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**Hayano et al.**

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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

(75) Inventors: **Takayuki Hayano**, Osaka (JP);  
**Masayuki Tsuji**, Osaka (JP); **Kohji Hayashi**, Osaka (JP)

(73) Assignee: **Sharp Kabushiki Kaisha**, Osaka-shi,  
Osaka (JP)

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**G02F 1/1335** (2006.01)  
**G02F 1/137** (2006.01)

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CPC .... **G02F 1/133753** (2013.01); **G02F 1/133528**  
(2013.01); **G02F 2001/133773** (2013.01); **G02F**  
**1/1337** (2013.01); **G02F 1/133784** (2013.01);  
**G02F 2001/133742** (2013.01); **G02F**  
**2001/133746** (2013.01); **G02F 2001/133757**  
(2013.01); **G02F 2001/13712** (2013.01); **G02F**  
**2203/64** (2013.01)

(58) **Field of Classification Search**

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USPC ..... 349/128, 129

See application file for complete search history.

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*Primary Examiner* — Wen-Ying P Chen

(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye, P.C.

(57) **ABSTRACT**

A normally black liquid crystal display device includes a liquid crystal layer in which liquid crystal molecules are arranged vertically when no voltage is applied, and arranged horizontally by applying a voltage. In each of pixel regions in alignment films which are segmented in a grid by source lines and gate lines, is divided into two along a direction parallel to the source lines. The first alignment film includes a first region and a second region. The second alignment film includes a third region facing the first region and a fourth region facing the second region. In an adjacent pair of the pixel regions, pairs of the regions are adjacent to each other with corresponding one of the source lines interposed therebetween.

**2 Claims, 19 Drawing Sheets**

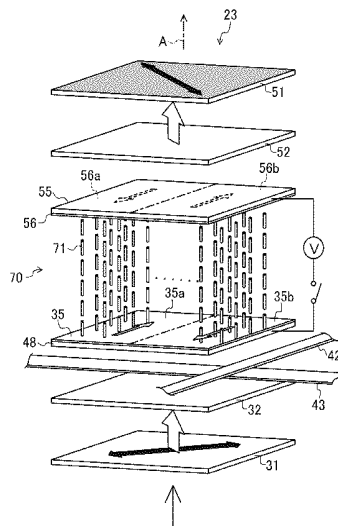


FIG.1

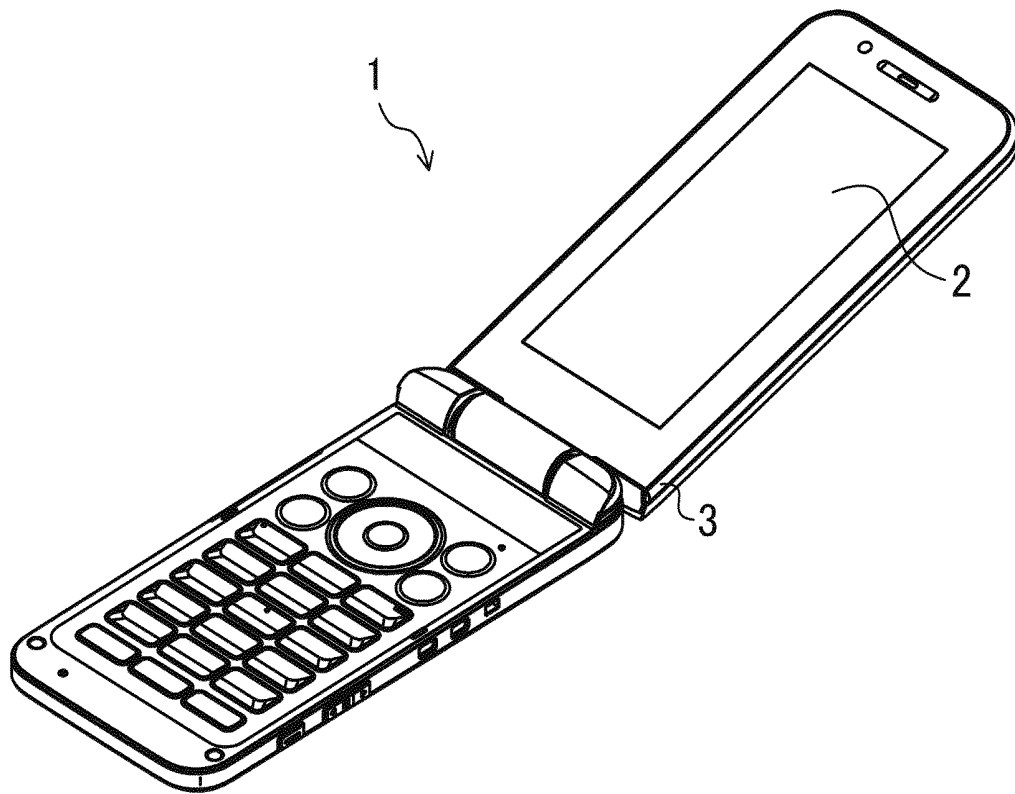


FIG.2

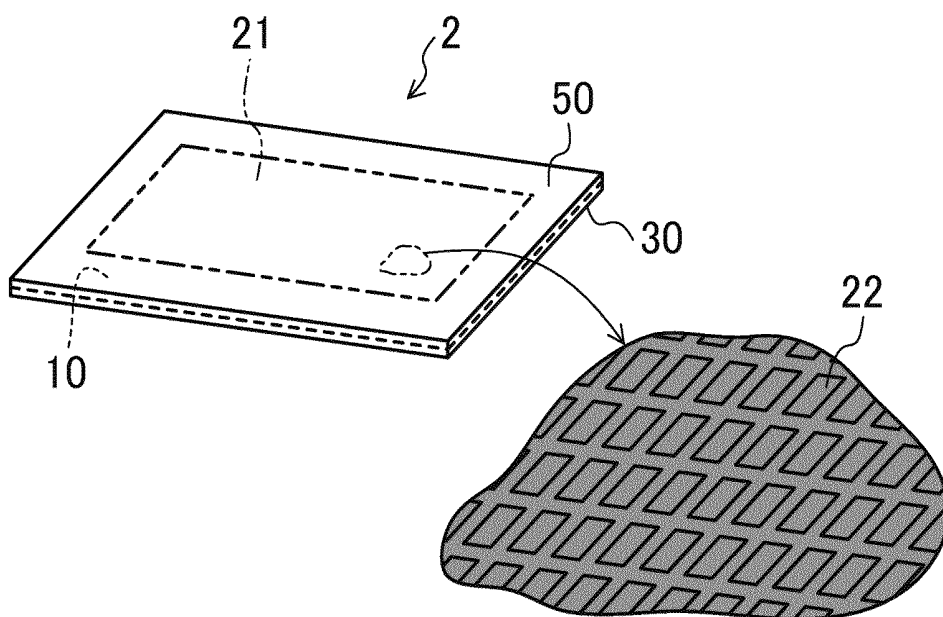


FIG.3

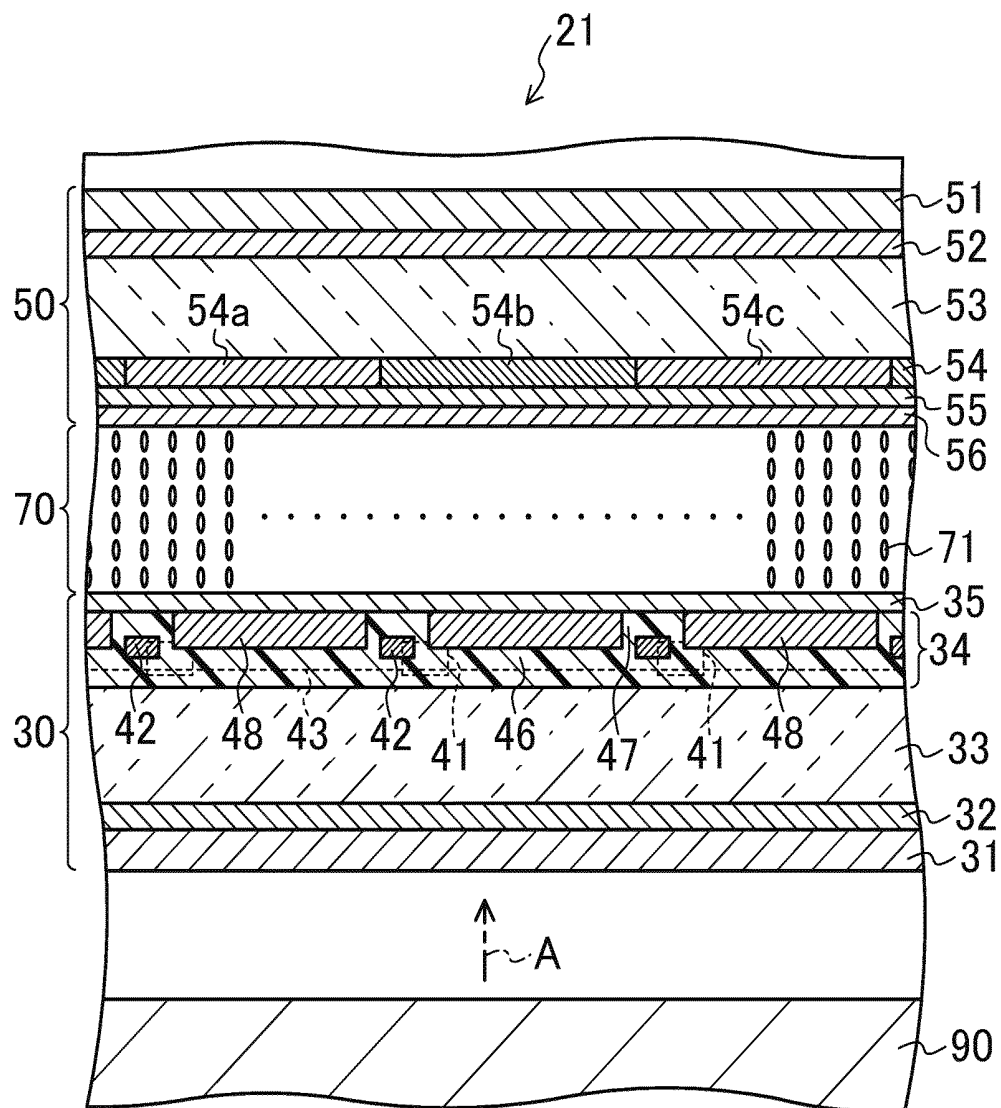


FIG. 4

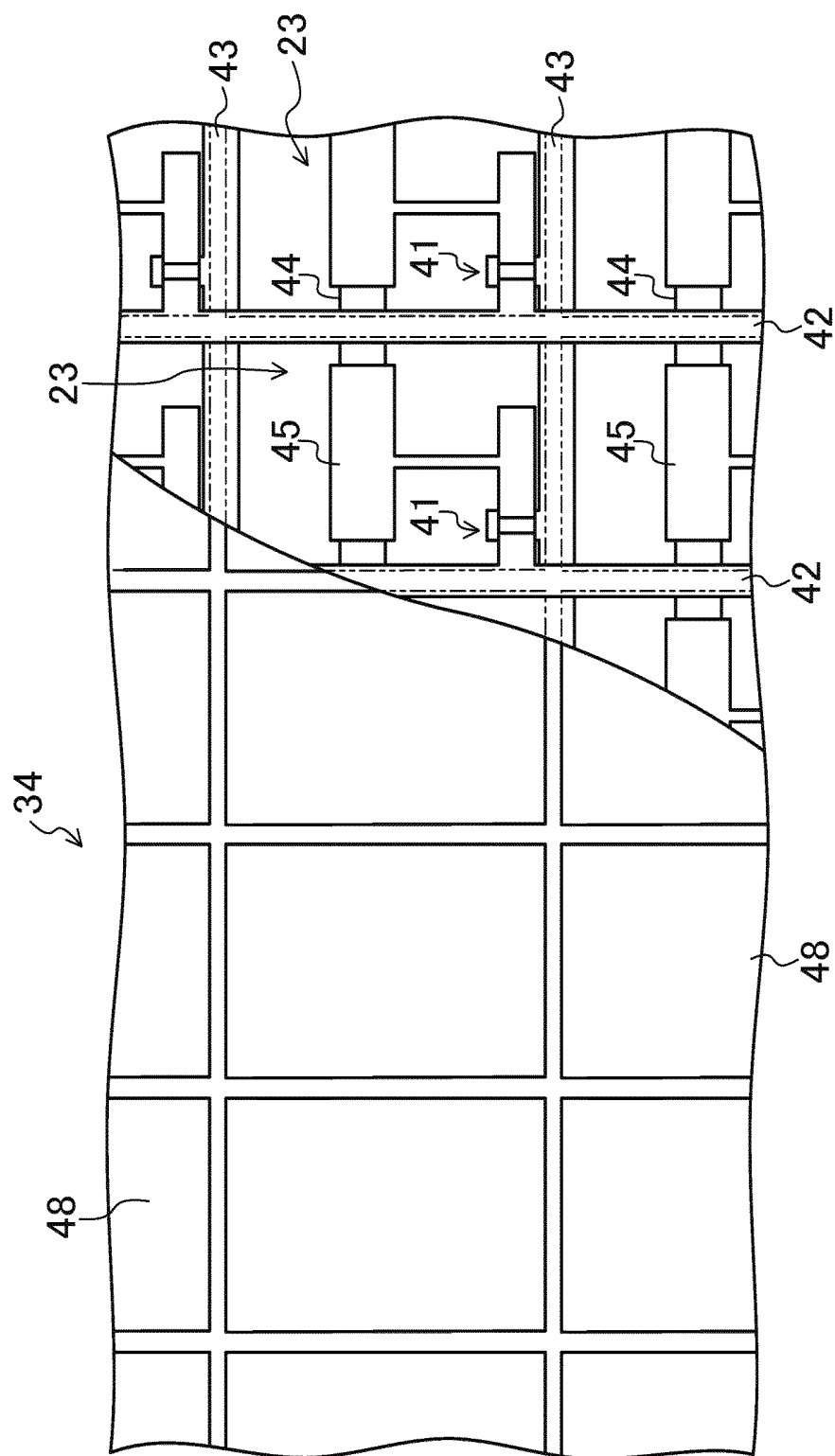


FIG. 5

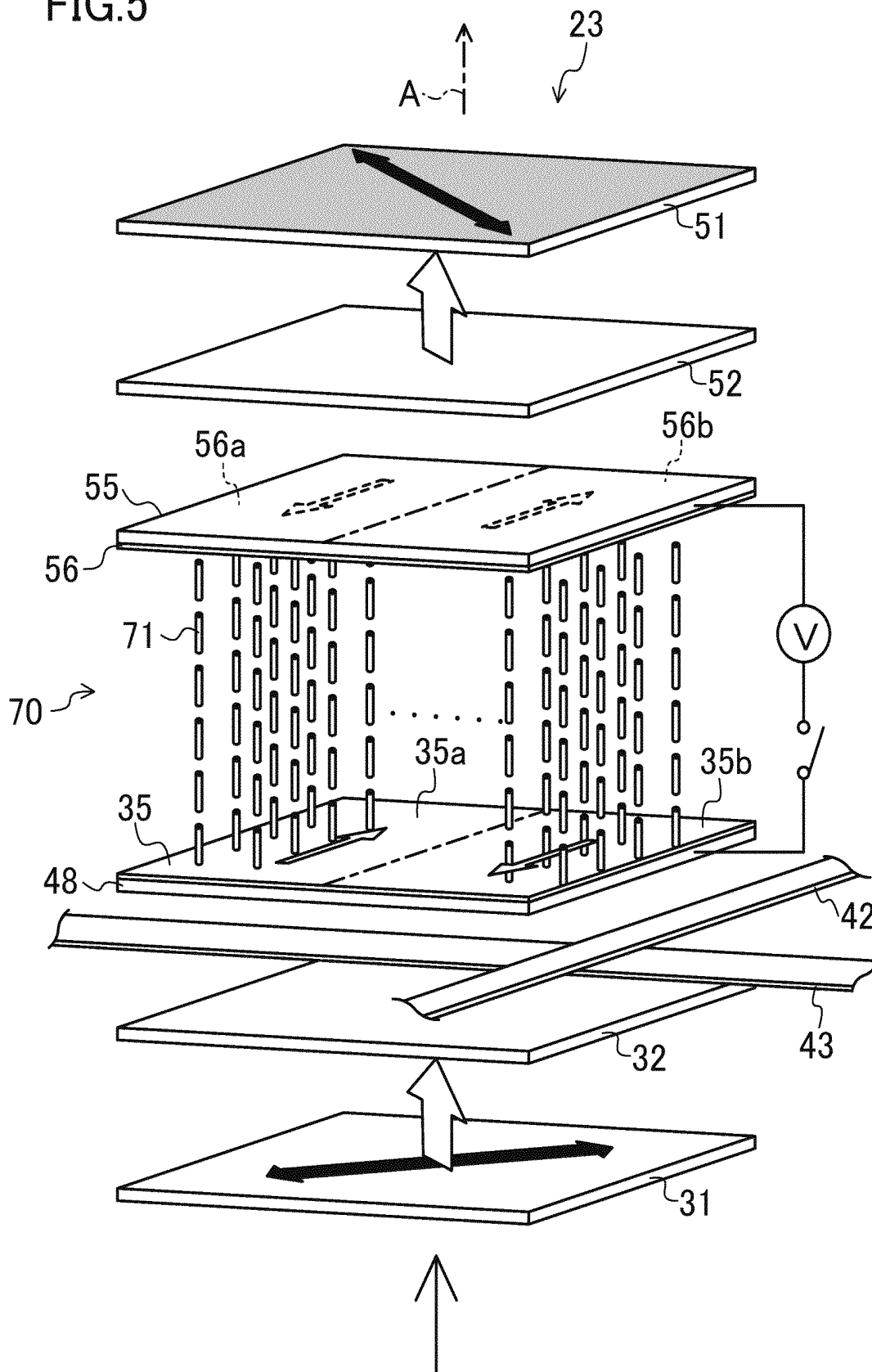


FIG. 6

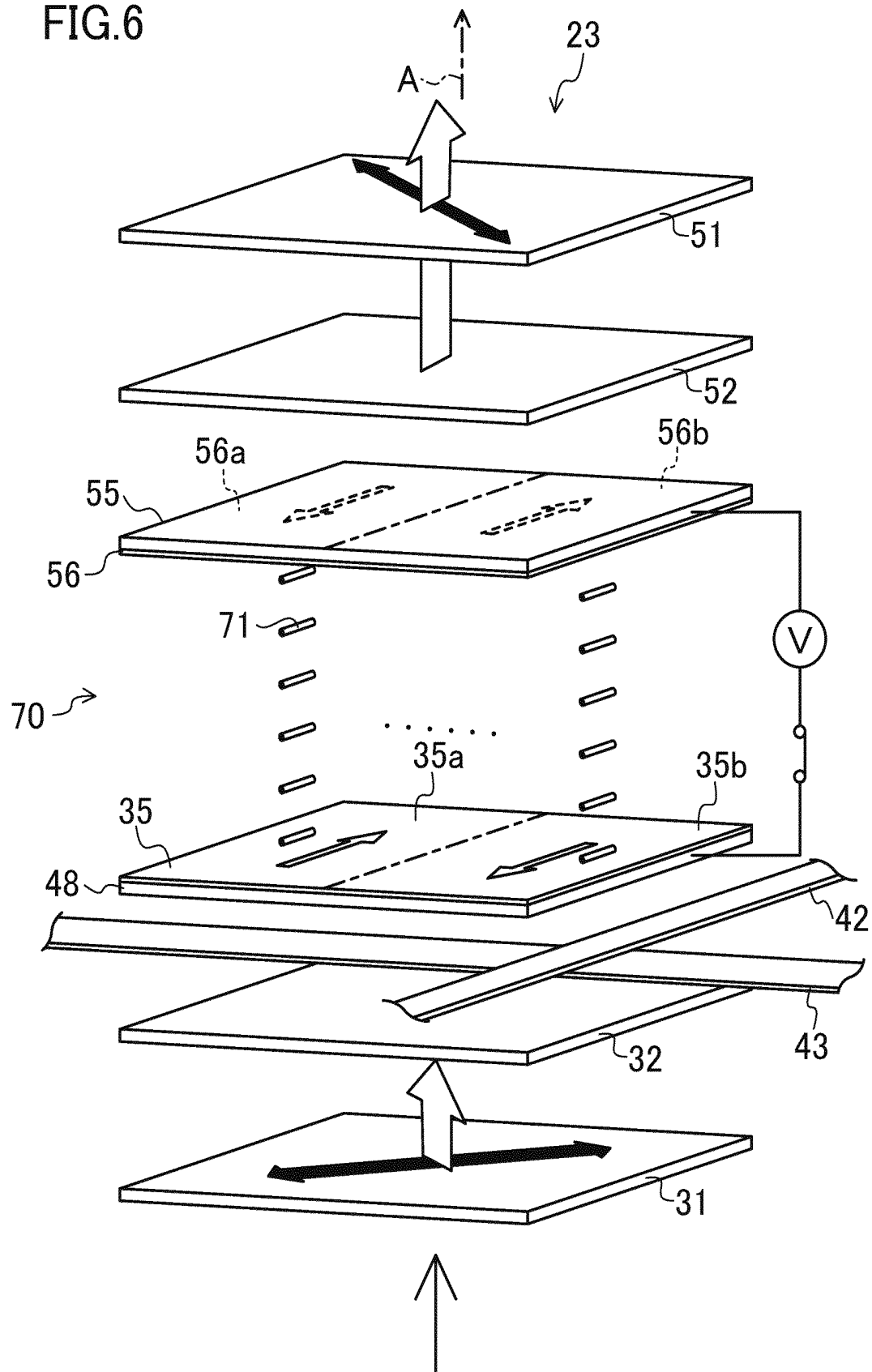


FIG. 7

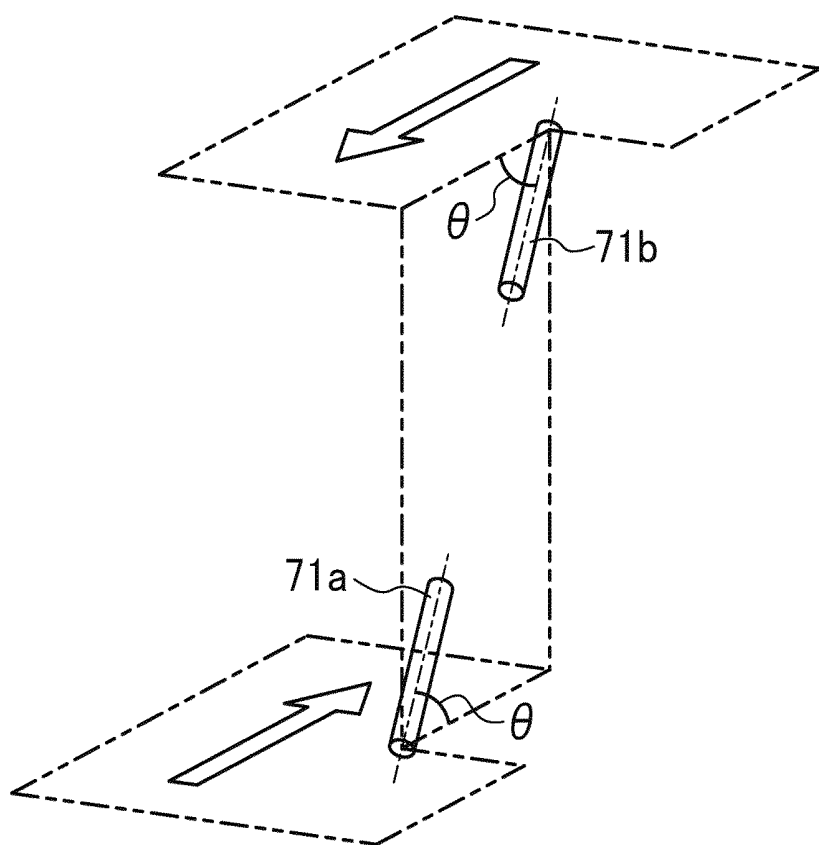


FIG. 8

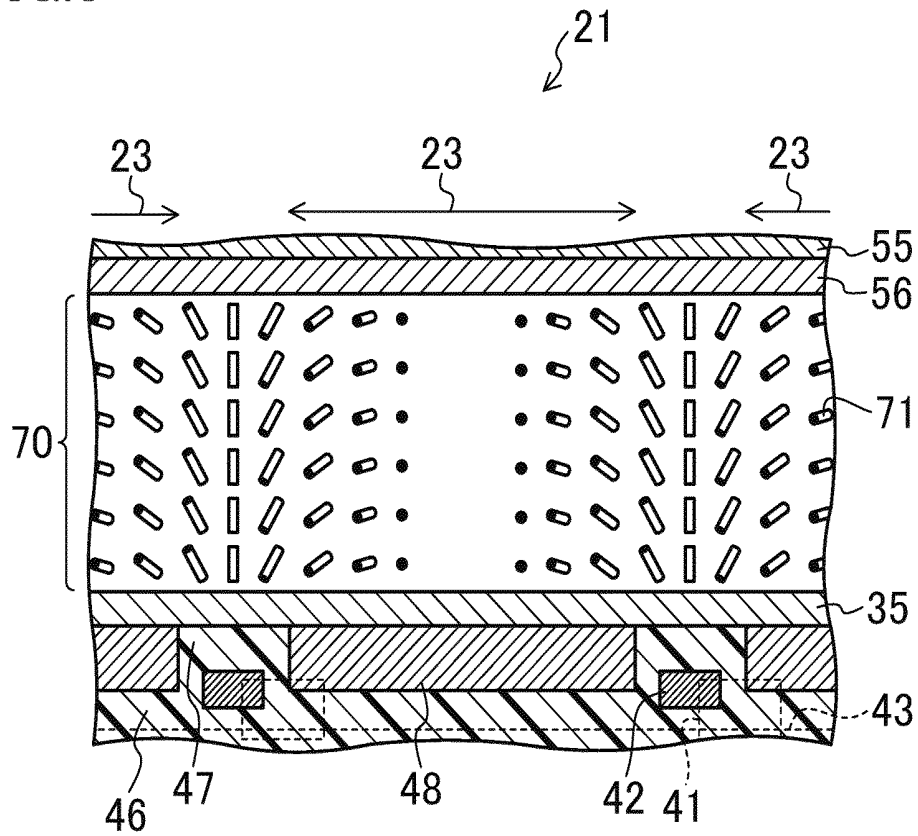




FIG. 9

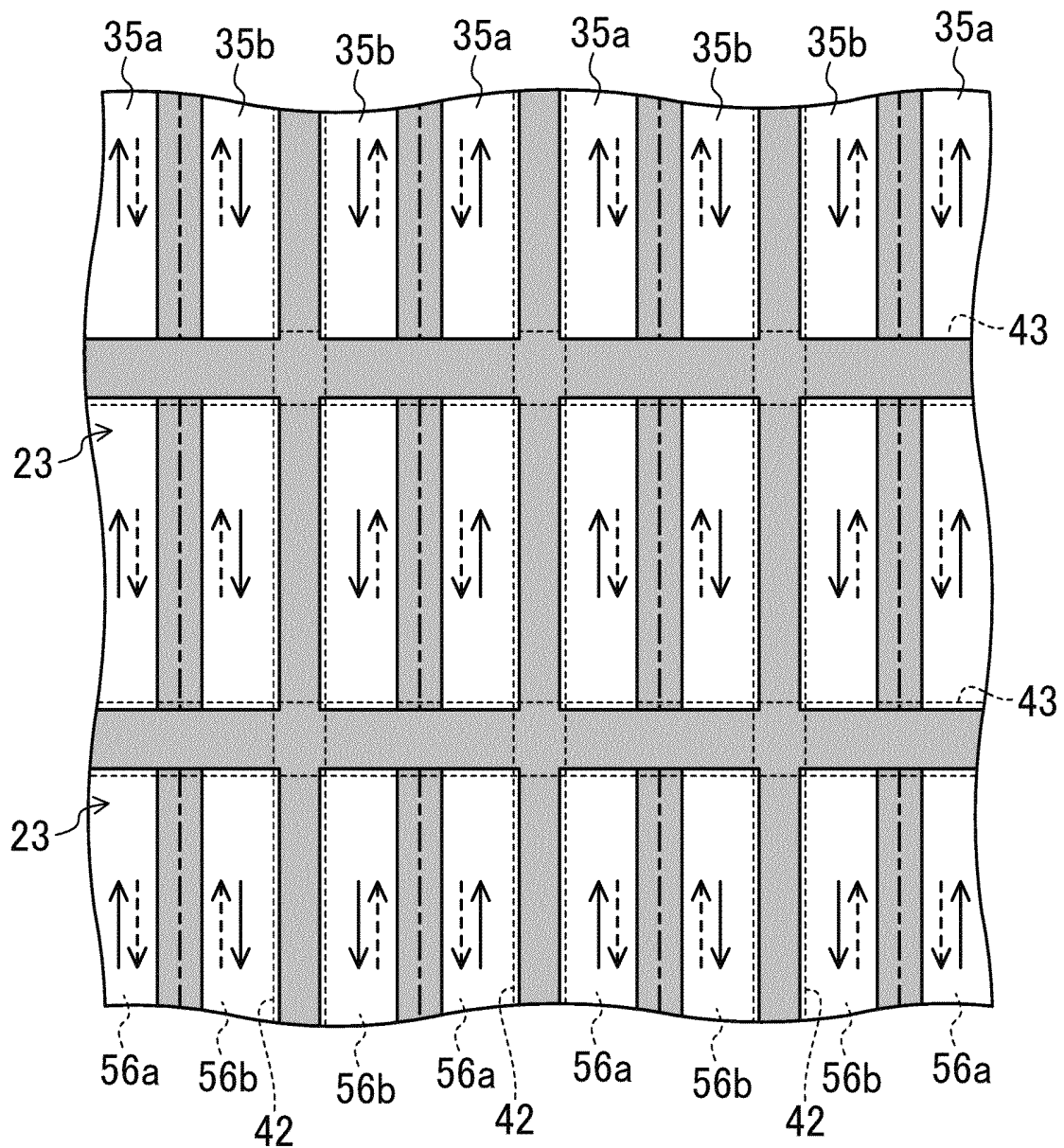


FIG. 10

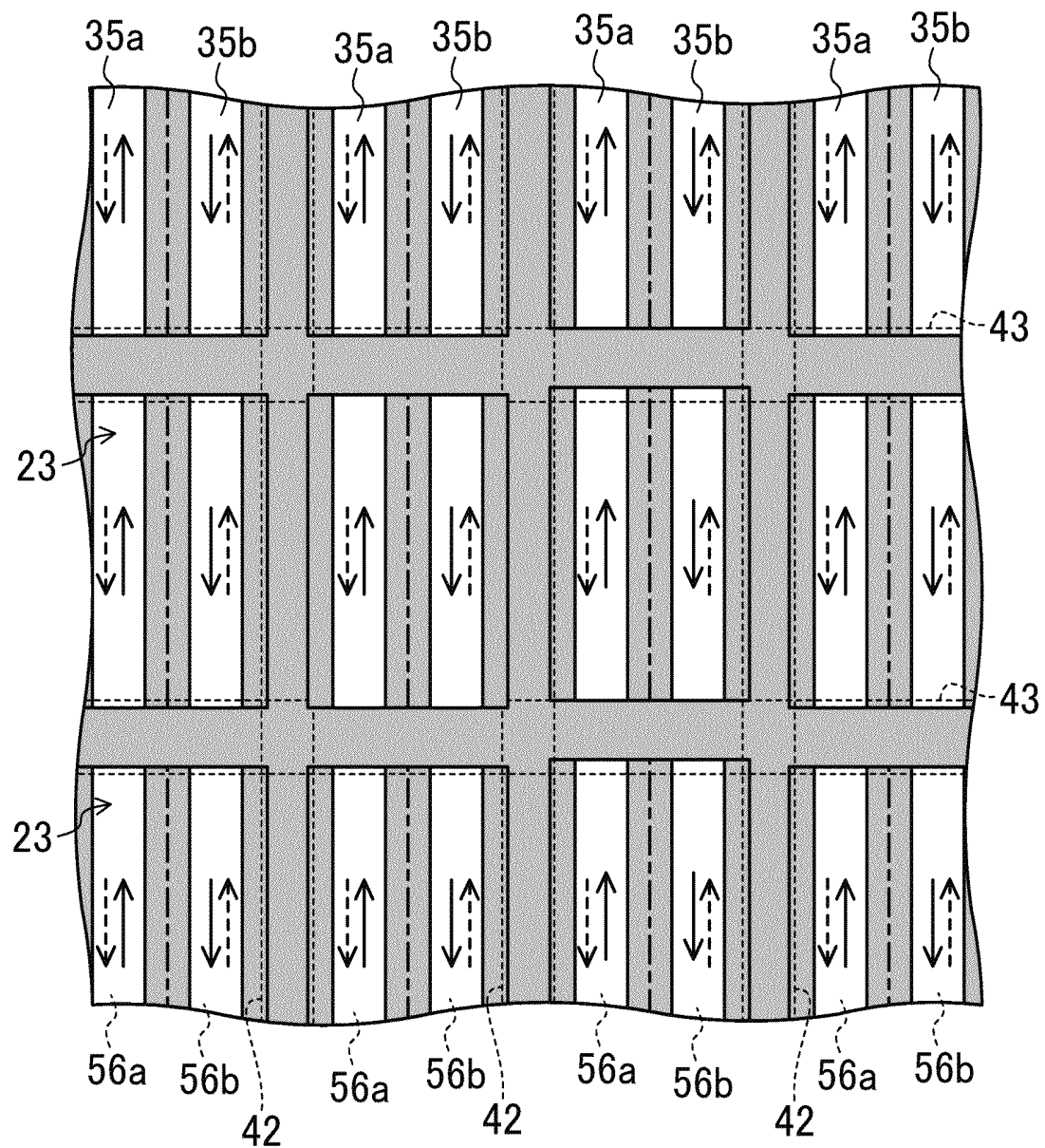


FIG. 11

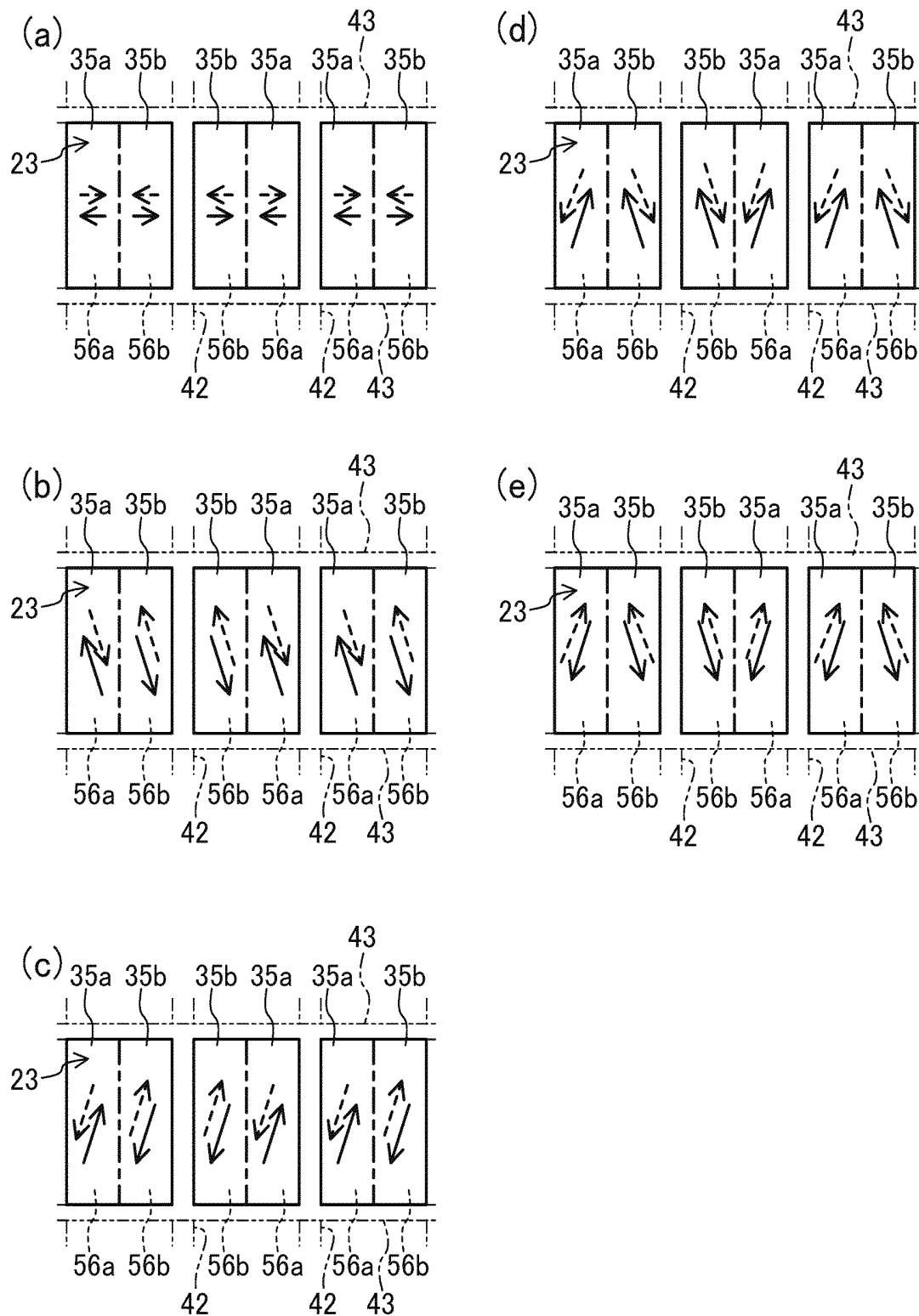


FIG.12

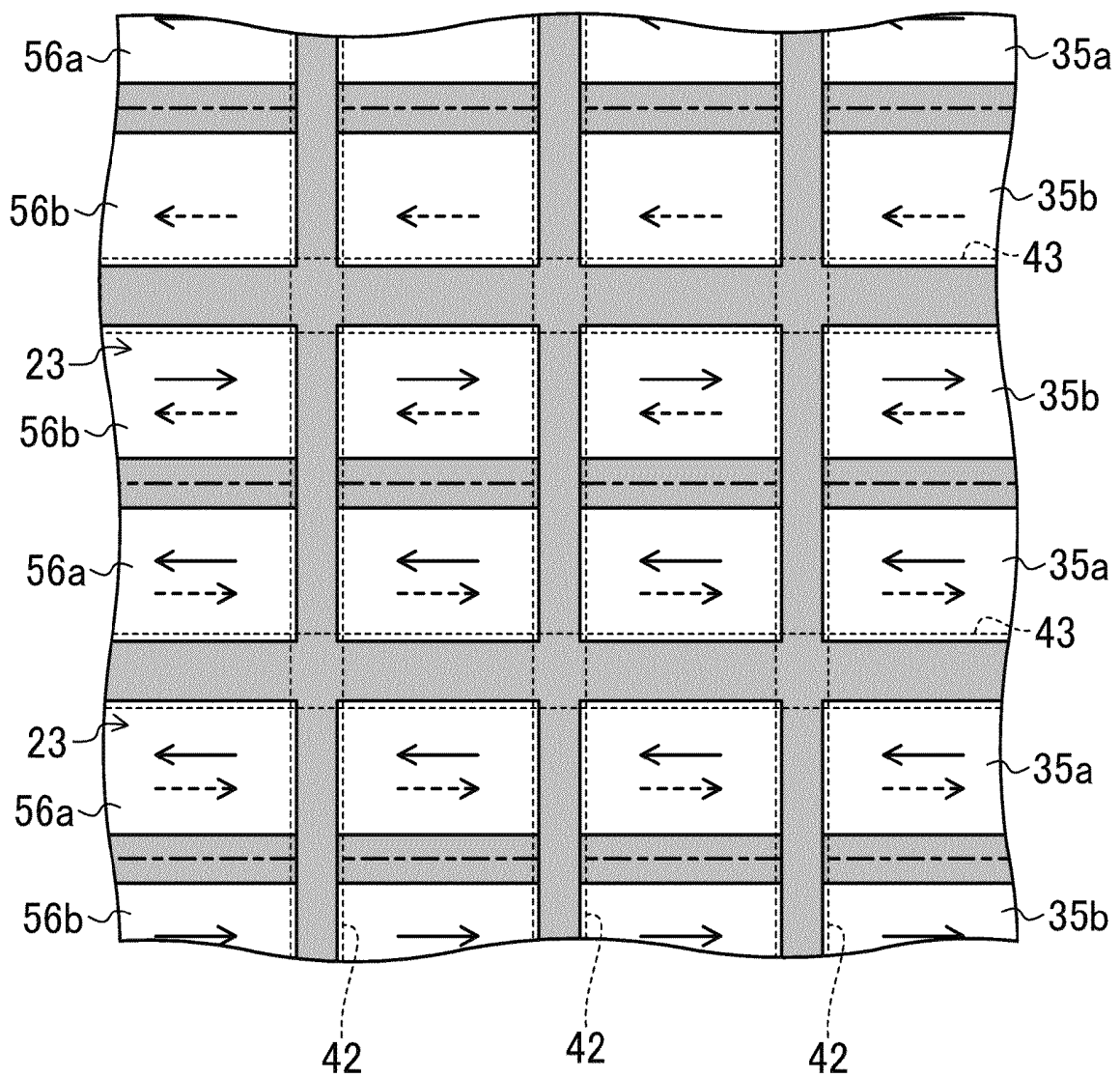


FIG. 13

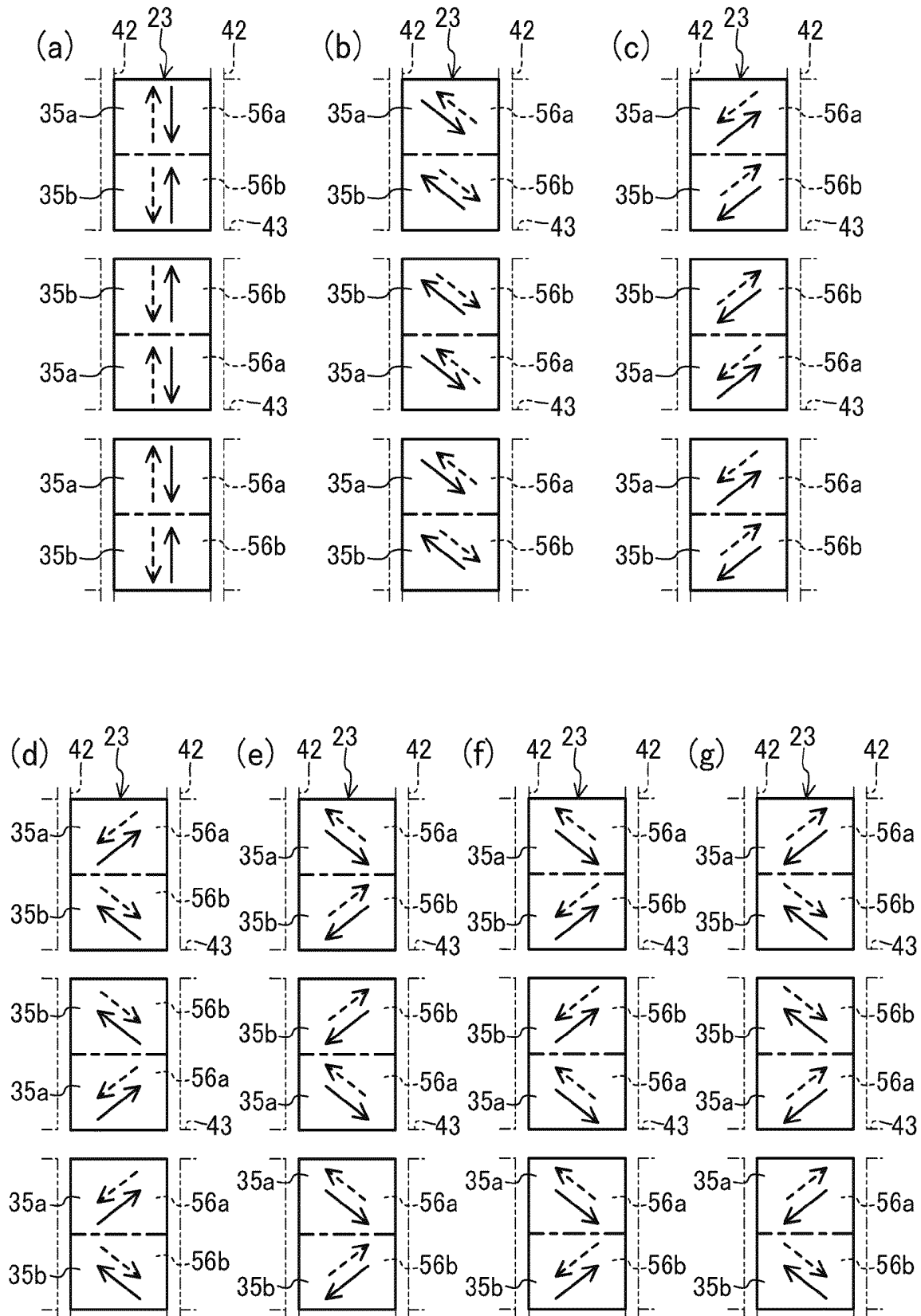


FIG.14

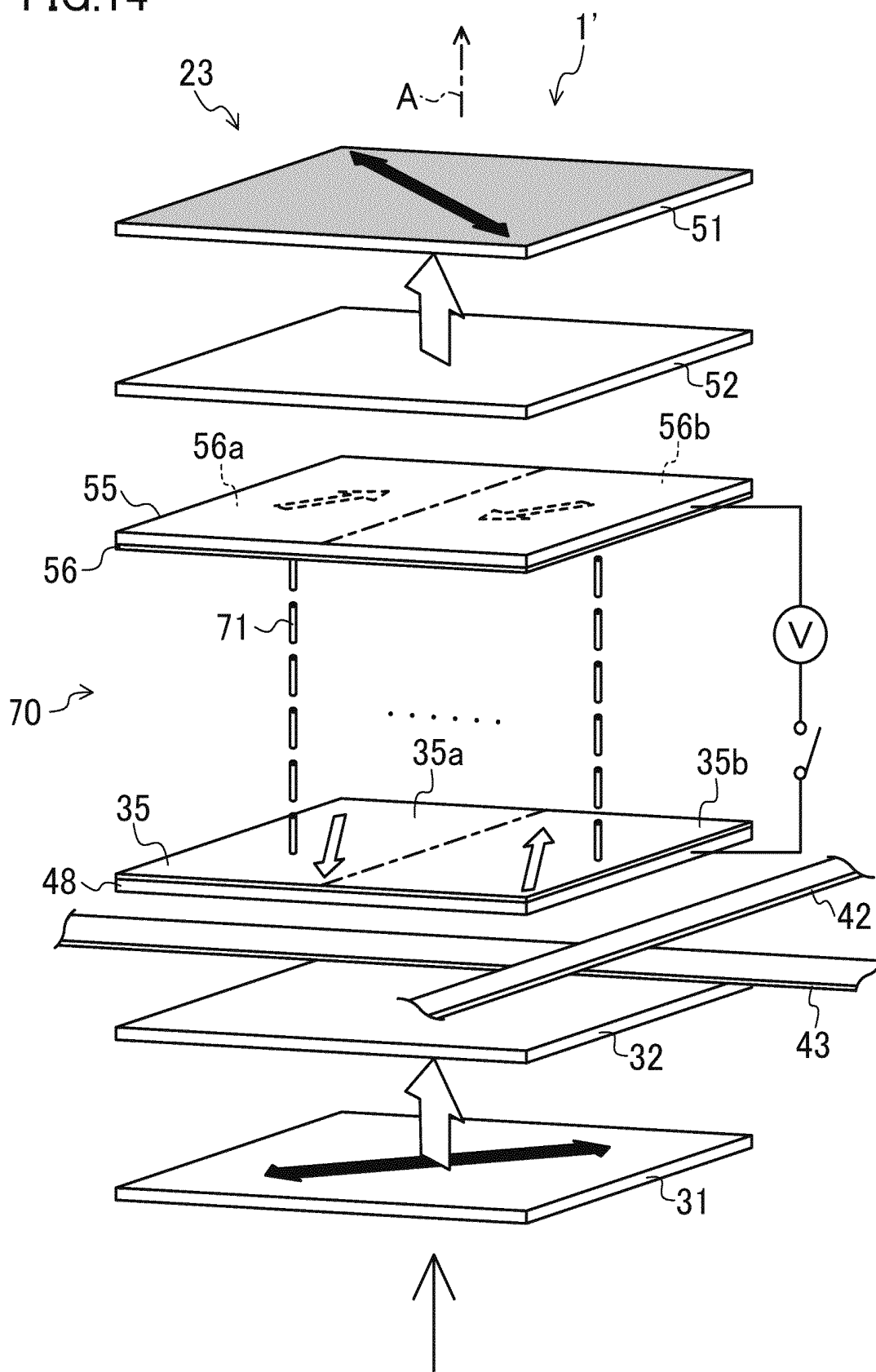


FIG. 15

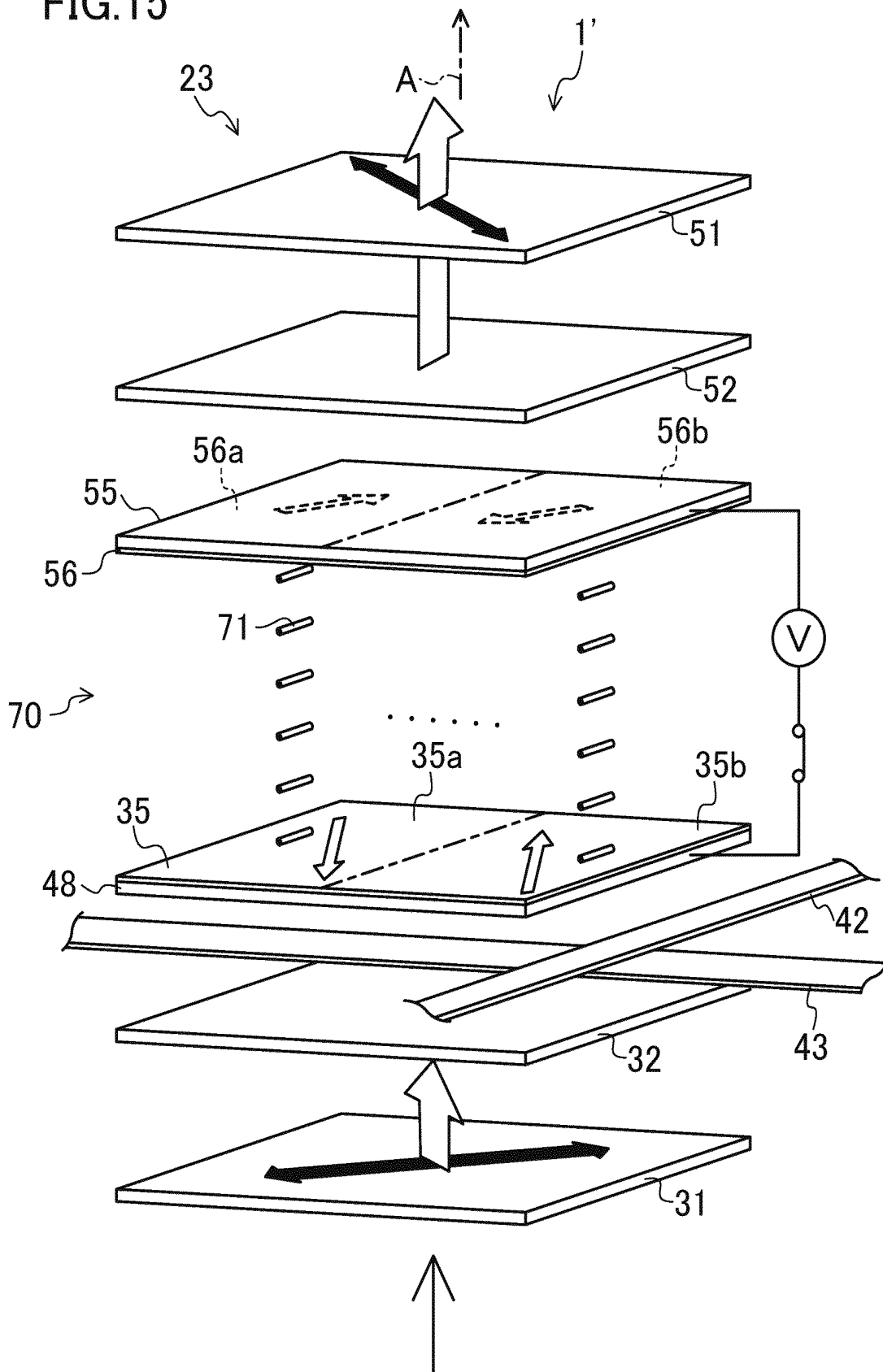


FIG. 16

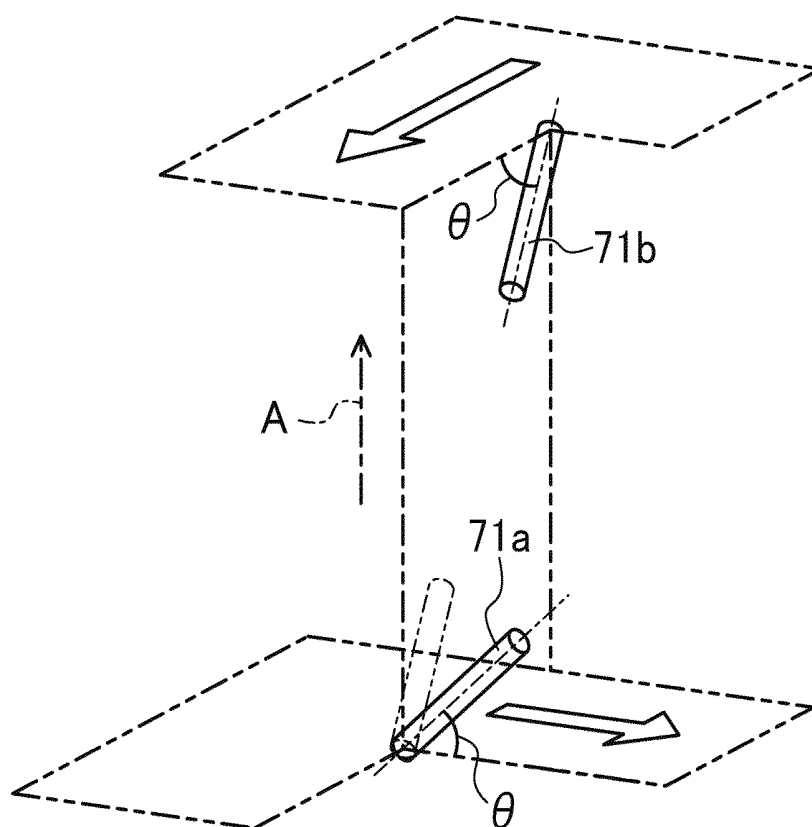




FIG. 17

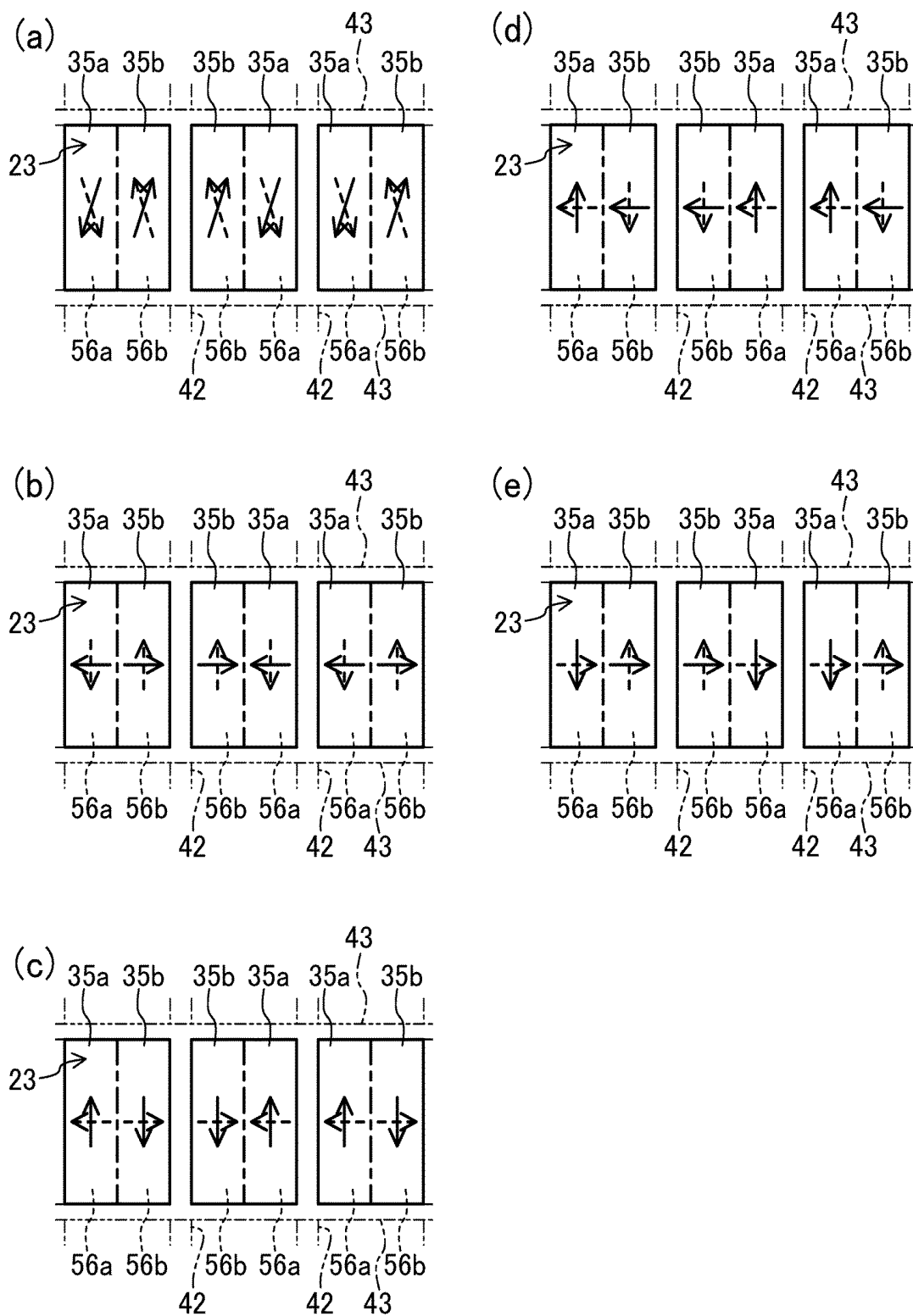


FIG. 18

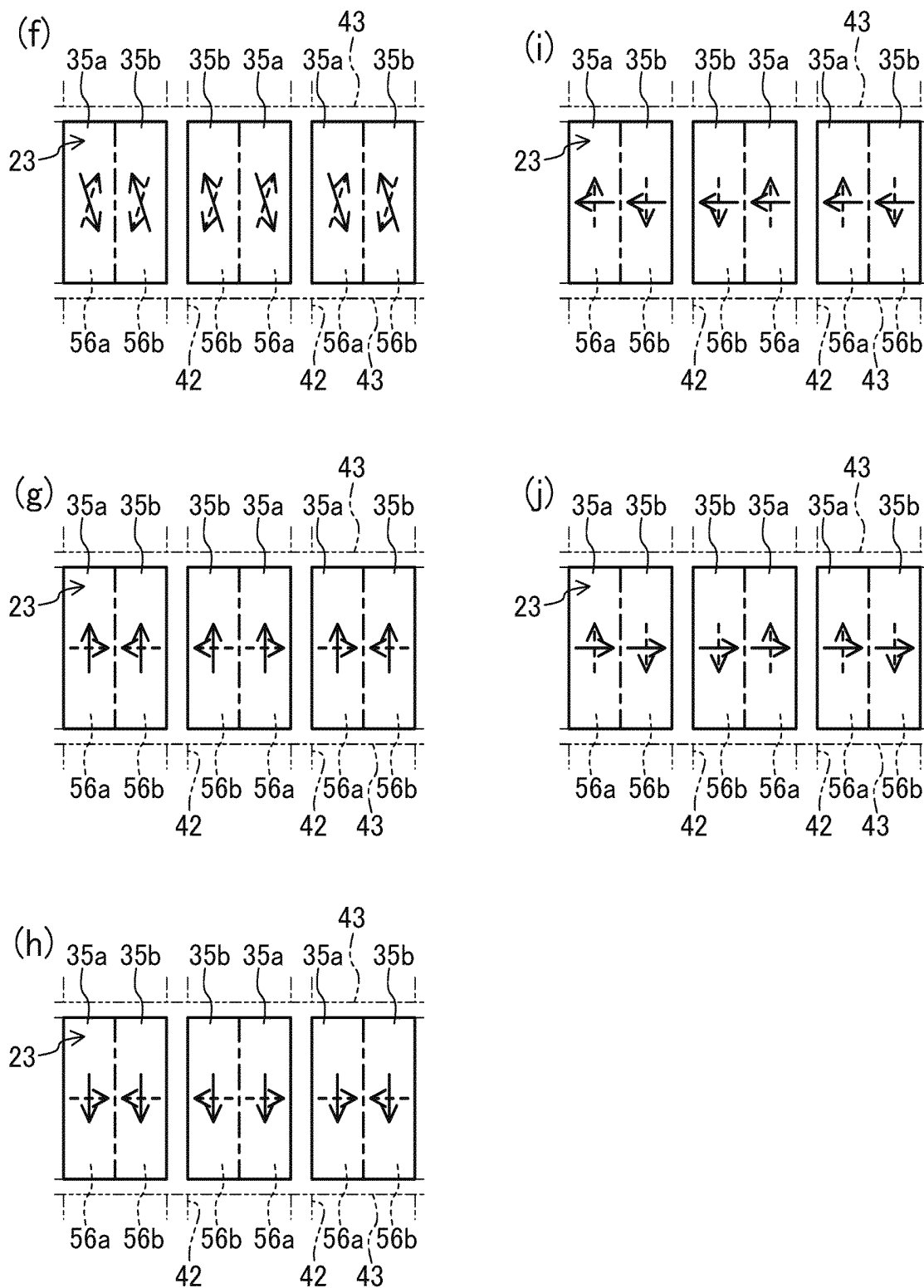


FIG. 19

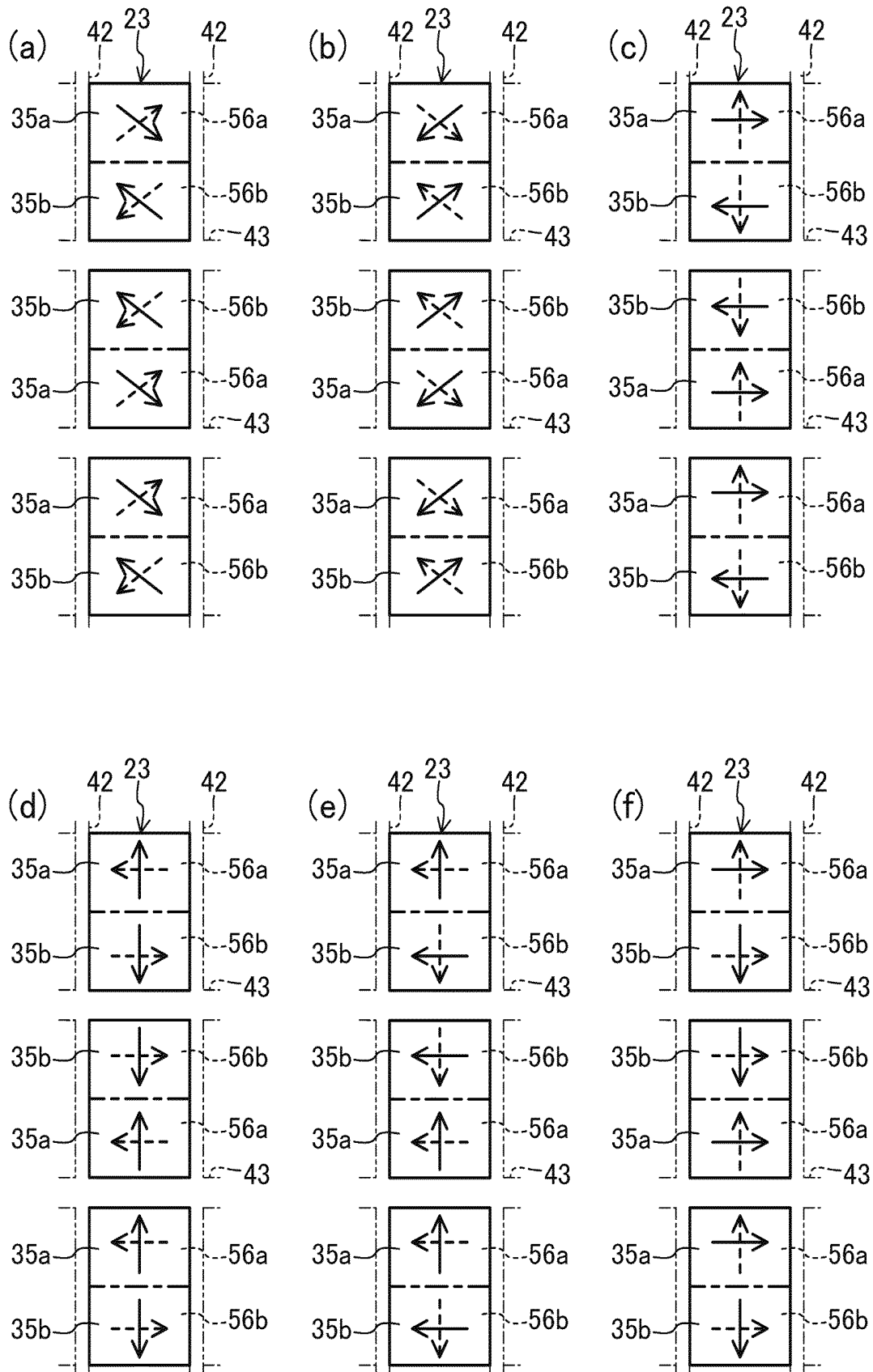
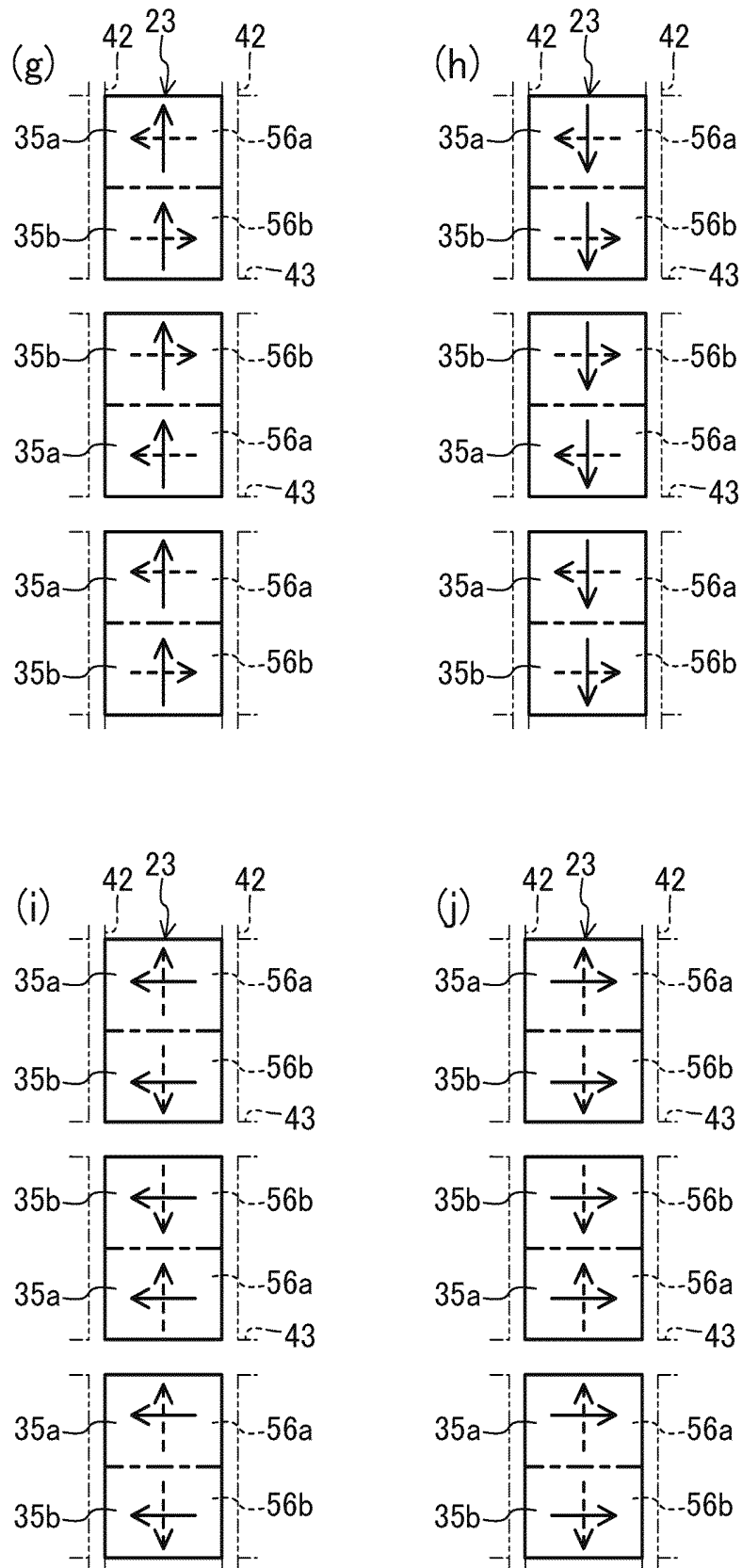


FIG. 20



**LIQUID CRYSTAL DISPLAY DEVICE**

This application is the U.S. national phase of International Application No. PCT/JP2011/003472, filed 17 Jun. 2011, which designated the U.S. and claims priority to Japan Application No. 2010-143048, filed 23 Jun. 2010, the entire contents of each of which are hereby incorporated by reference.

**TECHNICAL FIELD**

The present invention relates to normally black liquid crystal display devices using a VA mode.

**BACKGROUND ART**

A document (Patent Document 1) related to the present invention shows a liquid crystal display element in a normally black mode (i.e., the mode in which a screen is displayed in black when no voltage is applied) without using a black mask (i.e., a light shielding layer provided between pixels).

The liquid crystal display element includes, between a pair of transparent substrates, active matrix liquid crystal cells including a liquid crystal layer in a VA mode (i.e., the mode in which liquid crystal molecules are aligned perpendicular to a substrate), a pair of polarizing plates arranged with the liquid crystal cells interposed therebetween, two  $\lambda/4$  plates, each of which is arranged between one of the polarizing plates and the liquid crystal cells.

By applying a voltage to the liquid crystal cells, the liquid crystal molecules lie down and are aligned in the horizontal direction. In order to keep the alignment directions of the liquid crystal molecules uniform, rubbed vertical alignment films are formed on the inner surfaces of the pair of transparent substrates to be parallel to each other in opposite directions. However, no alignment division is performed.

As a technique for improving viewing angle characteristics, alignment division is known, in which each pixel is divided into regions having different alignment directions.

**CITATION LIST**

Patent Document

PATENT DOCUMENT 1: Japanese Patent Publication No. 2005-292302

**SUMMARY OF THE INVENTION****Technical Problem**

Compared to a conventional liquid crystal display device in a normally white mode (i.e., the mode in which a screen is displayed in white when no voltage is applied) using a TN mode, a normally black liquid crystal display device using a VA mode like Patent Document 1 provides high-contrast display. However, the latter case has the disadvantage of poorer light transmittance than the former and the tendency that the screen becomes dark, when the screen is displayed in white. In order to address the problems, the latter liquid crystal display device increases an output of a backlight and provides brightness similar to that of the TN mode.

The liquid crystal display element of Patent Document 1 has a disadvantage in viewing angle characteristics. However, when alignment division is performed to improve the viewing angle characteristics, light transmittance is reduced by disorder of the alignment directions of the liquid crystal molecules, thereby making the screen darker.

It is an objective of the present invention to improve viewing angle characteristics and to mitigate reduction in light transmittance in a normally black liquid crystal display device using a VA mode.

**Solution to the Problem**

In order to achieve the objective, the present invention provides creative alignment division to mitigate reduction in light transmittance.

A normally black liquid crystal display device according to the present invention includes a first substrate; a second substrate facing the first substrate; a liquid crystal layer sealed between the first substrate and the second substrate; a first polarizing plate provided on the first substrate; and a second polarizing plate provided on the second substrate.

The first substrate includes, on a facing surface, a plurality of source lines extending in parallel, a plurality of gate lines extending orthogonal to the source lines, a plurality of pixel electrodes provided to correspond to pixel regions segmented in a grid by the source lines and the gate lines, and a first alignment film in contact with the liquid crystal layer. The second substrate includes, on a facing surface, a single common electrode facing the pixel electrodes, and a second alignment film in contact with the liquid crystal layer.

The liquid crystal layer includes liquid crystal molecules arranged so that a light transmission axis orthogonal to the facing surfaces of the substrates substantially coincides with long axes of the molecules when no voltage is applied between the pixel electrodes and the common electrode. The liquid crystal molecules are aligned so that the long axes of the molecules are substantially orthogonal to the light transmission axis by application of a voltage.

Assume that each of the pixel regions in the first alignment film and the second alignment film is divided into regions along a direction parallel to either one of the source lines or the gate lines, each of the pixel regions in the first alignment film includes a first region and a second region, and each of the pixel regions in the second alignment film includes a third region facing the first region and a fourth region facing the second region.

At this time, at least one pair of the first region and the second region, or the third region and the fourth region has different directions of alignment treatment. In an adjacent pair of the pixel regions, pairs of the first regions, the second regions, the third regions, and the fourth regions are adjacent to each other with corresponding one of the lines interposed therebetween.

In the liquid crystal display device, the alignment division is performed at first, thereby improving the viewing angle characteristics. When the alignment division is performed, misalignment of the liquid crystal molecules causes reduction in the light transmittance. In this liquid crystal display device, however, a combination of alignment division mitigates the reduction in the light transmittance occurring at the boundaries between source lines etc. and the corresponding pixel regions.

That is, in an adjacent pair of the pixel regions, the pairs of the regions having the same direction of alignment treatment are adjacent to each other with the corresponding one of the source lines or the gate lines interposed therebetween, which is parallel to the direction of alignment division. Thus, the liquid crystal molecules above the source lines and the boundaries between the source lines and the corresponding pixel regions are aligned similarly to cause less misalignment under the influence of the regions on the both sides having the same alignment direction. As a result, the reduction in the

light transmittance at the boundaries between the source lines and the corresponding pixel regions is mitigated, thereby improving the brightness of the pixel regions.

More specifically, the first region and the second region are preferably formed to have opposite directions of alignment treatment. The third region and the fourth regions are preferably formed to have opposite directions of alignment treatment.

Then, the advantages of the alignment division are efficiently provided, thereby further improving the viewing angle characteristics.

Still more specifically, for example, the first region and the third region may be subjected to alignment treatment in opposite directions. The second region and the fourth region may be subjected to alignment treatment in opposite directions. As viewed from the light transmission axis, the first polarizing plate may be provided so that an absorption axis direction of the first polarizing plate is substantially shifted from the direction of alignment treatment of the first alignment film by an angle of 45°, and the second polarizing plate may be provided so that an absorption axis direction of the second polarizing plate is orthogonal to the absorption axis direction of the first polarizing plate.

Alternatively, the first region and the third region may be subjected to alignment treatment in orthogonal directions. The second region and the fourth region may be subjected to alignment treatment in orthogonal directions. As viewed from the light transmission axis, the first polarizing plate may be provided so that an absorption axis direction of the first polarizing plate coincides with the direction of alignment treatment of one of the first alignment film or the second alignment film, and the second polarizing plate may be provided so that an absorption axis direction of the second polarizing plate is orthogonal to the absorption axis direction of the first polarizing plate.

#### Advantages of the Invention

As described above, according to the present invention, reduction in light transmittance is mitigated, while improving viewing angle characteristics, by effectively combining alignment division in a normally black liquid crystal display device using a VA mode.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic perspective view illustrating a liquid crystal display device according to a first embodiment.

FIG. 2 is a schematic perspective view illustrating a display panel.

FIG. 3 is a schematic cross-sectional view illustrating a display region of the display panel.

FIG. 4 is a schematic top view illustrating a main part of a TFT substrate.

FIG. 5 is a conceptual view illustrating a pixel region when no voltage is applied.

FIG. 6 is a conceptual view illustrating a pixel region when a voltage is applied.

FIG. 7 illustrates alignment treatment.

FIG. 8 illustrates misalignment of liquid crystal when a voltage is applied.

FIG. 9 is a conceptual view illustrating the brightness of the display region when a voltage is applied.

FIG. 10 is a conceptual view illustrating the brightness of a display region according to a comparison example when a voltage is applied.

FIG. 11(a)-11(e) are schematic views illustrating a variation of alignment treatment.

FIG. 12 illustrates a variation of the liquid crystal display device and corresponds to FIG. 9.

FIG. 13(a)-13(g) are schematic views illustrating alignment treatment according to a variation in the liquid crystal display device according to the variation.

FIG. 14 illustrates a liquid crystal display device according to a second embodiment. This figure shows a pixel region when no voltage is applied.

FIG. 15 illustrates the liquid crystal display device according to the second embodiment. This figure shows the pixel region when a voltage is applied.

FIG. 16 illustrates alignment treatment according to the second embodiment.

FIG. 17(a)-17(e) are schematic views illustrating alignment treatment according to a variation of the second embodiment.

FIG. 18(f)-18(j) are schematic views illustrating the alignment treatment according to the variation of the second embodiment following FIG. 17.

FIG. 19(a)-19(f) are schematic views illustrating alignment treatment according to a variation in the liquid crystal display device according to the variation of the second embodiment.

FIG. 20(g)-20(j) are schematic views illustrating the alignment treatment according to the variation following FIG. 19.

#### DESCRIPTION OF EMBODIMENTS

##### Industrial Applicability

Embodiments of the present invention will be described in detail hereinafter with reference to the drawings. The following description is essentially illustrative only and should not be taken as limiting the invention, equivalents, or the usage.

##### First Embodiment

FIG. 1 illustrates a liquid crystal display device 1 according to this embodiment. The liquid crystal display device 1 is, for example, a personal digital assistance such as a mobile phone, and has the function of displaying still images and moving images in color by active matrix drive. The liquid crystal display device 1 includes a display panel (or simply referred to as a panel 2), and a body case 3 storing the panel 2. Although not shown, the body case 3 includes therein various types of hardware, software, batteries, etc., for driving and controlling the panel 2.

FIGS. 2 and 3 illustrate the panel 2. The panel 2 is a normally black liquid crystal panel, and has the minimum light transmittance so that the screen is displayed in black when no voltage is applied. The panel 2 includes a TFT substrate 30 (a first substrate), an facing substrate 50 (a second substrate), a liquid crystal layer 70, phase plates 32 and 52, and polarizing plates 31 and 51.

The facing substrate 50 faces the TFT substrate 30 with a surface facing the display side, and is opposed to the TFT substrate 30. The outer edges of the substrates are sealed by a sealing member 10. The liquid crystal layer 70 is enclosed between the both substrates 50 and 30. A rectangular display region 21, which displays an image, is formed in the center of the panel 2 surrounded by the sealing member 10. In the rectangular display region 21, a plurality of rectangular pixels 22, 22, . . . , are arranged in a matrix.

As shown in FIG. 3, the display region 21 of the facing substrate 50 includes the second polarizing plate 51, the sec-

ond phase plate **52**, a second glass substrate **53**, a color filter **54**, a common electrode **55**, and a second alignment film **56**. The second polarizing plate **51** and the second phase plate **52**, which are films, are formed on the display surface of the second glass substrate **53**. The color filter **54**, the common electrode **55**, and the second alignment film **56** are stacked on the facing surface of the second glass substrate **53**. These members **51-56** are formed in the entire surface of the display region **21**.

The color filter **54** includes regions **54a**, **54b**, and **54c** of three colors of red (R), green (G), and blue (B), which are arranged in predetermined positions to correspond to the pixels **22**. The common electrode **55** is a transparent conductive film made of ITO etc., exhibiting excellent light transmittance. The second alignment film **56** is located in the outermost position to be in contact with the liquid crystal layer **70**. The second alignment film **56** is subjected to predetermined alignment treatment for aligning liquid crystal molecules **71** included in the liquid crystal layer **70**, which will be described later.

The display region **21** of the TFT substrate **30** includes the first polarizing plate **31**, the first phase plate **32**, a first glass substrate **33**, a TFT layer **34**, and a first alignment film **35**. The first polarizing plate **31** and the first phase plate **32**, which are films, are stacked on the non-display surface of the first glass substrate **33**. The TFT layer **34** and the first alignment film **35** are stacked on the facing surface of the first glass substrate **33**. These members **31-35** are also formed in the entire surface of the display region **21**. Note that the first phase plate **32** and the second phase plate **52** are provided to improve viewing angle characteristics, and may be located collectively on the facing substrate **50** or the TFT substrate **30**.

FIG. 4 illustrates a part of the TFT layer **34** as viewed from its facing surface. As shown in the figure, thin film transistors **41** (TFTs), source lines **42**, gate lines **43**, auxiliary capacitor lines **44**, capacitors **45**, etc., which are patterned in predetermined forms, are stacked in the TFT layer **34**.

Specifically, the plurality of source lines **42**, **42**, . . . , extending in parallel, and the plurality of gate lines **43**, **43**, . . . , extending orthogonal to the source lines **42**, **42**, . . . , are provided on the facing surface. The display region **21** is segmented in a grid by the source lines **42**, **42**, . . . , and the gate lines **43**, **43**, . . . . A plurality of pixel regions **23**, **23**, . . . , are formed to correspond to the pixels **22**. An auxiliary capacitor line **44** is provided between each adjacent pair of the gate lines **43** and **43** in parallel to the gate lines **43**. Each of the capacitors **45**, which is coupled to the auxiliary capacitor line **44**, is provided in the center of each pixel region **23**. The capacitors **45** are coupled to the source lines **42** via the TFTs **41** having a switching function.

The TFTs **41** are provided near the intersections between the corresponding gate lines **43** and source lines **42**, and are arranged in the respective pixel regions **23**. The gate lines **43** are covered with a gate insulating film **46**, on which semiconductor of the TFTs **41** and the source lines **42** are provided. Furthermore, the semiconductor etc. is covered with an insulating protection film **47**, thereby forming the TFT layer **34**. In the upper portion of the TFT layer **34**, a plurality of rectangular pixel electrodes **48** are provided.

The pixel electrodes **48** are provided in the respective pixel regions **23**, and arranged in a matrix on the entire surface of the display region **21**. The pixel electrodes **48** are coupled to the source lines **42** via the TFTs **41**. The pixel electrodes **48** are transparent conductive films made of ITO etc. having excellent light transmittance.

The first alignment film **35** is provided in the outermost position to cover the pixel electrodes **48** to be in contact with

the liquid crystal layer **70**. The first alignment film **35** is subjected to predetermined alignment treatment, which will be also described later.

A backlight **90**, which is a light source, is provided at the side of the non-display surface of the TFT substrate **30**. That is, the liquid crystal display device **1** according to this embodiment is a transmission type and performs display utilizing the light of the backlight **90**. Specifically, a voltage applied between the common electrode **55** and the pixel electrodes **48** is controlled to change the alignment directions of the liquid crystal molecules **71** contained in the liquid crystal layer **70**. Display is performed by changing the transmittance of the light of the backlight **90** passing through the TFT substrate **30** etc.

In the panel **2** of this embodiment, a black matrix (BM) for covering the regions with the source lines **42** and the gate lines **43** is not provided to increase the aperture ratio.

The liquid crystal layer **70** is made of a liquid crystal material having negative dielectric anisotropy. Specifically, the liquid crystal layer **70** contains the rod-shaped liquid crystal molecules **71**. When no voltage is applied (i.e., in a non-voltage applied state), the liquid crystal molecules **71** are arranged vertically so that the long axes of the molecules substantially coincide with the direction orthogonal to the facing surfaces of the substrates (i.e., the direction indicated by a light transmission axis A). Then, when a voltage is applied (i.e., in a voltage applied state), the liquid crystal molecules **71** are arranged horizontally. That is, the liquid crystal display device **1** employs a (vertical alignment) VA mode.

FIG. 5 is a conceptual view illustrating a pixel region **23** in a non-voltage applied state. In the figure, light (randomly polarized light) of the backlight **90** is incident on the panel **2** from the direction indicated by the thin arrow below the first polarizing plate **31**. The incident light passes through the first polarizing plate **31** first, thereby becoming linearly polarized light orthogonal to an absorption axis (indicated by the thick arrow). Then, the linearly polarized light passes through the first phase plate **32** and is incident on the liquid crystal layer **70**.

At this time, since the liquid crystal molecules **71** are arranged along the light transmission axis A, the light is transmitted by the liquid crystal layer **70** without being influenced by birefringence, and passes through the second phase plate **52**. Thus, the light does not change from the linearly polarized light orthogonal to the absorption axis of the first polarizing plate **31**.

The absorption axis of the second polarizing plate **51** is provided to be orthogonal to the absorption axis of the first polarizing plate **31** (which is indicated by the thick arrow). Being parallel to the absorption axis of the second polarizing plate **51**, the polarized light incident on the second polarizing plate **51** is absorbed by the second polarizing plate **51** and cannot be output. As a result, the pixel region **23** is displayed in black (i.e., dark).

FIG. 6 is a conceptual view illustrating a pixel region **23** in a voltage applied state. At this time, the liquid crystal molecules **71** are aligned in the horizontal direction so that their long axes are orthogonal to the light transmission axis A. The polarized light having passed through the first phase plate **32** passes through the liquid crystal layer **70** under the influence of the birefringence, and passes through the second phase plate **52**, thereby becoming linearly polarized light orthogonal to the absorption axis of the second polarizing plate **51**. Since the linearly polarized light is output without being absorbed by the second polarizing plate **51**, the pixel region **23** is displayed in white (i.e., bright).

### Alignment Treatment

The surfaces of the first alignment film **35** and the second alignment film **56** are subjected to alignment treatment so that the liquid crystal molecules **71** are aligned in a predetermined direction. In particular, in the panel **2**, alignment division is performed to divide directions of alignment treatment into two in each of the pixel regions **23** in order to improve viewing angle characteristics, while improving the light transmittance of the pixel regions **23**.

Specifically, as indicated by the directional lines in FIGS. **5** and **6**, in this embodiment, in each of the first alignment film **35** and the second alignment film **56**, each of the pixel regions **23** are divided into two along the direction parallel to the source lines **42**. The obtained two regions have different directions of alignment treatment. Specifically, the first alignment film **35** includes a first region **35a** and a second region **35b**, which are subjected to alignment treatment in the direction parallel to the source lines **42**, and have opposite (anti-parallel) directions of alignment treatment. The second alignment film **56** includes a third region **56a** and a fourth region **56b**, which are subjected to alignment treatment in the direction parallel to the source lines **42** and have opposite directions of alignment treatment.

The first region **35a** faces the third region **56a**, and the second region **35b** faces the fourth region **56b**. The first region **35a** and the third region **56a** have opposite direction of alignment treatments, and the second region **35b** and the fourth region **56b** have opposite directions of alignment treatment. The liquid crystal display device **1** controls light transmittance by utilizing the birefringence of liquid crystal, as described above, and thus, as viewed from the light transmission axis A, the first polarizing plate **31** is provided so that its absorption axis direction is substantially shifted from the direction of alignment treatment of the first alignment film **35** by a degree of 45°. The second polarizing plate **51** is provided so that its absorption axis direction is substantially shifted from the direction of alignment treatment of the second alignment film **56** by a degree of 45°. That is, the second polarizing plate **51** is provided so that its absorption axis direction is orthogonal to the absorption axis direction of the first polarizing plate **31**.

By providing two regions having different directions of alignment treatment in a single pixel region **23**, the views of the liquid crystal molecules **71** from different angles are averaged, and thus the viewing angle is expanded. In particular, in this embodiment, two regions have opposite directions of alignment treatment, thereby effectively expand the viewing angle.

The alignment treatment may be performed by, for example, conventional rubbing, oblique vapor deposition utilizing a silicon oxide vapor deposited film, and a light alignment film method. The alignment treatment of this embodiment is, in particular, preferably performed by the light alignment film method with UV irradiation using a mask. Since the liquid crystal display device **1** employs the VA mode, a vertical alignment film having a pretilt angle  $\theta$  ranging from 86° to 89.5°.

FIG. **7** illustrates the relationship. The arrows in the figures denote directions of alignment treatment indicating, for example, rubbing directions in rubbing. Since two facing regions have opposite directions of alignment treatment, a liquid crystal molecule **71a** near the first alignment film **35** and a liquid crystal molecule **71b** near the second alignment film **56** are aligned in the same direction. As such, the liquid crystal molecules **71** near the alignment films are inclined slightly in advance, thereby stably aligning the liquid crystal

molecules **71** in a predetermined direction. In addition, since the liquid crystal molecules **71** tend to be inclined, thereby increasing response speed.

In alignment division in a VA mode, misalignment of the liquid crystal molecules **71** tends to increase to reduce the light transmittance. FIG. **8** illustrates a cross-section of the display region **21** in a voltage-applied state. As shown in the figure, the liquid crystal molecules **71** are aligned in the horizontal direction in the pixel regions **23**, in which the common electrode **55** faces the pixel electrodes **48**, under the influence of a voltage. Above the source lines **42** and the gate lines **43** without pixel electrodes **48**, there is no influence of a voltage, and thus, the liquid crystal molecules **71** are not aligned horizontally. At the boundaries between the source lines **42** and the corresponding pixel regions **23**, the alignment directions of the liquid crystal molecules **71** tend to be three-dimensionally greatly disordered.

At the boundary between the regions having different alignment directions, the alignment directions of the liquid crystal molecules **71** tend to be two-dimensionally greatly disordered. The light transmitted by the portion with disordered alignment directions of the liquid crystal molecules **71** tends to be absorbed by the second polarizing plate **51**, thereby reducing light transmittance to cause dark display.

The viewing angle characteristics are improved by increasing the number of alignment division, but the light transmittance decreases. Thus, in order to obtain good balance of the advantages of improving the viewing angle characteristics, and reducing the light transmittance under the condition of a small and fine pixel size, the alignment division is preferably the division into two.

In this case, with respect to the alignment direction, as shown in FIG. **9**, the adjacent pixel regions **23** are preferably arranged so that the regions adjacent to each other with the corresponding one of the source lines **42** interposed therebetween have the same alignment direction.

Specifically, the first regions **35a** and **35a** of the adjacent pair of the pixel regions **23** are arranged to be adjacent to each other with corresponding one of the source lines **42** interposed therebetween. Similarly, the second regions **35b** and **35b**, the third regions **56a** and **56a**, the fourth regions **56b** and **56b** are arranged to be adjacent to each other with corresponding one of the source lines **42** interposed therebetween.

The directional lines in the figure indicate the directions of alignment treatment. The solid lines indicate the directions of alignment treatment of the first alignment film **35**, and the broken lines indicate the directions of alignment treatment of the second alignment film **56**.

As a result, the liquid crystal molecules **71** above the source lines **42** are aligned similarly to cause less misalignment under the influence of the regions on the both sides having the same alignment direction, thereby mitigating reduction in the light transmittance occurring at the boundaries between the source lines **42** and the corresponding pixel regions **23**, and improving the brightness of the pixel regions **23**.

Assume that the adjacent pixel regions **23** are arranged so that the regions adjacent to each other with the corresponding one of the source lines **42** interposed therebetween have opposite alignment directions. As shown in FIG. **10**, the liquid crystal molecules **71** above the source lines **42** and at the boundaries between the source lines **42** and the corresponding pixel regions **23** are greatly misaligned, thereby causing dark display. Such dark displayed regions are hidden where a BM is provided, but are displayed without change where no BM is provided. Thus, the substantial advantage of increasing the aperture ratio is not provided even without BM.



In this respect, the panel 2 of this embodiment effectively provides excellent viewing angle characteristics and the advantage of increasing the aperture ratio, since the misalignment of the liquid crystal molecules 71 is reduced at the boundaries of the source lines 42 by appropriately combining alignment division.

#### Variation of Alignment Treatment

FIGS. 11(a)-11(e) illustrate a variation of alignment treatment according to this embodiment. In these figures, the directional lines (the solid lines) indicate the directions of alignment treatment of the first alignment film 35, and the directional lines (the broken lines) indicate the directions of alignment treatment of the second alignment film 56.

In short, the adjacent pixel regions 23 may be arranged so that the regions adjacent to each other with the corresponding one of the source lines 42 interposed therebetween have the same direction of alignment treatment. For example, as shown in FIG. 11(a), the pairs of the first regions 35a and the second regions 35b, and the pairs of the third regions 56a and the fourth regions 56b may be subjected to alignment treatment in the direction orthogonal to the source lines 42, and the pairs of the regions may have opposite directions of alignment treatment.

As shown in FIGS. 11(b) and 11(c), the pairs of the first regions 35a and the second regions 35b, and the pairs of the third regions 56a and the fourth regions 56b may be subjected to alignment treatment in the direction inclined from the source lines 42 by an angle of 45° to be parallel to each other, and the pairs of the regions may have opposite directions of alignment treatment.

As shown in FIGS. 11(d) and 11(e), the pairs of the first regions 35a and the second regions 35b, and the pairs of the third regions 56a and the fourth regions 56b may be subjected to alignment treatment in the direction inclined from the source lines 42 by an angle of 45° to intersect with each other, and the pairs of the regions may have the same direction of alignment treatment (in the direction in which the pairs of the regions are close to or apart from each other. In this case, the pairs of the regions may have opposite directions of alignment treatment (i.e., one of the regions may be close to the other and the other may be apart from the one).

#### Variation of Liquid Crystal Display Device 1

FIG. 12 illustrates a variation of the liquid crystal display device 1 according to this embodiment. This variation differs from the above-described embodiment in that alignment division is performed along the direction parallel to the gate lines 43. In this case, as shown in the figure, the reduction in the light transmittance occurring at the boundaries between the gate lines 43 and the corresponding pixel regions 23 is mitigated, and the brightness of the pixel regions 23 are improved.

In this variation, the adjacent pixel regions 23 may be arranged so that the regions adjacent to each other with the corresponding one of the gate lines 43 interposed therebetween have the same direction of alignment treatment. Similar to FIG. 11, FIGS. 13(a)-13(g) illustrate example directions of alignment treatment.

#### Second Embodiment

FIGS. 14 and 15 illustrate a liquid crystal display device 1' according to this embodiment. The liquid crystal display device 1' according to this embodiment mainly differs from the liquid crystal display device 1 of the first embodiment in that a first alignment film 35 and a second alignment film 56 are arranged to have orthogonal directions of alignment treatment. The other main elements are the same as those in the above-described embodiment. (The same reference charac-

ters are used to represent equivalent elements, and the explanation thereof will be omitted.)

Specifically, pairs of regions of the first alignment film 35 and the second alignment film 56 are subjected to alignment treatment in the direction inclined from source lines 42 by 45° as viewed from a light transmission axis A to be parallel to each other. A first region 35a and a second region 35b are subjected to alignment treatment in opposite directions, and a third region 56a and a fourth region 56b are subjected to alignment treatment in opposite directions. The first region 35a and the third region 56a are subjected to alignment treatment in the orthogonal directions toward one of the source lines 42. The second region 35b and the fourth region 56b are subjected to alignment treatment in the orthogonal directions toward one of the source lines 42.

As viewed from the light transmission axis A, a first polarizing plate 31 is provided so that the direction of alignment treatment of the second alignment film 56 coincides with the absorption axis direction. The second polarizing plate 51 is provided so that the direction of alignment treatment of the first alignment film 35 coincides with the absorption axis direction. Note that the first polarizing plate 31 may be provided so that the direction of alignment treatment of the first alignment film 35 coincides with the absorption axis direction, and the second polarizing plate 51 may be provided so that the direction of alignment treatment of the second alignment film 56 coincides with the absorption axis direction.

As shown in FIG. 14, in this embodiment as well, liquid crystal molecules 71 are arranged vertically in a non-voltage applied state, and thus, the process of transmission of light to a pixel region 23 is the same as that in the first embodiment.

By contrast, as shown in FIG. 15, in a voltage-applied state, facing regions of the first alignment film 35 and the second alignment film 56 have orthogonal directions of alignment treatment. The liquid crystal molecules 71 form skew alignment only at the interface of the first alignment film 35 and at the interface of the second alignment film 56 (in a TN mode). In the center of the liquid crystal layer 70, the liquid crystal molecules 71 are aligned in the horizontal direction so that their long axes are orthogonal to the light transmission axis A. Then, the linearly polarized light having passed through the first phase plate 32 passes through the liquid crystal layer 70 under the influence of the birefringence. As a result, the linearly polarized light output from the second phase plate 52 is orthogonal to the absorption axis of the second polarizing plate 51.

In this case, as shown in FIG. 16, since two facing regions of the first alignment film 35 and the second alignment film 56 have orthogonal directions of alignment treatment, a liquid crystal molecule 71a near the first alignment film 35 is aligned in the direction shifted from the liquid crystal molecules 71b near the second alignment film 56 by a degree of 90° more than in the first embodiment as viewed from the light transmission axis A.

Similar to the first embodiment, in this embodiment, alignment division may be performed by dividing each of the pixel regions 23 in the first alignment film 35 and the second alignment film 56 into two along the direction parallel to either one of the source lines 42 or the gate lines 43. The adjacent pixel regions 23 may be provided so that the regions adjacent to each other with the corresponding one of the gate lines 43, etc., interposed therebetween have the same alignment direction. As a result, similar to the first embodiment, excellent viewing angle characteristics and the advantage of improving the aperture ratio can be provided.

## 11

Similar to FIG. 11, FIGS. 17 and 18 illustrate various types of patterns of alignment treatment where alignment division is performed along the direction parallel to the source lines 42.

For example, as shown in FIG. 17(a), the directions of alignment treatment of the first regions 35a, the second regions 35b, the third regions 56a, and the fourth regions 56b may not be toward the source lines 42 as in the above-described second embodiment, but may be toward the gate lines 43.

As shown in FIGS. 17(b) and 17(c), one of the first alignment film 35 and the second alignment film 56 may be subjected to alignment treatment in the direction parallel to the source lines 42, and the other alignment film may be subjected to alignment treatment in the direction orthogonal to the source lines 42. The first regions 35a and the second regions 35b may have opposite directions of alignment treatment, and the third regions 56a and the fourth regions 56b have opposite directions of alignment treatment.

As shown in FIGS. 17(d) and 17(e), either one of the first regions 35a or the second regions 35b, and the third regions 56a or the fourth regions 56b may be subjected to alignment treatment in the direction parallel to the source lines 42, and the other regions may be subjected to alignment treatment in the direction orthogonal to the source lines 42. In this case, for example, the absorption axis direction of the first polarizing plate 31 may coincide with the direction of alignment treatment of one of the regions.

As shown in FIGS. 18(g)-18(j), one of the first alignment film 35 or the second alignment film 56 may not be subjected to alignment division, may have the same direction of alignment treatment, and only the other one may have different directions of alignment treatment. For example, as shown in FIGS. 18(g) and 18(h), the first regions 35a and the second regions 35b may have the same direction of alignment treatment parallel to the source lines 42, and the third regions 56a and the fourth regions 56b may have opposite directions of alignment treatment parallel to the gate lines 43.

Similar to the first embodiment, FIGS. 19(a)-20(j) illustrate variations where alignment division is performed along the direction parallel to the gate lines 43 in the liquid crystal display device 1' according to this embodiment. In the variations, the adjacent pixel regions 23 may be arranged so that the regions adjacent to each other with the corresponding one of the gate lines 43 interposed therebetween have the same direction of alignment treatment.

Others

The liquid crystal display device according to the present invention is not limited to the above-described embodiments, and includes other various configurations. For example, while no BM is provided in the above-described embodiments, for example, a BM with a width smaller than or equal to the width of each source line 42 etc. may be provided. BMs may be provided in either one of the source lines 42 or the gate lines 43, which are orthogonal to the direction of alignment division.

The drawings showing the above-described embodiments etc., the directions of alignment treatment indicated by the directional lines (the solid lines) and the directional lines (the broken lines) may be replaced with each other.

## INDUSTRIAL APPLICABILITY

The liquid crystal display device of the present invention can be utilized for, for example, displays of PCs and TVs, video cameras, digital cameras, navigation systems, sound reproducing systems (e.g., car audio systems, audio players,

## 12

etc.), game players, personal digital assistance (e.g., mobile computers, mobile phones, portable video game players, electronic dictionaries, electronic books, etc.), home electronics (e.g., refrigerators, air conditioners, air cleaners, their control terminals, liquid crystal clocks, etc.), etc.

## DESCRIPTION OF REFERENCE CHARACTERS

1, 1' Liquid Crystal Display Devices

2 Display Panel

21 Display Region

22 Pixel

23 Pixel Region

30 TFT Substrate (First Substrate)

31 First Polarizing Plate

32 First Phase Plate

33 First Glass Substrate

34 TFT Layer

35 First Alignment Film

35a First Region

35b Second Region

41 TFT

42 Source Line

43 Gate Line

48 Pixel Electrode

50 Facing Substrate (Second Substrate)

51 Second Polarizing Plate

52 Second Phase Plate

53 Second Glass Substrate

54 Color Filter

55 Common Electrode

56 Second Alignment Film

56a Third Region

56b Fourth Region

70 Liquid Crystal Layer

71 Liquid Crystal Molecule

A Light Transmission Axis

The invention claimed is:

1. A normally black liquid crystal display device, comprising:

a first substrate;

a second substrate facing the first substrate;

a liquid crystal layer sealed between the first substrate and the second substrate;

a first polarizing plate provided on the first substrate; and a second polarizing plate provided on the second substrate;

wherein:

the first substrate includes, on a facing surface,

a plurality of source lines extending in parallel,

a plurality of gate lines extending orthogonal to the source lines,

a plurality of pixel electrodes provided to correspond to pixel regions segmented in a grid by the source lines and the gate lines, and

a first alignment film in contact with the liquid crystal layer,

the second substrate includes, on a facing surface,

a single common electrode facing the pixel electrodes, and

a second alignment film in contact with the liquid crystal layer,

the liquid crystal layer includes liquid crystal molecules arranged so that a light transmission axis orthogonal to the facing surfaces of the substrates substantially coincides with long axes of the molecules when no voltage is applied between the pixel electrodes and the common electrode,

13

the liquid crystal molecules are aligned so that the long axes of the molecules are substantially orthogonal to the light transmission axis by application of a voltage, and

each of the pixel regions in the first alignment film and the second alignment film is divided into regions along a direction parallel to either one of the source lines or the gate lines, each of the pixel regions in the first alignment film includes a first region and a second region, and each of the pixel regions in the second alignment film includes a third region facing the first region and a fourth region facing the second region, at least one pair of the first region and the second region, or the third region and the fourth region has different directions of alignment treatment, in an adjacent pair of the pixel regions, pairs of the first regions, the second regions, the third regions, and the fourth regions are adjacent to each other with corresponding one of the lines interposed therebetween,

14

the first region and the third region are subjected to alignment treatment in opposite directions, the second region and the fourth region are subjected to alignment treatment in opposite directions, and

as viewed from the light transmission axis, the first polarizing plate is provided so that an absorption axis direction of the first polarizing plate is substantially shifted from the direction of alignment treatment of the first alignment film by an angle of  $45^\circ$ , and the second polarizing plate is provided so that an absorption axis direction of the second polarizing plate is orthogonal to the absorption axis direction of the first polarizing plate.

2. The liquid crystal display device of claim 1, wherein the first region and the second region are formed to have opposite directions of alignment treatment, and the third region and the fourth regions are formed to have opposite directions of alignment treatment.

\* \* \* \* \*

|                |                                                                                                                                                 |         |            |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|
| 专利名称(译)        | 液晶显示装置                                                                                                                                          |         |            |
| 公开(公告)号        | <a href="#">US9007552</a>                                                                                                                       | 公开(公告)日 | 2015-04-14 |
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| [标]申请(专利权)人(译) | 早野TAKAYUKI<br>辻MASAYUKI<br>Hayashi日本                                                                                                            |         |            |
| 申请(专利权)人(译)    | 早野, TAKAYUKI<br>辻MASAYUKI<br>HAYASHI, KOHJI                                                                                                     |         |            |
| 当前申请(专利权)人(译)  | 夏普株式会社                                                                                                                                          |         |            |
| [标]发明人         | HAYANO TAKAYUKI<br>TSUJI MASAYUKI<br>HAYASHI KOHJI                                                                                              |         |            |
| 发明人            | HAYANO, TAKAYUKI<br>TSUJI, MASAYUKI<br>HAYASHI, KOHJI                                                                                           |         |            |
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| 优先权            | 2010143048 2010-06-23 JP                                                                                                                        |         |            |
| 其他公开文献         | US20130208216A1                                                                                                                                 |         |            |
| 外部链接           | <a href="#">Espacenet</a> <a href="#">USPTO</a>                                                                                                 |         |            |

#### 摘要(译)

常黑型液晶显示装置包括液晶层，其中液晶分子在没有施加电压时垂直排列，并且通过施加电压水平排列。在通过源极线和栅极线以栅格分段的取向膜中的每个像素区域中，沿着与源极线平行的方向被分成两个。第一配向膜包括第一区域和第二区域。第二配向膜包括面对第一区域的第三区域和面对第二区域的第四区域。在相邻的一对像素区域中，成对的区域彼此相邻，其中相应的一个源极线插入其间。

