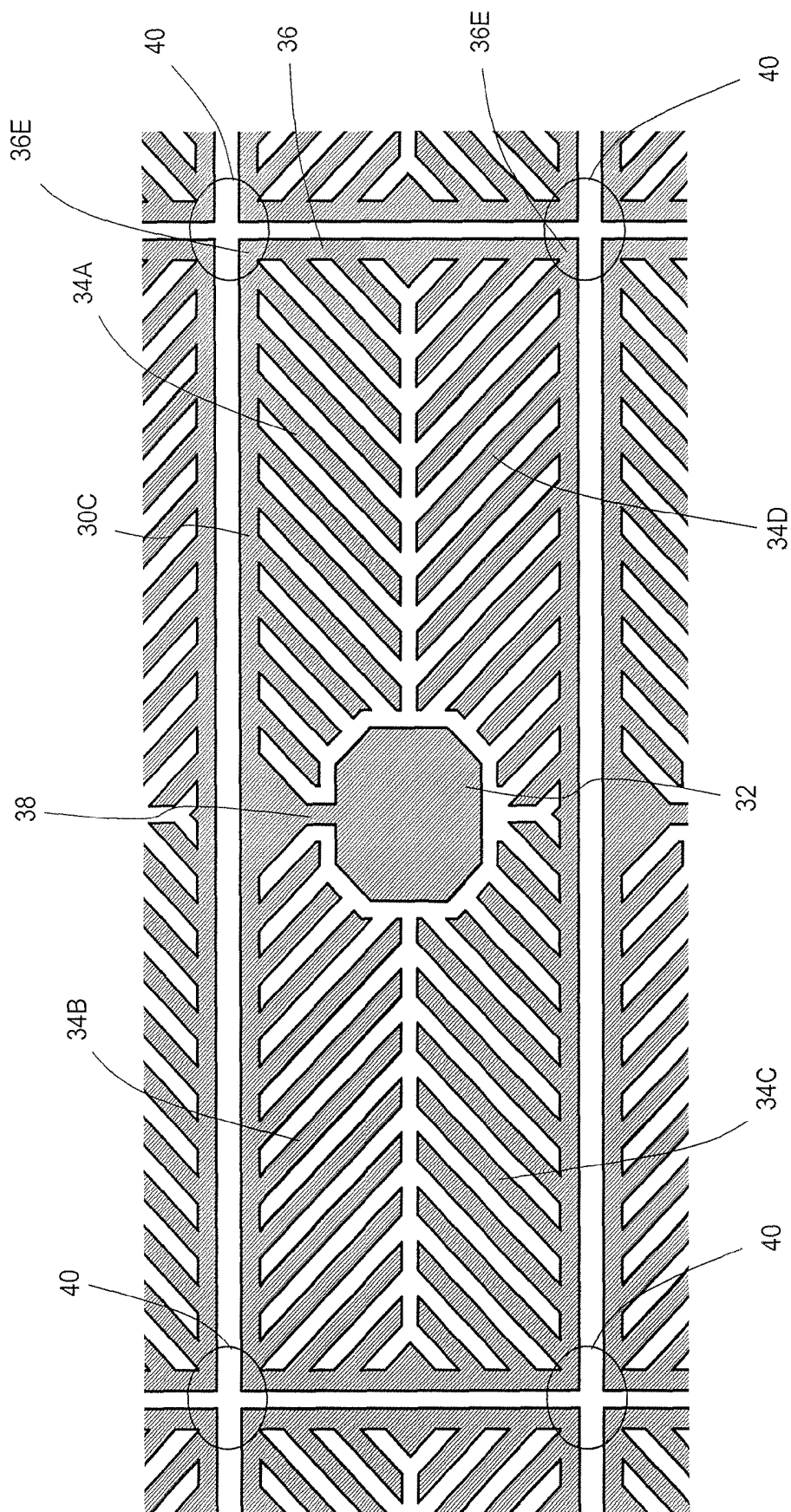


FIG. 10

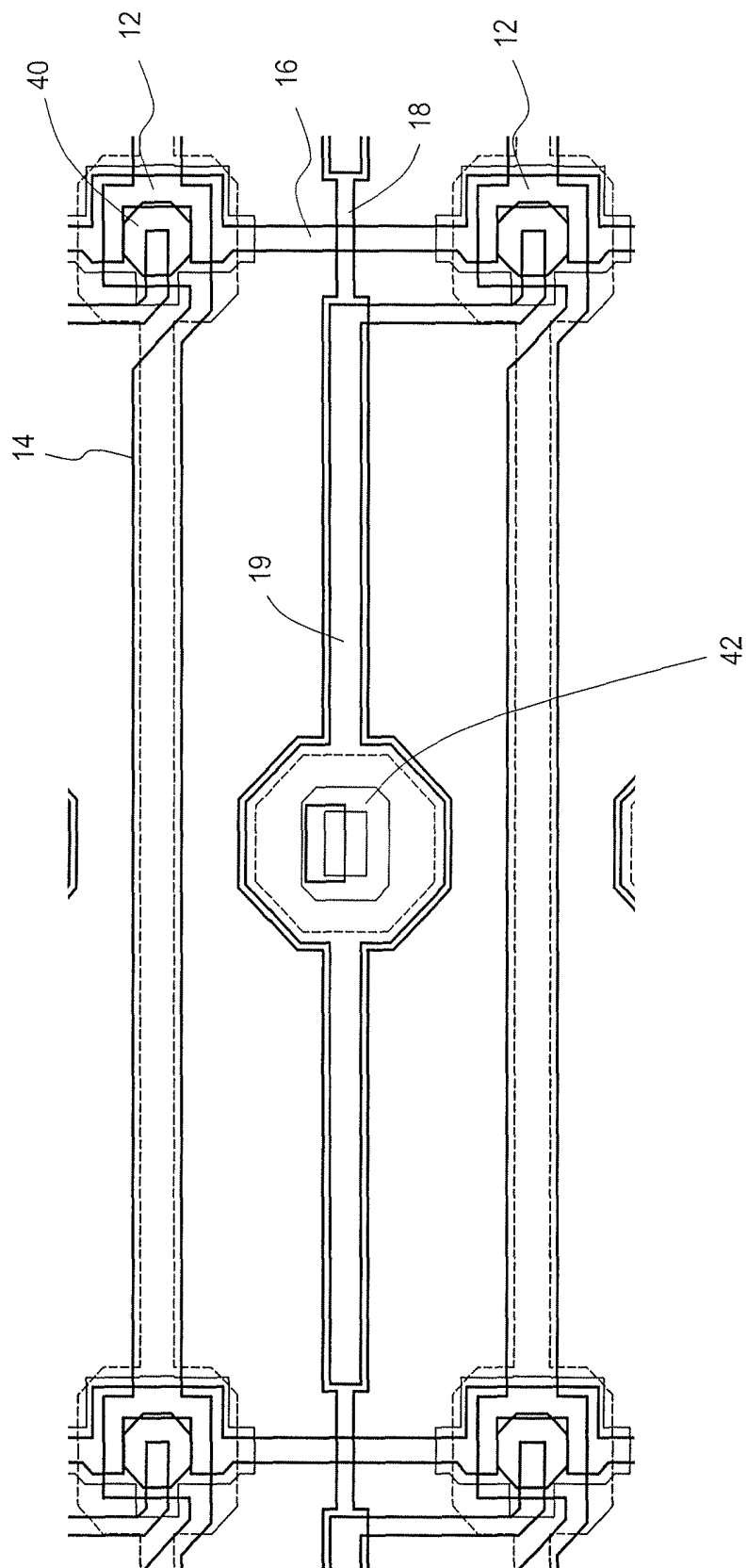


FIG. 11

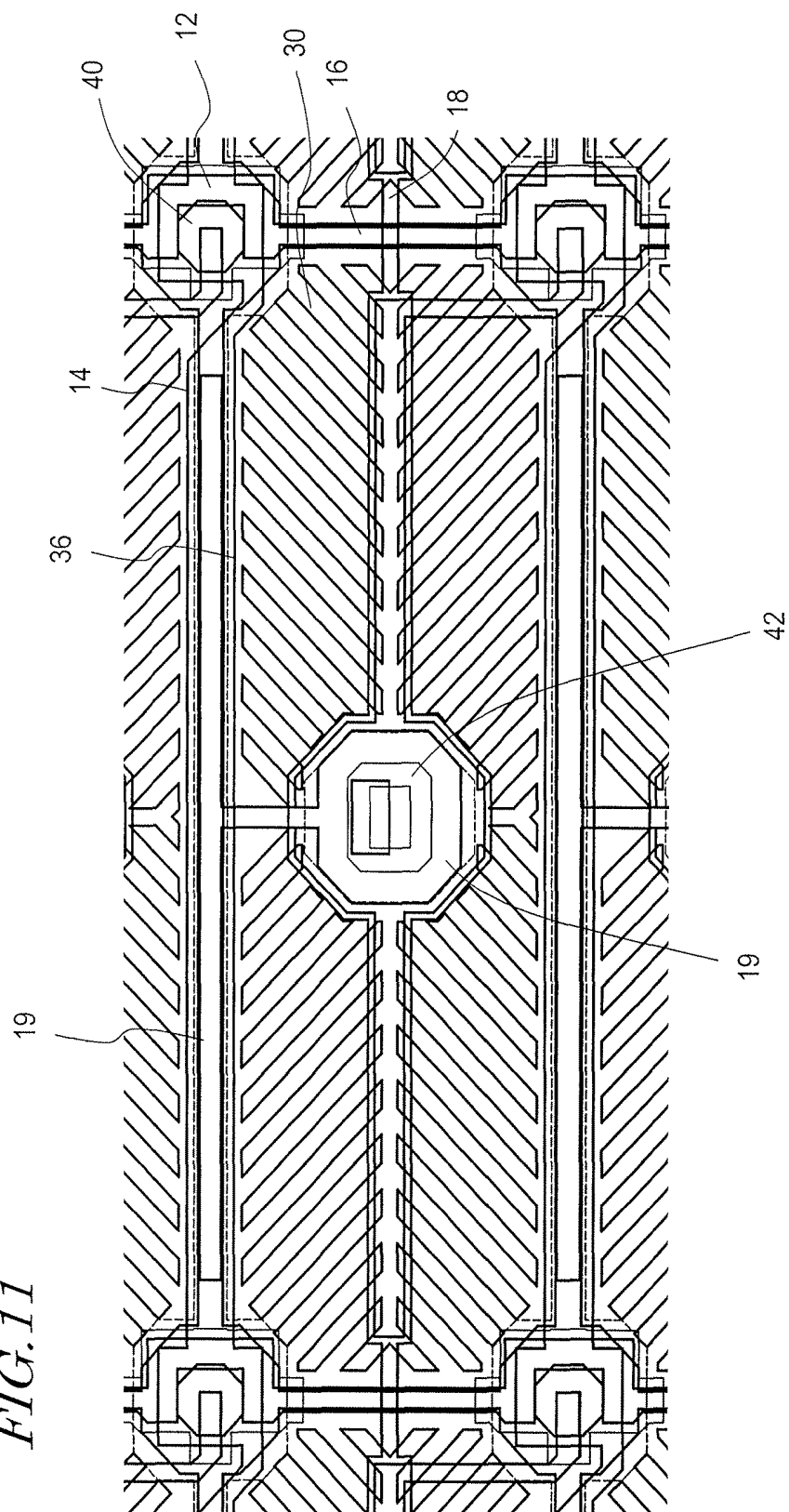


FIG. 12

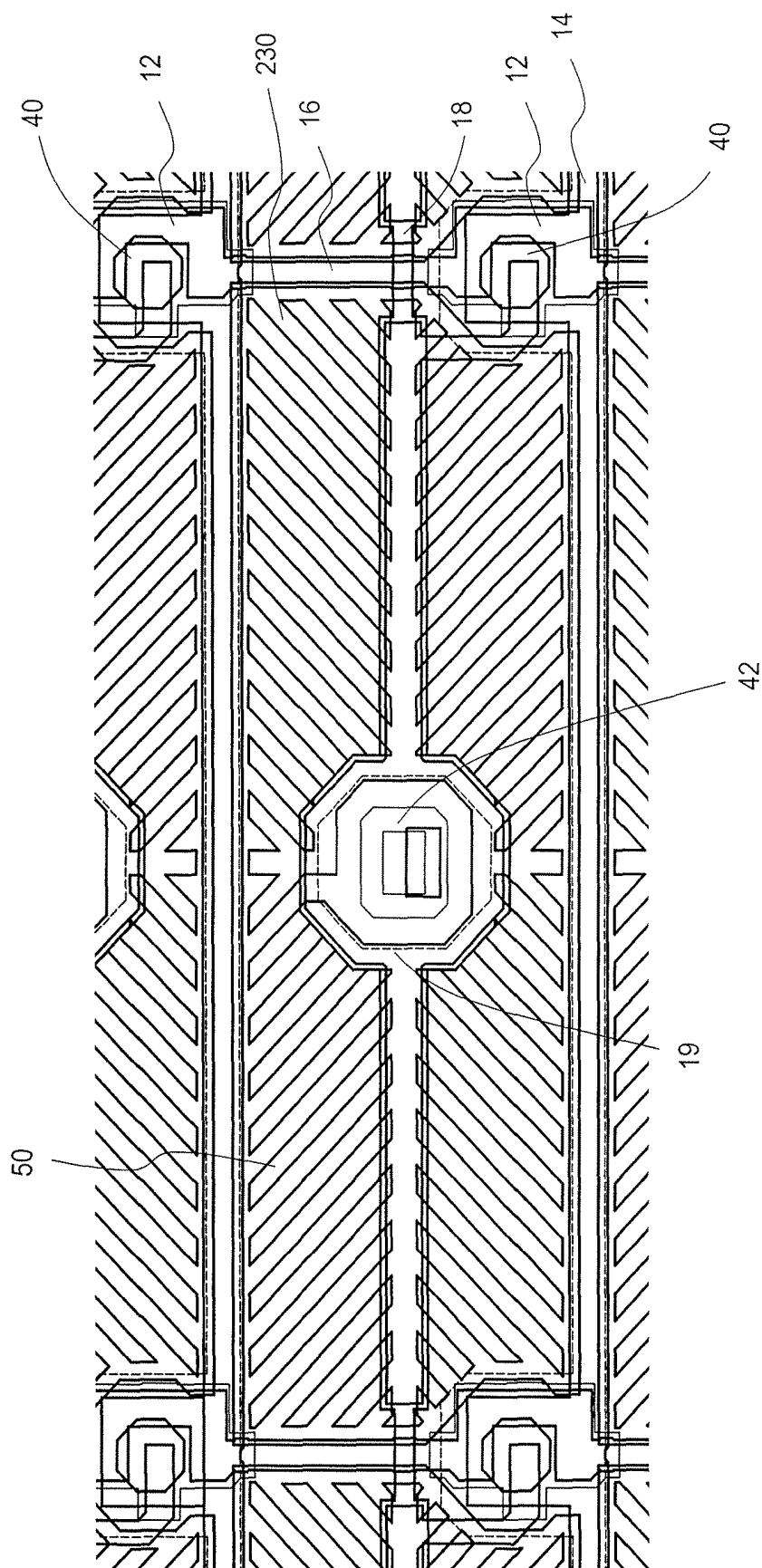


FIG. 13

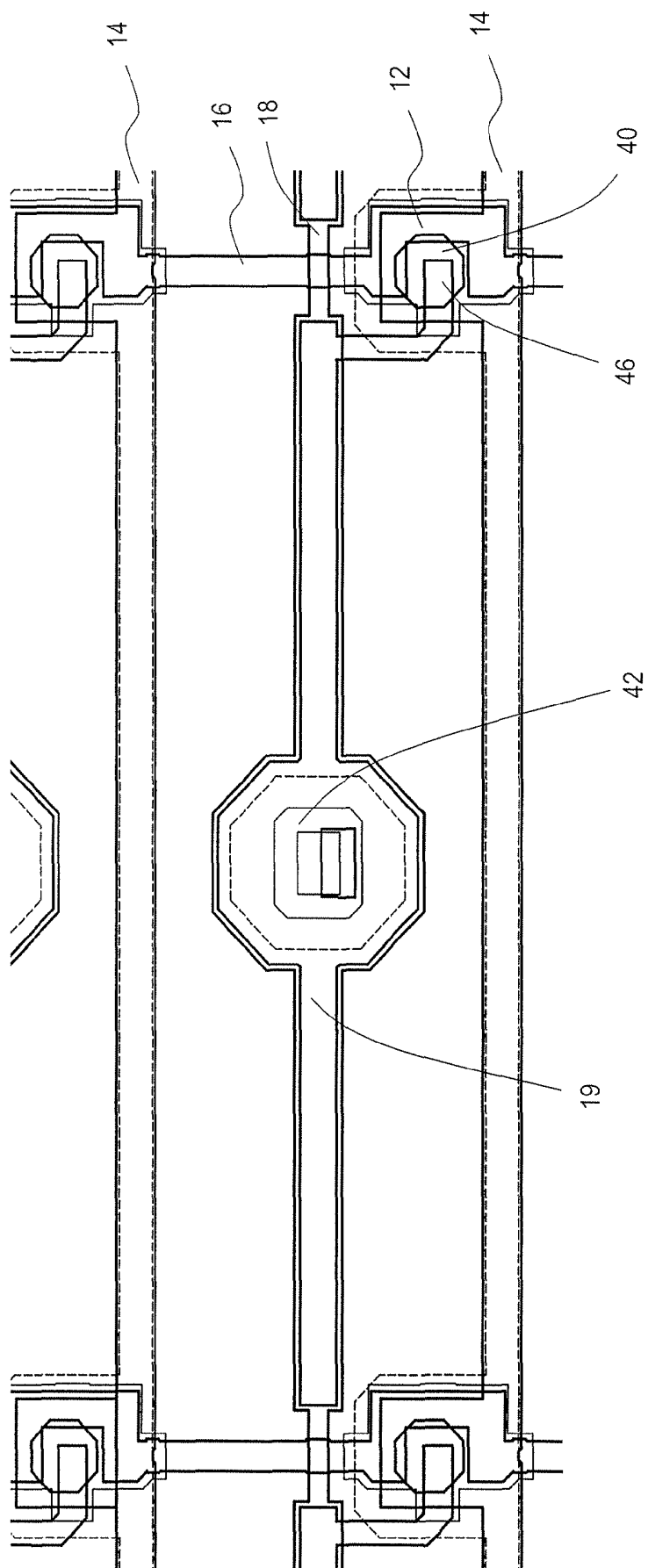


FIG. 14

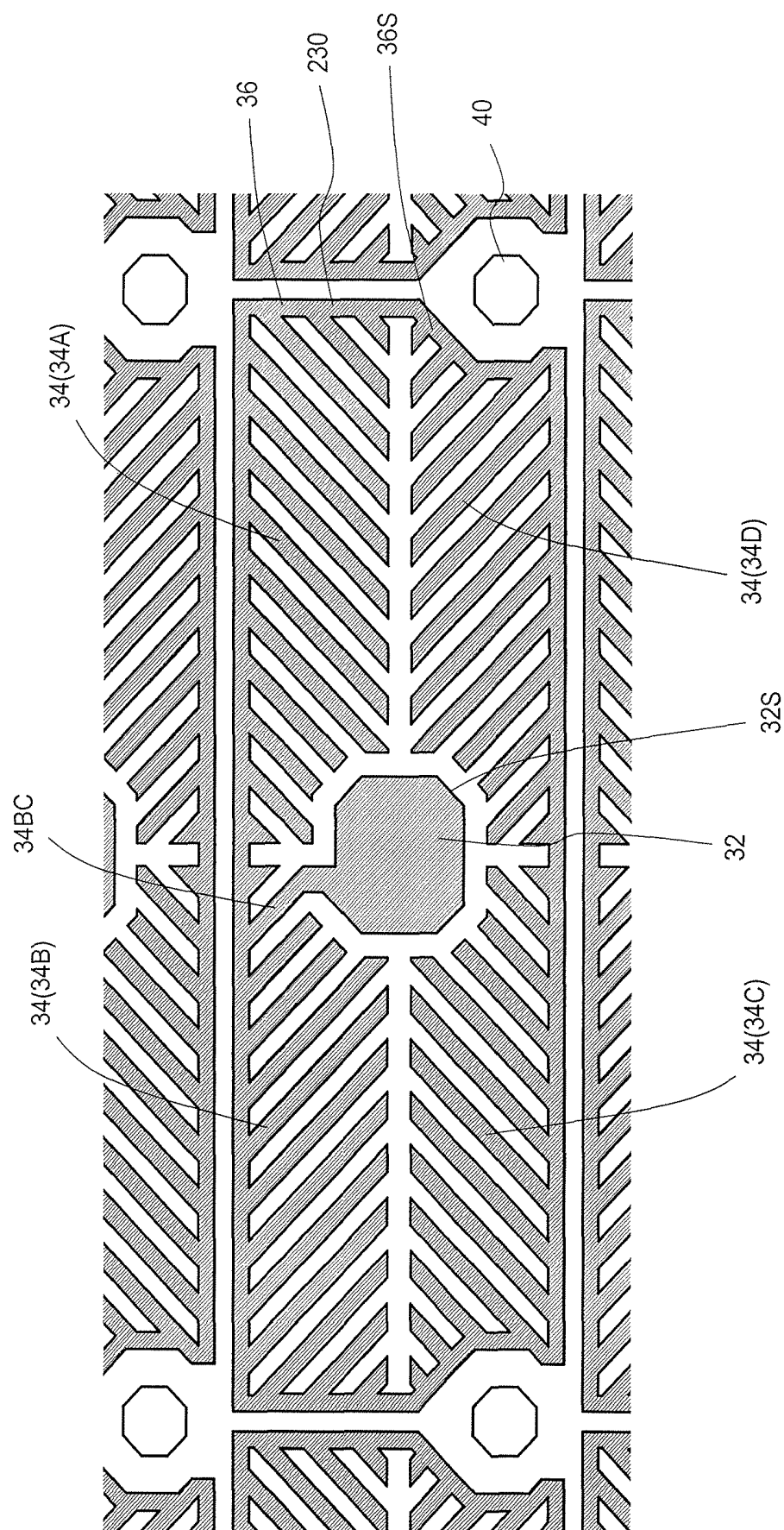


FIG. 15

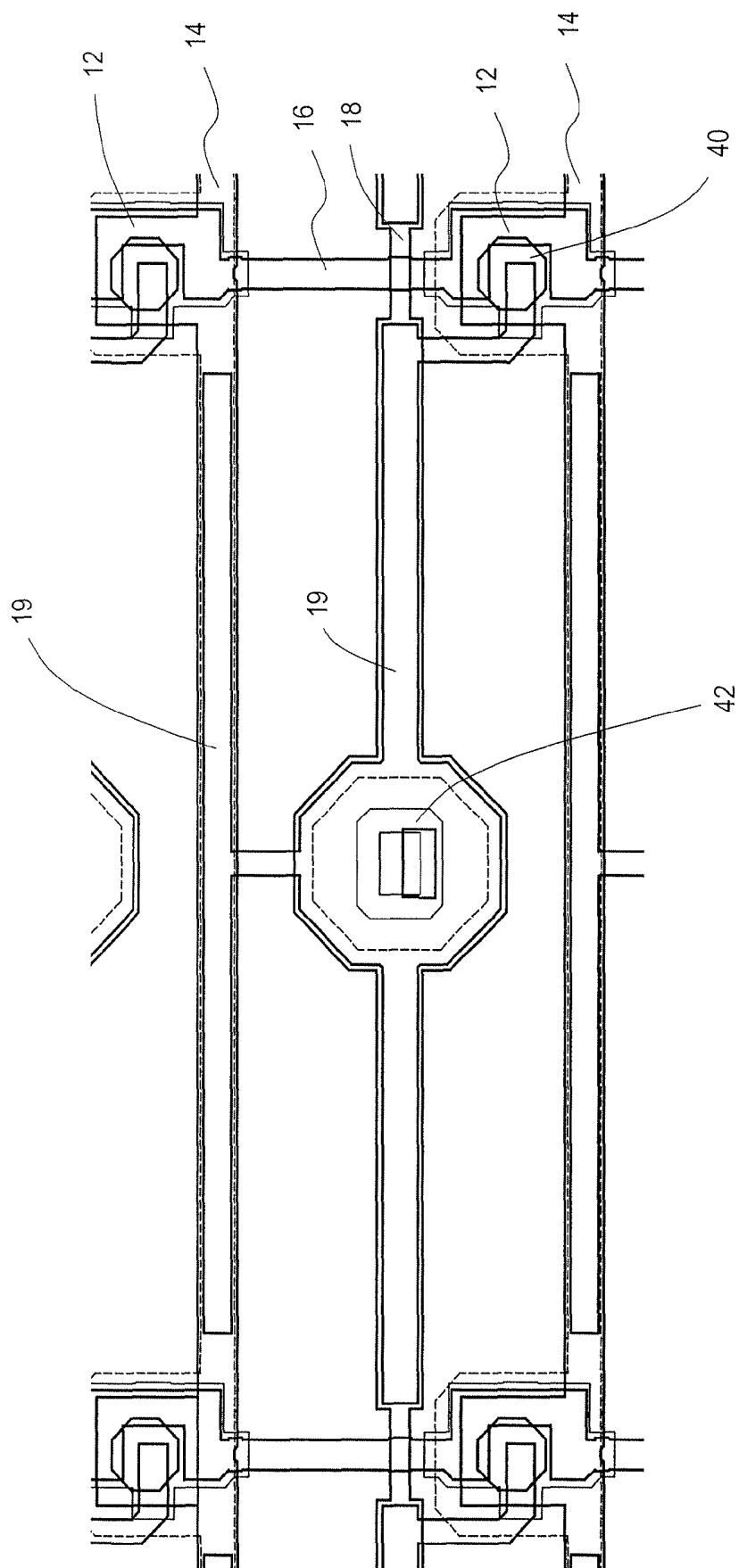


FIG. 16

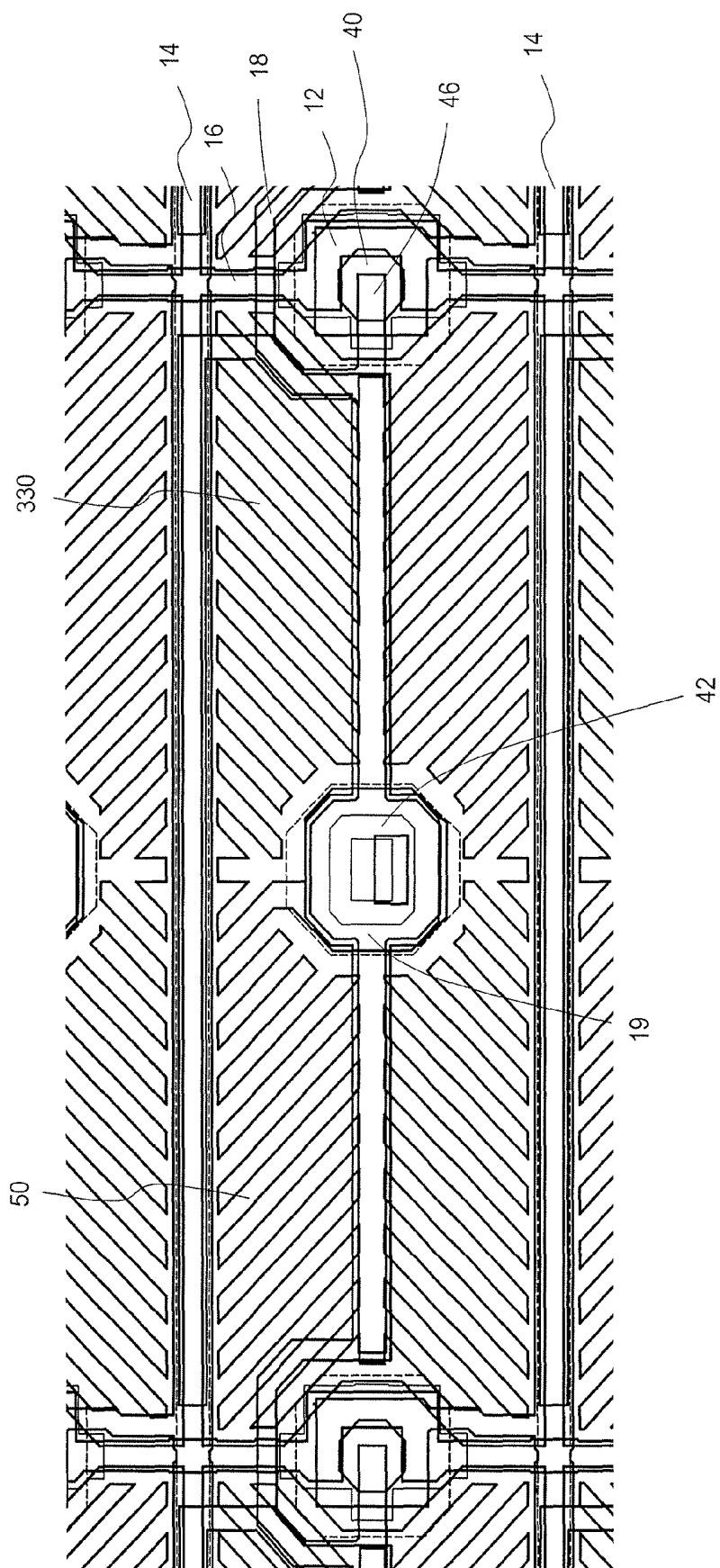


FIG. 17

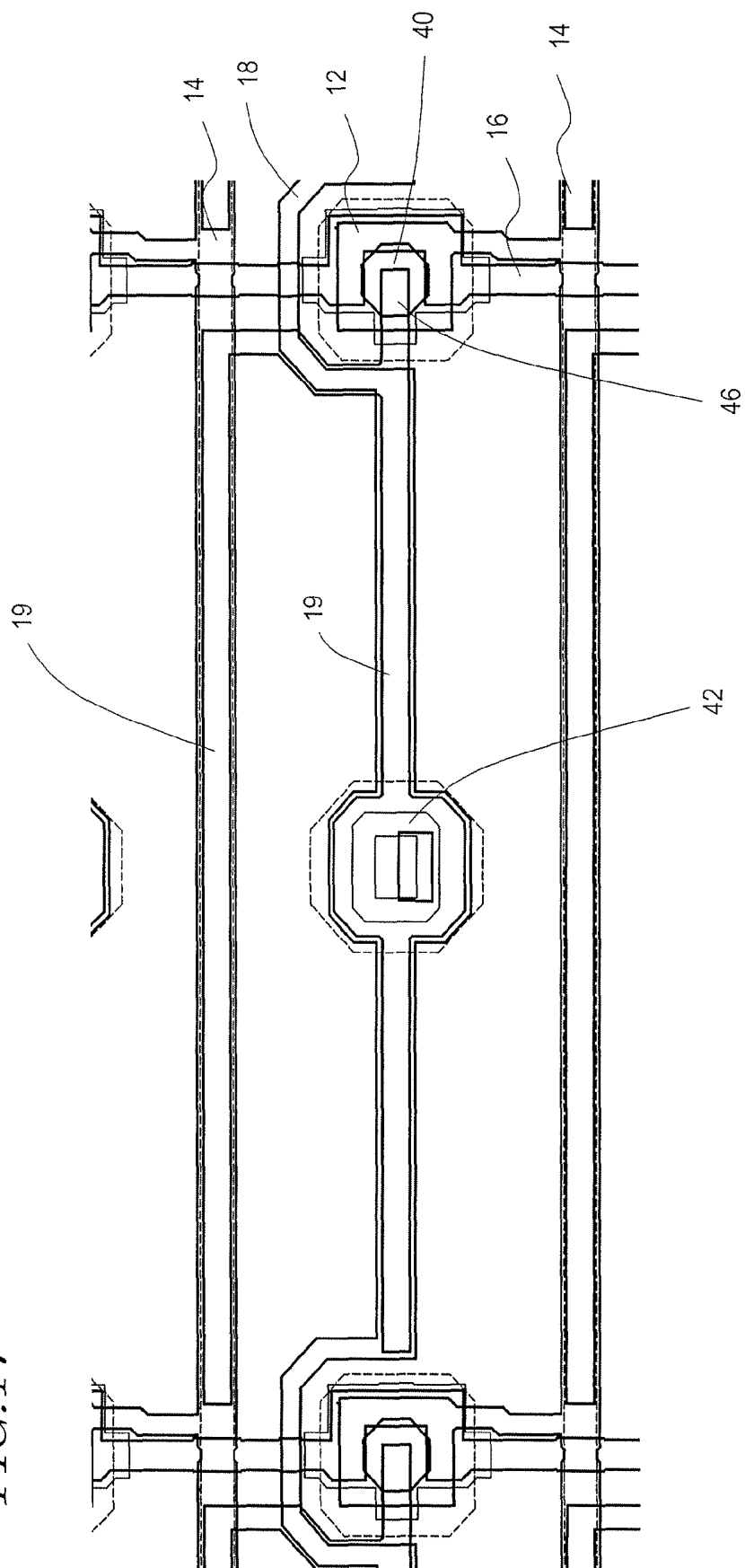
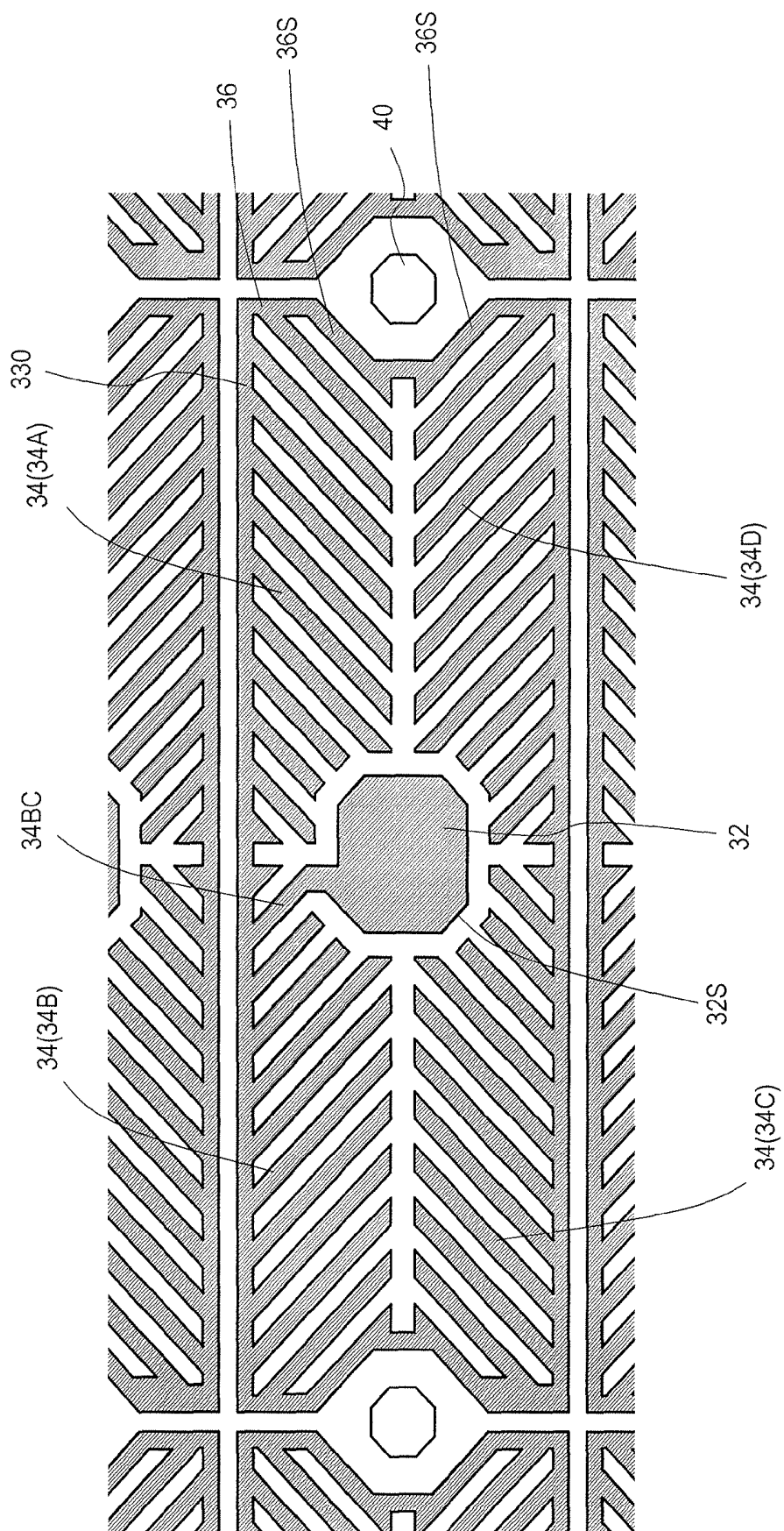


FIG. 18



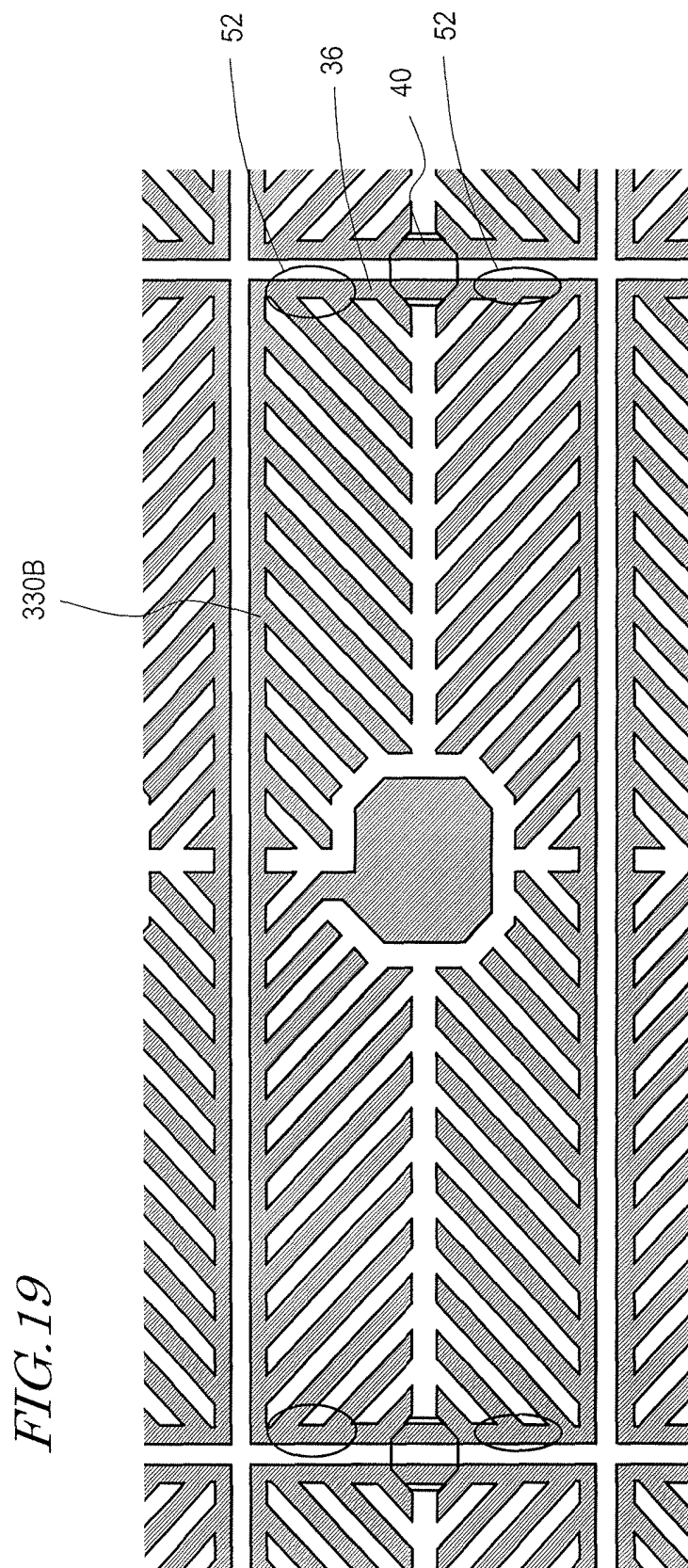


FIG. 20

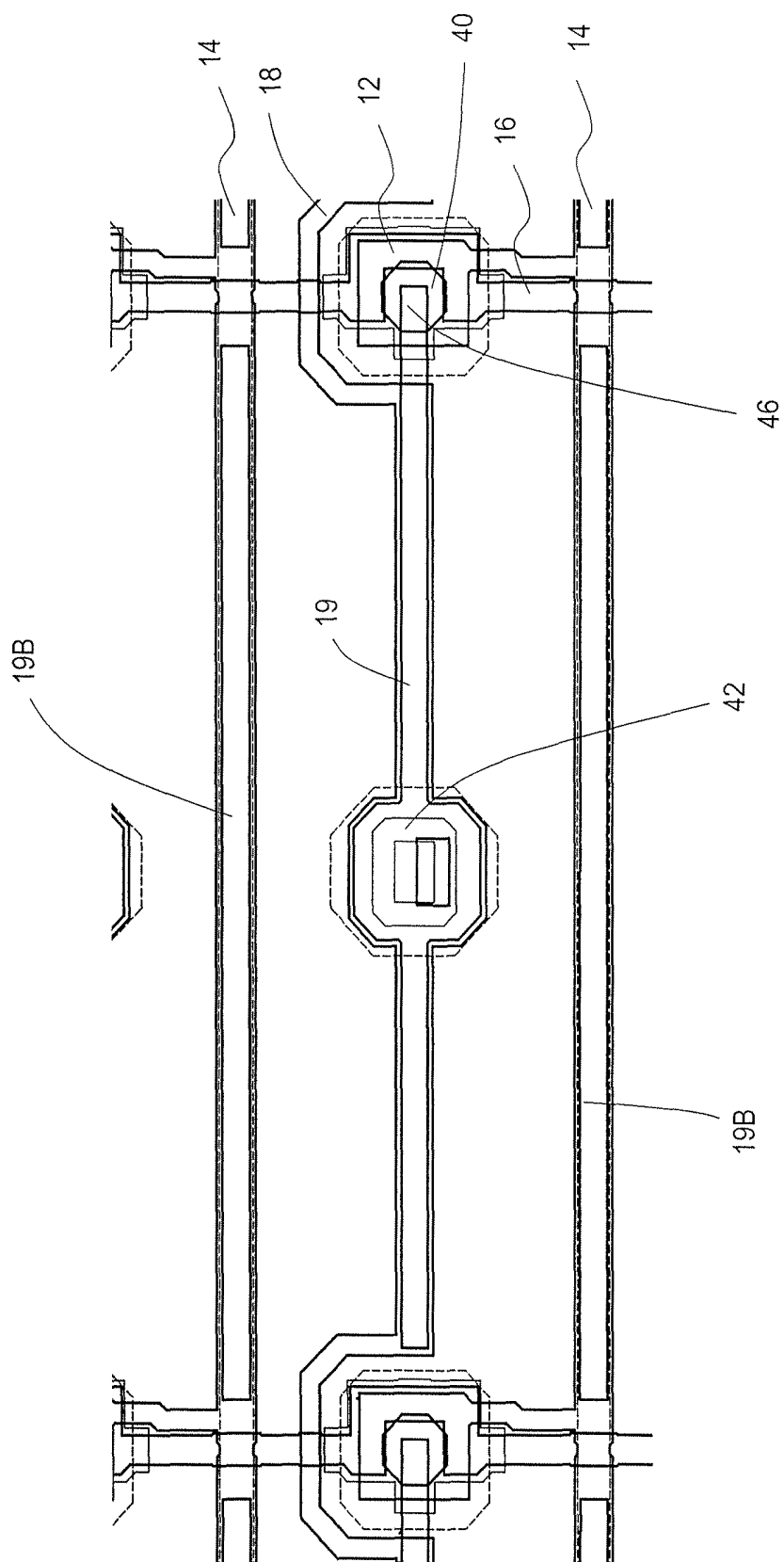


FIG. 21

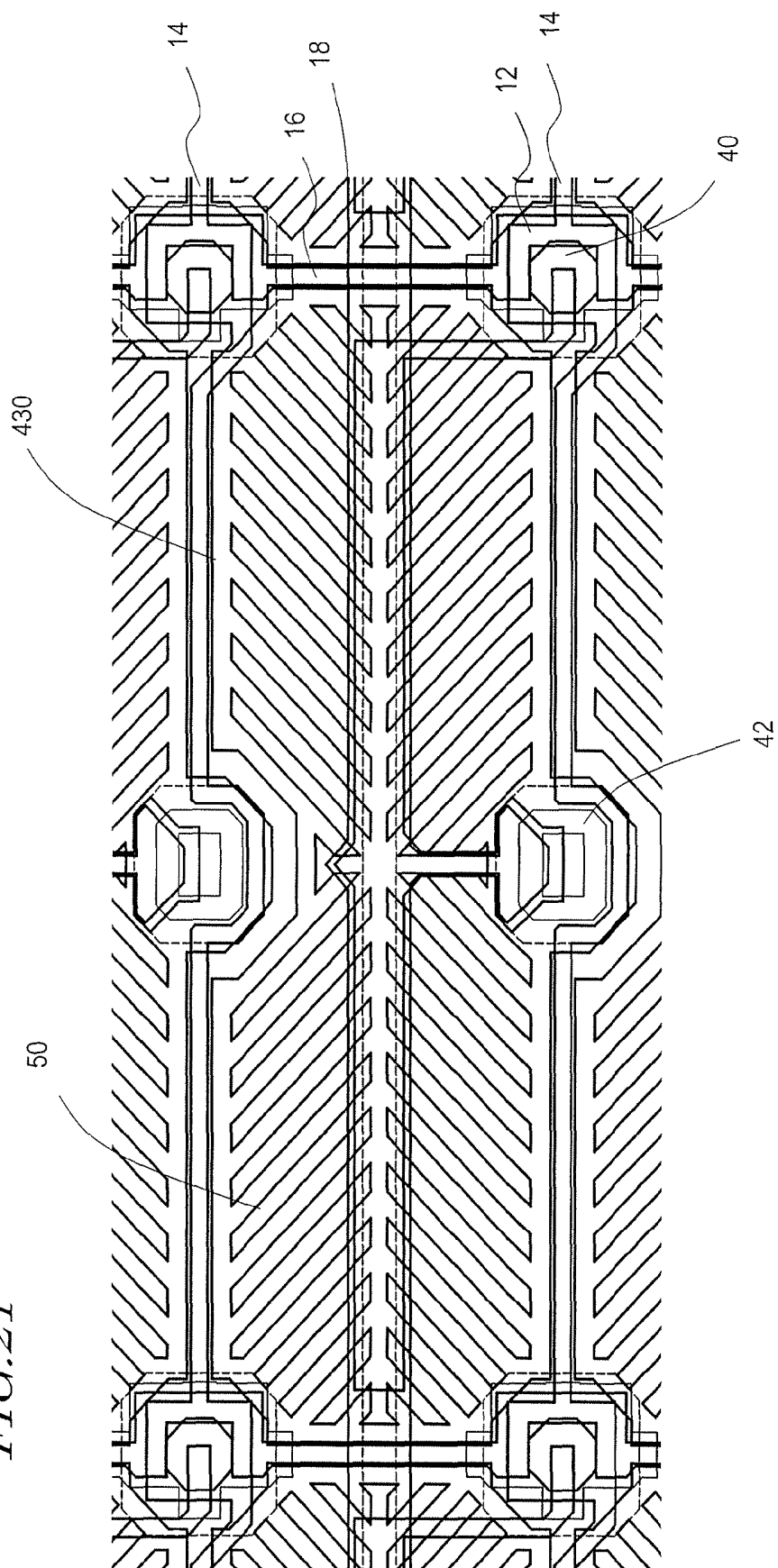


FIG. 22

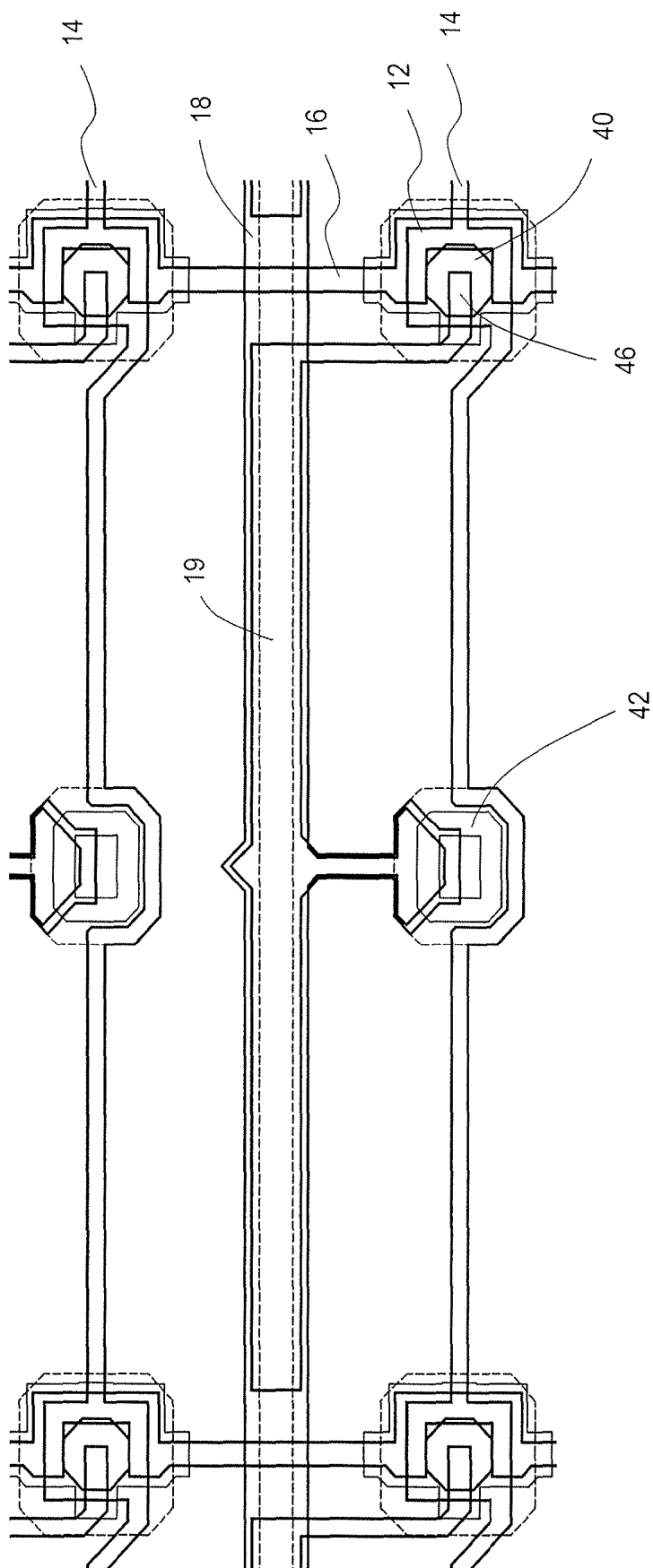


FIG. 23

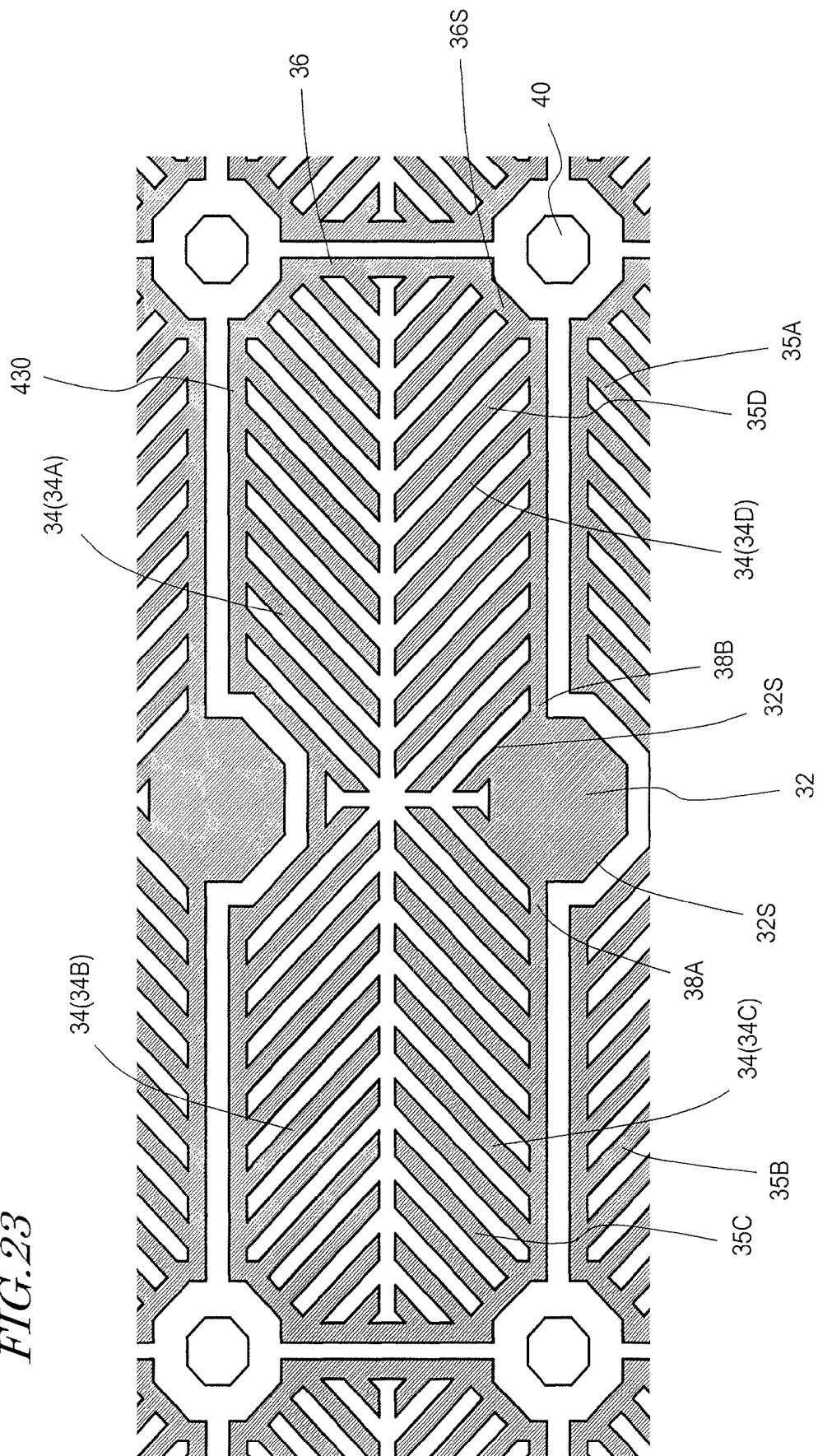


FIG. 25

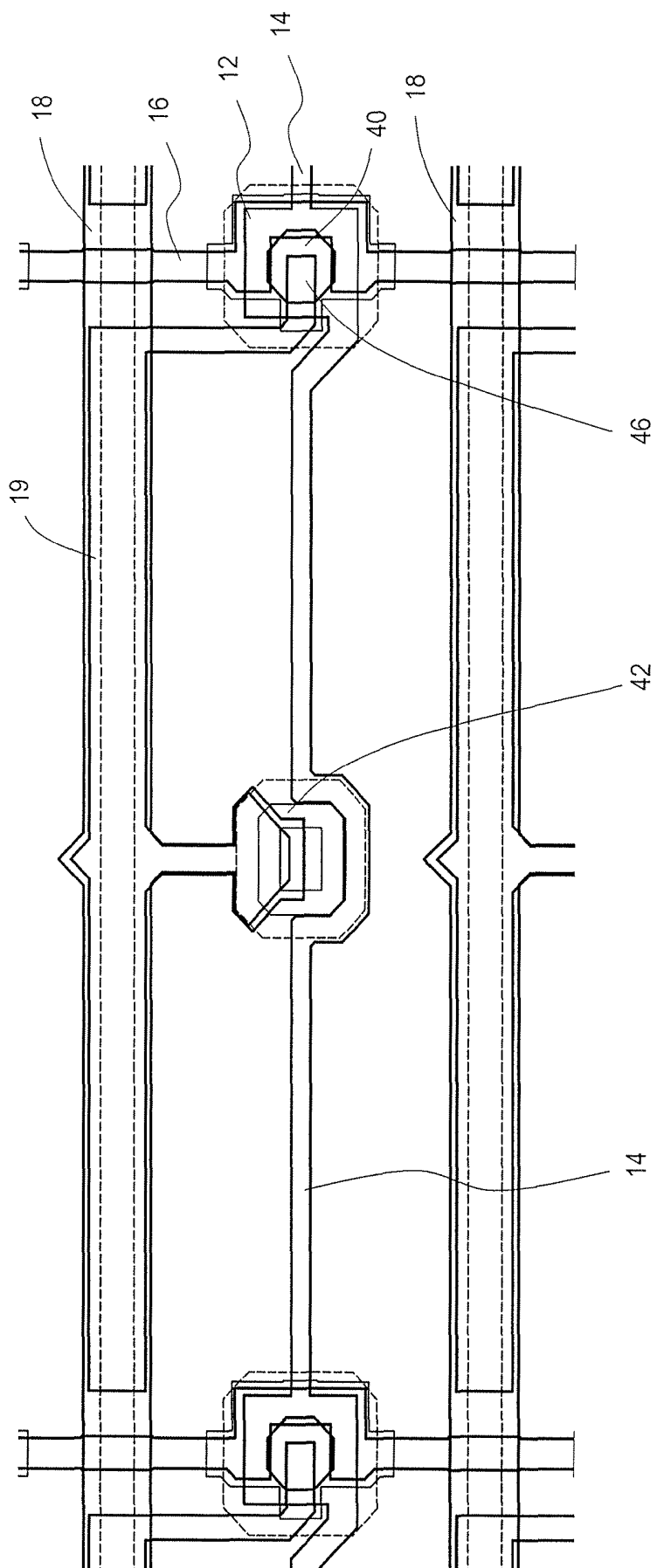


FIG. 26

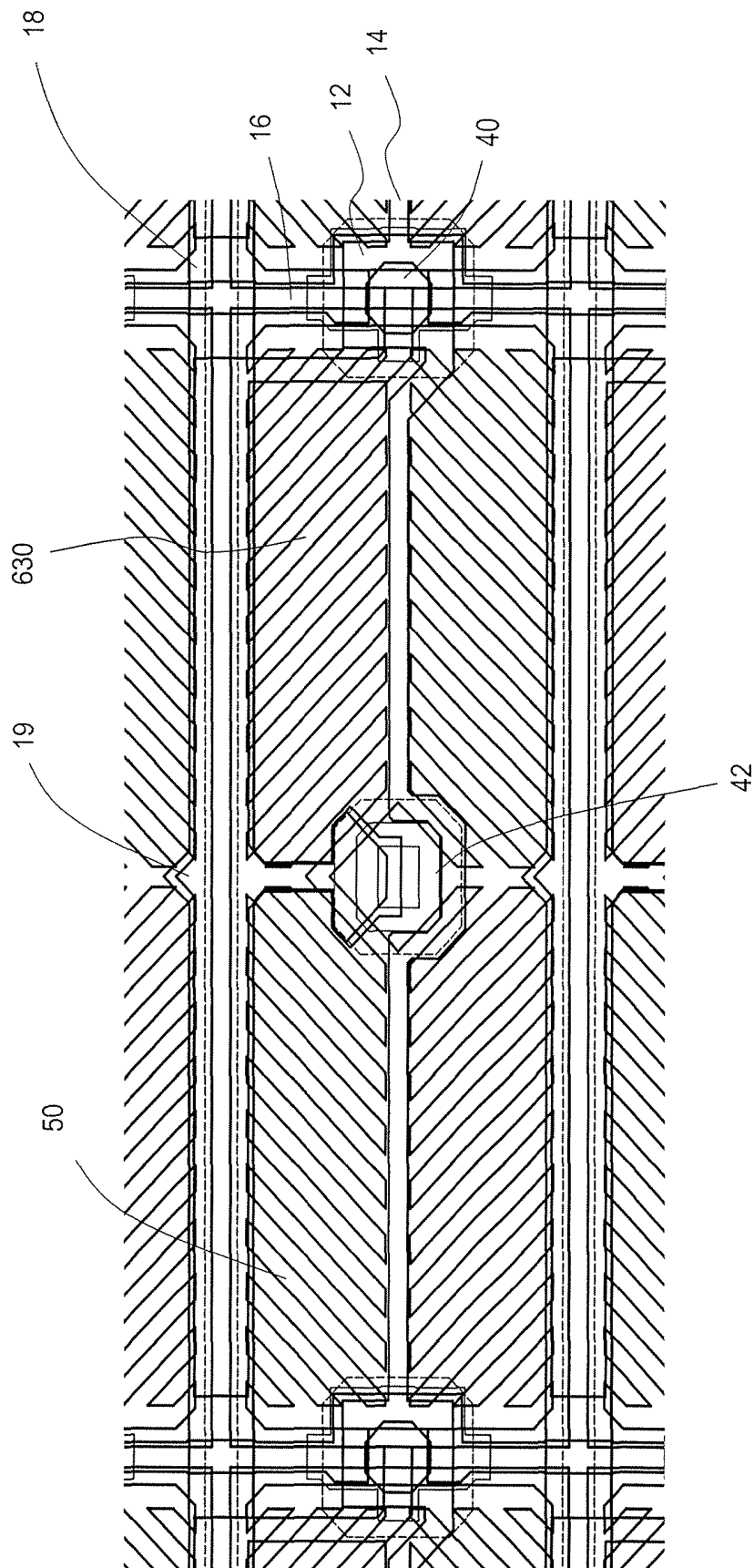


FIG. 27

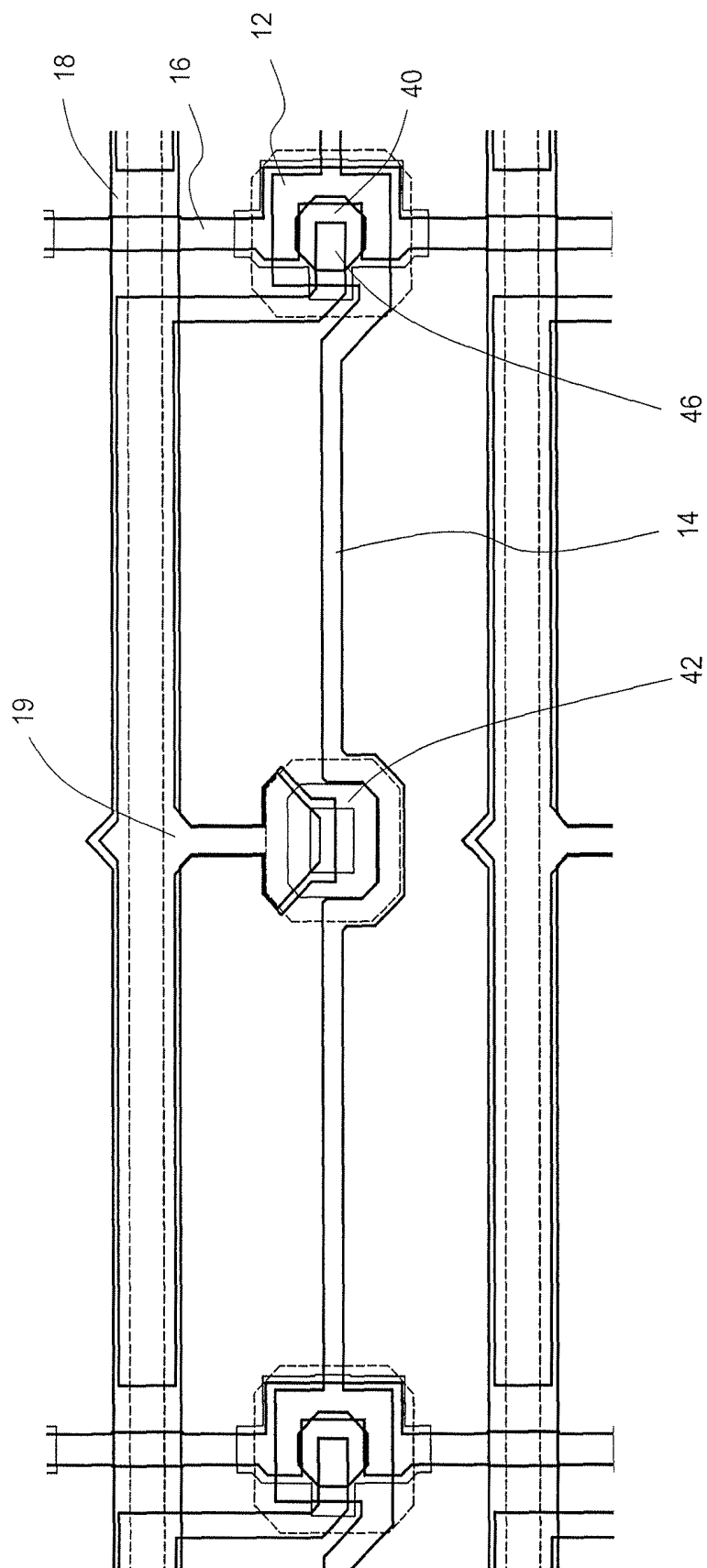


FIG. 28

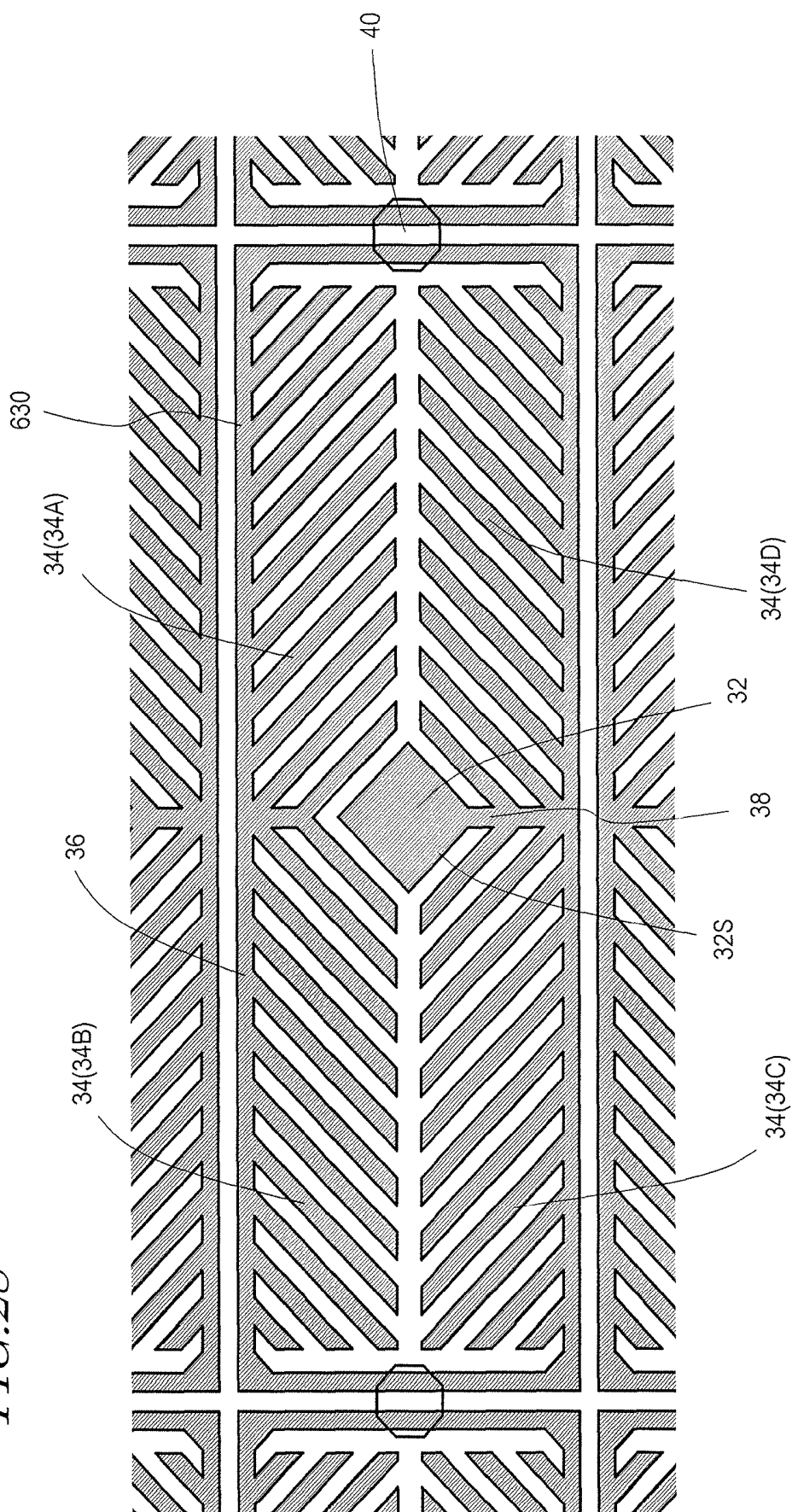


FIG. 29

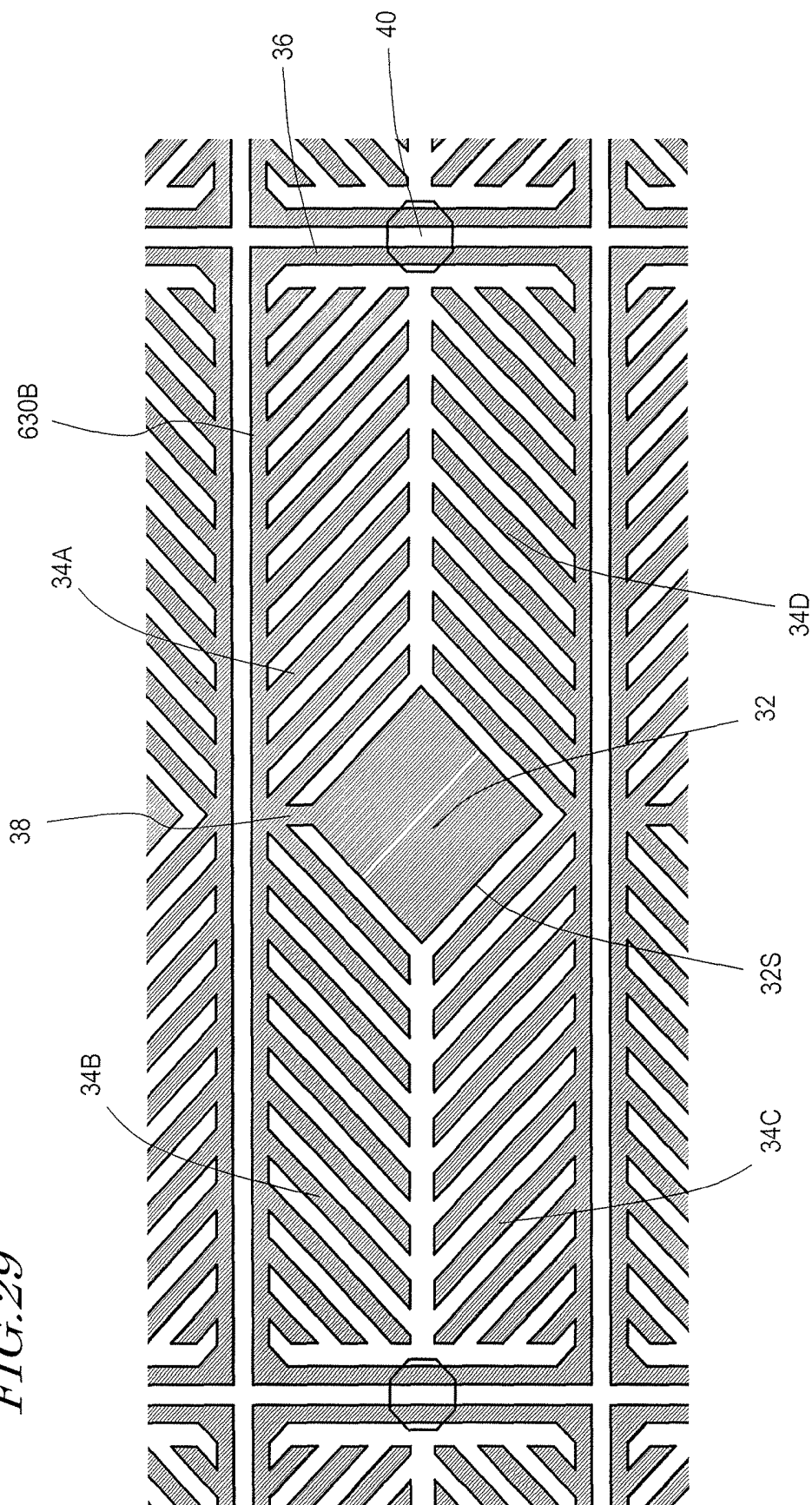


FIG. 30

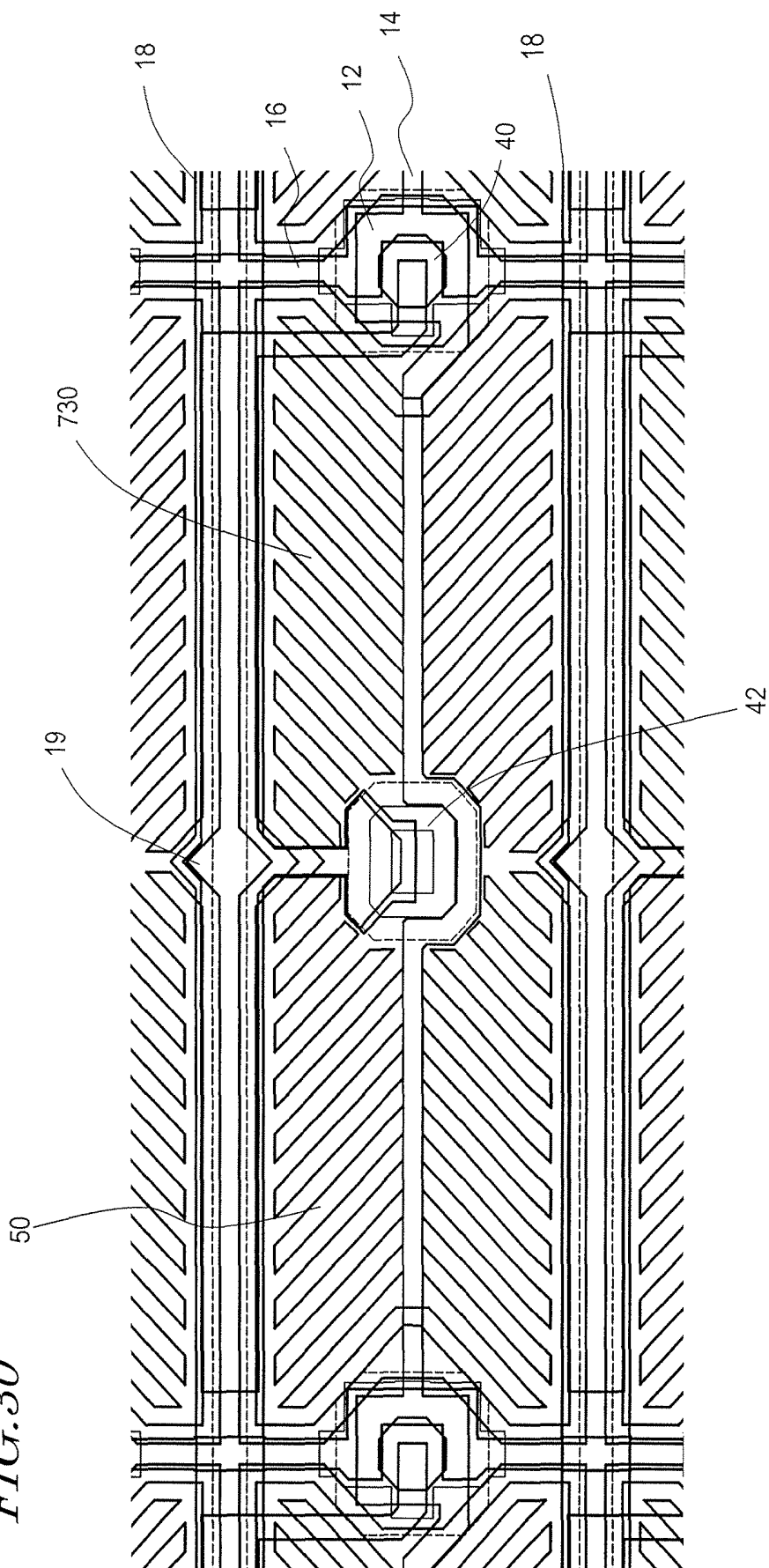


FIG. 31

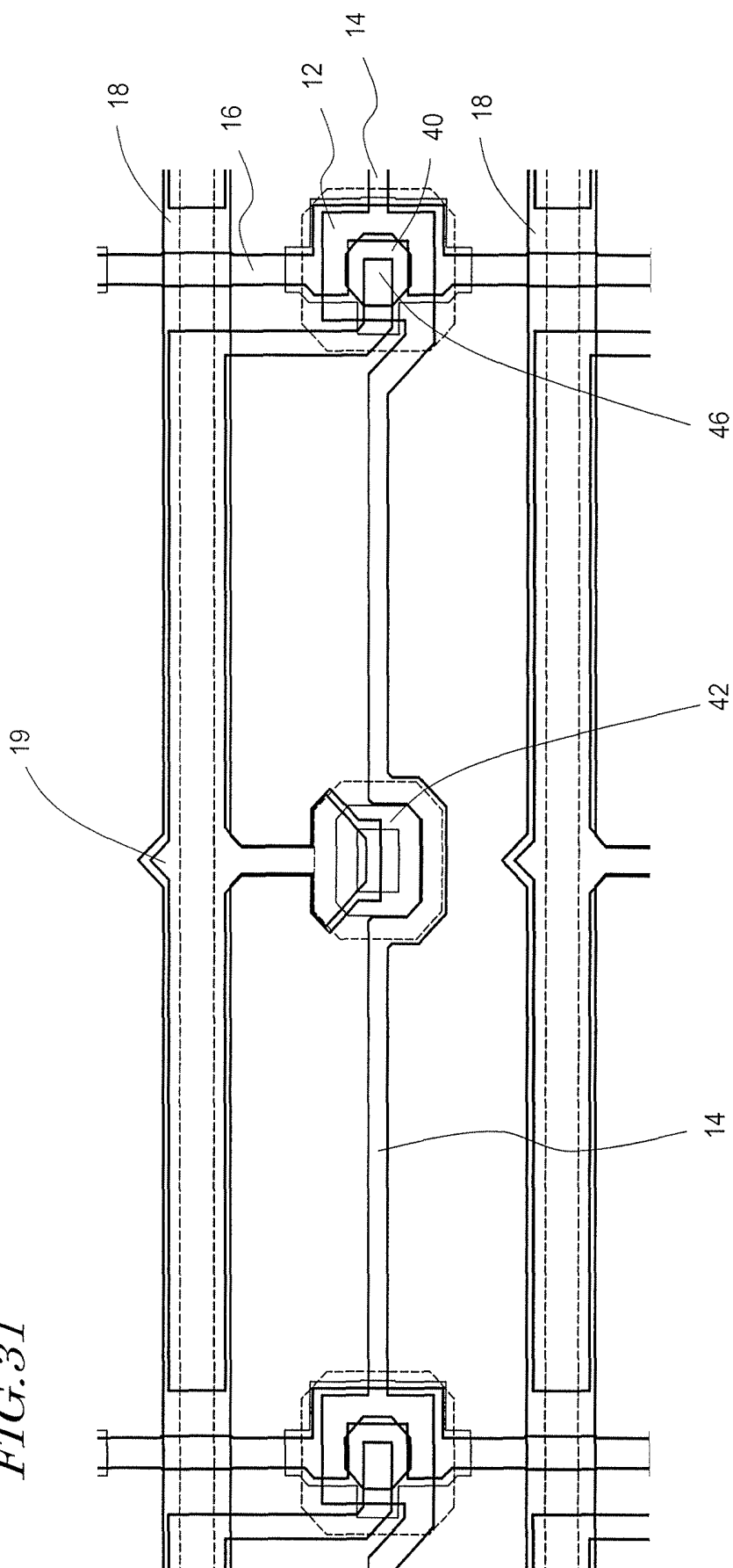


FIG. 32

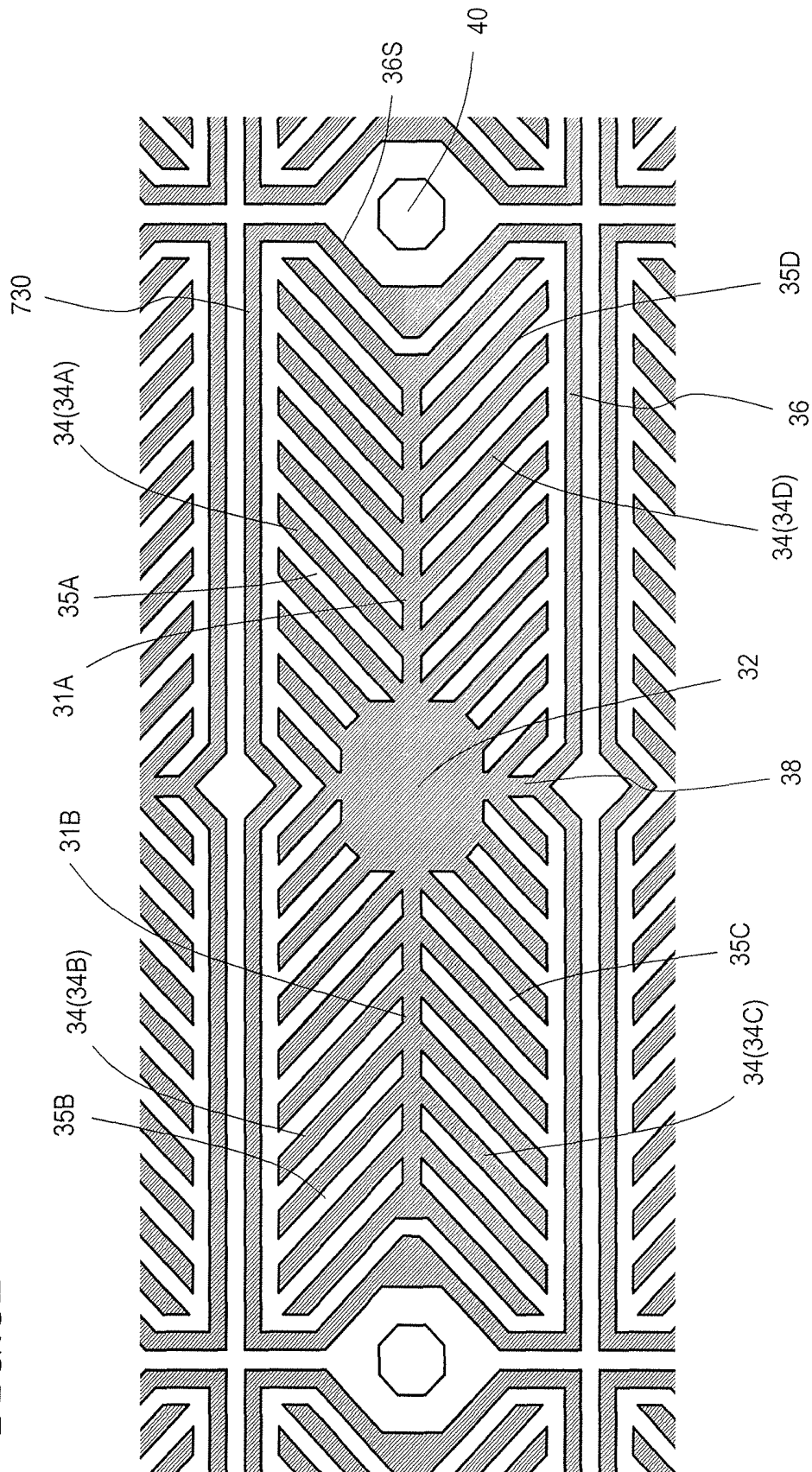
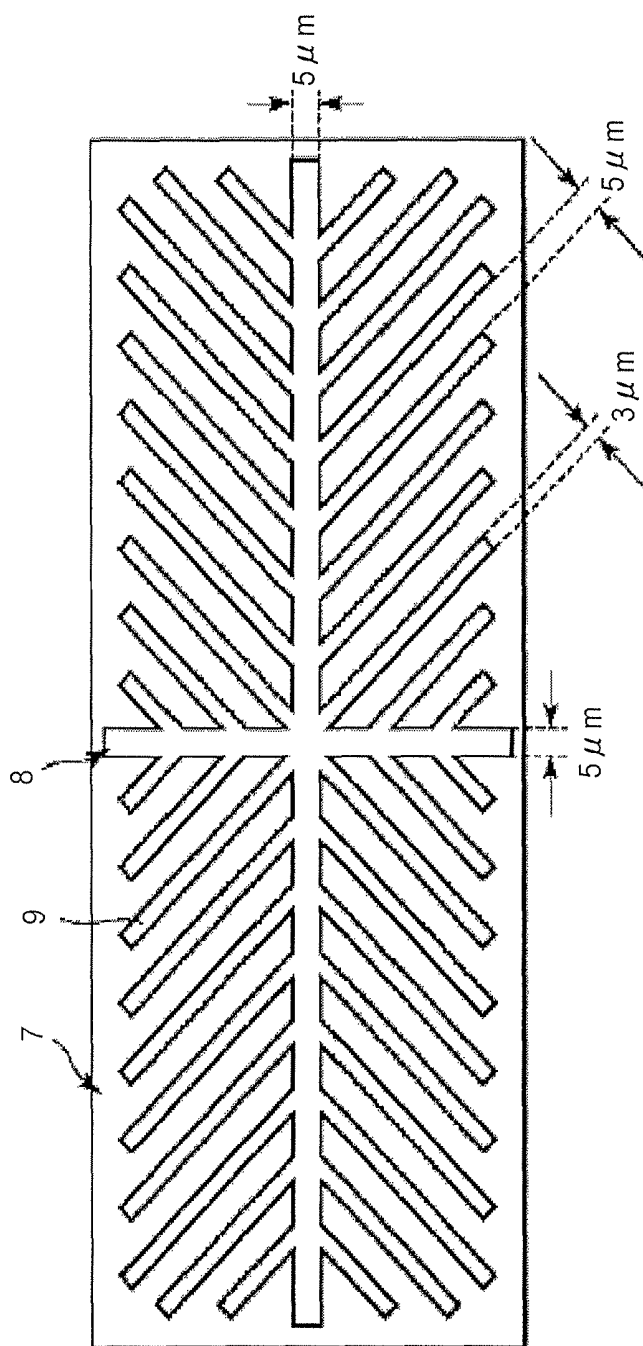


FIG. 33



LIQUID CRYSTAL DISPLAY DEVICE

This application is the U.S. national phase of International Application No. PCT/JP2010/063994, filed 19 Aug. 2010, which designated the U.S. and claims priority to JP Application No. 2009-193459, filed 24 Aug. 2009, the entire contents of each of which are hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates to a liquid crystal display device, and specifically to a liquid crystal display device having a plurality of alignment domains in a pixel.

BACKGROUND ART

Currently, as liquid crystal display devices having a wide viewing angle characteristic, the following liquid crystal display devices have been developed, for example: liquid crystal display devices using an IPS (In-Plane-Switching) mode or an FFS (Fringe Field Switching) mode, which are transverse electric field modes, and liquid crystal display devices using a VA (Vertical Alignment) mode.

VA-mode liquid crystal display devices include, for example, liquid crystal display devices of an MVA (Multidomain Vertical Alignment) mode in which a plurality of domains having different alignment directions of liquid crystal molecules are formed in one pixel, and liquid crystal display devices of a CPA (Continuous Pinwheel Alignment) mode in which the alignment direction of liquid crystal molecules is continuously varied around a rivet or the like formed on an electrode at a central position of the pixel.

An example of MVA-mode liquid crystal display device is described in Patent Document 1. In the liquid crystal display device described in Patent Document 1, alignment regulation means extending in two directions perpendicular to each other is provided. Owing to this, four liquid crystal domains are formed in one pixel in which an azimuthal angle of directors which are representative of the respective liquid crystal domains is 45° with respect to polarization axes (transmission axes) of a pair of polarizing plates placed in crossed Nicols. Where the azimuthal angle of 0° corresponds to a direction of the polarization axis of one of the polarizing plates and the counterclockwise direction is the positive direction, the azimuthal angles of the directors of the four liquid crystal domains are 45° , 135° , 225° , and 315° . Such a structure in which four domains are formed in one pixel is referred to as the "4-domain alignment structure" or simply as the "4D structure".

Other examples of MVA-mode liquid crystal display device are described in Patent Documents 2, 3 and 4. The liquid crystal display devices described in these patent documents each include pixel electrodes having many tiny slits (cutouts) extending in an azimuthal angle direction of 45° - 225° and an azimuthal angle direction of 135° - 315° (such pixel electrodes are referred to as the "comb-shaped pixel electrodes" or "fishbone-type pixel electrodes"). The 4-domain alignment structure is realized by aligning liquid crystal molecules to be parallel to these slits.

CITATION LIST

Patent Literature

Patent Document 1: Japanese Laid-Open Patent Publication No. 11-242225

Patent Document 2: Japanese Laid-Open Patent Publication No. 2002-357830

Patent Document 3: Japanese Laid-Open Patent Publication No. 2004-302168

Patent Document 4: Japanese Laid-Open Patent Publication No. 2009-151204

SUMMARY OF INVENTION

Technical Problem

FIG. 33 is a plan view showing a shape of a fishbone-type pixel electrode 7 in a liquid crystal display device described in Patent Document 2. The pixel electrode 7 has a trunk slit 8 and a branch slit 9 formed therein. The trunk slit 8 includes a trunk portion extending in a 0° - 180° direction (left-right direction in the figure) and a trunk portion extending in a 90° - 270° direction (top-bottom direction in the figure). The branch slit 9 includes a plurality of branch portions extending in a direction of 45° from the trunk slit 8, a plurality of branch portions extending in a direction of 135° from the trunk slit 8, a plurality of branch portions extending in a direction of 225° from the trunk slit 8, and a plurality of branch portions extending in a direction of 315° from the trunk slit 8. The 4D structure is provided by locating the branch slit 9 extending in four directions as described above.

In general, a TFT (Thin Film Transistor) substrate of a liquid crystal display device includes scanning lines (source bus lines) located on a base plate, TFTs formed on the scanning lines with a gate insulating film interposed therebetween, and pixel electrodes provided on the TFTs with an insulating layer interposed therebetween. A drain electrode of each TFT and the corresponding pixel electrode are electrically connected to each other via a contact hole formed in the insulating layer. The pixel electrode has a part which is formed along an inner face of the contact hole and thus has a recessed portion. The alignment of liquid crystal molecules may be disturbed by the recessed portion.

In many liquid crystal display devices, column-like spacers are located between the TFT substrate and a counter electrode in order to maintain the thickness of a liquid crystal layer at a prescribed value and thus to provide a high display quality. These spacers may also occasionally disturb the alignment of the liquid crystal molecules.

When the alignment of the liquid crystal molecules is disturbed by the elements such as the contact holes, the spacers or the like, there occurs a problem that the number of the liquid crystal molecules which effectively contribute to the formation of four domains of the 4D structure is decreased, which results in reduction of the transmittance or the viewing angle characteristic.

The above-described patent documents do not discuss, or propose any measure against, such a problem which may occur in a liquid crystal display device including fishbone-type pixel electrodes. Patent Document 4 describes a structure of forming contact holes and storage capacitance counter electrodes below the pixel electrode, but does not provide any measure for preventing the alignment disturbance of the liquid crystal molecules which is caused by the contact holes or the storage capacitance electrodes. In addition, these documents do not provide any consideration on a positional relationship, between the fishbone-type pixel electrode and the lines located below the pixel electrode, which provides an appropriate alignment of the liquid crystal molecules.

The present invention made to solve at least one of these problems has an object of providing a vertical alignment type

liquid crystal display device having a high transmittance or a high viewing angle characteristic.

Solution to Problem

A liquid crystal display device according to the present invention, which includes a plurality of pixels arrayed in a matrix, includes a TFT substrate including pixel electrodes respectively formed in correspondence with the plurality of pixels, TFTs respectively formed in correspondence with the plurality of pixels, and an insulating layer having a contact hole formed therein for electrically connecting a drain electrode of each of the TFTs and each of the pixel electrodes to each other; a counter substrate including a counter electrode facing the pixel electrodes; and a liquid crystal layer located between the TFT substrate and the counter substrate, the liquid crystal layer containing liquid crystal molecules having a negative dielectric anisotropy. The pixel electrodes each include a peripheral portion, an island portion including a portion which electrically contacts the drain electrode in the contact hole, and a plurality of branch portions extending from the peripheral portion; the plurality of branch portions include a plurality of first branch portions extending in a first direction, a plurality of second branch portions extending in a second direction, a plurality of third branch portions extending in a third direction, and a plurality of fourth branch portions extending in a fourth direction; the first direction, the second direction, the third direction and the fourth direction are different from each other; a first region in which the liquid crystal molecules are aligned along the first branch portions at the time of voltage application, a second region in which the liquid crystal molecules are aligned along the second branch portions at the time of voltage application, a third region in which the liquid crystal molecules are aligned along the third branch portions at the time of voltage application, and a fourth region in which the liquid crystal molecules are aligned along the fourth branch portions at the time of voltage application are formed by the first branch portions, the second branch portions, the third branch portions and the fourth branch portions; and when seen in a direction vertical to a surface of the TFT substrate, the island portion is surrounded by the first region, the second region, the third region and the fourth region; and the island portion is electrically connected to the peripheral portion by a connection portion other than the plurality of branch portions but not by any of the plurality of branch portions, or electrically connected to the peripheral portion by one of the first branch portions, one of the second branch portions, one of the third branch portions or one of the fourth branch portions.

In an embodiment, ends of all the plurality of branch portions opposite to the peripheral portion are separated from the island portion, and the peripheral portion and the island portion are electrically connected to each other by only one connection portion.

In an embodiment, ends of all the plurality of branch portions opposite to the peripheral portion are separated from the island portion, and the peripheral portion and the island portion are electrically connected to each other by only two connection portions.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the two connection portions are located to be symmetrical to each other with respect to the center of the island portion or the center of the pixel.

In an embodiment, the island portion is electrically connected to only one of the first branch portions, only one of the second branch portions, only one of the third branch portions and only one of the fourth branch portions.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, one of the first branch portions and one of the second branch portions are located to be symmetrical to one of the third second branch portions and one of the fourth branch portions with respect to the center of the island portion or a line which equally divides the pixel into two.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the island portion has a shape which is symmetrical with respect to the center thereof or the center of the pixel.

In an embodiment, the island portion is electrically connected to only one branch portion among all the first branch portions, the second branch portions, the third branch portions and the fourth branch portions.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, an outer edge of the island portion is surrounded by two among the four regions of a first pixel and two among the four regions of a second pixel adjoining the first pixel.

In an embodiment, ends of all the plurality of branch portions opposite to the peripheral portion are separated from the island portion, and the peripheral portion and the island portion are electrically connected to each other with none of the plurality of branch portions being connected therebetween.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, an outer edge of the island portion includes a first end facing the first region, a second end facing the second region, a third end facing the third region, and a fourth end facing the fourth region; and the first end includes an end portion extending along the first branch portions, the second end includes an end portion extending along the second branch portions, the third end includes an end portion extending along the third branch portions, and the fourth end includes an end portion extending along the fourth branch portions.

In an embodiment, the first end extends in the first direction, the second end extends in the second direction, the third end extends in the third direction, and the fourth end extends in the fourth direction.

In an embodiment, the first end and the third end extend parallel to each other, and the second end and the fourth end extend parallel to each other in a direction different by 90° from the first end.

In an embodiment, the liquid crystal display device further includes a first polarizing plate and a second polarizing plate located so as to hold the liquid crystal layer therebetween. An absorption axis of the first polarizing plate and an absorption axis of the second polarizing plate cross each other perpendicularly, and the first direction, the second direction, the third direction and the fourth direction are each different by 45° from the absorption axis of the first polarizing plate or the second polarizing plate.

In an embodiment, the liquid crystal display device further includes a spacer located between the TFT substrate and the counter substrate. When seen in the direction vertical to the surface of the TFT substrate, the spacer is located so as not to overlap the pixel electrode.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at least at one of four corners of each of the plurality of pixels.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, in the vicinity of the spacer, a part of the peripheral portion of the pixel electrode extends perpendicularly to a direction in which the plurality of corresponding branch portions extend.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at a central position of at least one of four sides of each of the plurality of pixels.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, in the vicinity of the spacer, a part of the peripheral portion of the pixel electrode extends along a direction in which the plurality of corresponding branch portions extend.

In an embodiment, the liquid crystal display device further includes a spacer located between the TFT substrate and the counter substrate. When seen in the direction vertical to the surface of the TFT substrate, the spacer is located so as to overlap the pixel electrode.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at least at one of four corners of each of the plurality of pixels.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at a central position of at least one of four sides of each of the plurality of pixels.

Another liquid crystal display device according to the present invention, which includes a plurality of pixels arrayed in a matrix, includes a TFT substrate including pixel electrodes respectively formed in correspondence with the plurality of pixels, TFTs respectively formed in correspondence with the plurality of pixels, and an insulating layer having a contact hole formed therein for electrically connecting a drain electrode of each of the TFTs and each of the pixel electrodes to each other; a counter substrate including a counter electrode facing the pixel electrodes; and a liquid crystal layer located between the TFT substrate and the counter substrate, the liquid crystal layer containing liquid crystal molecules having a negative dielectric anisotropy. The pixel electrodes each include a peripheral portion, an island portion including a portion which electrically contacts the drain electrode in the contact hole, a plurality of trunk portions extending from the island portion, and a plurality of branch portions extending from the plurality of trunk portions or the island portion; the plurality of branch portions include a plurality of first branch portions extending in a first direction, a plurality of second branch portions extending in a second direction, a plurality of third branch portions extending in a third direction, and a plurality of fourth branch portions extending in a fourth direction; the first direction, the second direction, the third direction and the fourth direction are different from each other; a first region in which the liquid crystal molecules are aligned along the first branch portions at the time of voltage application, a second region in which the liquid crystal molecules are aligned along the second branch portions at the time of voltage application, a third region in which the liquid crystal molecules are aligned along the third branch portions at the time of voltage application, and a fourth region in which the liquid crystal molecules are aligned along the fourth branch portions at the time of voltage application are formed by the first branch portions, the second branch portions, the third branch portions and the fourth branch portions; and when seen in a direction vertical to a surface of the TFT substrate, the island portion is surrounded by the first region, the second region, the third region and the fourth region; there is an insulating portion between ends of all the plurality of branch portions and the peripheral portion; and the island portion is electrically connected to the peripheral portion by a connection portion other than the plurality of branch portions.

In an embodiment, ends of all the branch portions opposite to the trunk portions or the island portion are separated from

the peripheral portion, and the peripheral portion and the island portion are electrically connected to each other by only one connection portion.

In an embodiment, the liquid crystal display device further includes a first polarizing plate and a second polarizing plate located so as to hold the liquid crystal layer therebetween. An absorption axis of the first polarizing plate and an absorption axis of the second polarizing plate cross each other perpendicularly, and the first direction, the second direction, the third direction and the fourth direction are each different by 45° from the absorption axis of the first polarizing plate or the second polarizing plate.

In an embodiment, the liquid crystal display device further includes a spacer located between the TFT substrate and the counter substrate. When seen in the direction vertical to the surface of the TFT substrate, the spacer is located so as not to overlap the pixel electrode.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at a central position of at least one of four sides of each of the plurality of pixels.

In an embodiment, when seen in the direction vertical to the surface of the TFT substrate, in the vicinity of the spacer, a part of the peripheral portion of the pixel electrode extends along a direction in which the plurality of corresponding branch portions extend.

Advantageous Effects of Invention

According to the present invention, a liquid crystal display device having a high transmittance or a high viewing angle characteristic can be provided.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is an isometric view schematically showing a structure of a liquid crystal display device **100** according to the present invention.

FIG. 2 is a plan view schematically showing a structure of a plurality of pixels **50** of the liquid crystal display device **100**.

FIG. 3 is a plan view showing a structure of a pixel **50** of a liquid crystal display device **100** in Embodiment 1 according to the present invention.

FIG. 4 is a cross-sectional view showing a structure of an A-D cross-section of the pixel **50** shown in FIG. 3 in Embodiment 1.

FIG. 5 is a plan view showing a line configuration of the pixel **50** in Embodiment 1.

FIG. 6 is a plan view showing a shape of a pixel electrode **30** in Embodiment 1.

FIG. 7 is a plan view showing a shape of a pixel electrode **30A** in a first modification of Embodiment 1.

FIG. 8 is a plan view showing a shape of a pixel electrode **30B** in a second modification of Embodiment 1.

FIG. 9 is a plan view showing a shape of a pixel electrode **30C** in a third modification of Embodiment 1.

FIG. 10 is a plan view showing a modification of the line configuration of the pixel **50** in Embodiment 1.

FIG. 11 is a plan view showing a modification of the structure of the pixel **50** in Embodiment 1.

FIG. 12 is a plan view showing a structure of a pixel **50** of a liquid crystal display device **100** in Embodiment 2 according to the present invention.

FIG. 13 is a plan view showing a line configuration of the pixel **50** in Embodiment 2.

FIG. 14 is a plan view showing a shape of a pixel electrode **230** in Embodiment 2.

FIG. 15 is a plan view showing a modification of the line configuration of the pixel 50 in Embodiment 2.

FIG. 16 is a plan view showing a structure of a pixel 50 of a liquid crystal display device 100 in Embodiment 3 according to the present invention.

FIG. 17 is a plan view showing a line configuration of the pixel 50 in Embodiment 3.

FIG. 18 is a plan view showing a shape of a pixel electrode 330 in Embodiment 3.

FIG. 19 is a plan view showing a shape of a pixel electrode 330B, which is a comparative example to the pixel electrode 330 in Embodiment 3.

FIG. 20 is a plan view showing a modification of the line configuration of the pixel 50 in Embodiment 3.

FIG. 21 is a plan view showing a structure of a pixel 50 of a liquid crystal display device 100 in Embodiment 4 according to the present invention.

FIG. 22 is a plan view showing a line configuration of the pixel 50 in Embodiment 4.

FIG. 23 is a plan view showing a shape of a pixel electrode 430 in Embodiment 4.

FIG. 24 is a plan view showing a structure of a pixel 50 of a liquid crystal display device 100 in Embodiment 5 according to the present invention.

FIG. 25 is a plan view showing a line configuration of the pixel 50 in Embodiment 5.

FIG. 26 is a plan view showing a structure of a pixel 50 of a liquid crystal display device 100 in Embodiment 6 according to the present invention.

FIG. 27 is a plan view showing a line configuration of the pixel 50 in Embodiment 6.

FIG. 28 is a plan view showing a shape of a pixel electrode 630 in Embodiment 6.

FIG. 29 is a plan view showing a shape of a pixel electrode 630B in a modification in Embodiment 6.

FIG. 30 is a plan view showing a structure of a pixel 50 of a liquid crystal display device 100 in Embodiment 7 according to the present invention.

FIG. 31 is a plan view showing a line configuration of the pixel 50 in Embodiment 7.

FIG. 32 is a plan view showing a shape of a pixel electrode 730 in Embodiment 7.

FIG. 33 is a plan view showing a shape of a fishbone-type pixel electrode 7 of a liquid crystal display device described in Patent Document 2.

DESCRIPTION OF EMBODIMENTS

Hereinafter, structures of vertical alignment type liquid crystal display devices 100 in embodiments according to the present invention will be described with reference to the drawings. It should be noted that the present invention is not limited to the following embodiments.

FIG. 1 is an isometric view schematically showing a structure of the liquid crystal display device 100, and FIG. 2 is a plan view schematically showing a structure of a plurality of pixels 50 of the liquid crystal display device 100.

As shown in FIG. 1, the liquid crystal display device 100 includes a TFT substrate 10 and a counter substrate (CF substrate) 20 which face each other while holding a liquid crystal layer 21 therebetween, polarizing plates 26 and 27 respectively located outer to the TFT substrate 10 and the counter substrate 20, and a backlight unit 28 for outputting light for display toward the polarizing plate 26.

The liquid crystal display device 100 is a vertical alignment type liquid crystal display device for providing display in a normally black mode by means of the pixels 50 which are,

shown in FIG. 2, arrayed in a matrix in an X direction (left-right direction in the figure) and a Y direction (top-bottom direction in the figure). A minimum display unit is formed of three primary colors of red (R), green (G) and blue (B). Each of the pixels 50 corresponds to a display area of one color among R, G and B. The minimum display unit may be formed of four or more primary colors (multi-color display). In such a case, each pixel 50 corresponds to a display area of one color among a plurality of primary colors which form the minimum display unit.

The TFT substrate 10 includes a plurality of scanning lines (gate bus lines) 14 and a plurality of signal lines (data bus lines) 16 which are located so as to cross each other perpendicularly. In the vicinity of each of intersections of the plurality of scanning lines 14 and the plurality of signal lines 16, a TFT 12 as an active element is formed in correspondence with each pixel 50. Each pixel 50 includes a pixel electrode 30 which is electrically connected to a drain electrode of the TFT 12 and is formed of, for example, ITO (Indium Tin Oxide) or IZO (Indium Zinc Oxide). Each two adjoining scanning lines 14 may have therebetween a storage capacitance line (also referred to as the "storage capacitance bus line" or the "Cs line") 18 extending parallel to the scanning lines 14. The scanning lines 14 and the storage capacitance lines 18 may be positionally replaced with each other so that the TFTs 12 are located in the vicinity of the corresponding scanning lines.

The plurality of scanning lines 14 are each connected to a scanning line driving circuit 22 shown in FIG. 1, and the plurality of signal lines 16 are each connected to a signal line driving circuit 23 shown in FIG. 1. The scanning line driving circuit 22 and the signal line driving circuit 23 are connected to a control circuit 24. In accordance with the control by the control circuit 24, a scanning signal for turning the TFT 12 on or off is supplied from the scanning line driving circuit 22 to the corresponding scanning line 14. In accordance with the control by the control circuit 24, a display signal (voltage to be applied to the pixel electrodes 30) is supplied from the signal line driving circuit 23 to the plurality of signal lines 16.

As described later with reference to FIG. 4, the counter substrate 20 includes color filters 13, a common electrode (counter electrode) 25 and a black matrix (BM) 11. In the case where the liquid crystal display device 100 provides display by three primary colors, the color filters 13 include an R (red) filter, a G (green) filter and a B (blue) filter each located in correspondence with a pixel. The common electrode 25 is formed so as to cover the plurality of pixel electrodes 30. In accordance with the difference in potentials given between the common electrode 25 and each pixel electrode 30, liquid crystal molecules between these electrodes are aligned in each pixel and thus display is provided.

Embodiment 1

FIG. 3 is a plan view showing a structure of a pixel of a liquid crystal display device 100 in Embodiment 1 according to the present invention. FIG. 4 is a cross-sectional view showing a structure of an A-D cross-section of the pixel 50 shown in FIG. 3. FIG. 5 is a plan view showing a line configuration, of the pixel 50, below the pixel electrode 30 of the TFT substrate. FIG. 6 is a plan view schematically showing a shape of the pixel electrode 30. FIG. 5 and FIG. 6 show a location arrangement of spacers 40 in addition to the line configuration or the pixel electrode 30.

As shown in FIG. 3 through FIG. 5, the TFT substrate 10 of the liquid crystal display device 100 includes the scanning lines 14, storage capacitance lines 18, the TFTs 12, the signal lines 16, storage capacitance counter electrodes 19 and the

fishbone-type pixel electrodes **30** formed on a transparent plate. On the scanning lines **14** and the storage capacitance lines **18**, a gate insulating film **15** is formed. Each TFT **12** is formed on the corresponding scanning line **14** with the gate insulating film **15** interposed therebetween, and each storage capacitance counter electrode **19** is formed on the corresponding storage capacitance line **18** with the gate insulating film **15** interposed therebetween. The scanning lines **14**, the storage capacitance lines **18**, the signal lines **16** and the storage capacitance counter electrodes **19** each have a single layer structure formed of Al (aluminum), Ti (titanium), TiN (titanium nitride), Mo (molybdenum) or the like, or an alloy thereof, or alternatively have a stacking structure including a plurality of such metal layers stacked.

Each TFT **12** includes a semiconductor layer **17** formed on the gate insulating film **15**. A source electrode of the TFT **12** is electrically connected to the corresponding signal line **16**, and the drain electrode **46** of the TFT **12** is electrically connected to the corresponding storage capacitance counter electrode **19** as shown in FIG. 3 and FIG. 5. A part of the storage capacitance line **18** and the storage capacitance counter electrode **19** which face each other while holding the gate insulating film **15** therebetween form a storage capacitance. As shown in FIG. 4, the TFT **12**, the signal line **16**, and the storage capacitance counter electrode **19** are covered with a protective insulating film **43**, and an interlayer insulating film **44** is formed on the protective insulating film **43**. One of, or both of, the protective insulating film **43** and the interlayer insulating film **44** may occasionally be referred to as the "insulating film".

In the protective insulating film **43** and the interlayer insulating film **44**, a contact hole **42** is formed at a position above the storage capacitance counter electrode **19**. The drain electrode **46** of the TFT **12** and the pixel electrode **30** are electrically connected to each other via the contact hole **42**. More specifically, a part of the pixel electrode **30** which is formed on an inner face of the contact hole **42** is connected to the storage capacitance counter electrode **19** or an electrode extending from the storage capacitance counter electrode **19** at a bottom of the contact hole **42**, and thus the pixel electrode **30** and the drain electrode **46** are electrically connected to each other.

As shown in FIG. 4, the counter substrate **20** includes the common electrode **25**, the color filters **13**, and the black matrix **11**. Between the TFT substrate **10** and the counter substrate **20**, a liquid crystal layer **21** containing a nematic liquid crystal molecules having a negative dielectric anisotropy ($\Delta\epsilon < 0$) is located. The liquid crystal layer **21** has a thickness of 3.1 μm . Preferably, the thickness of the liquid crystal layer **21** is 2.0 μm or greater and 5.0 μm or less. The liquid crystal layer **21** may contain a chiral agent. Although not shown, an alignment film (vertical alignment film) is formed on the interlayer insulating film **44** and the pixel electrodes **30** in the TFT substrate **10** (on the liquid crystal layer **21** side), and an alignment film (vertical alignment film) is formed on the common electrode **25** (on the liquid crystal layer **21** side). By the action of the alignment films, the liquid crystal molecules of the liquid crystal layer **21** are aligned vertically with respect to a surface of the TFT substrate **10** or the counter substrate **20** in the absence of a voltage.

On the alignment film of each of the TFT substrate **10** and the counter substrate **20**, an alignment sustaining layer may be formed for providing the liquid crystal molecules with a pretilt in the absence of a voltage. The alignment sustaining layer is a polymer layer which is formed as follows. A photo-polymerizable monomer is mixed in a liquid crystal material in advance, and after the liquid crystal cell is formed, the

photo-polymerizable monomer is photo-polymerized in the state where a voltage is applied to the liquid crystal layer. Owing to the alignment sustaining layers, a pretilt of the liquid crystal molecules in a direction tilted slightly (e.g., about 2 to 3°) from the direction vertical to the substrate surface, and the alignment direction (pretilt azimuth), can be sustained (stored) even in the absence of a voltage. This technology is referred to as the PSA (Polymer Sustained Alignment) technology, and use of this technology can improve the response speed regarding the alignment of liquid crystal molecules at the time of voltage application.

Between the TFT substrate **10** and the counter substrate **20**, column-like spacers **40** are located for maintaining the thickness of the liquid crystal layer **21** to a prescribed value or in a prescribed range. In this embodiment, the spacers are located above the TFTs **12** in the vicinity of four corners of the pixel electrode **30**, which has an approximately rectangular outer edge shape.

Now, with reference to FIG. 6, the pixel electrode **30** and the spacers **40** will be described in more detail. In the description of this embodiment, the direction in which the scanning lines **14** extend (left-right direction in the figure) is the X direction, the direction in which the signal lines **16** extend (top-bottom direction in the figure) is the direction, and the direction vertical to the surface of the substrates of the liquid crystal display device **100** is the Z direction. A positive X direction (direction from the left to the right in the figure) is the direction of an azimuthal angle of 0°, and the azimuthal angle is set counterclockwise. A positive Y direction (direction from the bottom to the top in the figure) is the direction of an azimuthal angle of 90°.

The pixel electrode **30** includes a peripheral portion **36** extending along an outer edge thereof, an island portion **32** formed so as to cover the contact hole **42** when seen in the Z direction, and a plurality of branch portions **34** extending from the peripheral portion **36** inward in the pixel **50**. The peripheral portion **36** includes portions extending in the X direction and portions extending in the Y direction. The plurality of branch portions **34** are formed of a plurality of first branch portions **34A** extending in a direction of 225° (first direction) from the peripheral portion **36**, a plurality of second branch portions **34B** extending in a direction of 315° (second direction) from the peripheral portion **36**, a plurality of third branch portions **34C** extending in a direction of 45° (third direction) from the peripheral portion **36**, and a plurality of fourth branch portions **34D** extending in a direction of 135° (fourth direction) from the peripheral portion **36**.

The island portion **32** is electrically connected to the peripheral portion **36** by one connection portion **38** of the pixel electrode **30** extending from the peripheral portion **36**, but not by any of the plurality of branch portions **34**. A narrowest part of the connection portion **38** has a length of 6.0 μm . Such a length of the narrowest part prevents the connection **38** from being broken, which can suppress production of defective products. In addition, all the branch portions **34** are connected to the peripheral portion **36**. Therefore, even if a part of the peripheral portion **36** is broken, all the branch portions **34** can be supplied with a voltage. In this manner, the peripheral portion **36** acts as redundant means for voltage supply (or means for avoiding disconnection of voltage supply) to the branch portions **34**.

None of ends of all the plurality of branch portions **34** opposite to the peripheral portion **36** is connected to any other portion of the pixel electrode or the island portion **32**. Namely, there is an insulating portion (or an electrode-absent portion) between the ends of all the plurality of branch portions **34** and the island portion **32**. The plurality of branch

portions **34** all have an identical width and extend with the same width. The width of each branch portion **34** is 3.5 μm . Preferably, the width of each branch portion **34** is in the range of 1.0 μm or greater and 5.0 μm or less.

Regarding each of the first through fourth branch portions **34A** through **34D**, each two adjoining branch portions have a branch slit (portion with no electrode material) therebetween. Each branch slit extends along the adjoining first branch portions **34A**, second branch portions **34B**, third branch portions **34C** or fourth branch portions **34D**. Each branch slit has a width of 3.0 μm . Preferably, the width of each branch slit is in the range of 1.0 μm or greater and 5.0 μm or less.

Between the first branch portions **34A** and the fourth branch portions **34D**, and between the second branch portions **34B** and the third branch portions **34C**, trunk slits are formed so as to extend on a straight line which equally divides the pixel electrode **30** into two in the Y direction. Between the third branch portions **34C** and the fourth branch portions **34D**, a trunk slit is formed so as to extend on a straight line which equally divides the pixel electrode **30** into two in the X direction. The trunk slits have a width of 3.5 μm . When the width of the trunk slits is 2.0 μm or less, the liquid crystal molecules may undesirably be aligned in a direction opposite to a desired direction from the trunk slits as the starting point at the time of voltage application. Therefore, the width of the trunk slits is preferably greater than 2.0 μm .

A border between each two pixel electrodes **30** adjoining each other in the Y direction is on the scanning line **14**, and a border between each two pixel electrodes **30** adjoining each other in the X direction is on the signal line **16**. Each two adjoining pixel electrodes **30** are away from each other by a distance of 3.5 μm . Preferably, the distance is 6.0 μm or less in order to widen the border between such two adjoining pixel electrodes **30** and thus to increase the area contributing to the display.

When a voltage is applied to liquid crystal molecules **52**, four liquid crystal alignment domains **35A**, **35B**, **35C** and **35D** are formed by the first branch portions **34A**, the second branch portions **34B**, the third branch portions **34C** and the fourth branch portions **34D**. The liquid crystal molecules **52** are aligned along the first branch portions **34A** in the alignment domain **35A**, along the second branch portions **34B** in the alignment domain **35B**, along the third branch portions **34C** in the alignment domain **35C**, and along the fourth branch portions **34D** in the alignment domain **35D**. It should be noted that the directions in which the liquid crystal molecules **52** are tilted in the alignment domains **35A**, **35B**, **35C** and **35D** at the time of voltage application are respectively opposite to the first, second, third and fourth directions mentioned above. As shown in FIG. 6, the liquid crystal molecules are each tilted such that a tip thereof (end on the counter substrate **20** side) is directed toward the peripheral portion **36** of the pixel electrode **30**.

As shown in FIG. 6, absorption axes **48** and **49** of the polarizing plates **26** and **27** extend in the X direction and the Y direction. The directions of the absorption axes **48** and **49** are different by 45° from any of the first through fourth directions. Accordingly, the alignment direction of the liquid crystal molecules in each alignment domain is different by 45° from the directions of the absorption axes **48** and **49**. This realizes display with little viewing angle dependence.

When seen in the Z direction, an outer edge **32S** of the island portion **32** faces all the four domains **35A**, **35B**, **35C** and **35D**. None of the ends of the first branch portions **34A**, the second branch portions **34B**, the third branch portions **34C** and the fourth branch portions **34D** (collectively referred to as the "plurality of branch portions") is connected to the

island portion **32**. Therefore, there is a gap (slit, or electrode-absent portion) between the outer edge **32S** of the island portion **32** and the plurality of branch portions. Owing to this gap, the liquid crystal molecules **52** in each of the alignment domains are not influenced easily by an electric field generated on the island portion **32** at the time of voltage application. Therefore, alignment disturbance of the liquid crystal molecules in each alignment domain can be reduced. This realizes display having a high transmittance or a high viewing angle characteristic. In order to provide superb display, it is preferable that at least 80% of the outer edge **32S** of the island portion **32** is surrounded by the gap.

The scanning lines **14**, the signal lines **16**, the storage capacitance lines **18**, and the storage capacitance counter electrodes **19** block light. In this embodiment, gaps each sandwiched by two pixel electrodes **30** are present above the scanning lines **14** and the signal lines **16**, the trunk slits are present above the storage capacitance lines **18**, and the island portions **32** are present above the storage capacitance counter electrodes **19**. The gaps, the trunk slits and the island portions **32** do not greatly contribute to the luminance. Therefore, in this embodiment, superb display in which the luminance, which is reduced due to the metal lines, is not reduced much is provided.

When seen in the Z direction, the pixel **50** is rectangular, and the spacers **40** are located at four corners of the pixel **50** so as not to overlap the pixel electrode **30**. The four corners of the pixel electrode **30** are recessed inward (the four corners are cut off), and a portion of the peripheral portion **36** in the vicinity of each spacer **40** includes a portion **36S** extending parallel to an outer edge of the spacer **40**. The portion **36S** of the peripheral portion **36** extends perpendicularly to a direction in which the plurality of branch portions **34** in the vicinity thereof extend. Owing to the portions **36S** of the peripheral portion **36**, the liquid crystal molecules at each of the corners can be aligned in a direction closer to the perpendicular direction to the direction in which the corresponding branch portions **34** extend at the time of voltage application. Therefore, display with a high luminance can be provided.

Since the spacers **40** are located at the corners, one of side surfaces of each spacer **40** on the pixel electrode **30** side is perpendicular to the direction in which the branch portions **34** in the vicinity of the corresponding spacer **40** extend. Namely, at each of the corners, the alignment direction of the liquid crystal molecules urged by an electric field generated by the plurality of branch portions **34** and the gaps therebetween, or the alignment direction of the liquid crystal molecules urged by a polymer layer formed in order to sustain (store) the initial alignment of the liquid crystal molecules, is not counteracted by the alignment direction of the liquid crystal molecules urged by the spacer **40** and an alignment film on a surface thereof, at the time of voltage application. Therefore, an area in the vicinity of each spacer **40** in which the alignment of the liquid crystal molecules is disturbed can be decreased. As a result, superb display having a high luminance with no coarseness can be provided. In addition, since gaps are present between the spacers **40** and the pixel electrode **30**, the alignment disturbance of the liquid crystal molecules which is caused by the surfaces of each spacer **40** other than the surface perpendicular to the direction in which the corresponding branch portions **34** extend is suppressed from being conveyed to the liquid crystal molecules on the pixel electrode **30**.

In this embodiment, the spacers **40** are located at all the four corners of the pixel **50**, but the spacers **40** do not need to be located at all the corners. The location arrangement of the spacers **40** may be different for each pixel **50**. All the spacers

40 do not need to have the same size or shape. In this embodiment, the spacers 40 have an octagonal cross-section, but there is no limitation on the cross-sectional shape of the spacers 40. For example, the spacers 40 may have a cross-section of any other polygonal shape or a cylindrical cross-section.

On the TFT 12, the black matrix 11 is located so as to cover the TFT 12. The presence of the spacers 40 may undesirably disturb the liquid crystal molecules 52 in the vicinity of the spacers 40 and this may cause inappropriate light transmission which may reduce the display quality. However, since the spacers 40 are located above the TFTs 12, such transmitted light is blocked by the black matrix 11 and thus reduction of the display quality is prevented.

Since the spacers 40 do not overlap the pixel electrode 30, even if a pressure is applied on the liquid crystal display device 100 during the production or use thereof, the spacers 40 do not contact the pixel electrode 30. Therefore, the pixel electrode 30 is prevented from being broken or delaminated, which reduces a leak current or variance of the cell thickness.

In this embodiment, when seen in the Z direction, each scanning line 14 overlaps the peripheral portion 36 of the pixel electrode 30. Therefore, the electric field leaking from the scanning line 14 is blocked by the peripheral portion 36. This reduces abnormal alignment of the liquid crystal molecules 52 or generation of flickers in the display area, which realizes high quality display. Since the storage capacitance counter electrode 19 is located also on the scanning line 14, a larger storage capacitance is provided. Since the storage capacitance counter electrode 19 can also block the electric field leaking from the scanning line 14, still higher quality display can be provided.

Now, with reference to FIG. 7, a pixel electrode 30A in a first modification of the liquid crystal display device 100 in Embodiment 1 will be described.

Regarding each of the following modifications and embodiments, identical elements, or elements having identical functions, to those of the liquid crystal display device 100 in Embodiment 1 will bear identical reference signs, and descriptions of these elements and descriptions of the effects provided by these elements will be omitted. The liquid crystal display devices 100 in the modifications and the embodiments include the same elements unless any difference is shown in a figure or described.

The pixel electrode 30A in the first modification includes two connection portions 38A and 38B for electrically connecting the island portion 32 and the peripheral portion 36 to each other. The ends of all the branch portions 34 are separated from the island portion 32. An outer edge of the peripheral portion 36 is surrounded by a gap except for the connection portions 38A and 38B.

When seen in the Z direction, the connection portion 38A and the connection portion 38B are located to be symmetrical to each other with respect to the center of the island portion 32, the center of the pixel electrode 30 or the center of the pixel 50. Therefore, even if slight alignment disturbance occurs by the connection portions 38A and 38B, the amount of alignment disturbance can be uniform among the alignment domains 35A through 35D. Accordingly, the transmittance is relatively uniform among the alignment domains 35A through 35D, which realizes display with a high viewing angle characteristic.

Since the two connection portions 38A and 38B are provided, even if one of the connection portions is broken, all the branch portions 34 can be supplied with a voltage by the other connection portion. This has an advantage that quality inferiority does not occur easily.

Now, with reference to FIG. 8, a pixel electrode 30B in a second modification of the liquid crystal display device 100 in Embodiment 1 will be described.

In the pixel electrode 30B in the second modification, the island portion 32 and the peripheral portion are electrically connected to each other by one branch portion 34AC among the first branch portions 34A, one branch portion 34BC among the second branch portions 34B, one branch portion 34CC among the third branch portions 34C, and one branch portion 34DC among the second branch portions 34D.

When seen in the Z direction, the branch portions 34AC and 34BC are formed symmetrically to the branch portions 34CC and 34DC with respect to a line which equally divides the island portion 32 or the pixel 50 into two in the Y direction (central line of the pixel 50 extending in the X direction). The branch portions 34AC and 34DC are formed symmetrically to the branch portions 34BC and 34CC with respect to a line which equally divides the island portion 32 or the pixel 50 into two in the X direction (central line of the pixel 50 extending in the Y direction). By locating the branch portions 34A through 34D symmetrically to each other in this manner, the transmittance can be uniformized among the alignment domains 35A through 35D and thus the viewing angle characteristic can be improved.

In addition, the four branch portions 34AC, 34BC, 34CC and 34DC are in contact with the island portion 32. Therefore, even if one through three among these four branch portions are broken, all the branch portions 34 can be supplied with a voltage by the other branch portion(s). Accordingly, quality inferiority does not occur easily.

Now, with reference to FIG. 9, a pixel electrode 30C in a third modification of the liquid crystal display device 100 in Embodiment 1 will be described.

The pixel electrode 30C in the third modification is formed to have a rectangular outer edge. Four corners 36E of the peripheral portion 36 are not recessed unlike in the pixel electrode 30 but are bent at a right angle. When seen in the Z direction, the spacers 40 overlap the corners 36E of the pixel electrode 30C. The pixel electrode 30C has a larger area contributing to display than the pixel electrode 30, and thus can provide display having a higher luminance.

Now, with reference to FIG. 10, a modification of the line configuration of the pixel 50 in Embodiment 1 will be described.

In this modification, the storage capacitance counter electrode 19 is mainly formed on the storage capacitance line 18, and is not formed on the scanning line 14 of the pixel 50. In the case where, for example, a liquid crystal display system of inputting an AC signal to the common electrode 25 and inputting a DC signal to the scanning line 14 during a gate-off period of the TFT 12 is adopted, a parasitic capacitance formed by the scanning line 14 and the storage capacitance counter electrode 19 may reduce an effective voltage value during a period in which the voltage is kept in the liquid crystal layer 21. This modification has an advantage that such reduction of the voltage applied to the liquid crystal layer due to the parasitic capacitance can be suppressed. In addition, this modification can reduce the load on the scanning line 14 and thus can contribute to reduction of the power consumption.

Now, with reference to FIG. 11, a modification of the structure of the pixel 50 in Embodiment 1 will be described.

In this modification, the storage capacitance counter electrodes 19 are formed on the storage capacitance line 18 and the scanning line 14. However, when seen in the Z direction,

15

the storage capacitance counter electrode **19** on the scanning line **14** does not overlap the peripheral portion **36** of the pixel electrode **30**.

When the storage capacitance counter electrode **19** of one pixel **50** overlaps the pixel electrode **30** of another pixel **50** adjoining the one pixel **50**, a relatively large parasitic capacitance as compared with the pixel electrode **30** of the another pixel **50** may be generated. In the case where, for example, a driving system of inverting the polarity of the voltage to be applied to the pixel electrode **30** at every third scanning line **14** is adopted, when the parasitic capacitance is large, there occurs a relatively large difference between the applied voltage kept by the storage capacitance counter electrodes **19** on the two outer scanning lines **14** among the three scanning lines **14** and the applied voltage kept by the storage capacitance counter electrode **19** on the central scanning line **14** among the three scanning lines **14**. Especially in the case of a liquid crystal display device in which color filters of three primary colors are arrayed in the Y direction, when there is a difference between the applied voltages kept at different pixels **50**, a fault may occur that the gray scales appear to have a tint of a specific color.

According to this modification, the applied voltages kept at the different pixels **50** do not differ easily. Therefore, higher quality display can be provided.

Embodiment 2

Now, with reference to FIG. **12** through FIG. **14**, a liquid crystal display device **100** in Embodiment 2 according to the present invention will be described.

FIG. **12** is a plan view showing a structure of a pixel **50** of the liquid crystal display device **100** in Embodiment 2. FIG. **13** is a plan view showing a line configuration of the pixel **50** in Embodiment 2. FIG. **14** is a plan view showing a shape of a pixel electrode **230** in Embodiment 2.

The pixel electrode **230** in Embodiment 2 does not include the connection portion **38** included in the pixel electrode **30** in Embodiment 1, and the island portion **32** is connected to the peripheral portion **36** by only one branch portion **34BC** among the second branch portions **34B**. Since the connection portion **38** is not formed, the area of the pixel which contributes to display can be increased. Therefore, display having a higher luminance is realized. The one branch portion which connects the island portion **32** and the peripheral portion **36** to each other does not need to be one of the second branch portions **34B**, and may be one of the first branch portions **34A**, one of the third branch portions **34C** or one of the fourth branch portions **34D**.

In this embodiment, the spacers **40** are located as being shifted by, for example, 7 μm in the Y direction from the spacers **40** in Embodiment 1. In the vicinity of each spacer **40**, the peripheral portion **36** includes a portion **36S** extending perpendicularly to the direction in which the corresponding branch portions **34** extend. Owing to this, the alignment disturbance of the liquid crystal molecules in the vicinity of the spacer **40** is prevented from being conveyed to the liquid crystal molecules on the pixel electrode **230**.

For each two pixels adjoining each other in the Y direction, color filters **13** of different colors are used. A border between such two pixels **50** is a border between two color filters **13** of different colors in the counter substrate **20**. In a step of stacking the color filters **13**, the color filters **13** of two colors may overlap at the border due to a shift of the stacking positions. When this occurs, a color filter layer having a thickness larger than a prescribed thickness may be formed.

16

In this embodiment, when seen in the Z direction, the border between the color filters **13** does not overlap the spacer **40**. Accordingly, even if a color filter layer having a thickness larger than a prescribed thickness is formed at the border between the color filters **13**, this does not make the thickness of the liquid crystal layer **21** larger than a prescribed thickness. Therefore, liquid crystal display devices providing a high display quality can be produced at a high production efficiency. In addition, it is not necessary to form an overcoat film or the like in order to stabilize the layer on which the spacer **40** is to be provided. Therefore, the liquid crystal display devices can be produced at low cost.

The thickness of the liquid crystal layer **21** is about 2.0 μm or greater and about 5.0 μm or less. In the case where, for example, color filters having a thickness of 2.0 μm overlap each other and a spacer **40** is located below the overlapping color filters, there occurs a significant difference in the thickness of the liquid crystal layer **21** and the display quality is deteriorated. In this embodiment, even if the color filters overlap each other, such an adverse influence thereof on the display can be prevented.

With reference to FIG. **15**, a modification of the line configuration of the pixel **50** in Embodiment 2 will be described.

In the liquid crystal display device **100** in Embodiment 2, the storage capacitance counter electrode **19** is not formed on the scanning line **14**. By contrast, according to the line configuration of this modification, the storage capacitance counter electrodes **19** are formed on the scanning line **14** and the storage capacitance line **18** as in Embodiment 1.

Embodiment 3

Now, with reference to FIG. **16** through FIG. **19**, a liquid crystal display device **100** in Embodiment 3 according to the present invention will be described.

FIG. **16** is a plan view showing a structure of a pixel **50** of the liquid crystal display device **100** in Embodiment 3. FIG. **17** is a plan view showing a line configuration of the pixel **50** in Embodiment 3. FIG. **18** is a plan view showing a shape of a pixel electrode **330** in Embodiment 3. FIG. **19** is a plan view showing a shape of a pixel electrode **330B**, which is a comparative example to the pixel electrode **330**.

In the pixel **50** in Embodiment 3, the spacer **40** is located at a central position of each of two sides of the pixel **50** extending in the Y direction. The storage capacitance line **18** bypasses so as not to pass below the TFT **12**. The storage capacitance counter electrode **19** on the storage capacitance line **18** and the storage capacitance counter electrode **19** on the scanning line **14** are connected to each other on the right side among the four sides of the pixel **50**. Except for these points, this embodiment basically has the same structure as that of Embodiment 2, and provides the same effects as those of Embodiment 2. Since the pixel electrode **330** can have a shape in which a top half and a bottom half are symmetrical to each other, display with little viewing angle dependence can be provided.

The pixel electrode **330B** shown in FIG. **19** as a comparative example does not have a recessed portion in the vicinity of each spacer **40**. Therefore, the liquid crystal molecules **52** in the vicinity of the right and left sides among the four sides of the pixel electrode **330B** are easily aligned along the top-bottom direction (toward the spacers **40**) by the influence of the spacers **40**. Since this direction is different from the alignment direction of the liquid crystal molecules regulated by the branch portions **34**, the transmittance is reduced.

In this embodiment, the peripheral portion **36** has the plurality of portions **36S** mentioned above, and there is a gap

17

between each spacer **40** and the peripheral portion **36**. Therefore, the liquid crystal molecules are not disturbed easily and thus display having a higher luminance is realized. In a comparison conducted by use of 4.3-type liquid crystal display devices (dot size: $198\ \mu\text{m} \times 66\ \mu\text{m}$), a liquid crystal display device using the pixel electrode **330** in this embodiment provided a transmittance 1.5% higher than a liquid crystal display device using the pixel electrode **330B** of the comparative example.

Now, with reference to FIG. **20**, a modification of the line configuration of the pixel **50** in Embodiment 3 will be described.

According to the line configuration of this modification, the storage capacitance counter electrode **19** connected to the drain electrode **46** is formed on the storage capacitance line **18** but not on the scanning line **14**. On the scanning line **14**, an electrode **19B** electrically separated from the drain electrode **46** and also from the storage capacitance counter electrode **19** is formed.

In the case where a topmost layer of the scanning line **14** is formed of Al or an Al alloy, or in the case where the entire scanning line **14** is formed of a single layer of Al or an Al alloy, external light incident from the counter substrate **20** side may occasionally be reflected by the scanning line **14** to reduce the contrast or cause a tint of a specific color. Such reduction of the display quality caused by external light can be suppressed by providing an opaque film formed of a material having a lower reflectance on the scanning line **14**.

Embodiment 4

Now, with reference to FIG. **21** through FIG. **23**, a liquid crystal display device **100** in Embodiment 4 according to the present invention will be described.

FIG. **21** is a plan view showing a structure of a pixel **50** of the liquid crystal display device **100** in Embodiment 4. FIG. **22** is a plan view showing a line configuration of the pixel **50** in Embodiment 4. FIG. **23** is a plan view showing a shape of a pixel electrode **430** in Embodiment 4.

In Embodiment 4, the island portion **32** and the contact hole **42** are formed at a position, which is in the vicinity of a border between each two pixel electrodes **430** adjoining each other in the Y direction and also is in the vicinity of the center of the pixels **50** in the X direction. The island portion **32** is surrounded by four regions, namely, the third region **35C** and the fourth region **35D** of a pixel **50** (first pixel) and the first region **35A** and the second region **35B** of a pixel **50** (second pixel) adjoining to the first pixel in the Y direction.

Ends of all the branch portions **34** opposite to the peripheral portion **36** are separated from the island portion **32**, and the peripheral portion **36** and the island portion **32** are directly connected to each other at two positions. Herein, these two positions will be referred to as the connection portions **38A** and **38B**.

When seen in the Z direction, the outer edge **32S** of the island portion **32** includes a first edge facing the first region **35A** of the second pixel, a second edge facing the second region **35B** of the second pixel, a third edge facing the third region **35C** of the first pixel, and a fourth edge facing the fourth region **35D** of the first pixel. The first edge includes a portion extending along the first branch portions **34A**, the second edge includes a portion extending along the second branch portions **34B**, the third edge includes a portion extending along the third branch portions **34C**, and the fourth edge includes a portion extending along the fourth branch portions **34D**.

18

Accordingly, a desired alignment of the liquid crystal molecules is also provided by the outer edge **32S** of the island portion **32**. As a result, high quality display in which the alignment disturbance of the liquid crystal molecules caused by the outer edge **32S** is suppressed is realized. Since the island portion **32** and the peripheral portion **36** do not have a narrow connection portion therebetween, there is an advantage that the lines for the pixel electrode **430** are not broken easily.

Embodiment 5

Now, with reference to FIG. **24** and FIG. **25**, a liquid crystal display device **100** in Embodiment 5 according to the present invention will be described.

FIG. **24** is a plan view showing a structure of a pixel **50** of the liquid crystal display device **100** in Embodiment 5. FIG. **25** is a plan view showing a line configuration of the pixel **50** in Embodiment 5.

In the liquid crystal display device **100** in Embodiment 5, the scanning line **14** extends in the X direction through the center of the pixel **50**, and the storage capacitance line **18** extends in the X direction along a border between each two pixels **50** adjoining each other in the Y direction. The storage capacitance counter electrode **19** is formed on the storage capacitance line **18**.

According to this line configuration, a trunk slit of the pixel electrode **530** is located above the scanning line **14**. Therefore, the load on the scanning line **14** can be alleviated, which contributes to reduction of the power consumption. The form of any of the pixel electrodes described in Embodiments 1 through 3 may be applied to this embodiment.

The location arrangement of the spacers **40** in this embodiment is the same as that in Embodiment 3, and thus is not described. Any of the location arrangements of the spacers **40** described in Embodiments 1 and 2 may be applied to this embodiment.

Embodiment 6

Now, with reference to FIG. **26** through FIG. **28**, a liquid crystal display device **100** in Embodiment 6 according to the present invention will be described.

FIG. **26** is a plan view showing a structure of a pixel **50** of the liquid crystal display device **100** in Embodiment 6. FIG. **27** is a plan view showing a line configuration of the pixel **50** in Embodiment 6. FIG. **28** is a plan view showing a shape of a pixel electrode **630** in Embodiment 6.

The pixel electrode **630** includes a peripheral portion **36**, an island portion **32**, and a plurality of branch portions **34** extending from the peripheral portion **36** inward in the pixel **50**. The plurality of branch portions **34** are formed of a plurality of first branch portions **34A** extending in a direction of 315° from the peripheral portion **36**, a plurality of second branch portions **34B** extending in a direction of 225° from the peripheral portion **36**, a plurality of third branch portions **34C** extending in a direction of 135° from the peripheral portion **36**, and a plurality of fourth branch portions **34D** extending in a direction of 45° from the peripheral portion **36**.

The island portion **32** is generally square, and is connected to the peripheral portion **36** by one connection portion **38** but not by any of the plurality of branch portions **34**. An outer edge **32S** of the island portion **32** includes four ends respectively extending parallel to the branch portions **34A** through **34D**. Accordingly, a desired alignment of the liquid crystal molecules is also provided by the outer edge **32S**. As a result,

the alignment disturbance caused by the presence of the island portion 32 can be significantly suppressed.

In order to provide high quality display having a high transmittance with no coarseness, it is more preferable that the island portion 32 is smaller. In this embodiment, the interlayer insulating film 44 has a thickness of 3.0 μm . The contact hole 42 has a size of 10.5 μm $\times$ 7.5 μm when seen in the Z direction. Each of the straight line portions of the outer edge 32S has a length of 18.0 μm . The island portion 32 may be formed to be smaller by forming the interlayer insulating film 44 to be thinner and making the contact hole 42 smaller. For example, the thickness of the interlayer insulating film 44 may be 1.0 μm , the size of the contact hole may be 4.0 μm $\times$ 4.0 μm , and the length of each of the straight line portions of the outer edge 32S may be 8.0 μm .

By contrast, the island portion 32 may be formed to be larger. FIG. 29 is a plan view showing a shape of a pixel electrode 630B in a modification of Embodiment 6. The island portion 32 of the pixel electrode 630B is larger than the island portion 32 of the pixel electrode 630 described above. Each of straight line portions of the outer edge 32S of the island portion 32 of the pixel electrode 630B has a length of 31 μm . This structure allows an alignment margin of the island portion 32 for the contact hole 42 to be larger. Therefore, during the formation of the island portion 32 by photolithography, a situation is avoided that a layer below the contact hole 42 (e.g., drain electrode layer) cannot be sufficiently covered with a resist material used for patterning for forming the island portion 32 and thus is exposed, resulting in being exposed to an etching solution. Since such a situation is avoided, reduction of the production yield or the like can be suppressed.

With the structure shown in FIG. 28, the shortest distance between the outer edge 32S of the island portion 32 and the contact hole 42 is 2.6 μm . By contrast, with the structure shown in FIG. 29, the shortest distance is 9.2 μm . The contact hole 42 may be formed to be larger. In such a case, even where the interlayer insulating film 44 is thicker than 3.0 μm , the above-mentioned fault which can occur during the photolithography can be suppressed.

In a comparison conducted by use of 4.3-type liquid crystal display devices, a liquid crystal display device using the pixel electrode 630 including the smaller island portion 32 provided display having a transmittance 10% higher and less coarseness than a liquid crystal display device using the pixel electrode 630B having the larger island portion 32.

The line configuration of this embodiment is the same as that of Embodiment 5 and thus is not described. Any of the line configurations and any of the location arrangements of the spacers 40 described in Embodiments 1 through 4 may be applied to this embodiment.

Embodiment 7

Now, with reference to FIG. 30 through FIG. 32, a liquid crystal display device 100 in Embodiment 7 according to the present invention will be described.

FIG. 30 is a plan view showing a structure of a pixel 50 of the liquid crystal display device 100 in Embodiment 7. FIG. 31 is a plan view showing a line configuration of the pixel 50 in Embodiment 7. FIG. 32 is a plan view showing a shape of a pixel electrode 730 in Embodiment 7.

The pixel electrode 730 includes a peripheral portion 36, an island portion 32, trunk portions 31A and 31B extending in directions of 0° and 180° from the island portion 32, and a plurality of branch portions 34 extending from the trunk portion 31A or 31B or from the island portion 32. The plu-

rality of branch portions 34 are formed of a plurality of first branch portions 34A extending in a direction of 45°, a plurality of second branch portions 34B extending in a direction of 135°, a plurality of third branch portions 34C extending in a direction of 225°, and a plurality of fourth branch portions 34D extending in a direction of 315°.

When a voltage is applied to the liquid crystal molecules 52, four alignment domains 35A, 35B, 35C and 35D are formed by the first branch portions 34A, the second branch portions 34B, the third branch portions 34C and the fourth branch portions 34D.

None of ends of the plurality of branch portions 34 is connected to the peripheral portion 36, and there is a gap (insulating portion) therebetween. The island portion 32 is connected to the peripheral portion 36 by a connection portion 38 but not by any of the plurality of branch portions 34. When seen in the Z direction, the island portion 32 is surrounded by the first through fourth regions 35A through 35D.

In the vicinity of the spacers 40, the peripheral portion 36 is bent along the shape of the corresponding spacer 40 and includes a plurality of portions 36S each extending perpendicularly to the direction in which the corresponding branch portions 34 extend. Since there is a gap between each spacer 40 and the peripheral portion 36, the alignment disturbance of the liquid crystal molecules is suppressed from being conveyed to the liquid crystal molecules on the pixel electrode 30.

The line configuration of this embodiment is the same as that of Embodiment 5 and the location arrangement of the spacers 40 are the same as those of Embodiment 3, and thus these are not described. Any of the line configurations described in Embodiments 1 through 4, and any of the location arrangements of the spacers 40 described in Embodiments 1 and 2 may be applied to this embodiment.

INDUSTRIAL APPLICABILITY

The present invention is usable for improving the display characteristics of a vertical alignment type liquid crystal display device.

REFERENCE SIGNS LIST

- 7 Pixel electrode
- 8 Branch slit
- 9 Trunk slit
- 10 TFT substrate
- 11 Black matrix (BM)
- 12 TFT
- 13 Color filter
- 14 Scanning line
- 15 Gate insulating film
- 16 Signal line
- 17 Semiconductor layer
- 18 Storage capacitance line
- 19 Storage capacitance counter electrode
- 20 Counter substrate
- 21 Liquid crystal layer
- 22 Scanning line driving circuit
- 23 Signal line driving circuit
- 24 Control circuit
- 25 Common electrode (counter electrode)
- 26, 27 Polarizing plate
- 28 Backlight unit
- 30, 230, 330, 430, 630, 730 Pixel electrode
- 30A, 30B, 30C, 330B, 630B Pixel electrode in a modification

31A First trunk portion
 31B Second trunk portion
 32 Island portion
 32A Outer edge (edge of the island portion)
 34 Branch portion
 34A-34D First through fourth branch portions
 35A-35D Alignment domains (first through fourth regions)
 36 Peripheral portion
 36S Portion of the peripheral portion
 36E Corner (corner of the peripheral portion)
 38 Connection portion
 40 Spacer
 42 Contact hole
 43 Protective insulating film
 44 Interlayer insulating film (insulating layer)
 46 Drain electrode
 48, 49 Absorption axis
 50 Pixel
 52 Liquid crystal molecules
 100 Liquid crystal display device
 The invention claimed is:

1. A liquid crystal display device including a plurality of pixels arrayed in a matrix, the liquid crystal display device comprising:

- a TFT substrate including pixel electrodes respectively formed in correspondence with the plurality of pixels, TFTs respectively formed in correspondence with the plurality of pixels, and an insulating layer having a contact hole formed therein for electrically connecting a drain electrode of each of the TFTs and each of the pixel electrodes to each other;
- a counter substrate including a counter electrode facing the pixel electrodes; and
- a liquid crystal layer located between the TFT substrate and the counter substrate, the liquid crystal layer containing liquid crystal molecules having a negative dielectric anisotropy;

wherein:

the pixel electrodes each include a peripheral portion, an island portion including a portion which electrically contacts the drain electrode in the contact hole, and a plurality of branch portions extending from the peripheral portion;

the plurality of branch portions include a plurality of first branch portions extending in a first direction, a plurality of second branch portions extending in a second direction, a plurality of third branch portions extending in a third direction, and a plurality of fourth branch portions extending in a fourth direction;

the first direction, the second direction, the third direction and the fourth direction are different from each other;

a first region in which the liquid crystal molecules are aligned along the first branch portions at the time of voltage application, a second region in which the liquid crystal molecules are aligned along the second branch portions at the time of voltage application, a third region in which the liquid crystal molecules are aligned along the third branch portions at the time of voltage application, and a fourth region in which the liquid crystal molecules are aligned along the fourth branch portions at the time of voltage application are formed by the first branch portions, the second branch portions, the third branch portions and the fourth branch portions; and

when seen in a direction vertical to a surface of the TFT substrate, the island portion is surrounded by the first region, the second region, the third region and the fourth region; and the island portion is electrically connected to

the peripheral portion by a connection portion other than the plurality of branch portions but not by any of the plurality of branch portions, or electrically connected to the peripheral portion by only one of the first branch portions, only one of the second branch portions, only one of the third branch portions or only one of the fourth branch portions.

2. The liquid crystal display device of claim 1, wherein ends of all the plurality of branch portions opposite to the peripheral portion are separated from the island portion, and the peripheral portion and the island portion are electrically connected to each other by only one connection portion.

3. The liquid crystal display device of claim 1, wherein ends of all the plurality of branch portions opposite to the peripheral portion are separated from the island portion, and the peripheral portion and the island portion are electrically connected to each other by only two connection portions.

4. The liquid crystal display device of claim 3, wherein when seen in the direction vertical to the surface of the TFT substrate, the two connection portions are located to be symmetrical to each other with respect to the center of the island portion or the center of the pixel.

5. The liquid crystal display device of claim 1, wherein the island portion is electrically connected to only one of the first branch portions, only one of the second branch portions, only one of the third branch portions and only one of the fourth branch portions.

6. The liquid crystal display device of claim 5, wherein when seen in the direction vertical to the surface of the TFT substrate, one of the first branch portions and one of the second branch portions are located to be symmetrical to one of the third branch portions and one of the fourth branch portions with respect to the center of the island portion or a line which equally divides the pixel into two.

7. The liquid crystal display device of claim 1, wherein when seen in the direction vertical to the surface of the TFT substrate, the island portion has a shape which is symmetrical with respect to the center thereof or the center of the pixel.

8. The liquid crystal display device of claim 1, wherein the island portion is electrically connected to only one branch portion among all the first branch portions, the second branch portions, the third branch portions and the fourth branch portions.

9. The liquid crystal display device of claim 1, wherein when seen in the direction vertical to the surface of the TFT substrate, an outer edge of the island portion is surrounded by two among the four regions of a first pixel and two among the four regions of a second pixel adjoining the first pixel.

10. The liquid crystal display device of claim 9, wherein ends of all the plurality of branch portions opposite to the peripheral portion are separated from the island portion, and the peripheral portion and the island portion are electrically connected to each other with none of the plurality of branch portions being connected therebetween.

11. The liquid crystal display device of claim 1, wherein: when seen in the direction vertical to the surface of the TFT substrate, an outer edge of the island portion includes a first end facing the first region, a second end facing the second region, a third end facing the third region, and a fourth end facing the fourth region; and

the first end includes an end portion extending along the first branch portions, the second end includes an end portion extending along the second branch portions, the third end includes an end portion extending along the third branch portions, and the fourth end includes an end portion extending along the fourth branch portions.

23

12. The liquid crystal display device of claim 11, wherein the first end extends in the first direction, the second end extends in the second direction, the third end extends in the third direction, and the fourth end extends in the fourth direction.

13. The liquid crystal display device of claim 12, wherein the first end and the third end extend parallel to each other, and the second end and the fourth end extend parallel to each other in a direction different by 90° from the first end.

14. The liquid crystal display device of claim 1, further comprising a first polarizing plate and a second polarizing plate located so as to hold the liquid crystal layer therebetween; wherein an absorption axis of the first polarizing plate and an absorption axis of the second polarizing plate cross each other perpendicularly, and the first direction, the second direction, the third direction and the fourth direction are each different by 45° from the absorption axis of the first polarizing plate or the second polarizing plate.

15. The liquid crystal display device of claim 1, further comprising a spacer located between the TFT substrate and the counter substrate; wherein when seen in the direction vertical to the surface of the TFT substrate, the spacer is located so as not to overlap the pixel electrode.

16. The liquid crystal display device of claim 15, wherein when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at least at one of four corners of each of the plurality of pixels.

17. The liquid crystal display device of claim 16, wherein when seen in the direction vertical to the surface of the TFT substrate, in the vicinity of the spacer, a part of the peripheral portion of the pixel electrode extends perpendicularly to a direction in which the plurality of corresponding branch portions extend.

18. The liquid crystal display device of claim 15, wherein when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at a central position of at least one of four sides of each of the plurality of pixels.

19. The liquid crystal display device of claim 18, wherein when seen in the direction vertical to the surface of the TFT substrate, in the vicinity of the spacer, a part of the peripheral portion of the pixel electrode extends along a direction in which the plurality of corresponding branch portions extend.

20. The liquid crystal display device of claim 1, further comprising a spacer located between the TFT substrate and the counter substrate; wherein when seen in the direction vertical to the surface of the TFT substrate, the spacer is located so as to overlap the pixel electrode.

21. The liquid crystal display device of claim 20, wherein when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at least at one of four corners of each of the plurality of pixels.

22. The liquid crystal display device of claim 20, wherein when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the spacer is located at a central position of at least one of four sides of each of the plurality of pixels.

23. A liquid crystal display device including a plurality of pixels arrayed in a matrix, the liquid crystal display device comprising:

a TFT substrate including pixel electrodes respectively formed in correspondence with the plurality of pixels, TFTs respectively formed in correspondence with the plurality of pixels, and an insulating layer having a con-

24

tact hole formed therein for electrically connecting a drain electrode of each of the TFTs and each of the pixel electrodes to each other;

a counter substrate including a counter electrode facing the pixel electrodes; and

a liquid crystal layer located between the TFT substrate and the counter substrate, the liquid crystal layer containing liquid crystal molecules having a negative dielectric anisotropy;

wherein:

the pixel electrodes each include a peripheral portion, an island portion including a portion which electrically contacts the drain electrode in the contact hole, a plurality of trunk portions extending from the island portion, and a plurality of branch portions extending from the plurality of trunk portions or the island portion;

the plurality of branch portions include a plurality of first branch portions extending in a first direction, a plurality of second branch portions extending in a second direction, a plurality of third branch portions extending in a third direction, and a plurality of fourth branch portions extending in a fourth direction;

the first direction, the second direction, the third direction and the fourth direction are different from each other;

a first region in which the liquid crystal molecules are aligned along the first branch portions at the time of voltage application, a second region in which the liquid crystal molecules are aligned along the second branch portions at the time of voltage application, a third region in which the liquid crystal molecules are aligned along the third branch portions at the time of voltage application, and a fourth region in which the liquid crystal molecules are aligned along the fourth branch portions at the time of voltage application are formed by the first branch portions, the second branch portions, the third branch portions and the fourth branch portions; and

when seen in a direction vertical to a surface of the TFT substrate, the island portion is surrounded by the first region, the second region, the third region and the fourth region; there is an insulating portion between ends of all the plurality of branch portions and the peripheral portion; and the island portion is electrically connected to the peripheral portion by a connection portion other than the plurality of branch portions.

24. The liquid crystal display device of claim 23, wherein ends of all the branch portions opposite to the trunk portions or the island portion are separated from the peripheral portion, and the peripheral portion and the island portion are electrically connected to each other by only one connection portion.

25. The liquid crystal display device of claim 23, further comprising a first polarizing plate and a second polarizing plate located so as to hold the liquid crystal layer therebetween; wherein an absorption axis of the first polarizing plate and an absorption axis of the second polarizing plate cross each other perpendicularly, and the first direction, the second direction, the third direction and the fourth direction are each different by 45° from the absorption axis of the first polarizing plate or the second polarizing plate.

26. The liquid crystal display device of claim 23, further comprising a spacer located between the TFT substrate and the counter substrate; wherein when seen in the direction vertical to the surface of the TFT substrate, the spacer is located so as not to overlap the pixel electrode.

27. The liquid crystal display device of claim 26, wherein when seen in the direction vertical to the surface of the TFT substrate, the plurality of pixels are each rectangular, and the

25

spacer is located at a central position of at least one of four sides of each of the plurality of pixels.

28. The liquid crystal display device of claim **27**, wherein when seen in the direction vertical to the surface of the TFT substrate, in the vicinity of the spacer, a part of the peripheral portion of the pixel electrode extends along a direction in which the plurality of corresponding branch portions extend.

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26

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[标]申请(专利权)人(译)	吉田正弘 田代国广		
申请(专利权)人(译)	吉田正洋 田代国广		
当前申请(专利权)人(译)	夏普株式会社		
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发明人	YOSHIDA, MASAHIRO TASHIRO, KUNIHIRO		
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摘要(译)

本发明的目的是提供一种具有高透射率或高视角特性的液晶显示装置。根据本发明的液晶显示装置包括像素电极（30），该像素电极包括外围部分（36），岛部分（32）和多个分支部分（34）。多个分支部分（34）由分别在第一至第四方向上延伸的多个第一至第四分支部分（34A至34D）形成。通过这些分支部分，形成第一至第四区域（35A至35D），其中液晶分子在施加电压时在彼此不同的方向上排列。岛部分（32）由第一至第四区域（35A至35D）围绕，并且通过连接部分（38）连接到周边部分（36），但不通过多个分支部分（34）中的任何一个连接到周边部分（36）。或者通过第一至第四分支部分（34A至34D）之一连接至外围部分（36）。

