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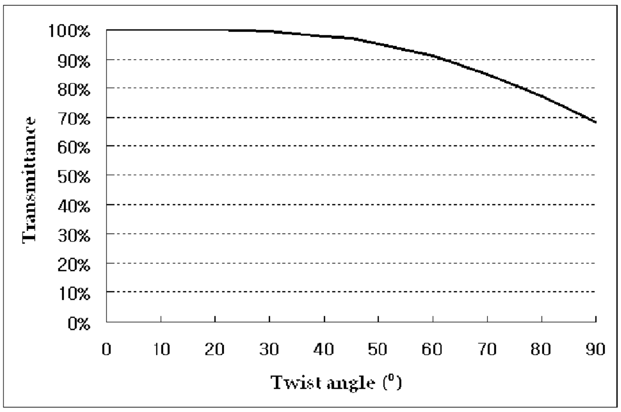
(54) **Title:** LIQUID CRYSTAL DISPLAY DEVICE



(57) **Abstract:** The present invention relates to a liquid crystal display device characterized by improved transmittance and response time. An embodiment of the present invention comprises a nematic LCD panel having a pair of substrates, on both of which an alignment film is formed and on one of which a plurality of pixels are arranged in matrix form; a light source located near the panel; and a field sequential drive module electrically connected to the panel and the light source. The nematic liquid crystal layer of the embodiment is characterized by reduced thickness, small twist angle, and high refractive index anisotropy. Advantages of this embodiment include: improved photoefficiency due to adoption of a field sequential drive method; wider viewing angle and higher transmittance; ease and lower cost of manufacturing as well as a more compact design due to the fact that an expensive, complicated optical engine is not required; and availability of a larger view free from motion artifacts when viewing video images.

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Description

LIQUID CRYSTAL DISPLAY DEVICE

Technical Field

[1] The present invention, in general, relates to a liquid crystal display (LCD) device employing a field sequential drive method to reproduce color images and, in particular, relates to an LCD device optimized for a field sequential drive method by offering, among others, an improved liquid crystal response time.

[2]

Background Art

[3] A conventional LCD device is composed primarily of an LCD panel comprising a pair of glass substrates bonded together, with a liquid crystal layer interposed between them and a backlight unit placed behind the first glass substrate to provide light to the LCD panel. In order to reproduce color, such an LCD device must have three cells with a red, green, or blue color filter in front of each. This filter only allows light within a specific range of wavelengths to pass through, absorbing more than two thirds of the incident light. To compensate for the reduced luminance requires a commensurate increase in the power consumption of the backlight unit. Furthermore, color filters are expensive compared to other LCD materials, thus increasing the manufacturing cost considerably. An effort to solve these problems, a field sequential LCD device can reproduce a full range of colors without color filters.

[4] FIG. 1 illustrates a conventional field sequential LCD device. The construction of a field sequential LCD device is almost identical to that of a general LCD device except for their light source and the absence of color filters in the former. Referring to FIG. 1, a field sequential LCD device is composed of an LCD panel and the red, green, and blue light sources 11: the former comprising a first transparent glass substrate 12 and a second transparent glass substrate 13 bonded together, between which a liquid crystal layer 14 is sandwiched; the latter placed at the back of the first glass substrate 12 to provide light to the LCD panel.

[5] In contrast to a conventional LCD device where a white backlight is always switched on while in use, a field sequential LCD device sequentially turns on and off the red, green, and blue light sources 11 for a given frame to display a color image. However, it was difficult to develop a liquid crystal mode offering a response time faster enough to meet such a high speed operations of the light sources. Since prior technologies using a nematic liquid crystal, in particular, proved incapable of providing an adequate response time, a new technology to replace them was required.

[6] One example of the recent progress in LCD technologies is a field sequential LCD

device using a ferroelectric liquid crystal, which offers a substantially faster response time. In a ferroelectric liquid crystal display, the response of each molecule is directly driven by a force proportional to the product of its dipole moment and the strength of the electric field. Accordingly, the response time of a ferroelectric liquid crystal is in the range of 1 to 100μs, which is incomparably superior to that of a nematic liquid crystal. In addition, since change of luminance in a ferroelectric liquid crystal display is achieved by inversion of spontaneous polarization, the rising and falling time are always identical. However, a ferroelectric liquid crystal alignment is extremely susceptible to impact. Furthermore, ferroelectric liquid crystal displays are fairly expensive and poor at reproducing gray scale tones.

[7] FIG. 2 illustrates a projection LCD. Projection LCDs are meant to meet the demand for larger TV sets that are not as expensive as plasma display panel (PDP) equivalents.

[8] Referring to FIG. 2, a conventional projection LCD device has a complicated optical engine comprising a light source 21, an illuminating lens system 22, a plurality of dichroic mirrors 23, relay lenses 25, reflecting mirrors 24, a cross dichroic prism 26, and liquid crystal panels 27. The projection LCD system requires three separate LCD panels through which red, green, and blue signals respectively pass. Designing and manufacturing such a complicated device in a manner to ensure a high resolution inevitably leads to a high manufacturing cost. Besides the cost involved, such a lot of components will increase the floor space a set housing them takes up. Furthermore, the use of a cooling fan may result in airborne particles getting stuck on the mirrors and lenses and thus distorting images.

[9]

Disclosure of Invention

Technical Problem

[10] An object of the present invention is to provide a projection type full-color field sequential LCD device, characterized by high transmittance and luminance, without a complicated optical engine.

[11]

Technical Solution

[12] An embodiment of the present invention uses a nematic liquid crystal having a high refractive index anisotropy and a reduced twist angle. The thickness of the liquid crystal layer has been reduced as well.

[13]

Advantageous Effects

[14] Advantages of this embodiment include: improved photoefficiency due to adoption of a field sequential drive method; wider viewing angle and higher transmittance; ease

and lower cost of manufacturing as well as a more compact design due to the fact that an expensive, complicated optical engine is not required; and availability of a larger view free from ghosting, or motion artifacts (blur), when viewing video images.

[15]

Brief Description of the Drawings

[16] FIG. 1 illustrates a conventional field sequential LCD device;

[17] FIG. 2 illustrates a conventional projection LCD device;

[18] FIGS. 3 and 4 are cross-sectional views of an LCD panel according to the present invention having a horizontally aligned liquid crystal layer when no voltage is applied and when a voltage is applied;

[19] FIGS. 5 and 6 are cross-sectional views of an LCD panel according to the present invention having a vertically aligned liquid crystal layer when no voltage is applied and when a voltage is applied;

[20] FIG. 7 is a graph showing the relationship between the thickness and response time of a liquid crystal layer according to the present invention;

[21] FIG. 8 is a graph showing the relationship between the twist angle and transmittance of a liquid crystal layer according to the present invention;

[22] FIG. 9 is a schematic diagram illustrating the construction of a transmissive LCD device according to an embodiment of the present invention;

[23] FIG. 10 is a schematic diagram showing the construction of a reflective LCD device according to another embodiment of the present invention;

[24] FIG. 11 is a schematic diagram illustrating the construction of a projection LCD device according to yet another embodiment of the present invention; and

[25] FIG. 12 is a schematic diagram illustrating the construction of a projection LCD device according to still another embodiment of the present invention.

[26]

Best Mode for Carrying Out the Invention

[27] FIG. 10 is a schematic diagram illustrating the construction of a reflective LCD according to a preferred embodiment of the present invention. The reflective LCD comprises an LCD panel having a pair of alignment films 35 and a liquid crystal layer 36 formed between a first substrate 33 and a second substrate 34; a light source 71; and a polarizing beam splitter 82. A transparent electrode (not shown) is formed of a transparent conductive material such as indium tin oxide between the second substrate 34 and the alignment film 35. The electrode placed between the first substrate 33 and the alignment film 35 may preferably be a reflective electrode formed of aluminum or other material capable of reflecting incident light. A field sequential drive module (not shown) and the light source 71 are connected to the LCD panel. Light emitted from the

light source 71 is transmitted via the polarizing beam splitter 82 to the reflective electrode 81 where it is reflected straight back to the outside.

[28]

Mode for the Invention

[29] The present invention will now be described more fully with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the concept of the invention to those skilled in the art.

[30] FIGS. 3 and 4 are cross-sectional views of an LCD panel according to the present invention having a horizontally aligned liquid crystal layer. FIG. 3 illustrates the alignment configuration of a liquid crystal layer when no voltage is applied; FIG. 4 illustrates the alignment configuration of the liquid crystal layer when a voltage has been applied. The LCD panel comprises a pair of substrates 33 and 34 coated with conductive electrodes; a pair of alignment films 35 formed on the first and second substrates 33 and 34 respectively; and a liquid crystal layer 36 interposed in a specified thickness (d) between the alignment films 35. In a transmissive LCD the electrodes are formed of indium tin oxide (ITO), and in a reflexive LCD any one of the electrodes may be formed of a thin aluminum film. The two alignment films 35, formed on the first and second substrates 33 and 34 respectively, have a crossing angle of less than 45°, and the twist angle of the liquid crystal is likewise less than 45°. When the crossing angle of the alignment films is 0° and thus the rubbing directions of the alignment films are opposite to each other, an electrically controlled birefringence (ECB) mode is applicable. Liquid crystal molecules adjacent to the alignment films form a pre-tilt angle (a) of less than 30°. An LCD panel thus formed may adopt either a passive matrix or an active matrix drive method. An active matrix LCD panel can use a plurality of transistors for switching pixels on and off. In that case, the semiconductor active regions may be formed of amorphous silicon for application in a transmissive LCD and of either monocrystalline or polycrystalline silicon for a projection LCD.

[31] FIGS. 5 and 6 are cross-sectional views of an LCD panel according to the present invention having a vertically aligned liquid crystal layer. FIG. 5 illustrates the alignment configuration of a liquid crystal layer when no voltage is applied; FIG. 6 illustrates the alignment configuration of the liquid crystal layer when a voltage has been applied. Liquid crystal molecules adjacent to the alignment films 35 form a pre-tilt angle of greater than 60°. Except for this pre-tilt angle, the configuration of the LCD panel illustrated in FIGS. 5 and 6 is identical to that of the LCD panel illustrated

in FIGS. 3 and 4.

[32] FIG. 7 is a graph showing the relationship between the thickness and response time of the liquid crystal layer according to the present invention. The liquid crystal layer according to the present invention has a thickness range of 0.5 through 2.5 □ and can be driven at 180 Hz with a response time of faster than 5 □ at temperatures around 60°C, which is the usual operating temperature range for projection LCDs. Reducing the thickness of the liquid crystal layer in favor of a faster response time, however, results in a lower transmittance. This problem can be solved by using a liquid crystal having a high refractive index anisotropy.

[33] FIG. 8 is a graph showing the relationship between the twist angle and transmittance of the liquid crystal according to the present invention. As shown in FIG. 8, transmittance can be improved by reducing the twist angle of the liquid crystal. It can be noted that as far as the twist angle is less than 45°, the transmittance ratio remains greater than 95% with little variation. It is preferable, therefore, that the twist angle range of the liquid crystal is set between 0° and 45°. Decreasing the twist angle also results in a faster response time. In addition, the fact that transmittance variation caused by twist angle variance is small will lead to a higher manufacturing yield. The transmittance of a liquid crystal is proportional to $\Delta n \cdot d$. Accordingly, in order to maintain or increase the transmittance ratio while reducing the thickness (d) of the liquid crystal layer for a faster response time, the liquid crystal used must have a high refractive index anisotropy (Δn). A refractive index anisotropy range of 0.13 to 0.22, which is the highest possible value for a nematic liquid crystal, satisfies the minimum transmittance requirement. One remaining problem, however, is the contrast deterioration associated with a low twist angle of the liquid crystal molecules in a horizontal alignment. With a twist angle of 90° the molecules adjacent to each substrate of the panel have a crossing angle of 90°, and thus their effect on the incident light is counterbalanced. With a much lower twist angle, however, such compensation effect is unavailable, and thus the contrast ratio is significantly lowered. Application of a compensation film between the substrate and the polarizer may compensate for the change in birefringence caused by the director pattern near the substrate.

[34] FIG. 9 is a schematic diagram illustrating the construction of a transmissive LCD according to an embodiment of the present invention. Referring to FIG. 9, the transmissive LCD includes an LCD panel and a light source 71. The LCD panel comprises a pair of substrates coated with conductive transparent electrodes formed of indium tin oxide; alignment films 35 and a liquid crystal layer 36 formed between the first and second substrates 33 and 34; and a pair of polarizers 72 attached to the outer surface of the first and second substrates 33 and 34. The light source 71 is a combination of diodes consisting either of red, green, and blue light sources or of red,

green, blue, and white light sources. Connected to the LCD panel, a field sequential driving module (not shown) applies scan pulses to the gate circuit and sequential scan pulses to the data circuit. The "color breaking" problem associated with prior field sequential color drive methods can be effectively controlled by subdividing the light-emitting interval of each color in two, three, or four.

[35] According to another embodiment of the present invention, a compensation film (not shown) is formed between the first substrate 33 and the polarizer 72 in order to improve the contrast ratio for a horizontally aligned liquid crystal panel such as one illustrated in FIG. 3. The compensation film can be of a uniaxial, biaxial, hybrid, tilted, or twisted structure. FIG. 11 is a schematic diagram illustrating the construction of a projection LCD according to yet another embodiment of the present invention. The projection LCD comprises a panel 92, a light source 71, and an optical engine. The panel 92 has a pair of substrates coated with electrodes formed of a transparent conductive material such as indium tin oxide (not shown), on and between which a pair of alignment films and a liquid crystal layer are formed. The optical engine may include a condenser lens system 91 for concentrating light on the panel and a set of mirrors 93 for guiding and redirecting the path of the projected image onto a screen 94.

[36] FIG. 12 is a schematic diagram illustrating the construction of a projection LCD according to still another embodiment of the present invention. The projection LCD comprises a panel, a light source 71, a field sequential drive module 112, and a color wheel 111. The panel has a pair of substrates 33 and 34 coated with electrodes formed of a transparent conductive material such as indium tin oxide (not shown), on and between which a pair of alignment films 35 and a liquid crystal layer 36 are formed. A couple of polarizers 32 are attached to the outer surfaces of the panel. The light source 71 uses a white light such as a high-pressure mercury lamp. The field sequential drive module 112 is connected to the color wheel and both substrates of the panel.

[37] Although the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the concept and scope of the present invention as defined by the following claims.

Claims

[1] A liquid crystal display device having a pair of substrates, on both of which an alignment film is formed and on one of which a plurality of pixels are arranged in matrix form, the liquid crystal display device comprising:
a panel including a nematic liquid crystal layer formed between the alignment films;
a light source located near the panel; and
a field sequential drive module electrically connected to the panel and the light source.

[2] The liquid crystal display device according to claim 1, wherein the thickness of the liquid crystal layer is in the range of 0.5 to 2.5 □.

[3] The liquid crystal display device according to claim 2, wherein the liquid crystal twist angle is in the range of 0° to 45°.

[4] The liquid crystal display device according to claim 3, wherein the rubbing direction of one of the alignment films is opposite to that of the other facing it when the liquid crystal twist angle is 0°.

[5] The liquid crystal display device according to any one of claims 1, 2, 3, and 4, wherein the liquid crystal has a refractive index anisotropy of 0.13 through 0.22.

[6] The liquid crystal display device according to claim 5, wherein the liquid crystal molecules are aligned either vertically or horizontally with respect to the substrates.

[7] The liquid crystal display device according to claim 6, wherein the liquid crystal molecules are horizontally aligned with respect to the substrates, and a compensation film having a uniaxial, biaxial, hybrid, tilted, or twisted structure is interposed between a polarizer and the substrate to compensate for a loss in contrast ratios.

[8] The liquid crystal display device according to claim 6, wherein the liquid crystal molecules are vertically aligned with respect to the substrates, and the liquid crystal has negative dielectric anisotropy.

[9] The liquid crystal display device according to claim 5, wherein the panel includes a switching element whose active region is formed of polycrystalline silicon.

[10] The liquid crystal display device according to claim 5, wherein the panel includes a switching element whose active region is formed of monocrystalline silicon.

[11] The liquid crystal display device according to claim 5, further comprising:
a pair of transparent electrodes each formed between the first substrate and the

alignment film and between the second substrate and the alignment film; and
a pair of polarizers attached to the outer surfaces of both substrates.

[12] The liquid crystal display device according to claim 11, wherein the transparent electrodes are formed of indium tin oxide.

[13] The liquid crystal display device according to claim 2, further comprising:
a reflective electrode formed between the first substrate and the alignment film;
a transparent electrode formed between the second substrate and the alignment film; and
a polarizing beam splitter for redirecting the light emitted from the light source to the panel.

[14] The liquid crystal display device according to claim 13, wherein the liquid crystal molecules are aligned either vertically or horizontally with respect to the substrates.

[15] The liquid crystal display device according to claim 14, wherein the liquid crystal molecules are horizontally aligned with respect to the substrates, and a compensation film having a uniaxial, biaxial, hybrid, tilted, or twisted structure is interposed between the polarizing beam splitter and the second substrate to compensate for a loss in contrast ratios.

[16] The liquid crystal display device according to claim 14, wherein the liquid crystal molecules are vertically aligned with respect to the substrates, and the liquid crystal has negative dielectric anisotropy.

[17] The liquid crystal display device according to claim 13, wherein the transparent electrode is formed of indium tin oxide.

[18] The liquid crystal display device according to claim 17, wherein the reflective electrode is formed of aluminum.

[19] The liquid crystal display device according to claim 5, further comprising:
a condenser lens system for focusing light emitted from the light source on the panel;
a screen for displaying images transmitted via the panel; and
a set of mirrors for guiding and redirecting the path of the images transmitted via the panel onto the screen.

[20] The liquid crystal display device according to claim 5, wherein the light source is a combination of diodes emitting red, green, and blue lights, respectively.

[21] The liquid crystal display device according to claim 5, wherein the light source is a combination of diodes emitting red, green, blue, and white lights, respectively.

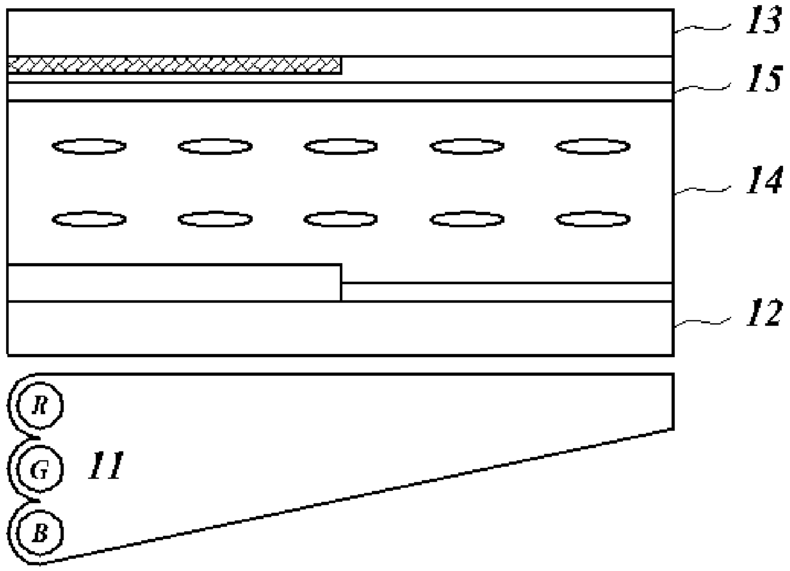
[22] The liquid crystal display device according to claim 5, wherein the field sequential drive module comprises:
a gate drive circuit for supplying the panel with scan pulses; and

a data drive circuit for splitting the abovementioned pulses to provide the panel with data.

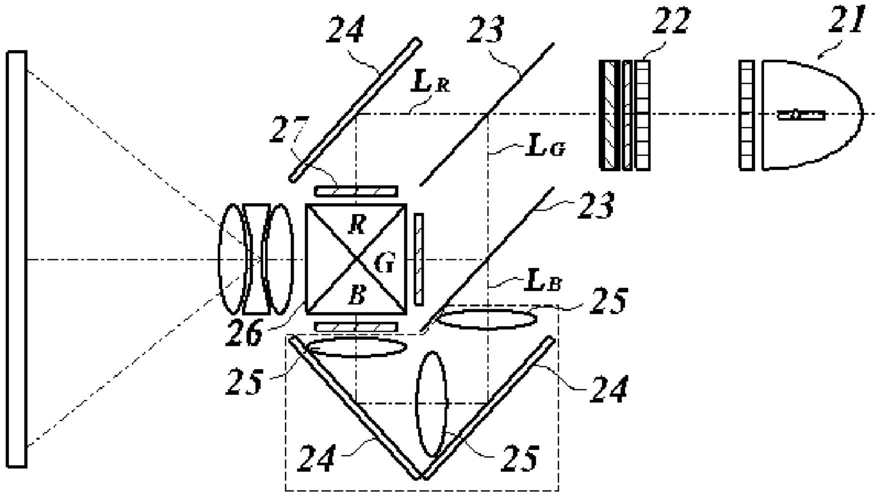
[23] The liquid crystal display device according to claim 22, wherein the data drive circuit splits a pulse into two, three, or four.

[24] The liquid crystal display device according to claim 5, further comprising a color wheel placed between the panel and the light source.

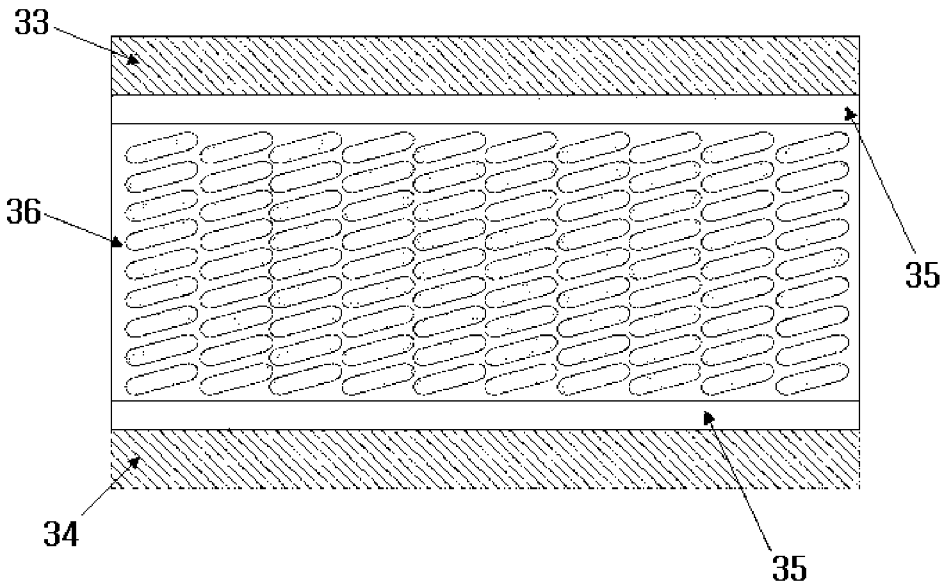
[Fig. 1]



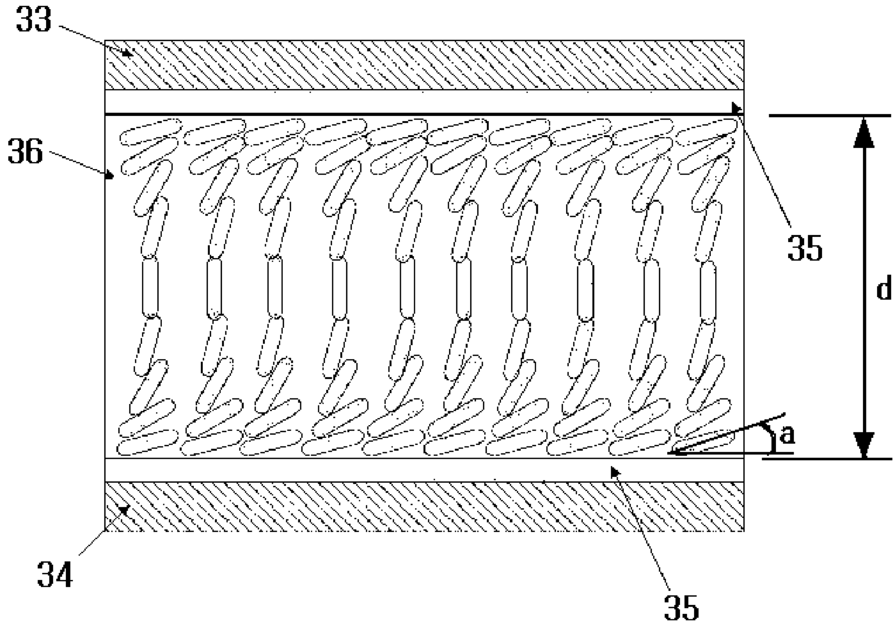
[Fig. 2]



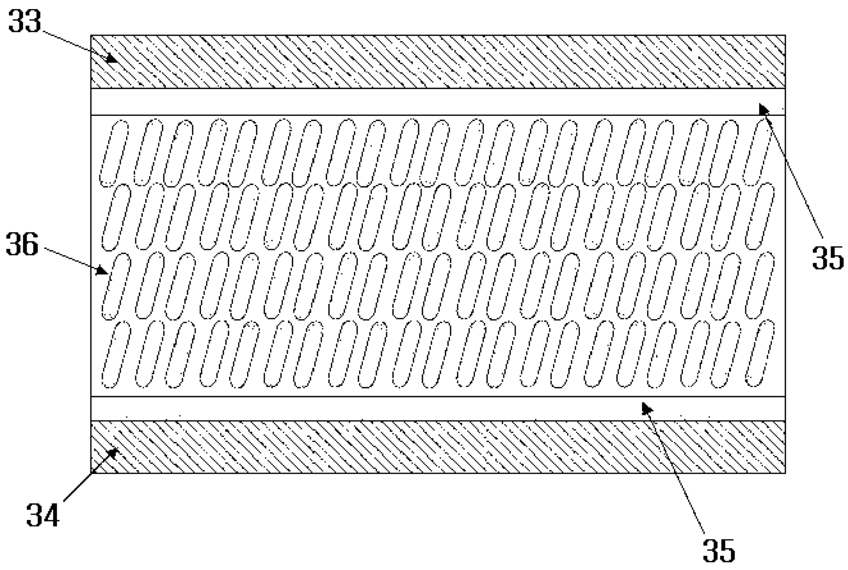
[Fig. 3]



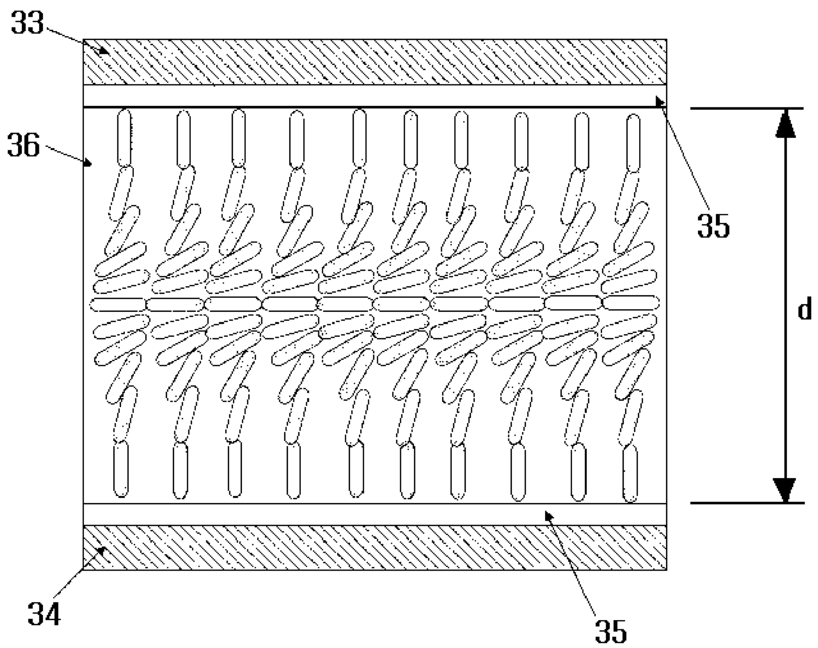
[Fig. 4]



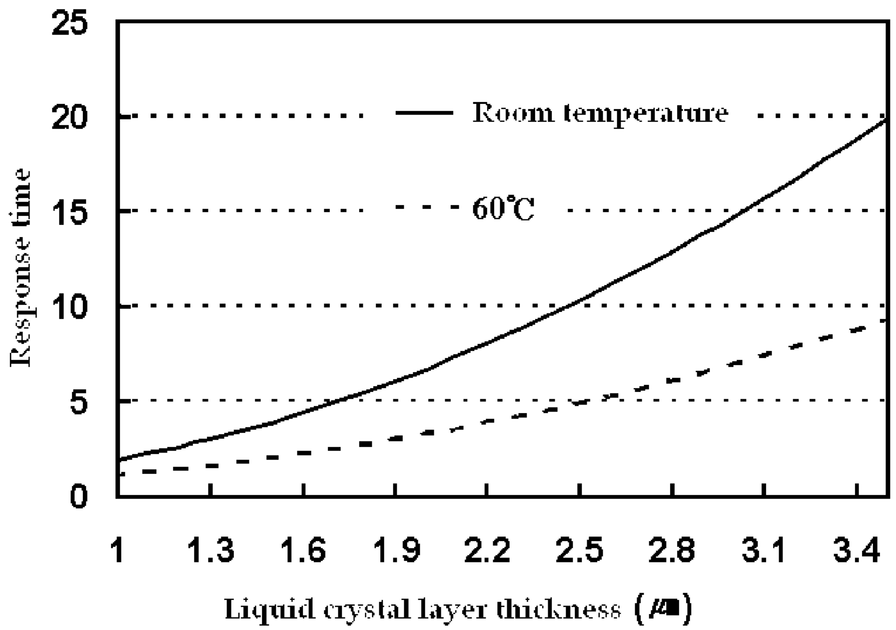
[Fig. 5]



[Fig. 6]



[Fig. 7]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5
0
Response time
Room temperature
60℃
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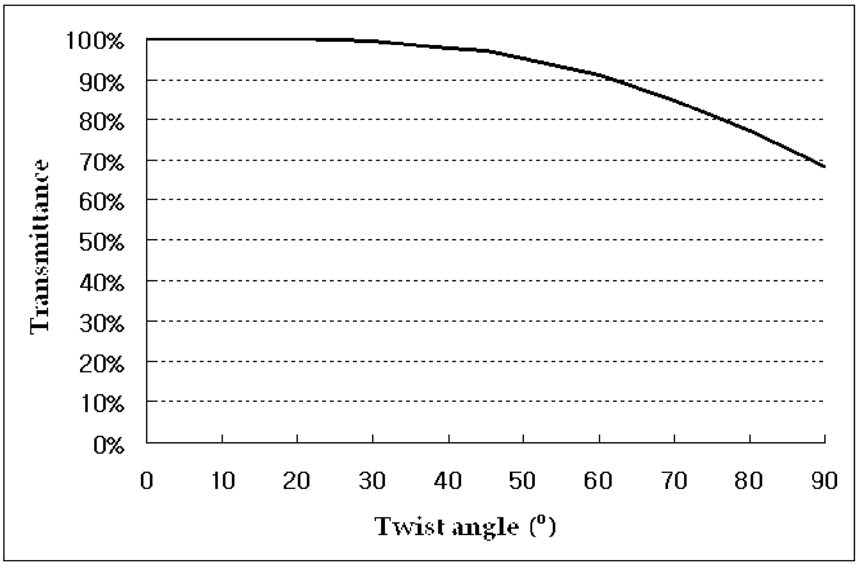
2.5
2.8
3.1
3.4
Liquid crystal layer thickness (㎛)

[Fig. 8]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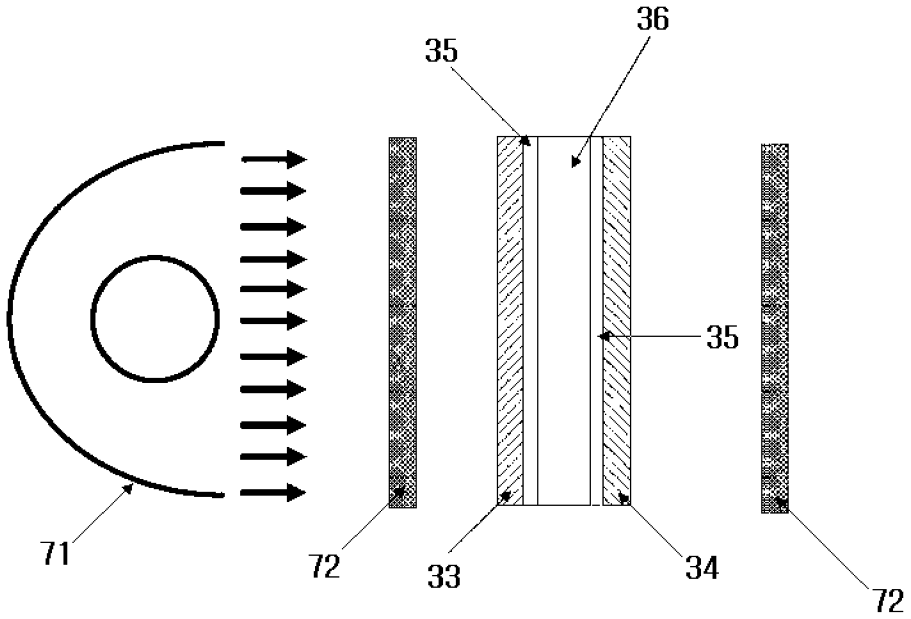
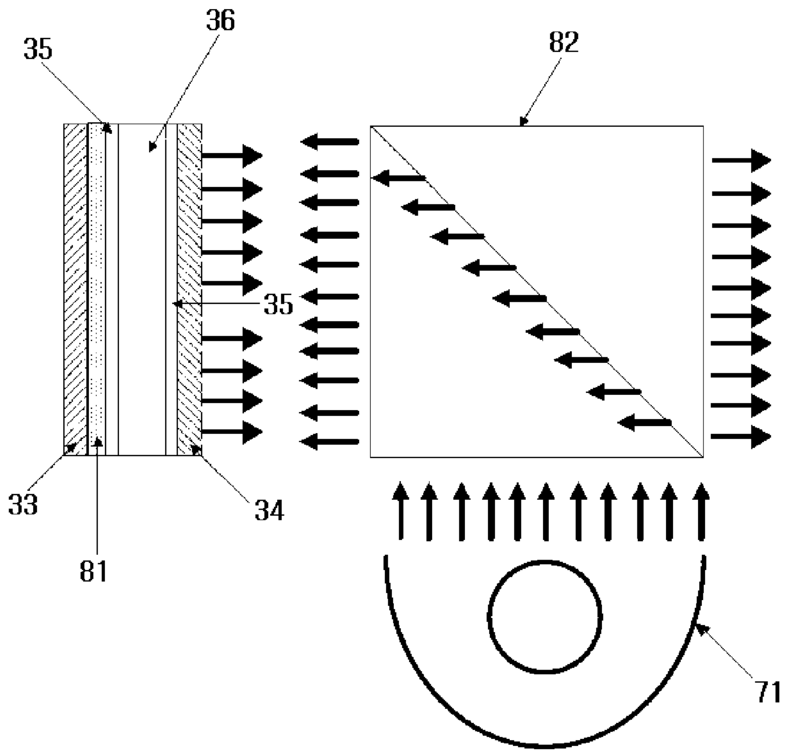
Twist angle (°)

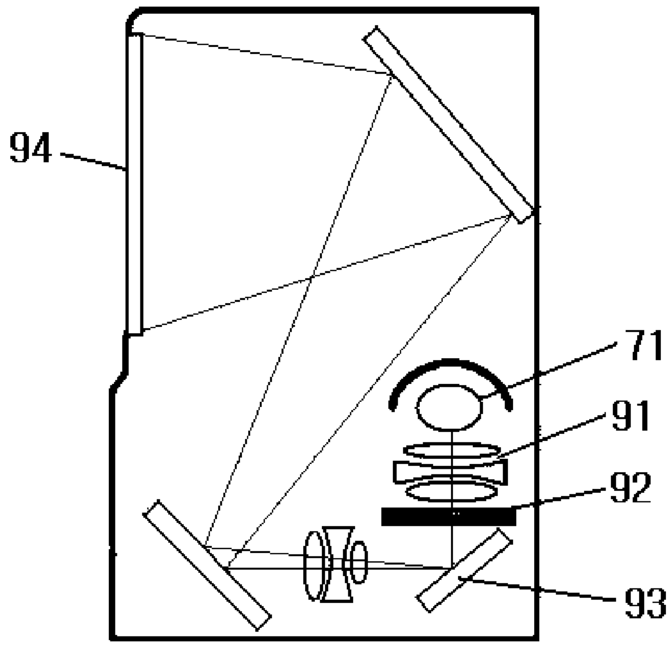
[Fig. 9]



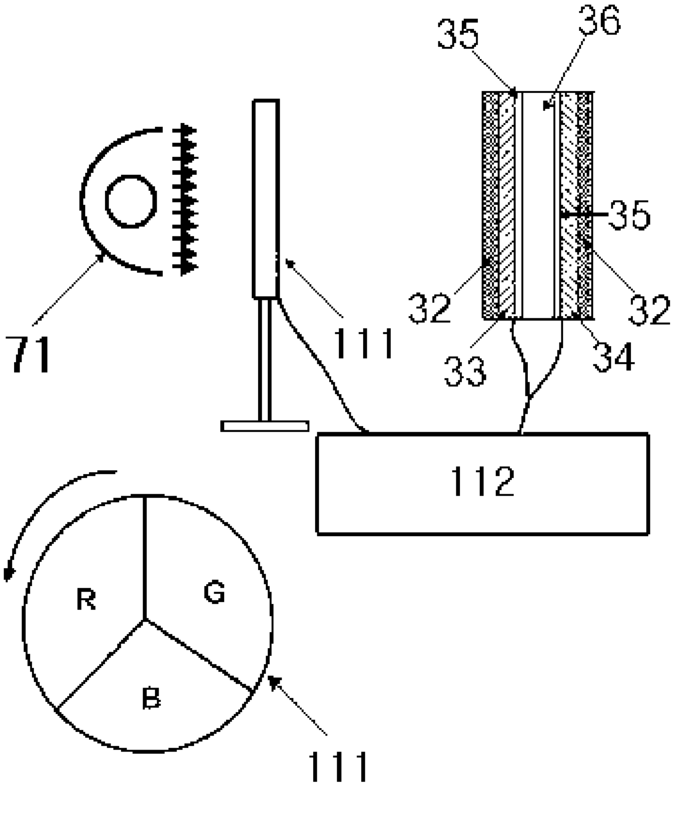
[Fig. 10]



[Fig. 11]



[Fig. 12]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2006/002693

A. CLASSIFICATION OF SUBJECT MATTER

G02F 1/135(2006.01)i, G02F 1/133(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 8 C09K, G02F, G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Patents and applications for inventions since 1975
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and application for Utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)
eKIPASS (KIPO internal) & keywords: "nematic", "field sequential"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2003-0098836 A1 (JIRO TAKEI) 29 May 2003 See figures 2 and 6, and paragraphs [0051, 0053, 0054].	1 5-7, 9-12, 19-24 2-4, 8, 13-18
Y	JP 2003-058113 A (MATSUSHITA ELECTRIC INDUSTRY CO., LTD.) 28 February 2003 See claims 9 and 10.	5-7, 9-12, 19-24
Y	KR 10-2002-0039800 A (SAMSUNG SDI CO., LTD.) 30 May 2002 See figure 1.	19
Y	US 2004-0252272 A1 (KENICHI TAKATORI, et. al) 16 December 2004 See claims 1 and 19, and paragraph [0098].	11, 12
Y	JP 2005-233982 A (MATSUSHITA ELECTRIC INDUSTRY CO., LTD.) 2 September 2005 See figures 1 and 4.	20, 21
Y	US 2005-0225545 A1 (KENICHI TAKATORI, et. al) 13 October 2005 See figures 19-21.	22, 23
Y	JP 07-333574 A (CASIO COMPUTER CO., LTD.) 22 December 1995 See figure 1.	24

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
19 DECEMBER 2006 (19.12.2006)

Date of mailing of the international search report
19 DECEMBER 2006 (19.12.2006)

Name and mailing address of the ISA/KR
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