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Miyachi

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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

(75) Inventor: **Koichi Miyachi**, Soraku-gun (JP)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 114 days.

(21) Appl. No.: **10/377,660**

(22) Filed: **Mar. 4, 2003**

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(30) **Foreign Application Priority Data**

Mar. 8, 2002 (JP) 2002-064472

(51) **Int. Cl.**
G02F 1/13 (2006.01)

(52) **U.S. Cl.** **349/118**; 349/119

(58) **Field of Classification Search** 349/117, 349/118, 119, 149, 152, 150, 151
See application file for complete search history.

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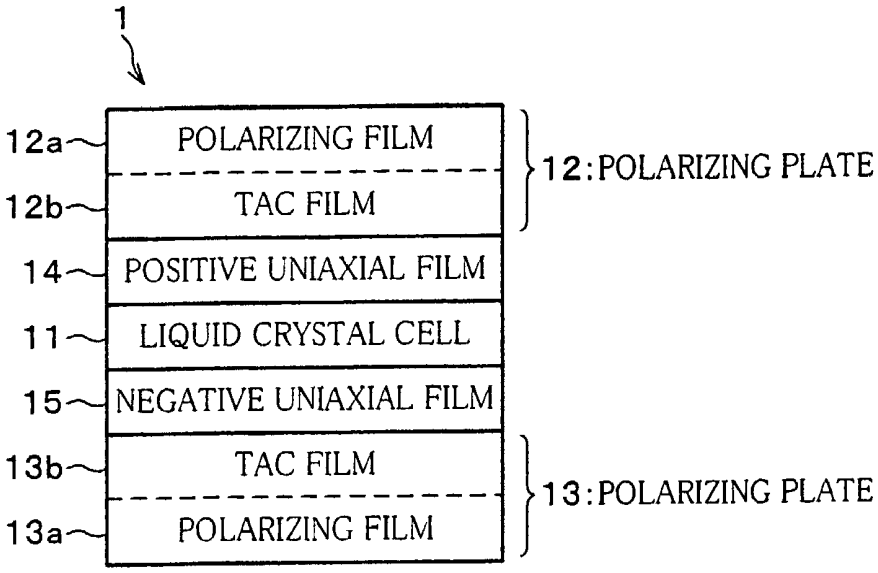
Primary Examiner—James A. Dudek
(74) *Attorney, Agent, or Firm*—Nixon & Vanderhye, P.C.

(57) **ABSTRACT**

A positive uniaxial film **14** with a retardation of Rp [nm] in an in-plane direction is provided between a vertical alignment mode liquid crystal cell **11** and a polarizing plate **12**, and a negative uniaxial film **15** with a retardation of Rn [nm] in a thickness direction is provided between the liquid crystal cell **11** and a polarizing plate **13**. Further, when a parameter $\alpha 1$ [nm] relative to Rp is: $\alpha 1 = 135 - 0.7 \times Rtac$; and a parameter $\beta 1$ [nm] relative to Rn is: $\beta 1 = Rlc - 65 - 1.4 \times Rtac$, where Rtac [nm] is a retardation in a thickness direction of the respective triacetyl cellulose films **12***b* and **13***b* of polarizing plates **12** and **13**, the retardations Rp and Rn are set to be values greater than 90% but smaller than 110% with reference to the parameters $\alpha 1$ and $\beta 1$, respectively. This makes it possible to surely provide a vertical alignment mode liquid crystal display device which can maintain a high contrast when viewed from an oblique direction.

26 Claims, 16 Drawing Sheets



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U.S. Appl. No. 10/377,655, filed Mar. 4, 2003 entitled "Liquid Crystal Display Device".

Japanese Office Action mailed Oct. 18, 2005 (w/English translation thereof).

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FIG. 1

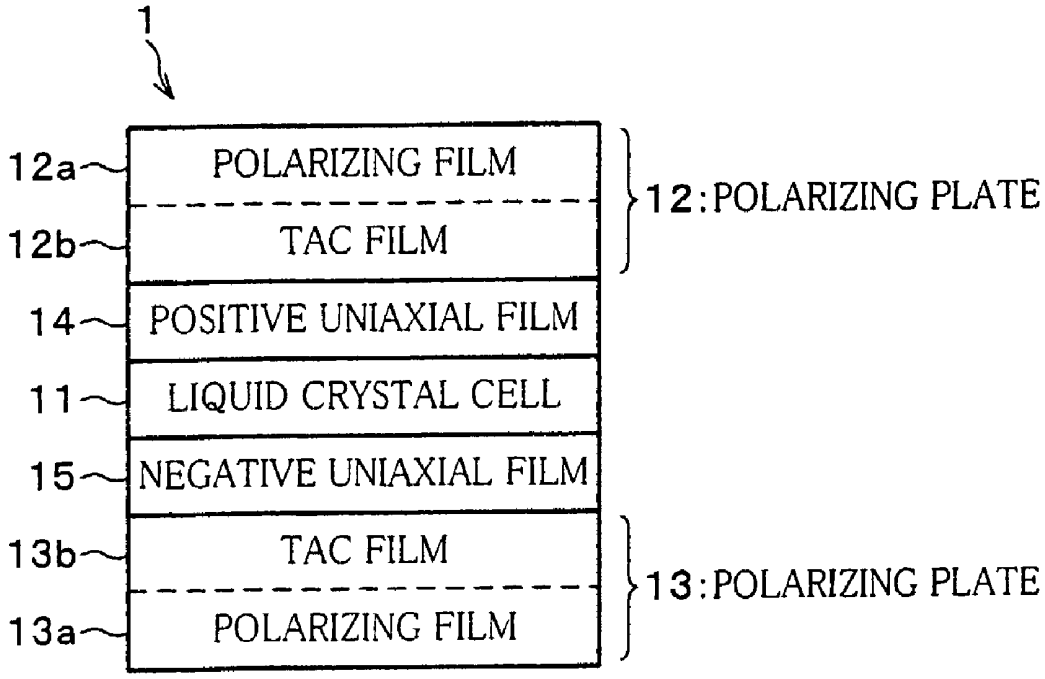

1
12a
POLARIZING FILM
12b
TAC FILM
12:POLARIZING PLATE
14
POSITIVE UNIAXIAL FILM
11
LIQUID CRYSTAL CELL
15
NEGATIVE UNIAXIAL FILM
13b
TAC FILM
13a
POLARIZING FILM
13:POLARIZING PLATE

FIG. 2

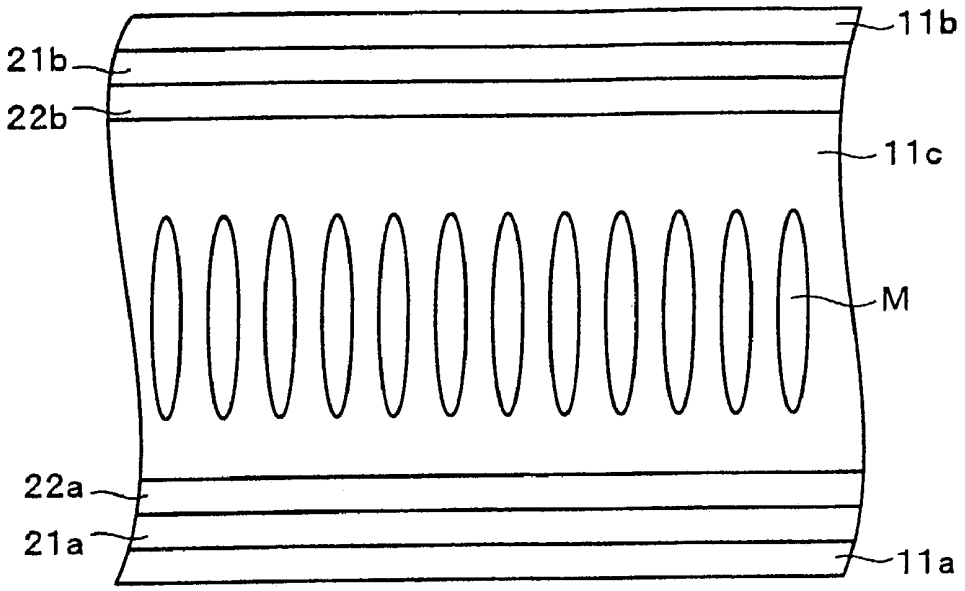


FIG. 3

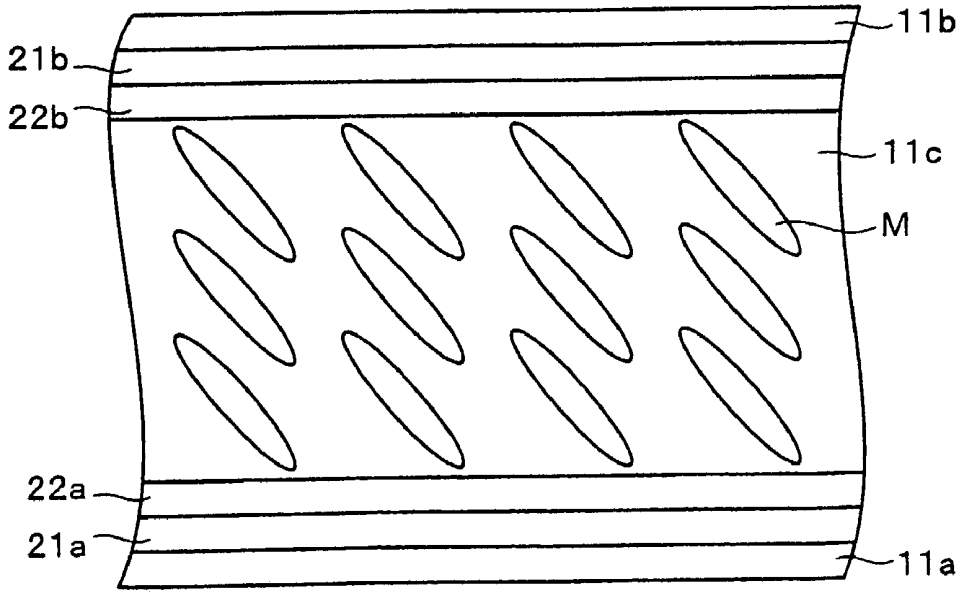


FIG. 4

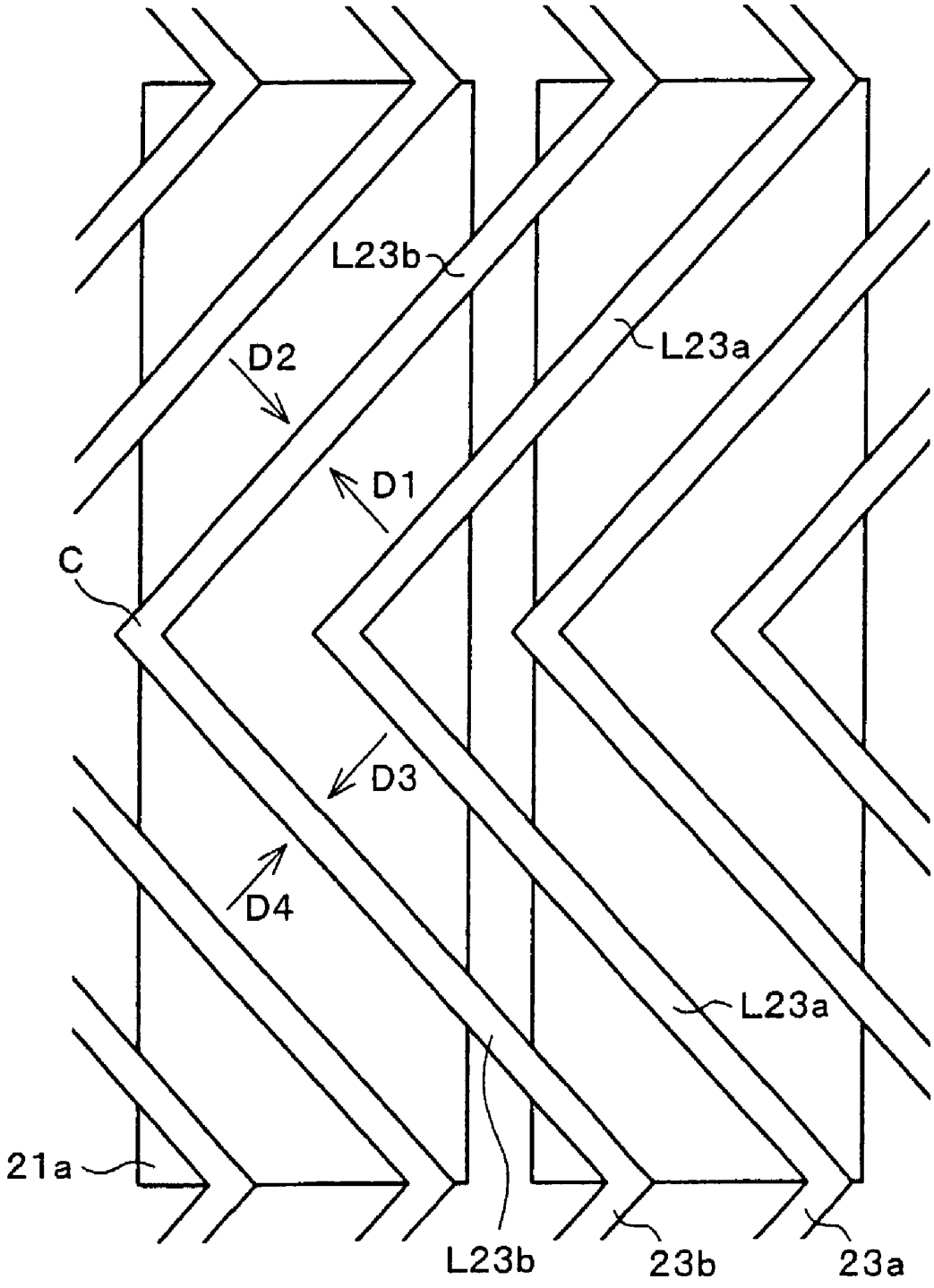
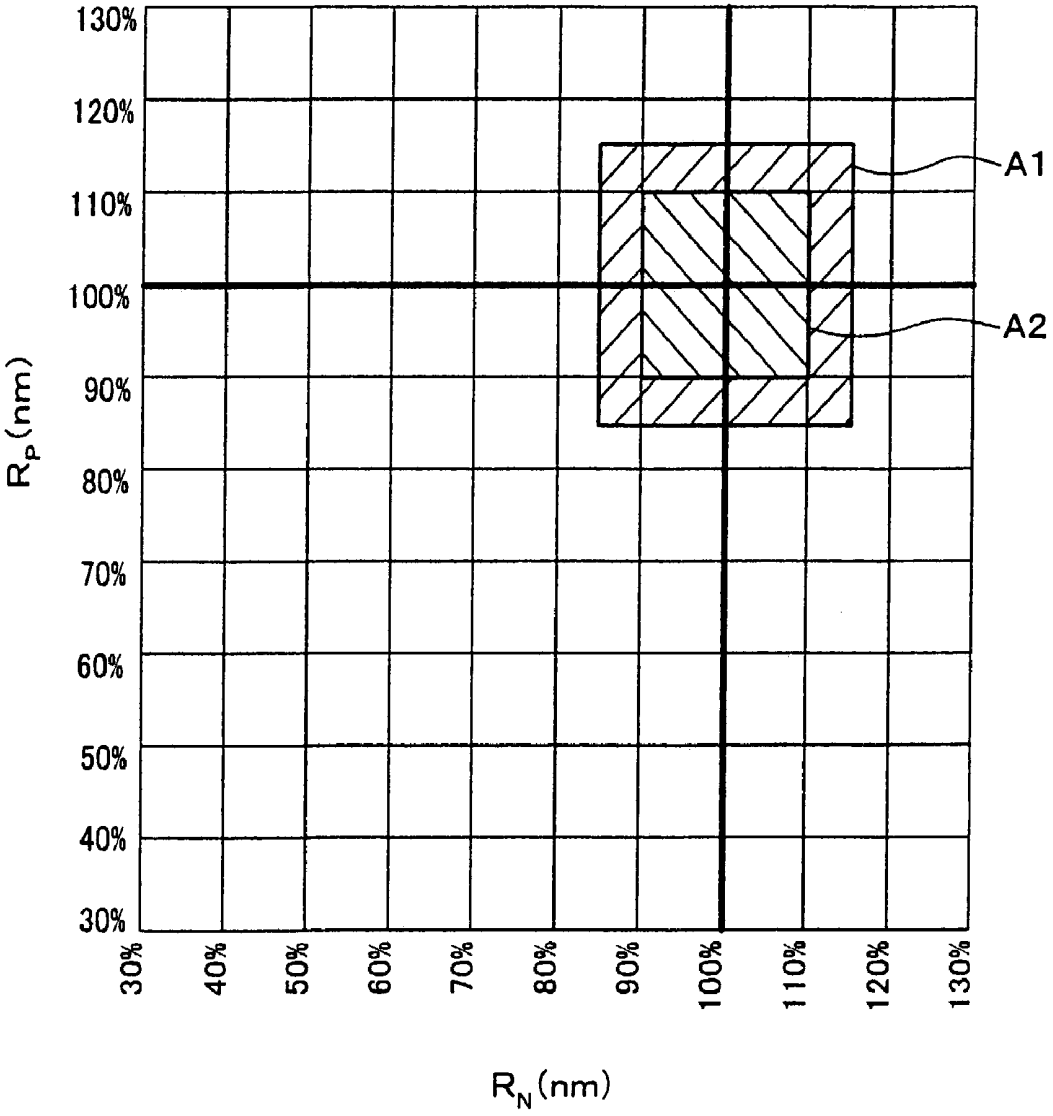


FIG. 5


130%
120%
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100%
90%
80%
70%
60%
50%
40%
30%
R_P(nm)
30%
40%
50%
60%
70%
80%
90%
100%
110%
120%
130%
R_N(nm)
A1
A2

FIG. 6

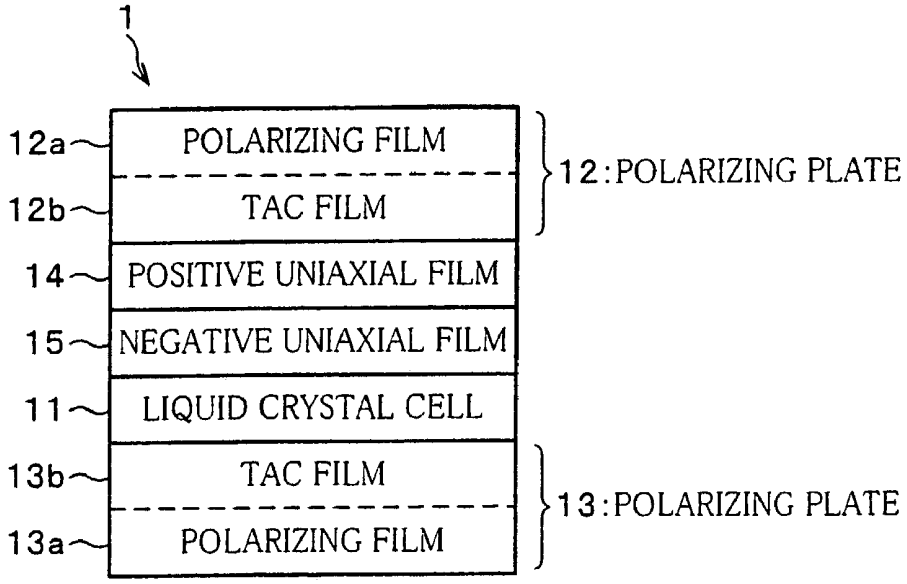


FIG. 7

THICKNESS OF LIQUID CRYSTAL CELL [μm]	R_{TAC} [nm]	Rp [nm]	Rn [nm]
3.0	0	137	173
	30	109	138
	50	93	110
	80	74	62
4.0	0	137	260
	30	109	225
	50	93	197
	80	74	149
5.0	0	137	348
	30	109	313
	50	93	284
	80	74	236

FIG. 8

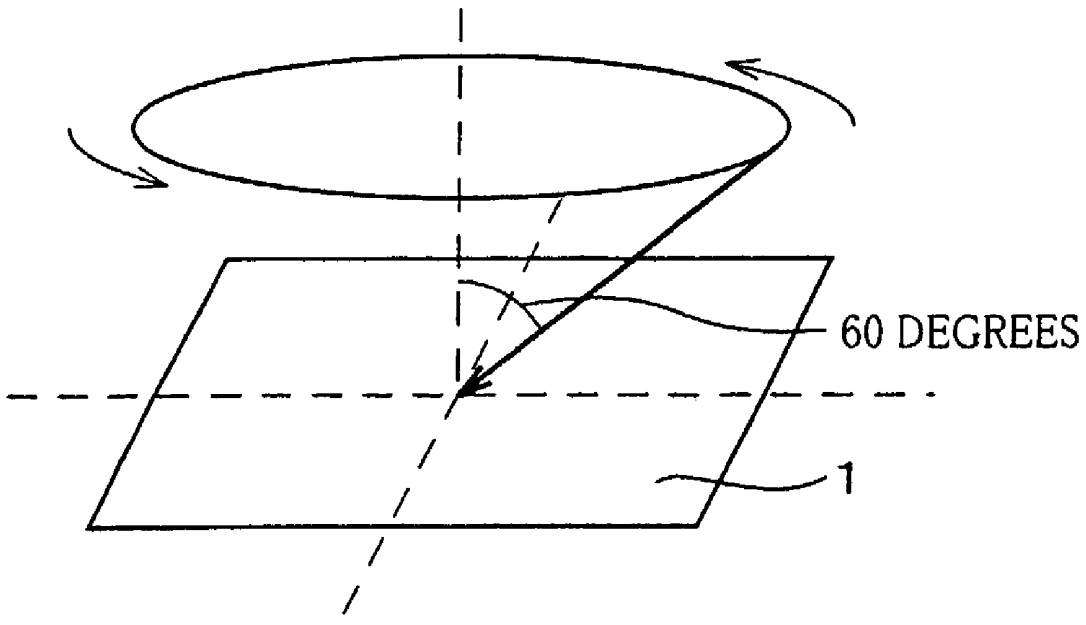


FIG. 9

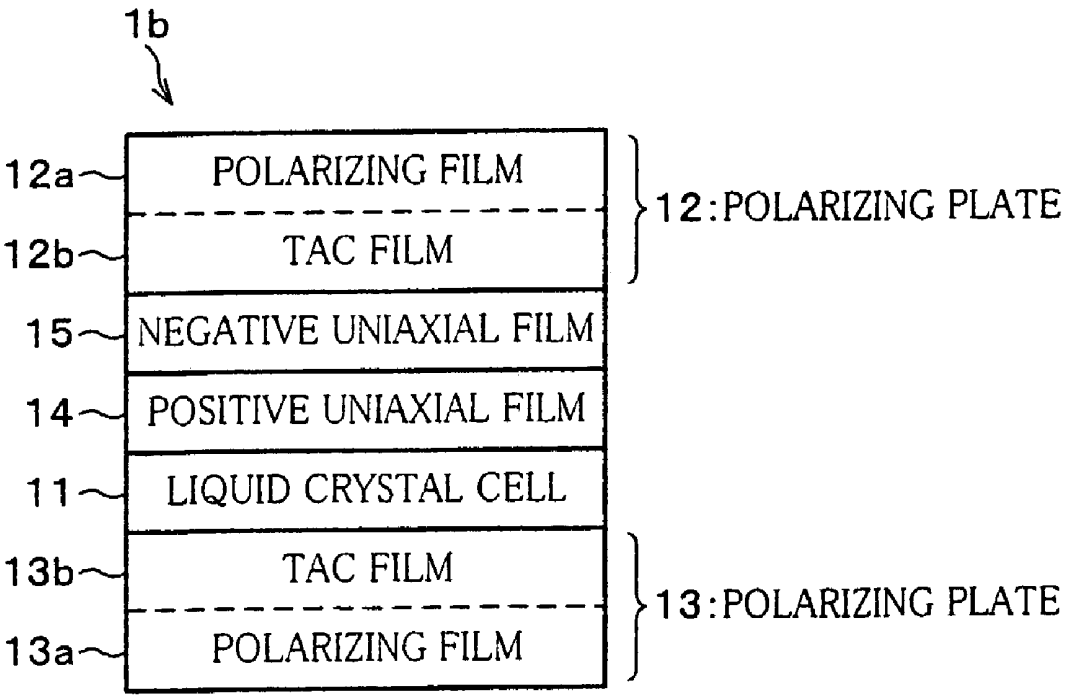

1b
12a
POLARIZING FILM
12b
TAC FILM
12:POLARIZING PLATE
15
NEGATIVE UNIAXIAL FILM
14
POSITIVE UNIAXIAL FILM
11
LIQUID CRYSTAL CELL
13b
TAC FILM
13a
POLARIZING FILM
13:POLARIZING PLATE

FIG. 10

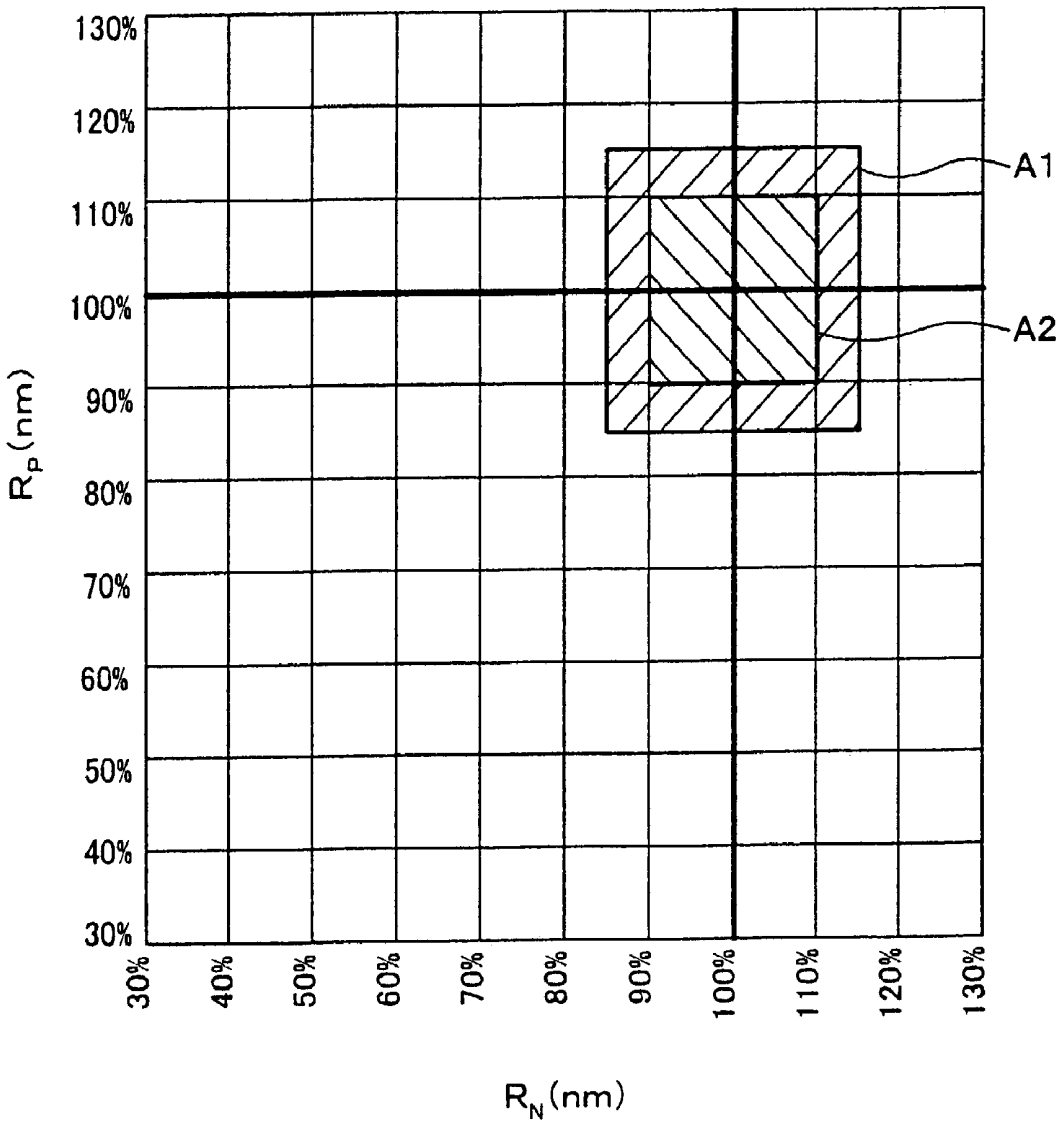

130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
R_P(nm)
A1
A2
30%
40%
50%
60%
70%
80%
90%
100%
110%
120%
130%
R_N(nm)

FIG. 11

THICKNESS OF LIQUID CRYSTAL CELL [μm]	R_{TAC} [nm]	Rp [nm]	Rn [nm]
3.0	0	38	243
	30	41	181
	50	43	140
	80	49	77
4.0	0	35	331
	30	36	270
	50	36	230
	80	38	169
4.5 (Rlc=360[nm])	0	37	371
	30	36	311
	50	36	271
	80	37	211
5.0	0	39	417
	30	37	358
	50	36	318
	80	35	259

FIG. 12

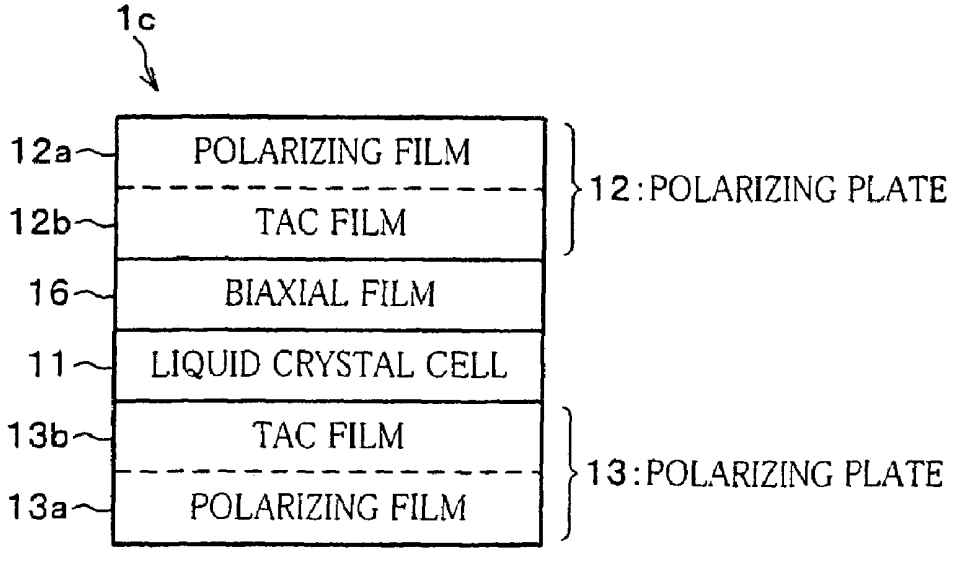
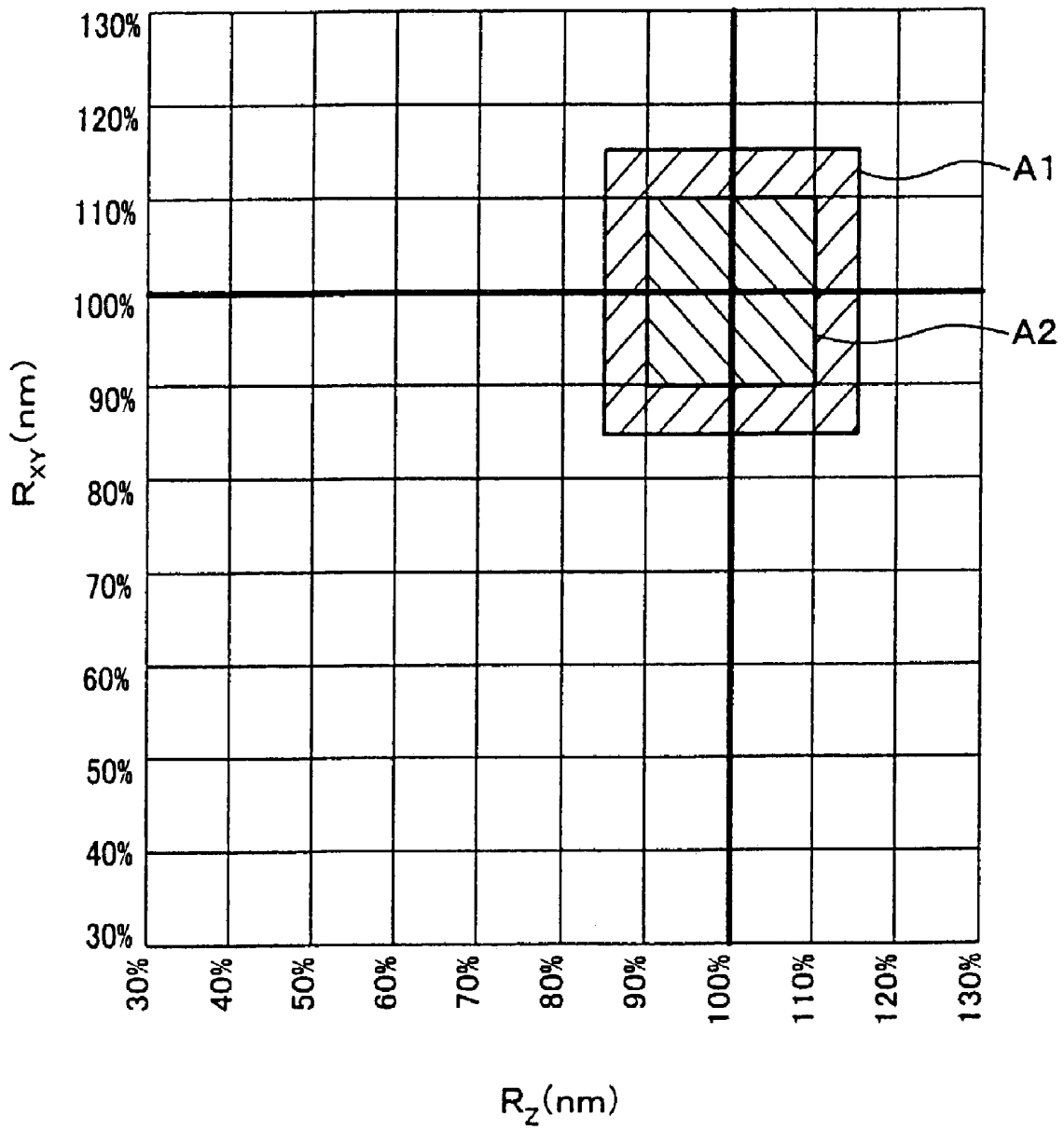


FIG. 13


130%
120%
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30%
R_{XY}(nm)
30%
40%
50%
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70%
80%
90%
100%
110%
120%
130%
R_Z(nm)
A1
A2

FIG. 14

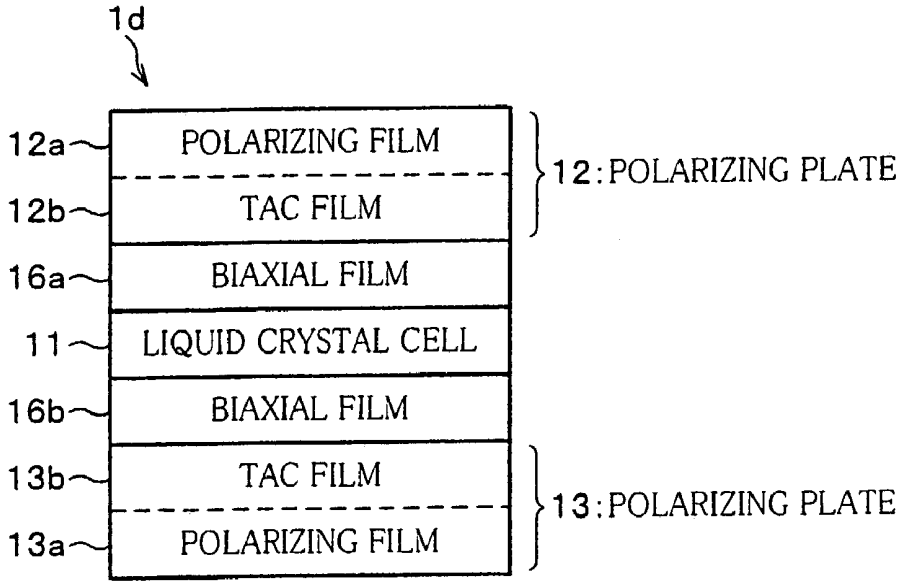


FIG. 15

THICKNESS OF LIQUID CRYSTAL CELL [μm]	R_{TAC} [nm]	Rp [nm]	Rn [nm]
3.0	0	65	250
	30	63	194
	50	62	156
	80	62	98
4.0	0	55	337
	30	53	280
	50	52	240
	80	51	183
5.0	0	50	425
	30	48	367
	50	47	328
	80	45	271

FIG. 16

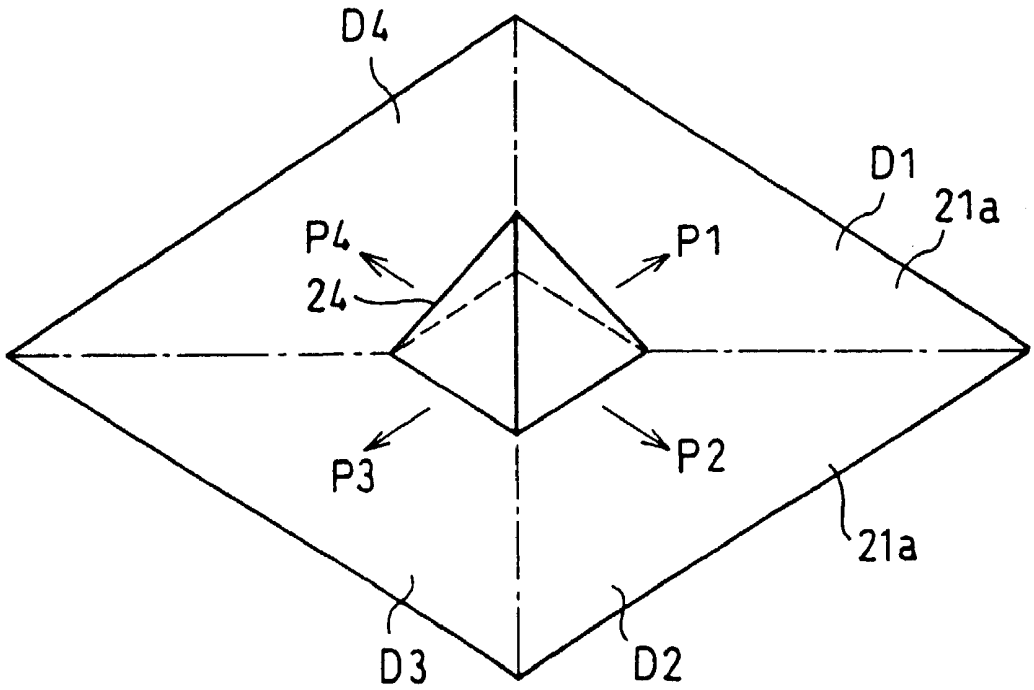


FIG. 17

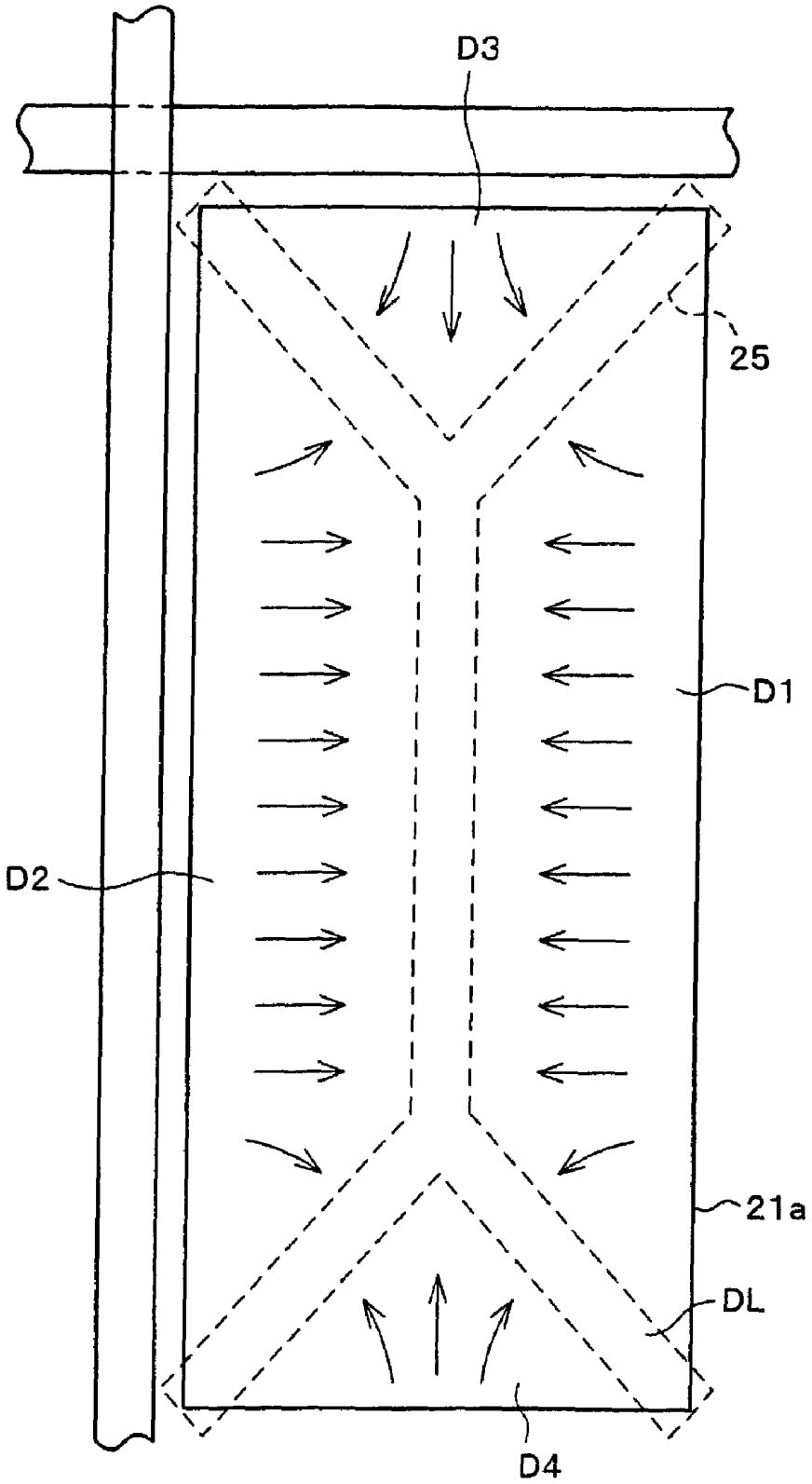


FIG. 18

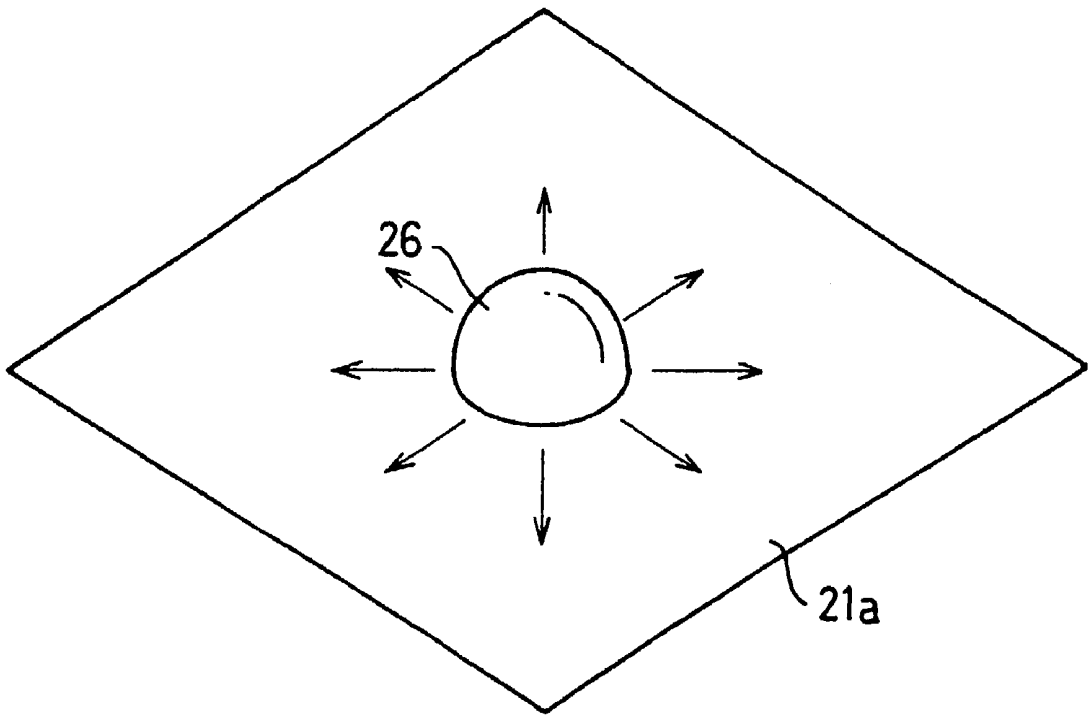


FIG. 19

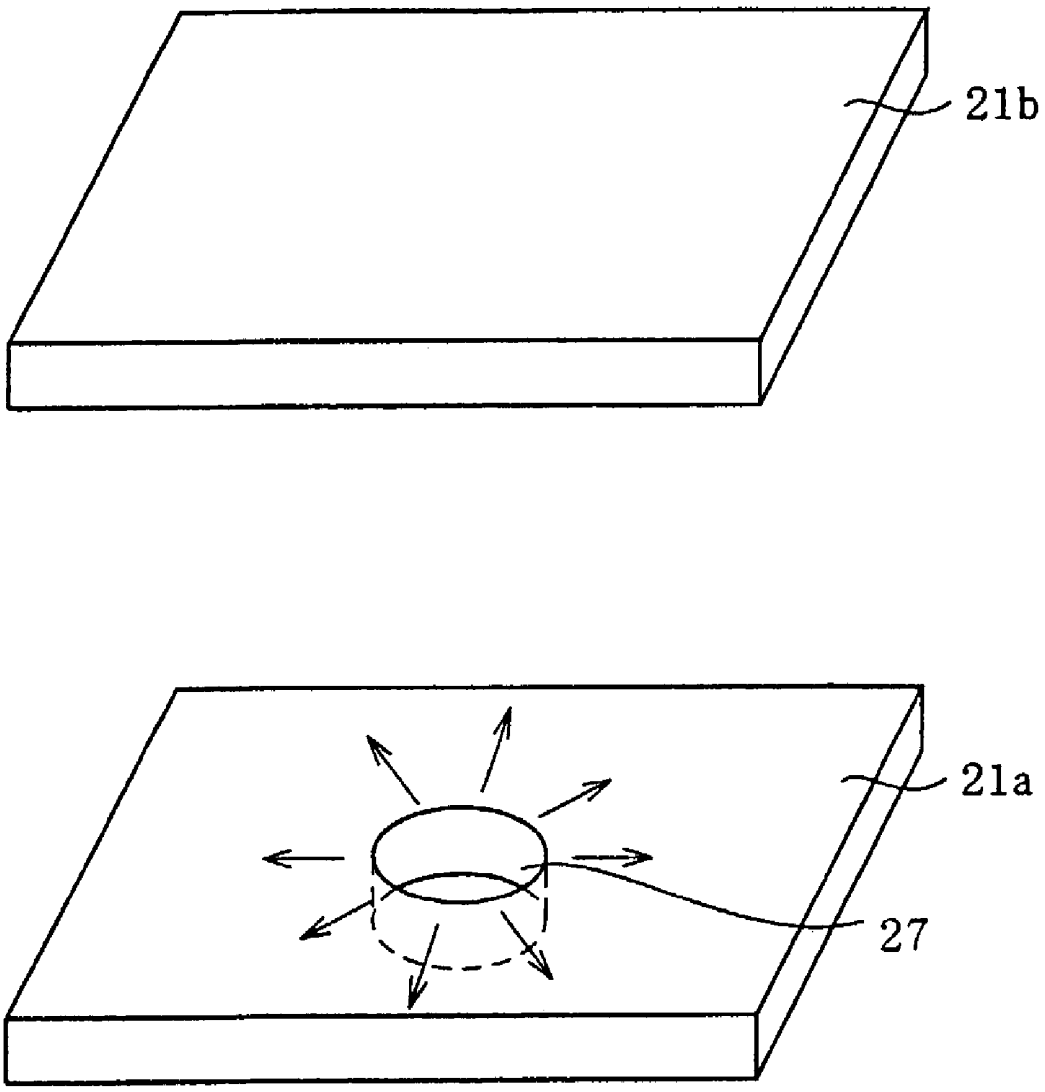


FIG. 20

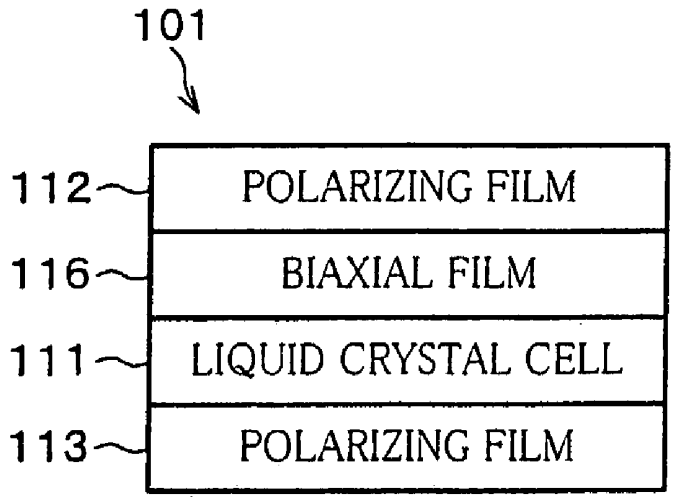
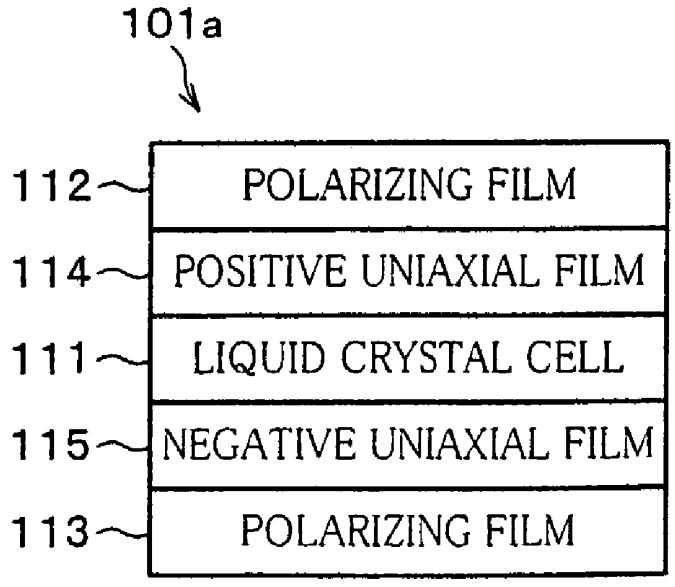

101
112
POLARIZING FILM
116
BIAXIAL FILM
111
LIQUID CRYSTAL CELL
113
POLARIZING FILM

FIG. 21


101a
112
POLARIZING FILM
114
POSITIVE UNIAXIAL FILM
111
LIQUID CRYSTAL CELL
115
NEGATIVE UNIAXIAL FILM
113
POLARIZING FILM

LIQUID CRYSTAL DISPLAY DEVICE

FIELD OF THE INVENTION

The present invention relates to a vertical alignment mode liquid crystal display device.

BACKGROUND OF THE INVENTION

Conventionally, a liquid crystal display device has been widely used for the screen of a word processor and computer. In recent years, the liquid crystal display device has spread rapidly as a television screen. Many of these liquid crystal display devices adopt TN (Twisted Nematic) mode. However, the TN mode liquid crystal display device has the problems of tendencies to degrade a contrast and to reverse a gradation property when viewed from an oblique direction.

For this reason, in recent years, in light of the improvement in viewing angle property, a VA (Vertical Alignment) mode liquid crystal display device has been attracting attention. A liquid crystal cell of the VA mode liquid crystal display device is arranged in combination of a nematic liquid crystal having a negative dielectric anisotropy with a vertical alignment film.

Further, for example, Japanese Laid-Open Patent Publication No. 2000-39610 (Tokukai 2000-39610, published on Feb. 8, 2000, which is a counterpart publication to U.S. Pat. No. 6,339,460) and Japanese Patent No. 2947350 (granted on Jul. 2, 1999), as shown in FIGS. **20** and **21**, respectively, disclose a liquid crystal display device **101** in which a biaxial film **116** is provided between a liquid crystal cell **111** and a polarizing plate **112**; and a liquid crystal display device **101***a* in which a positive uniaxial film **114** and a negative uniaxial film **115** are provided between the liquid crystal cell **111** and the polarizing plate **112** and between the liquid crystal cell **111** and a polarizing plate **113**, respectively, in order to compensate the optical anisotropy of the liquid crystal cell **111** when black image is displayed.

With the above arrangement, even though the liquid crystal cell **111** brings a phase difference depending on a polar angle to transmitting light when the liquid crystal cell **111** in which liquid crystal molecules are oriented vertically is viewed from an oblique direction, properly setting the respective retardations of the films **116** (**114** and **115**) can compensate the phase difference. Therefore, black displaying can be performed substantially as in the case when the liquid crystal cell **111** is viewed from a front direction, that is, as in the case where the liquid crystal molecules maintain the polarizing state of the transmitting light. As a result of this, it is possible to prevent light leakage, thus enhancing the contrast when viewed from an oblique direction.

However, under the situation where a liquid crystal display device with a wider viewing angle and higher display quality is expected, there is a demand for the improvement in contrast when viewed from an oblique direction nowadays. The liquid crystal display devices using the respective films **116** (**114** and **115**) with the retardations described in Japanese Patent No. 2947350 and Japanese Laid-Open Patent Publication No. 2000-39610, however, are not always satisfactory and still leave room for improvement.

SUMMARY OF THE INVENTION

In a vertical alignment mode liquid crystal display device, the present invention has been attained as a result of the consideration of the influence that base films of polarizing plates have on the retardations of films which are suitable for the enhancement of contrast when viewed from an oblique direction. An object of the present invention is to surely provide a liquid crystal display device which can maintain a high contrast when viewed from an oblique direction, to such an extent that the contrast is not visually different from that in the case where the retardations of the films are set to be the optimum.

In order to attain the above object, a liquid crystal display device according to the present invention includes:

a liquid crystal cell which is provided with two substrates to sandwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other;

a first phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a positive uniaxial anisotropy; and

a second phase difference film, provided between the second polarizing plate and the liquid crystal cell, having a negative uniaxial anisotropy,

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the first phase difference film being provided so that a retardation axis of the first phase difference film is orthogonal to the absorption axis of the first polarizing plate,

the second phase difference film being provided so that an optical axis of the second phase difference film is substantially vertical to the substrates, taking the following means.

More specifically, when a parameter α [nm] relative to Rp is:

$$\alpha = 135 - 0.7 \times Rtac; \text{ and}$$

a parameter β [nm] relative to Rn is:

$$\beta = Rlc - 65 - 1.4 \times Rtac,$$

where Rp [nm] is a retardation in an in-plane direction of the first phase difference film, Rn [nm] is a retardation in a thickness direction of the second phase difference film, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal, the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller than 110% of the parameter β.

Further, the second phase difference film, instead of being disposed on the opposite side to the first phase difference film viewed from the liquid crystal, may be disposed on the same side of the first phase difference film as well as between the first phase difference film and the polarizing plate.

In the liquid crystal display device of the foregoing arrangements, liquid crystal molecules oriented substantially vertically to the substrates, although not bringing a phase difference to light incident from the normal direction to the substrate, bring a phase difference depending on a polar angle (tilt angle to the normal direction) to obliquely incident light. Therefore, the liquid crystal display device cannot completely absorb the light supposed to be absorbed by the polarizing plate on the side from where the light emits, without the first and second phase difference films. This results in the occurrence of light leakage. Accordingly,

perfectly black displaying cannot be acquired, which degrades the contrast when viewed from an oblique direction.

In order to solve the problem, since the above arrangement is provided with first and second phase difference films, the phase difference that the liquid crystal has brought depending on the polar angle can be compensated by the first and second phase difference films. As a result of this, it is possible to prevent light leakage when viewed from an oblique direction, thus enhancing the contrast.

However, when the respective retardations of the first and second phase difference films are determined, it cannot be always said that just subtracting the retardation in the thickness direction of the base films from each of the respective retardations in the thickness direction of the first and second phase difference films, which is an optimum retardation when base films are absent, is a sufficient compensation, because much better contrast when viewed from an oblique direction is required.

The inventors of the present application, as a result of extensive research to further enhance the contrast when a vertical alignment mode liquid crystal display device is viewed from an oblique direction, have found that the retardation in the thickness direction of the base films does not always function as equally as each of the retardation in the thickness direction of the first phase difference film and the retardation in the thickness direction of the second phase difference film. Specifically, the inventors have found to complete the present invention that when the retardation in the in-plane direction of the first phase difference film with a positive uniaxial anisotropy is set so that the contrast becomes the maximum, the retardation does not depend on the retardation of the liquid crystal, but on the retardation in the thickness direction of the base films.

In the liquid crystal display device of the present invention, the retardation Rp in the in-plane direction of the first phase difference film is set according to the retardation Rtac in the thickness direction of the base films; the retardation Rn in the thickness direction of the second phase difference film is set according to the retardation Rlc in the thickness direction of the liquid crystal and the retardation Rtac in the thickness direction of the base films; and the retardations Rp and Rn are set to be in the area where the contrast when viewed from an oblique direction is not visually different from that in the case where the retardations Rp and Rn are set to be the optimum. With this arrangement as compared with the arrangement in which the retardation in the thickness direction of the base films is treated equally to the retardation in the thickness direction of the first phase difference film and the retardation in the thickness direction of the second phase difference film, it is possible to enhance the contrast and increase a viewing angle.

Further, since the area of the retardation Rp in the in-plane direction of the first phase difference film does not depend on the retardation Rlc in the thickness direction of the liquid crystal, the area of the retardation Rp does not change even in the case of the use with another liquid crystal having different thickness. Therefore, it is possible to use the base films and the first phase difference film in common between liquid crystals having mutually different retardations Rlc in the thickness direction, leading to better productivity.

In the liquid crystal display device according to the present invention, the second phase difference film, instead of being disposed on the same side of the first phase difference film as well as between the first phase difference film and the polarizing plate, is disposed between the first phase difference film and the liquid crystal. Further, when a parameter α [nm] relative to Rp is:

$$\alpha=35+(Rlc/80-4)^2\times 3.5+(360-Rlc)\times Rtac/850;\ \text{and}$$

a parameter β [nm] relative to Rn is:

$$\beta=Rlc-1.9\times Rtac,$$

instead of the foregoing area of the retardations Rp and Rn, the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller 110% of the parameter β.

Also in the foregoing arrangement, phase difference that the liquid crystal has brought to the light in an oblique direction, in the state where liquid crystal molecules are oriented substantially vertically to the substrates, is compensated by both of the phase difference films. This prevents the light leakage when viewed from an oblique direction, thus enhancing the contrast.

However, even in the foregoing arrangement, when the respective retardations of the first and second phase difference films are determined, it cannot be always said that just subtracting the retardation in the thickness direction of the base films from each of the respective retardations in the thickness direction of the first and second phase difference films, which is an optimum retardation when base films are absent, is a sufficient compensation, because much better contrast when viewed from an oblique direction is required.

The inventors of the present application, as a result of extensive research to further enhance the contrast when a vertical alignment mode liquid crystal display device is viewed from an oblique direction, have found that the retardation in the thickness direction of the base films does not always function as equally as each of the retardation in the thickness direction of the first phase difference film and the retardation in the thickness direction of the second phase difference film, as in the case of the foregoing liquid crystal display device. Specifically, the inventors have found to complete the present invention that when the retardation Rp in the in-plane direction of the first phase difference film with a positive uniaxial anisotropy is set so that the contrast becomes the maximum, the dependency of the retardation Rp on the retardation in the thickness direction of the base films, reverses depending on whether the retardation of the liquid crystal is over 360 [nm].

In the liquid crystal display device of the present invention, each of the retardation Rp in the in-plane direction of the first phase difference film and the retardation Rn in the thickness direction of the second phase difference film is set according to the retardation Rlc in the thickness direction of the liquid crystal and the retardation Rtac in the thickness direction of the base films; and the retardations Rp and Rn are set to be in the area where the contrast when viewed from an oblique direction is not visually different from that in the case where the retardations Rp and Rn are set to be the optimum. With this arrangement as compared with the arrangement in which the retardation in the thickness direction of the base films is treated equally to the retardation in the thickness direction of the first phase difference film and the retardation in the thickness direction of the second phase difference film, it is possible to enhance the contrast and increase a viewing angle.

Further, in addition to the above arrangement, the retardation Rlc in the thickness direction of the liquid crystal may be set to be a value greater than 342 [nm] but smaller than 378 [nm], and the retardation Rp in the in-plane direction of the first phase difference film may be set to be a value greater than 33.3 [nm] but smaller than 38.6 [nm].

Under the condition that the retardations Rlc and Rp are set in the foregoing ranges, the retardation Rp can be set to be greater than 90% but smaller than 110% of the parameter α even when the retardation in the thickness direction of the base film changes due to the variations of the base films caused in the manufacturing process. As a result of this, even in the case where there occurs the variation of the retardation in the thickness direction of the base films, the same first phase difference film can be used, leading to better productivity.

Further, in the case where the enhancement in the contrast is especially required, it is desirable that the retardation Rp is set to be the parameter α, and the retardation Rn is set to be the parameter β, in addition to the above arrangements. This makes it possible to obtain a liquid crystal display device with an especially high contrast when viewed from an oblique direction.

Meanwhile, in order to attain the above object, a liquid crystal display device according to the present invention includes:

a liquid crystal cell which is provided with two substrates to sandwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other; and

a phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a biaxial anisotropy,

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the phase difference film being provided so that an in-plane retardation axis of the phase difference film is orthogonal to the absorption axis of the first polarizing plate, taking the following means.

More specifically, when a parameter α [nm] relative to Rxy is:

$$\alpha=85-0.09\times Rlc-Rtac/20;\ \text{and}$$

a parameter β [nm] relative to Rz is:

$$\beta=1.05\times Rlc-1.9\times Rtac,$$

where Rxy [nm] is a retardation in an in-plane direction of the phase difference film, Rz [nm] is a retardation in a thickness direction of the phase difference film, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal, the retardation Rxy is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rz is set to be greater than 90% but smaller than 110% of the parameter β.

Further, in order to attain the above object, a liquid crystal display device according to the present invention includes:

a liquid crystal cell which is provided with two substrates to sandwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other;

a first phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a biaxial anisotropy; and

a second phase difference film, provided between the second polarizing plate and the liquid crystal cell, having a biaxial anisotropy;

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the first and second phase difference films being provided so that in-plane retardation axes of the first and second phase difference films are orthogonal to the absorption axes of the first and second polarizing plates, respectively, taking the following means.

More specifically, when a parameter α [nm] relative to Rxy is:

$$\alpha=42.5-0.045\times Rlc-Rtac/40;\ \text{and}$$

a parameter β [nm] relative to Rz is:

$$\beta=0.525\times Rlc-0.95\times Rtac,$$

where Rxy [nm] is a retardation in an in-plane direction of each of the first and second phase difference films, Rz [nm] is a retardation in a thickness direction of each of the first and second phase difference films, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal, the retardation Rxy of the first and second phase difference films is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rz of the first and second phase difference films is set to be greater than 90% but smaller than 110% of the parameter β.

In the above-arranged liquid crystal display device, phase difference that the liquid crystal has brought to the light in an oblique direction, in the state where liquid crystal molecules are oriented substantially vertically to the substrates, is compensated by the phase difference film or the first and second phase difference films. This prevents the light leakage when viewed from an oblique direction, thus enhancing the contrast.

However, even in the foregoing arrangement, when the retardation of the phase difference film or the respective retardations of the first and second phase difference films is determined, it cannot be always said that just subtracting the retardation in the thickness direction of the base films from each of the respective retardations in the thickness direction of the phase difference films, which is an optimum retardation when base films are absent, is a sufficient compensation, because much better contrast when viewed from an oblique direction is required.

The inventors of the present application, as a result of extensive research to further enhance the contrast when a vertical alignment mode liquid crystal display device is viewed from an oblique direction, have found that the retardation in the thickness direction of the base films does not always function as equally as the retardation in the thickness direction of the phase difference film or each of the respective retardations in the thickness direction of the first and second phase difference films, as in the case of the foregoing liquid crystal display device. Specifically, the inventors have found to complete the present invention that the retardation Rxy in the in-plane direction of the phase difference film with a biaxial anisotropy and the retardation Rtac in the thickness direction of the base films are different in the direction of the retardation from each other; however,

the influence of the retardation Rtac should be also added in order to properly set the retardation Rxy.

In the liquid crystal display device of the present invention, the retardation Rxy in the in-plane direction of the phase difference film or each of the first and second phase difference films and the retardation Rz in the thickness direction of the phase difference film or each of the first and second phase difference films are set according to the retardation Rlc in the thickness direction of the liquid crystal and the retardation Rtac in the thickness direction of the base films; and the retardations Rxy and Rz are set to be in the area where the contrast when viewed from an oblique direction is not visually different from that in the case where the retardations Rxy and Rz are set to be the optimum. With this arrangement as compared with the arrangement in which the retardation in the thickness direction of the base films is treated equally to the retardation in the thickness direction of the phase difference film and each of the respective retardations in the thickness direction of the first and second phase difference films, it is possible to enhance the contrast and increase a viewing angle.

Further, in the case where the enhancement in the contrast is especially required, it is desirable that the retardation Rxy is set to be the parameter α, and the retardation Rz is set to be the parameter β, in addition to the above arrangements. This makes it possible to obtain a liquid crystal display device with an especially high contrast when viewed from an oblique direction.

Further, in the liquid crystal display device according to the present invention, it is desirable that the liquid crystal has a negative dielectric anisotropy, regardless of whether or not the phase difference films have biaxial anisotropy.

According to this arrangement, liquid crystal molecules oriented in the normal direction to the substrate can be tilted depending on electric intensity by applying an electric field substantially in the vertical direction to the substrate. This can simplify the structure of electrodes, as compared with the case of using a liquid crystal having a positive dielectric anisotropy.

For a fuller understanding of the nature and advantages of the invention, reference should be made to the ensuing detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram showing the main arrangement of a liquid crystal display device according to an embodiment of the present invention.

FIG. **2** is a schematic diagram showing a liquid crystal cell provided in the liquid crystal display device in the state where no voltage is applied.

FIG. **3** is a schematic diagram showing a liquid crystal cell provided in the liquid crystal display device in the state where a voltage is applied.

FIG. **4** is a plan view showing the vicinity of a pixel electrode in an arrangement example of the liquid crystal cell.

FIG. **5** shows preferable areas for retardation in the in-plane direction of a positive uniaxial film and retardation in the thickness direction of a negative uniaxial film which are provided in the liquid crystal display device, where the retardations are expressed by relative values to the respective parameters.

FIG. **6** is a schematic diagram showing the main arrangement of a liquid crystal display device which is a variant example of the liquid crystal display device shown in FIG. **1**.

FIG. **7** shows experimental results of optimal values for the retardations with respect to the combination of a liquid crystal cell with a polarizing plate in an example of the present invention.

FIG. **8** shows a contrast evaluation method in a liquid crystal display device.

FIG. **9** is a schematic diagram showing the main arrangement of a liquid crystal display device according to another embodiment of the present invention.

FIG. **10** shows preferable areas for retardation in the in-plane direction of a positive uniaxial film and retardation in the thickness direction of a negative uniaxial film which are provided in the liquid crystal display device, where the retardations are expressed by relative values to the respective parameters.

FIG. **11** shows experimental results of optimal values for the retardations with respect to the combination of a liquid crystal cell with a polarizing plate in another example of the present invention.

FIG. **12** is a schematic diagram showing the main arrangement of a liquid crystal display device according to still another embodiment of the present invention.

FIG. **13** shows preferable areas for retardations in the in-plane direction and thickness direction of a biaxial film which is provided in the liquid crystal display device, where the retardations are expressed by relative values to the respective parameters.

FIG. **14** is a schematic diagram showing the main arrangement of a liquid crystal display device which is a variant example of the liquid crystal display device shown in FIG. **12**.

FIG. **15** shows experimental results of optimal values for the retardations with respect to the combination of a liquid crystal cell with a polarizing plate in an example of the present invention.

FIG. **16** is a perspective view showing a pixel electrode of a liquid crystal cell in another arrangement example of the foregoing liquid crystal display devices.

FIG. **17** is a plan view showing the vicinity of a pixel electrode in a liquid crystal cell in still another arrangement example of the foregoing liquid crystal display devices.

FIG. **18** is a perspective view showing a pixel electrode of a liquid crystal cell in yet another arrangement example of the foregoing liquid crystal display devices.

FIG. **19** is a perspective view showing a pixel electrode and a counter electrode of a liquid crystal cell in still another arrangement example of the foregoing liquid crystal display devices.

FIG. **20** is a schematic diagram showing the main arrangement of a liquid crystal display device with a conventional art.

FIG. **21** is a schematic diagram showing the main arrangement of a liquid crystal display device with another conventional art.

DESCRIPTION OF THE EMBODIMENTS

First Embodiment

Referring to FIGS. **1** through **8**, the following will explain one embodiment of the present invention. Note that, as described in detail later, the present invention can be applied to other liquid crystal cell; however, the following will

explain a multi-domain vertical alignment liquid crystal cell as one preferable example of a liquid crystal cell.

A liquid crystal display device **1** according to the present embodiment is, as shown in FIG. **1**, has a layer structure, including a vertical alignment (VA) mode liquid crystal cell **11**, polarizing plates **12** and **13** which are respectively disposed on the two sides of the liquid crystal cell **11**, a positive uniaxial film (first phase difference film) **14** which is disposed between the polarizing plate **12** and the liquid crystal cell **11**, and a negative uniaxial film (second phase difference film) **15** which is disposed between the polarizing plate **13** and the liquid crystal cell **11**.

The liquid crystal cell **11**, as shown in FIG. **2**, includes: a TFT (Thin Film Transistor) substrate **11***a* provided with a pixel electrode **21***a* corresponding to a pixel (described later); a counter substrate **11***b* provided with a counter electrode **21***b*; and a liquid crystal layer **11***c*, sandwiched between the substrates **11***a* and **11***b*, which is a nematic liquid crystal with negative dielectric anisotropy. Note that, the liquid crystal display device **1** according to the present embodiment is capable of color display, and a color filter including the colors of pixels is formed on the counter substrate **11***b*.

Further, under the TFT substrate **11***a* provided with the pixel electrode **21***a*, a vertical alignment film **22***a* is formed on one side surface of the liquid crystal layer **11***c*. Similarly, under the counter substrate **11***b* provided with the counter electrode **21***b*, a vertical alignment film **22***b* is formed on the other side surface of the liquid crystal layer **11***c*. With this arrangement, in the state where a voltage is not applied between the two electrodes **21***a* and **21***b*, liquid crystal molecules M in the liquid crystal layer **11***c*, which is disposed between the two substrates **11***a* and **11***b*, are oriented vertically to the surfaces of the substrates **11***a* and **11***b*. On the other hand, when a voltage is applied between the two electrodes **21***a* and **21***b*, the liquid crystal molecules M in the state of being oriented in the normal direction to the substrates **11***a* and **11***b* (in the state where no voltage is applied) tilt at a tilt angle depending on the applied voltage (see FIG. **3**). Note that, the two substrates **11***a* and **11***b* are opposed to each other, so that the normal direction and in-plane direction with respect to the substrates **11***a* and **11***b* are hereinafter referred to just as normal direction and in-plane direction, except for the case where they are required to be distinguished.

Here, the liquid crystal cell **11** according to the present embodiment is a multi-domain vertical alignment liquid crystal cell in which each pixel is divided into a plurality of regions (domains), and is controlled so that the domains have mutually different orientation directions, i.e. azimuths of the liquid crystal molecules M tilted when a voltage is applied (in-plane components at a tilt angle).

More specifically, as shown in FIG. **4**, the pixel electrode **21***a* has protrusions **23***a* formed thereon in a stripe pattern, and each of the protrusions **23***a* zigzags appropriately at right angles in the in-plane direction with a mountain shape in cross-section. Similarly, the counter electrode **21***b* has protrusions **23***b* formed thereon in a stripe pattern, and each of the protrusions **23***b* zigzags appropriately at right angles in the in-plane direction with a mountain shape in the normal direction. The two protrusions **23***a* and **23***b* in the in-plane direction are disposed at such a distance that the normal to the slope of the protrusion **23***a* is substantially equal to the normal to the slope of the protrusion **23***b*. Further, the protrusions **23***a* and **23***b* are formed by the application of a photosensitive resin on the pixel electrode **21***a* and the counter electrode **21***b*, respectively, and the process of photolithography.

Here, the liquid crystal molecules near the protrusions **23***a* are oriented so as to be vertical to the slopes of the protrusions **23**. In addition, when a voltage is applied, the electric field near the protrusions **23***a* tilts so as to be parallel to the slopes of the protrusions **23***a*. Here, the long axes of the liquid crystal molecules tilt in the vertical direction with respect to the electric field. According to the continuity of liquid crystal, the liquid crystal molecules away from the slopes of the protrusions **23***a* are oriented as well in the same direction as the direction in which the liquid crystal molecules near the slopes of the protrusions **23***a* tilt. Similarly, when a voltage is applied, the electric field near the protrusions **23***b* tilts so as to be parallel to the slopes of the protrusions **23***b*. Here, the long axes of the liquid crystal molecules tilt in the vertical direction with respect to the electric field. According to the continuity of liquid crystal, the liquid crystal molecules away from the slopes of the protrusions **23***b* are oriented as well in the same direction as the direction in which the liquid crystal molecules near the slopes of the protrusions **23***b* tilt.

Consequently, as to the protrusions **23***a* and **23***b*, when parts except for a corner part C are referred to as line parts, in the region between a line part L**23***a* of the protrusion **23***a* and a line part L**23***b* of the protrusion **23***b*, in-plane component as the orientation direction of the liquid crystal molecules when a voltage is applied is equal to that in the direction from the line part L**23***a* to the line part L**23***b*.

Here, in the protrusions **23***a* and **23***b*, the corner part C bends approximately at right angles. Therefore, the orientation directions of the liquid crystal molecules are divided into four parts in a pixel, and this can form domains D**1** to D**4** of mutually different orientation directions of the liquid crystal molecules in the pixel.

On the other hand, the polarizing plates **12** and **13** shown in FIG. **1** are respectively provided with polarizing films **12***a* and **13***a* and triacetyl cellulose (TAC) films **12***b* and **13***b* as base films for holding the polarizing films **12***a* and **13***a*. The two TAC films **12***b* and **13***b* have negative optically uniaxial anisotropy, and the respective optical axes are set so as to be substantially equal to the normal direction of the liquid crystal cell **11**. The two polarizing plates **12** and **13** are disposed so that an absorption axis AA**12** of the polarizing plate **12** is orthogonal to an absorption axis AA**13** of the polarizing plate **13**. Further, the two polarizing plates **12** and **13** are disposed so that each of the absorption axes AA**12** and AA**13** forms an angle of 45 degrees with the in-plane component in the orientation direction of the liquid crystal molecules in each of the domains D**1** to D**4** when a voltage is applied.

Further, the positive uniaxial film **14**, which is layered on one surface of the liquid crystal cell **11**, is an optically anisotropic film having the property of nxp>nyp=nzp, where nxp and nyp are refractive indexes in the in-plane direction of the film, and nzp is a refractive index in the normal direction. Let a film thickness be dp, retardation Rp in the in-plane direction can be calculated by the following expression (1):

$$Rp=dp\cdot(nxp-nyp) \tag{1}$$

Further, the positive uniaxial film **14** is disposed so that its retardation axis SL**14** is orthogonal to the absorption axis AA**12** of the polarizing plate **12** at the same side when viewed from the liquid crystal cell **11**.

Meanwhile, the negative uniaxial film **15**, which is layered on the other surface of the liquid crystal cell **11**, is an optically anisotropic film having the property of nxn=nyn>nzn, where nxn and nyn are refractive indexes in the in-plane direction of the film, and nzn is a refractive index in the normal direction. Let a film thickness be dn, retardation Rn in the thickness direction can be calculated by the following expression (2):

$$Rn=dn\cdot\{(nxn+nyn)/2-nzn\} \quad (2).$$

Further, the negative uniaxial film **15** is disposed so that its optical axis is substantially equal to the normal direction of the liquid crystal cell **11**.

With the above-arranged liquid crystal display device **1**, while a voltage is applied between the pixel electrode **21***a* and the counter electrode **21***b*, the liquid crystal molecules in the liquid crystal cell **11**, as shown in FIG. **3**, are obliquely oriented to the normal direction just at the angle depending on the applied voltage. This brings a phase difference depending on the applied voltage to light passing through the liquid crystal cell **11**.

Here, the absorption axes AA**12** and AA**13** of the polarizing plates **12** and **13** are disposed so as to be orthogonal to each other. As described in detail later, the positive uniaxial film **14** and negative uniaxial film **15** are arranged so as to compensate the phase difference that the liquid crystal cell **11** brings to transmitting light in the case where the liquid crystal molecules in the liquid crystal cell **11** are oriented in the normal direction, as shown in FIG. **2**.

Therefore, light incident to a polarizing plate on the side from where the light emits (e.g. the polarizing plate **12**) turns elliptically polarized light depending on the phase difference that the liquid crystal cell **11** brings, and a part of the incident light passes through the polarizing plate **12**. As a result of this, the amount of light emitted from the polarizing plate **12** can be controlled in accordance with the applied voltage. This makes it possible to display with gradations.

Further, the liquid crystal cell **11** has domains D**1** to D**4** formed of mutually different orientation directions of the liquid crystal molecules in a pixel. Therefore, even in the case where the liquid crystal molecules cannot bring phase difference to transmitting light when the liquid crystal cell **11** is viewed from the direction which is parallel to the orientation direction of liquid crystal molecules which belong to a certain domain (e.g. the domain D**1**), the liquid crystal molecules in the rest of domains (the domains D**2** to D**4** in this case) can bring phase difference to transmitting light. Thus, the domains can optically compensate with one another. As a result of this, it is possible to improve a display quality level of the liquid crystal cell **11** and to increase a viewing angle when viewed from an oblique direction.

On the other hand, while a voltage is not applied between the pixel electrode **21***a* and the counter electrode **21***b*, the liquid crystal molecules in the liquid crystal cell **11**, as shown in FIG. **2**, are in the state of being oriented vertically. In this state (when no voltage is applied), the light incident from the normal direction to the liquid crystal cell **11**, which cannot be brought phase difference by the liquid crystal molecules, passes through the liquid crystal cell **11**, maintaining a polarized state. As a result of this, light incident to a polarizing plate on the side from where the light emits (e.g. the polarizing plate **12**) turns linearly polarized light which is substantially parallel to the absorption axis AA**12** of the polarizing plate **12** and cannot pass through the polarizing plate **12**. This allows the liquid crystal display device **1** to display black image.

Here, to the light incident from an oblique direction to the liquid crystal cell **11**, brought by liquid crystal molecules is the phase difference depending on the angle between the incident light and the orientation direction of the liquid crystal molecules, that is, the angle (polar angle) between the incident light and the normal direction to the liquid crystal cell **11**. Therefore, without the positive uniaxial film **14** and the negative uniaxial film **15**, the light incident to the polarizing plate **12** turns elliptically polarized light depending on the polar angle, and a part of the polarized light passes through the polarizing plate **12**. This results in the occurrence of light leakage even in the state where the liquid crystal molecules are oriented vertically to display black image, which may degrade displaying contrast.

However, with the arrangement shown in FIG. **1** in which the positive uniaxial film **14** and the negative uniaxial film **15** are provided, if the respective retardations are properly set, the phase difference brought depending on the polar angle by the liquid crystal cell **11** can be cancelled, thus preventing light leakage. As a result of this, it is possible to enhance the contrast when viewed from an oblique direction.

Here, in the liquid crystal display device **1** according to the present embodiment, the respective retardations of the positive uniaxial film **14** and the negative uniaxial film **15** are set as described below so that the contrast can be kept at an extremely high value of 20 or more.

Note that, if the contrast is 20 or more, it is possible to surely prevent the decrease in the display quality level, such as gradation reversal caused by the light leakage, for example, even when the liquid crystal display device **1** is used, for example, for a large size display, such as a display with a screen of 20 inch or more, with a wide viewing angle and the strongly desired enhancement of contrast.

Specifically, when retardation Rtac [nm] in the thickness direction of the TAC films **12***b* and **13***b* and a parameter α1 [nm] relative to the retardation Rp are expressed by the following expression (3):

$$\alpha 1=135-0.7\times Rtac \quad (3),$$

the retardation Rp in the in-plane direction of the positive uniaxial film **14** is set to be a value greater than 85% but smaller than 115% of the parameter α1.

Further, when retardation Rlc [nm] in the thickness direction of the liquid crystal cell **11** and a parameter β1 [nm] relative to the retardation Rn are expressed by the following expression (4):

$$\beta 1=Rlc-65-1.4\times Rtac \quad (4),$$

the retardation Rn in the thickness direction of the negative uniaxial film **15** is set to be a value greater than 85% but smaller than 115% of the parameter β1.

Thus, by setting the retardations Rp and Rn to be in an area A**1** shown in FIG. **5** with reference to the parameters α1 and β1, it is possible to surely attain the liquid crystal display device **1** with the contrast of an extremely high value of 20 or more when viewed from an oblique direction.

Further, the contrast when viewed from an oblique direction becomes the maximum when the retardations Rp and Rn are set to be equal to the parameters α1 and β1, respectively. However, especially by setting the retardations Rp and Rn to be greater than 90% but smaller than 110% of the parameters α1 and β1, respectively, as an area A**2** shown in FIG. **5**, it is possible to surely attain the liquid crystal display device **1** with a sufficiently high contrast when viewed from an oblique direction to such an extent that a

viewer cannot visually recognize the difference from the liquid crystal display device in which the retardations Rp and Rn are set so that the contrast becomes the maximum value.

Further, a liquid crystal display device la shown in FIG. **6**, which differs from the liquid crystal display device **1** shown in FIG. **1** in that the negative uniaxial film **15** is layered between the positive uniaxial film **14** and the liquid crystal cell **11**, can obtain the same effect as well.

Here, as apparent from the expression (3) and FIG. **7** described later, the retardation Rp of the positive uniaxial film **15** does not depend on a cell thickness dlc of the liquid crystal cell **11**, i.e. the retardation Rlc in the thickness direction of the liquid crystal cell **11**, but only on the retardation Rtac in the thickness direction of the TAC films **12***b* and **13***b*.

Therefore, even in the case where the positive uniaxial film **15** is used together with the liquid crystal cell **11** of a different thickness, there are no changes in optimal values of the positive uniaxial film **14** and TAC films **12***b* and **13***b*. As a result of this, in the liquid crystal display device **1** (**1***a*) in which the liquid crystal cell **11**, polarizing plates **12** and **13**, the positive uniaxial film **14**, and the negative uniaxial film **15** are layered in the order shown FIG. **1** or FIG. **6**, the positive uniaxial film **14** and TAC films **12***b* and **13***b* can be used in common between mutually different liquid crystal cells **11**. Note that, even in this case, the negative uniaxial film **15** is selected in accordance with the liquid crystal cell **11**.

EXAMPLE 1

In the present example, as the liquid crystal cell **11** prepared were liquid crystal cells with a refractive index anisotropy Δn of 0.08 each in the liquid crystal layer **11***c*, and respective thicknesses (cell thickness dlc) of 3.0 [μm], 4.0 [μm], and 5.0 [μm], i.e. liquid crystal cells with respective retardations Rlc (=dlc·Δn) in the thickness direction of 240 [nm], 320 [nm], and 400 [nm]. Also, as TAC films **12***b* and **13***b* prepared were TAC films with respective retardations Rtac in the thickness direction of 0 [nm], 30 [nm], 50 [nm], and 80 [nm]. Further, for all combinations of the liquid crystal cells **11** with the TAC films **12***b* and **13***b* calculated were the respective retardations Rp and Rn where the contrast when viewed from an oblique direction became the maximum. As a result of this, the experimental result shown in FIG. **7** could be obtained.

Note that, a viewing angle in the case where the liquid crystal device **1** is actually used is an angle (polar angle) from the normal to the liquid crystal cell **11** in the range from 0 degree to 60 degrees. Because the increase of the polar angle degrades the contrast, the contrast was measured from the direction in which the polar angle is 60 degrees, as shown in FIG. **8**. Further, the contrast was measured at an azimuth (in-plane direction) of 45 degrees with reference to the absorption axes AA**12** and AA**13** of the polarizing films **12***a* and **13***a* because the contrast becomes the minimum at the azimuth of 45 degrees with reference to the absorption axes AA**12** and AA**13**.

According to this, it is confirmed that the liquid crystal display device **1** with the maximum contrast could be obtained under the condition that the retardation Rp in the in-plane direction of the positive uniaxial film **14** was equal to the foregoing parameter α1, and the retardation Rn in the thickness direction of the negative uniaxial film **15** was equal to the foregoing parameter β1. Further, by approximating the experimental result with a linear expression, the foregoing expressions (3) and (4) could be calculated.

From the estimation of the contrast with changes in the retardations Rp and Rn by 5% each at a time, it was confirmed that even in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** and the retardation Rtac of the TAC films **12***b* and **13***b* had any of the foregoing values, the contrast from the oblique direction (at the polar angle of 60 degrees) was above 20 under the condition that the retardations Rp and Rn were values ranging from 85% to 115% of the parameters α1 and β1, respectively.

In addition, it was confirmed that even in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** and the retardation Rtac of the TAC films **12***b* and **13***b* had any of the foregoing values under the condition that the retardations Rp and Rn were in the ranges from 90% to 110% of the parameters α1 and β1, respectively, the viewer from the oblique direction (at the polar angle of 60 degrees) could not visually recognize the differences from the liquid crystal display devices **1** with the values shown in FIG. **7**.

Further, also in a liquid crystal display device, as the liquid crystal display device **1***a* shown in FIG. **6**, which differed from the liquid crystal display device **1** shown in FIG. **1** in that the negative uniaxial film **15** was layered between the positive uniaxial film **14** and the liquid crystal cell **11**, it was confirmed that the retardations Rp and Rn for obtaining the maximum contrast at the oblique viewing angle (at the polar angle of 60 degrees) were the same as those of the liquid crystal display device **1** shown in FIG. **1** even if the retardations Rlc and Rtac were any of the foregoing values. Further, also in the case of the liquid crystal display device **1***a*, as in the case of the liquid crystal display device **1**, it was confirmed that the contrast from the oblique direction (at the polar angle of 60 degrees) was above 20 under the condition that the retardations Rp and Rn were in the range from 85% to 115% of the parameters α1 and β1, respectively, and the difference from the liquid crystal display device in which the retardations Rp and Rn were set so that the contrast became the maximum could not be visually recognized from the oblique direction under the condition that the retardations Rp and Rn were in the ranges from 90% to 110% of the parameters α1 and β1, respectively.

Second Embodiment

As shown in FIG. **9**, a liquid crystal display device **1***b* according to the present embodiment differs from the liquid crystal display device **1** shown in FIG. **1** in that the negative uniaxial film **15** is layered between the positive uniaxial film **14** and the polarizing plate **12**. Further, in the liquid crystal display device **1***b* according to the present embodiment, the respective retardations of the positive uniaxial film **14** and the negative uniaxial film **15** are set as described below so that the contrast can be kept at an extremely high value of 20 or more when viewed from an oblique direction.

Specifically, when retardation Rtac [nm] in the thickness direction of the TAC films **12***b* and **13***b* and a parameter α2 [nm] relative to the retardation Rp are expressed by the following expression (5):

$$\alpha 2=35+(Rlc/80-4)^2\times 3.5+(360-Rlc)\times Rtac/850 \quad (5),$$

the retardation Rp in the in-plane direction of the positive uniaxial film **14** is set to be a value greater than 85% but smaller than 115% of the parameter α2.

Further, when retardation Rlc [nm] in the thickness direction of the liquid crystal cell **11** and a parameter β2 [nm] relative to the retardation Rn are expressed by the following expression (6):

$$\beta 2 = Rlc - 1.9 \times Rtac \quad (6),$$

the retardation Rn in the thickness direction of the negative uniaxial film **15** is set to be a value greater than 85% but smaller than 115% of the parameter β2.

Thus, by setting the retardations Rp and Rn to be in an area A**1** shown in FlG. **10** with reference to the parameters α2 and β2, it is possible to surely attain the liquid crystal display device **1***b* with the contrast of an extremely high value of 20 or more when viewed from an oblique direction.

Further, the contrast when viewed from an oblique direction becomes the maximum when the retardations Rp and Rn are set to be equal to the parameters α2 and β2, respectively. However, especially by setting the retardations Rp and Rn to be greater than 90% but smaller than 110% of the parameters α2 and β2, respectively, as an area A**2** shown in FlG. **10**, it is possible to surely attain the liquid crystal display device **1***b* with a sufficiently high contrast when viewed from an oblique direction to such an extent that a viewer cannot visually recognize the difference from the liquid crystal display device in which the retardations Rp and Rn are set so that the contrast becomes the maximum value.

Note that, the liquid crystal display device **1***b* shown in FlG. **9** differs from the liquid crystal display devices **1** and la shown respectively in FlGS. **1** and **6** in that the positive uniaxial film **14** is provided between the negative uniaxial film **15** and the liquid crystal cell **11**. Thus, in the liquid crystal display device **1***b*, elliptically polarized light beams having optically passed through the liquid crystal cell **11** pass through the positive uniaxial film **14** before generally compensated by the negative uniaxial film **15**. Therefore, unlike the arrangements in FlGS. **1** and **6**, i.e. the arrangement in which the optimal value of the retardation Rp in the in-plane direction of the positive uniaxial film **14** is not subjected to the retardation Rlc in the thickness direction of the liquid crystal cell **11** because light after the negative uniaxial film **15** has generally compensated the phase difference brought by the liquid crystal cell **11** enters to the positive uniaxial film **14**, in the arrangement of the liquid crystal display device **1***b*, the optimal value of the retardation Rp in the in-plane direction of the positive uniaxial film **14** is subjected to the retardation Rlc in the thickness direction of the liquid crystal cell **11**.

Here, as obvious from the expression (5), the increase or degrease in the optimal value of the retardation Rp in the in-plane direction of the positive uniaxial film **14** according to the retardation Rtac in the thickness direction of the TAC films **12***b* and **13***b* depends on the retardation Rlc in the thickness direction of the liquid crystal cell **11**. On the border of the retardation Rlc of 360 [nm] of the liquid crystal cell **11**, dependency of the optimal retardation Rp on the retardation Rtac is reversed.

Therefore, by setting the retardation Rlc in the thickness direction of the liquid crystal cell **11** to 360 [nm], it is possible to fix the retardation Rp in the in-plane direction of the positive uniaxial film **14** to 35.9 [nm] regardless of the retardation Rtac.

Further, in the case where the retardation Rlc is in the range from 324 [nm] to 396 [nm] and the retardation Rp is in the range from 32.6 [nm] to 39.9 [nm], the retardation Rp is within the range from 85% to 115% of the parameter α2 under the condition that the retardation Rtac is a general value, i.e. approximately 30 [nm] to 80 [nm]. As a result of this, by setting the retardation Rn to be 85% to 115% of the parameter β2, it is possible to keep the contrast with an extremely high value of 20 or more when the liquid crystal display device **1***b* is viewed from an oblique direction.

Therefore, in the case where it is placed importance on the improvement in productivity, it is desirable that the retardation Rlc in the thickness direction of the liquid crystal cell **11** is set to be in the range from 324 [nm] to 396 [nm], and the retardation Rp in the in-plane direction of the positive uniaxial film **14** is set to be in the range from 32.6 [nm] to 39.9 [nm].

According to this, even in the case where the retardation Rtac changes depending on the variations of the TAC films **12***b* and **13***b* caused in the manufacturing process, it is possible to realize the liquid crystal display device **1***b* with such an excellent viewing angle property as described above, using the positive uniaxial film **14** with the same value of the retardation Rp in the in-plane direction. As a result of this, even in the case of the variations of the TAC films **12***b* and **13***b* caused in the manufacturing process, it is possible to fix a type of the positive uniaxial film **14**, thus improving the productivity.

Further, in the case where it is placed importance on both the improvement in productivity and more excellent viewing angle property, it is desirable that the retardation Rlc is set to be a value greater than 342 [nm] but smaller than 378 [nm], and the retardation Rp is set to be a value greater than 33.3 [nm] but smaller than 38.6 [nm]. ln this case, the retardation Rp is a value greater than 90% but smaller than 110% of the parameter α2 under the condition that the retardation Rtac is a general value, i.e. approximately 30 [nm] to 80 [nm]. Therefore, by setting the retardation Rn to be a value greater than 90% but smaller than 110% of the parameter β2, it is possible to realize the liquid crystal display device **1***b* having values within the area A**2**, i.e. the liquid crystal display device **1***b* with an extremely excellent viewing angle property. Also in this case, even in the case where the retardation Rtac varies depending on the variations of the TAC films **12***b* and **13***b* caused in the manufacturing process, it is possible to fix a type of the positive uniaxial film **14**, thus improving the productivity.

EXAMPLE 2

ln the present example, the same liquid crystal cells **11** and the TAC films **12***b* and **13***b* were prepared as in the Example 1. For all combinations of the liquid crystal cells **11** with the TAC films **12***b* and **13***b* calculated were the respective retardations Rp and Rn where the contrast when viewed from the same oblique direction as that in Example 1 became the maximum. According to this, the experimental result shown in FlG. **11** could be obtained.

As result of this, in the arrangement in which the positive uniaxial film **14** was layered between the negative uniaxial film **15** and the liquid crystal cell **11**, as shown in FlG. **9**, it was confirmed that the liquid crystal display device **1***b* with the maximum contrast could be attained under the condition that the retardation Rp in the in-plane direction of the positive uniaxial film **14** was equal to the foregoing parameter α2 and the retardation Rn in the thickness direction of the negative uniaxial film **15** was equal to the foregoing parameter β2. Further, the foregoing expressions (5) and (6) could be calculated from the experimental result.

Further, it was confirmed that in the case of the liquid crystal cells **11** prepared above, using the above-prepared

general TAC films **12***b* and **13***b* (Rtac=30, 50, 80 [nm]), the optimal value of the retardation Rp in the in-plane direction of the positive uniaxial film **14** was from 35 to 49 [nm], and in the case where the thickness of the liquid crystal cell **11** was 3.0 [μm] and 4.0 [μm], that is, in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** was 240 [nm] and 320 [nm], the optimal value of the retardation Rp increased with the increase in the retardation Rtac. lt was also confirmed that in the case where the thickness of the crystal cell **11** was 5.0 [μm] (the retardation Rlc was 400 [nm]), the optimal value of the retardation Rp decreased with the increase in the retardation Rtac.

Further, by setting the retardation Rlc in the thickness direction of the liquid crystal cell **11** to 360 [nm], it was confirmed that the retardation Rp where the contrast became the maximum when viewed from the foregoing oblique direction is approximately constant in spite of the change in the retardation Rtac.

ln addition, from the estimation of the contrast with changes in the retardations Rp and Rn by 5% each at a time, it was confirmed that even in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** and the retardation Rtac of the TAC films **12***b* and **13***b* had any of the foregoing values, the contrast from the oblique direction (at the polar angle of 60 degrees) was above 20 under the condition that the retardations Rp and Rn were values ranging from 85% to 115% of the parameters α2 and β2, respectively.

Further, it was confirmed that even in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** and the retardation Rtac of the TAC films **12***b* and **13***b* had any of the foregoing values under the condition that the retardations Rp and Rn were in the ranges from 90% to 110% of the parameters α2 and β2, respectively, the viewer from the oblique direction (at the polar angle of 60 degrees) could not visually recognize the differences from the liquid crystal display devices **1***b* with the values shown in FlG. **11**.

Further, by setting the retardation Rlc of the liquid crystal cell **11** to be in the range from 324 [nm] to 396 [nm] and setting the retardation Rp in the in-plane direction of the positive uniaxial film **14** to be in the range from 32.6 [nm] to 39.9 [nm], it was confirmed that the contrast when the liquid crystal display device **1***b* was viewed from an oblique direction was above 20 under the condition that the retardation Rtac was a general value. lt was also confirmed that the viewer from the oblique direction could not visually recognize the differences from the liquid crystal display devices **1***b* with the values shown in FlG. **11** under the condition that the retardation Rlc was a value greater than 342 [nm] but smaller than 378 [nm], and the retardation Rp was a value greater than 33.3 [nm] but smaller than 38.6 [nm].

Third Embodiment

A liquid crystal display device **1***c* according to the present embodiment has an arrangement similar to that of the liquid crystal display device **1** shown in FlG. **1**. However, instead of the positive uniaxial film **14** and the negative uniaxial film **15**, a biaxial film (phase difference film) **16** is layered between the liquid crystal cell **11** and the polarizing plate **12** shown in FlG. **12**.

The biaxial film **16** is an optically anisotropic film having the property of nx2>ny2>nz2, where nx2 and ny2 are refractive indexes in the in-plane direction of the film, and nz2 is a refractive index in the normal direction. Let a film thickness be d2, retardation Rxy in the in-plane direction and retardation Rz in the thickness direction can be calculated by the following respective expressions (7) and (8):

$$Rxy=d2\cdot(nx2-ny2) \tag{7}$$

$$Rz=d2\cdot\{(nx2+ny2)/2-nz2\} \tag{8}$$

Further, the biaxial film **16** is disposed so that its in-plane retardation axis SL**16** is orthogonal to the absorption axis AA**12** of the polarizing plate **12** at the same side when viewed from the liquid crystal cell **11**.

Also in such a case, in the case where a liquid crystal cell **11** in which liquid crystal molecules are vertically oriented is viewed from an oblique direction, the biaxial film **16** compensates the phase difference that the liquid crystal cell **11** brings to transmitting light. Therefore, if the retardation of the biaxial film **16** is properly set, the contrast when viewed from an oblique direction can be enhanced.

Further, in the liquid crystal display device **1***c* according to the present embodiment, the retardation of the biaxial film **16** is set as described below so that the contrast when viewed from an oblique direction can be kept at an extremely high value of 20 or more.

Specifically, when retardation Rtac [nm] in the thickness direction of the TAC films **12***b* and **13***b* and a parameter α3 [nm] relative to the retardation Rxy in the in-plane direction are expressed by the following expression (9):

$$\alpha3=85-0.09\times Rlc-Rtac/20 \tag{9},$$

the retardation Rxy in the in-plane direction of the biaxial film **16** is set to be a value greater than 85% but smaller than 115% of the parameter α3.

Further, when retardation Rlc [nm] in the thickness direction of the liquid crystal cell **11** and a parameter β3 [nm] relative to the retardation Rz are expressed by the following expression (10):

$$\beta3=1.05\times Rlc-1.9\times Rtac \tag{10},$$

the retardation Rz in the thickness direction of the biaxial film **16** is set to be a value greater than 85% but smaller than 115% of the parameter β3.

Thus, by setting the retardations Rxy and Rz to be in an area A**1** shown in FlG. **13** with reference to the parameters α3 and β3, it is possible to surely attain the liquid crystal display device **1***c* with the contrast of an extremely high value of 20 or more when viewed from an oblique direction.

Further, the contrast when viewed from an oblique direction becomes the maximum when the retardations Rxy and Rz are set to be equal to the parameters α3 and β3, respectively. However, especially by setting the retardations Rxy and Rz to be greater than 90% but smaller than 110% of the parameters α3 and β3, respectively, as an area A**2** shown in FlG. **13**, it is possible to surely attain the liquid crystal display device **1***c* with a sufficiently high contrast when viewed from an oblique direction to such an extent that a viewer cannot visually recognize the difference from the liquid crystal display device in which the retardations Rxy and Rz are set so that the contrast becomes the maximum value.

As a liquid crystal display device **1***d* shown in FlG. **14**, biaxial films **16***a* and **16***b* into which the biaxial film **16** shown in FlG. **12** is divided may be disposed on the two sides of the liquid crystal cell **11**, respectively. Note that, in this case, the biaxial films **16***a* and **16***b* respectively correspond to first and second phase difference films recited in the claims.

In this case, the biaxial film **16***a* is disposed so that its retardation axis SL**16***a* in the in-plane direction is orthogonal to the absorption axis AA**12** of the polarizing plate **12** at the same side when viewed from the liquid crystal cell **11**. Similarly, the biaxial film **16***b* is disposed so that its retardation axis SL**16***b* is orthogonal to the absorption axis AA**13** of the polarizing plate **13** at the same side when viewed from the liquid crystal cell **11**. Also in this case, the same effect can be obtained by setting each of the retardations Rxya and Rxyb in the in-plane direction of the respective biaxial films **16***a* and **16***b* to be half of the retardation Rxy in the in-plane direction of the biaxial film **16** and setting each of the retardations Rza and Rzb in the thickness direction of the respective biaxial films **16***a* and **16***b* to be half of the retardation Rz in the thickness direction of the biaxial film **16**.

Specifically, when retardation Rtac [nm] in the thickness direction of the TAC films **12***b* and **13***b* and a parameter α4 [nm] relative to the retardations Rxya and Rxyb in the in-plane direction are expressed by the following expression (11):

$$\alpha 4 = 42.5 - 0.045 \times Rlc - Rtac/40 \quad (11),$$

each of the retardations Rxya and Rxyb in the in-plane direction of the respective biaxial films **16***a* and **16***b* are set to be values greater than 85% but smaller than 115% of the parameter α4.

Further, when retardation Rlc [nm] in the thickness direction of the liquid crystal cell **11** and a parameter β4 [nm] relative to the retardations Rza and Rzb are expressed by the following expression (12):

$$\beta 4 = 0.525 \times Rlc - 0.95 \times Rtac \quad (12),$$

each of the retardations Rza and Rzb in the thickness direction of the respective biaxial films **16***a* and **16***b* are set to be values greater than 85% but smaller than 115% of the parameter β4.

As in the case of the liquid crystal display device **1***c*, this makes it possible to surely attain the liquid crystal display device **1***d* with the contrast of an extremely high value of 20 or more when viewed from an oblique direction.

Further, as in the case of the liquid crystal display device **1***c*, the contrast when viewed from an oblique direction becomes the maximum when each of the retardations Rxya and Rxyb are set to be equal to the parameter α4, and each of the retardations Rza and Rzb are set to be equal to the parameter β4. However, especially by setting each of the retardations Rxya and Rxyb to be greater than 90% but smaller than 110% of the parameter α4, and setting each of the retardations Rza and Rzb to be greater than 90% but smaller than 110% of the parameter β4, it is possible to surely attain the liquid crystal display device **1***d* with a sufficiently high contrast when viewed from an oblique direction to such an extent that a viewer cannot visually recognize the difference from the liquid crystal display device in which the retardations Rxya, Rxyb, Rza, and Rzb are set so that the contrast becomes the maximum value.

EXAMPLE 3

In the present example, the same liquid crystal cells **11** and the TAC films **12***b* and **13***b* were prepared as in the Example 1. For all combinations of the liquid crystal cells **11** with the TAC films **12***b* and **13***b* calculated were the respective retardations Rxy and Rz where the contrast when viewed from the same oblique direction as that in Example 1 became the maximum. According to this, the experimental result shown in FIG. **15** could be obtained.

As shown in FIG. **12**, in the arrangement in which the biaxial film **16** was layered between one of the polarizing plates **12** and **13** (the polarizing plate **12** in FIG. **12**) and the liquid crystal cell **11**, it was confirmed that the liquid crystal display device **1***c* with the maximum contrast could be attained under the condition that the retardation Rxy in the in-plane direction of the biaxial film **16** was equal to the foregoing parameter α3 and the retardation Rz in the thickness direction of the biaxial film **16** was equal to the foregoing parameter β3. Further, by approximating the experimental result with a linear expression, the foregoing expressions (9) and (10) could be calculated.

Further, it was confirmed that in the case of the liquid crystal cells **11** prepared above, using the above-prepared general TAC films **12***b* and **13***b* (Rtac=30, 50, 80 [nm]), the optimal value of the retardation Rxy in the in-plane direction was from 45 to 65 [nm], and although the retardation Rtac was a retardation in the thickness direction, the retardation Rtac was influential to the retardation Rxy in the in-plane direction of the biaxial film **16**, and it was impossible to easily handle the influence of the TAC films **12***b* and **13***b*.

In addition, from the estimation of the contrast with changes in the retardations Rxy and Rz by 5% each at a time, it was confirmed that even in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** and the retardation Rtac of the TAC films **12***b* and **13***b* had any of the foregoing values, the contrast from the oblique direction (at the polar angle of 60 degrees) was above 20 under the condition that the retardations Rxy and Rz were values ranging from 85% to 115% of the parameters α3 and β3, respectively.

Further, it was confirmed that even in the case where the retardation Rlc in the thickness direction of the liquid crystal cell **11** and the retardation Rtac of the TAC films **12***b* and **13***b* had any of the foregoing values under the condition that the retardations Rxy and Rz were in the ranges from 90% to 110% of the parameters α3 and β3, respectively, the viewer from the oblique direction (at the polar angle of 60 degrees) could not visually recognize the differences from the liquid crystal display devices **1***c* with the values shown in FIG. **15**.

Also in the arrangement in which the biaxial film **16** was divided into two films, as the liquid crystal display device id shown in FIG. **14**, even when the retardations Rlc and Rtac were any of the foregoing values, each of the retardations Rxya, Rxyb, Rza, and Rzb for obtaining the maximum contrast at the oblique viewing angle (polar angle of 60 degrees) were half of the values in the liquid crystal display device **1***c* shown in FIG. **12**. Also in the liquid crystal display device **1***d*, as in the case of the liquid crystal display device **1***c*, it was confirmed that the contrast from the oblique direction (at the polar angle of 60 degrees) was above 20 under the condition that the retardations Rxya and Rxyb and the retardations Rza and Rzb were values ranging from 85% to 115% of the parameters α4 and β4, respectively, and the difference from the liquid crystal display device in which the retardations Rxya, Rxyb, Rza, and Rzb were set so that the contrast became the maximum could not be visually recognized from the oblique direction under the condition that the retardations Rxya and Rxyb and the retardations Rza and Rzb were in the ranges from 90% to 110% of the parameters α4 and β4, respectively.

Note that, explained in the foregoing first to third embodiments is the case where the orientation direction of the liquid crystal molecules in the pixel is divided into four directions in the liquid crystal cell **11** arranged as shown in FIGS. **2**

though **4**. However, the present invention is not limited to this. For example, other structures, such as structures shown in FIGS. **16** and **17**, in which the orientation direction is divided into four directions, can also obtain the same effect.

More specifically, a liquid crystal cell using a pixel electrode **21***a* shown in FIG. **16** is provided with a quadrangular pyramid-shaped protrusion **24** formed on the pixel electrode **21***a*, instead of the protrusions **23***a* and **23***b* shown in FIG. **4**. Note that, the protrusion **24**, as the protrusions **23***a*, can be formed by the application of a photosensitive resin on the pixel electrode **21***a* and the process of photolithography.

Also in this arrangement, the liquid crystal molecules near the protrusion **24** are oriented so as to be vertical to each of the slopes. In addition, when a voltage is applied, the electric filed in the part of the protrusion **24** tilts in the parallel direction to the slope of the protrusion **24**. As a result of these, when a voltage is applied, the in-plane component of the orientation angle in the liquid crystal molecules is equal to the in-plane component in the normal direction to the slope that is the nearest to the liquid crystal molecules (directions P**1**, P**2**, P**3** or P**4**). Therefore, the pixel region is divided into four domains D**1** to D**4** of mutually different orientation directions when the liquid crystal molecules tilt. As a result of this, it is possible to obtain the same effect as that of the liquid crystal cell **11** with the structure shown in FIGS. **2** through **4**.

Note that, in the case where a large-size liquid crystal television such as a 40-inch liquid crystal television, for example, is manufactured, the size of each pixel becomes as large as 1 mm square, and one protrusion **24** alone provided each on the pixel electrode **21***a* produces week orientation control force, which may cause an unstable orientation. Thus, as in this case, in the case where orientation control force is insufficient, it is desirable that a plurality of protrusions **24** are provided on each of the pixel electrode **21***a*.

Further, a multi-domain vertical alignment can be also realized with the arrangement in which an orientation control window **25** where Y-shaped slits are connected symmetrically in the up-and-down direction (the in-plane direction that is parallel to any of the sides of the substantially square pixel electrode **21***a*) is provided on the counter electrode **21***b* of the counter substrates **11***b*, for example, as shown in FIG. **17**.

When a voltage is applied, the foregoing arrangement does not produce enough electric field to tilt the liquid crystal molecules in the region right below the orientation control window **25**, of the surface area of the counter substrate **11***b*, and the liquid crystal molecules are vertically oriented. On the other hand, in the region surrounding the orientation control window **25**, of the surface area of the counter substrate **11***b*, as it goes close to the counter substrate **11***b*, an electric field spreads so as to escape from the orientation control window **25**. Here, the long axes of the liquid crystal molecules tilt in the vertical direction to the electric field, and the in-plane component in the orientation direction of the liquid crystal molecules become substantially vertical to each side of the orientation control window **25**, as indicated by arrows in FIG. **17**. Therefore, also in this arrangement, the orientation direction of the liquid crystal molecules in the pixel can be divided into four directions, and it is possible to obtain the same effect as that of the liquid crystal cell **11** with the structure shown in FIGS. **2** though **4**.

Further, explained in the above description is the case where the orientation direction is divided into four directions. The structure using a radial alignment liquid crystal cell **11**, as shown in FIGS. **18** and **19**, can also obtain the same effect.

More specifically, in the structure shown in FIG. **18**, instead of the protrusion **24** shown in FIG. **16**, a substantially hemispherical protrusion **26** is provided. Also in this case, the liquid crystal molecules near the protrusion **26** are oriented so as to be vertical to the surface of the protrusion **26**. In addition, when a voltage is applied, an electric field in the part of the protrusion **26** tilts in the parallel direction to the surface of the protrusion **26**. From these results, the liquid crystal molecules, in tilting when a voltage is applied, tend to tilt in a radial pattern about the protrusion **26** in the in-plane direction, and the liquid crystal molecules in the liquid crystal cell **11** can tilt and orient in a radial pattern. Note that, the protrusion **26** can be formed in the same process as that of the protrusion **24**. Further, as the protrusion **24**, in the case where orientation control force is insufficient, it is desirable that a plurality of protrusions **26** are provided on each of the pixel electrodes **21***a*.

In the structure shown in FIG. **19**, instead of the protrusion **24** shown in FIG. **16**, a circular slit **27** is provided to the pixel electrode **21***a*. When a voltage is applied, this arrangement does not produce enough electric field to tilt the liquid crystal molecules in the region right on the slit **27**, of the surface of the pixel electrode **21***a*. Therefore, in this region, even when a voltage is applied, the liquid crystal molecules are oriented vertically. On the other hand, in the region near the slit **27**, of the surface of the pixel electrode **21***a*, as it gets close to the slit **27** in the thickness direction, the electric field spreads obliquely so as to escape from the slit **27**. Here, the long axes of the liquid crystal molecules tilt in the vertical direction. According to the continuity of liquid crystal, the liquid crystal molecules away from the slit **27** are also oriented in the same direction. Thus, when a voltage is applied to the pixel electrode **21***a*, the liquid crystal molecules can be oriented so that the in-plane components of the orientation direction spread in a radial pattern about the slit **27** as indicated by arrows in FIG. **19**, that is, the liquid crystal molecules can be oriented symmetrically to the center of the slit **27**. Here, since the tilt of the electric field varies depending on applied voltage, a substrate's normal direction component (tilt angle) in the orientation direction of the liquid crystal molecules can be controlled by applied voltage. Note that, since the increase in applied voltage increases a tilt angle to the substrate's normal direction, the liquid crystal molecules are oriented substantially in parallel with a display screen as well as in a radial pattern in a plane. Further, as the protrusion **26**, in the case where orientation control force is insufficient, it is desirable that a plurality of slits **27** are provided on each of the pixel electrodes **21***a*.

Incidentally, explained in the above description is the case where the orientation direction of the liquid crystal molecules in the pixel is divided. However, a liquid crystal cell without orientation division (a mono-domain liquid crystal cell) can also obtain the same effect.

In this case, the pixel electrode **21***a* and the counter electrode **21***b*, which are not provided with the protrusions **23***a* and others, are formed evenly. In the mono-domain vertical alignment liquid crystal cell, unlike a multi-domain vertical alignment or radial tilt alignment liquid crystal cell, a rubbing process is included in the manufacturing process, and rubbing directions of the liquid crystal molecules in the liquid crystal layer **11***c* are set so as not to be parallel between the substrates **11***a* and **11***b*. The liquid crystal cell **11** and the polarizing plate **12** and **13** are disposed so that the rubbing direction forms an angle of 45 degrees with the

absorption axes AA12 and AA13 of the respective polarizing plates **12** and **13**. Also in this case, when no voltage is applied, the liquid crystal molecules in the pixel are oriented in the substrate's normal direction (in the vertical direction), as in the case of FIG. **2**. Therefore, it is possible to obtain the same effect by using the same polarizing plates **12** and **13** and phase difference plates (**14** to **16**, **16***a* and **16***b*) as those in the above embodiments.

Incidentally, according to the liquid crystal display devices **1**, **1***a*, **1***b*, and **1***c* shown in FIGS. **1**, **6**, **9** and **12**, respectively, the optical properties of members disposed from the liquid crystal cell **11** to the polarizing plate **12** on one side are not equal to those of members disposed from the liquid crystal cell **11** to the polarizing plate **13** on the other side, so that there is the possibility that the contrast when the liquid crystal cell **11** is viewed from an azimuth on the left side may be different from that viewed from an azimuth on the right side, and the contrast when the liquid crystal cell **11** is viewed from an azimuth on the upper side may different from that viewed from an azimuth on the bottom side. Therefore, in the case where these liquid crystal display devices **1**, **1***a*, **1***b*, and **1***c* requires the viewing angle property balanced in the left, right, upper, and bottom directions, it is desirable to use a liquid crystal cell in which the orientation direction of the liquid crystal molecules in each pixel is divided into four or more directions, such as four division alignment liquid crystal cells and radial alignment liquid crystal cells.

Further, as an example explained in the above description is the case where the liquid crystal cell **11** has the liquid crystal layer **11***c* with a negative dielectric anisotropy; however, the present invention is not limited to this. The liquid crystal cell **11** having the liquid crystal layer **11***c* with a positive dielectric anisotropy can also obtain the same effect, provided that the liquid crystal cell is the one in which the liquid crystal molecules are oriented vertically to the substrate of the liquid crystal cell **11** in black displaying, as the structure in FIG. **2**.

In this case, an electric field is applied to the liquid crystal layer **11***c* in the parallel direction to substrates by using an electrode that produces an electric field in the parallel direction to substrates, as an electrode of a comblike structure which is used in the IPS (In-Plane Switching) mode. Also in this case, when no voltage is applied (when there is no electric field), the liquid crystal molecules in the pixel are oriented in the vertical direction to the substrates, as the structure in FIG. **2**. Therefore, it is possible to obtain the same effect by using the same polarizing plates **12** and **13** and the phase difference plates (**14** to **16**, **16***a* and **16***b*) as those in the above embodiments.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art intended to be included within the scope of the following claims.

What is claimed is:

1. A liquid crystal display device, comprising:

a liquid crystal cell which is provided with two substrates to sandwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other;

a first phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a positive uniaxial anisotropy; and

a second phase difference film, provided between the second polarizing plate and the liquid crystal cell, having a negative uniaxial anisotropy,

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the first phase difference film being provided so that a retardation axis of the first phase difference film is orthogonal to the absorption axis of the first polarizing plate,

the second phase difference film being provided so that an optical axis of the second phase difference film is substantially vertical to the substrates,

wherein:

when a parameter α [nm] relative to Rp is:

$$\alpha=135-0.7\times Rtac;\ \text{and}$$

a parameter β [nm] relative to Rn is:

$$\beta=Rlc-65-1.4\times Rtac,$$

where Rp [nm] is a retardation in an in-plane direction of the first phase difference film, Rn [nm] is a retardation in a thickness direction of the second phase difference film, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal,

the retardation Rp is set to be in a range from 85% to 115% of the parameter α, and the retardation Rn is set to be in a range from 85% to 115% of the parameter β.

2. The liquid crystal display device according to claim **1**, wherein:

the retardation Rp is set to be the parameter α, and the retardation Rn is set to be the parameter β.

3. The liquid crystal display device according to claim **1**, wherein the liquid crystal has a negative dielectric anisotropy.

4. The liquid crystal display device according to claim **1**, wherein the liquid crystal cell is a multi-domain vertical alignment liquid crystal cell.

5. A liquid crystal display device, comprising:

a liquid crystal cell which is provided with two substrates to sahdwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other;

a first phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a positive uniaxial anisotropy; and

a second phase difference film, provided between the first phase difference film and the liquid crystal cell, having a negative uniaxial anisotropy,

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the first phase difference film being provided so that a retardation axis of the first phase difference film is orthogonal to the absorption axis of the first polarizing plate,

the second phase difference film being provided so that an optical axis of the second phase difference film is substantially vertical to the subtrates,

wherein:

when a parameter α [nm] relative to Rp is:

$$\alpha=135-0.7\times Rtac; \text{ and}$$

a parameter β [nm] relative to Rn is:

$$\beta=Rlc-65-1.4\times Rtac,$$

where Rp [nm] is a retardation in an in-plane direction of the first phase difference film, Rn [nm] is a retardation in a thickness direction of the second phase difference film, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] isa retardation in a thickness direction of the liquid crystal,

the retardation Rp is set to be in,a range from 85% to 115% of ihe parameter α, and the retardation Rn is set to be in a range from 85% to 115% of the parameter β.

6. The liquid crystal display device according to claim **5**, wherein:

the retardation Rp is set to be the parameter α, and the retardation Rn is set to be the parameter β.

7. The liquid crystal display device according to clain **5**, wherein the liquid crystal has a negative dielectric anisotropy.

8. The liquid crystal display device according to claim **5**, wherein the liquid crystal cell is a multi-domain vertical alignment liquid crystal cell.

9. A liquid crystal display device, comprising:

a liquid crystal cell which is provided with two substrates to sahdwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other;

a first phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a positive uniaxial anisotropy; and

a second phase difference film, provided between the first polarizing plate and the first phase difference film, having a negative uniaxial anisotropy,

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the first phase difference film being provided so that a retardation axis of the first phase difference film is orthogonal to the absorption axis of the first polarizing plate,

the second phase difference film being provided so that an optical axis of the second phase difference film is substantially vertical to the substrates,

wherein:

when a parameter α [nm] relative to Rp is:

$$\alpha=35+(RIc/80-4)^2\times 3.5+(360\sim Rlc)\times Rtac/850; \text{ and}$$

a parameter β [nm] relative to Rn is:

$$\beta=Rlc-1.9\times Rtac,$$

where Rp [nm] is a retardation in an in-plane direction of the first phase difference film, Rn [nm] is a retardation in a thickness direction of the second phase difference film, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal,

the retardation Rp is set to be in a range from 85% to 115% of the parameter α, and the retardation Rn is set to be in a range from 85% to 115% of the parameter β.

10. The liquid crystal display device according to claim **9**, wherein:

the retardation Rlc in the thickness direction of the liquid crystal is set to be a value greater than 342 [nm] but smaller than 378 [nm], and the retardation Rp in the in-plane direction of the first phase difference film is set to be a value greater than 33.3 [nm] but smaller than 38.6 [nm].

11. The liquid crystal display device according to claim **9**, wherein:

the retardation Rp is set to be the parameter α, and the retardation Rn is set to be the parameter β.

12. The liquid crystal display device according to claim **9**, wherein the liquid crystal has a negative dielectric anisotropy.

13. The liquid crystal display device according to claim **9**, wherein the liquid crystal cell is a multi-domain vertical alignment liquid crystal cell.

14. A liquid crystal display device, comprising:

a liquid crystal cell which is provided with two substrates to sandwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other; and

a phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a biaxial anisotropy,

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the phase difference film being provided so that an in-plane retardation axis of the phase difference film is orthogonal to the absorption axis of the first polarizing plate,

wherein:

when a parameter α [nm] relative to Rxy is:

$$\alpha=85-0.09\times Rlc-Rtac/20; \text{ and}$$

a parameter β [nm] relative to Rz is:

$$\beta=1.05\times Rlc\ 1.9\times Rtac,$$

where Rxy [nm] is a retardation in an in-plane direction of the phase difference film, Rz [nm] is a retardation in a thickness direction of the phase difference film, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal,

the retardation Rxy is set to be in a range from 85% to 115% of the parameter α, and the retardation Rz is set to be in a range from 85% to 115% of the parameter β.

15. The liquid crystal display device according to claim **14**, wherein:

the retardation Rxy is set to be the parameter α, and the retardation Rz is set to be the parameter β.

16. The liquid crystal display device according to claim **14**, wherein the liquid crystal has a negative dielectric anisotropy.

17. The liquid crystal display device according to claim **14**, wherein the liquid crystal cell is a multi-domain vertical alignment liquid crystal cell.

18. A liquid crystal display device, comprising:

a liquid crystal cell which is provided with two substrates to sandwich a liquid crystal and to cause liquid crystal molecules in the liquid crystal to orient substantially vertically to surfaces of the two substrates;

first and second polarizing plates which are provided on two sides of the liquid crystal cell, respectively, so that absorption axes of the polarizing plates are orthogonal to each other;

a first phase difference film, provided between the first polarizing plate and the liquid crystal cell, having a biaxial anisotropy; and

a second phase difference film, provided between the second polarizing plate and the liquid crystal cell, having a biaxial anisotropy;

the first and second polarizing plates being provided with respective base films, which are provided so that optical axes of the base films are substantially vertical to the substrates, each of the base films having a negative uniaxial anisotropy,

the first and second phase difference films being provided so that in-plane retardation axes of the first and second phase difference films are orthogonal to the absorption axes of the first and second polarizing plates, respectively,

wherein:

when a parameter α [nm] relative to Rxy is:

$$\alpha=42.5-0.045\times Rlc-Rtac/40;\ \text{and}$$

a parameter β [nm] relative to Rz is:

$$\beta=0.525\times Rlc-0.95\times Rtac,$$

where Rxy [nm] is a retardation in an in-plane direction of each of the first and second phase difference films, Rz [nm] is a retardation in a thickness direction of each of the first and second phase difference films, Rtac [nm] is a retardation in a thickness direction of the base films, and Rlc [nm] is a retardation in a thickness direction of the liquid crystal,

the retardation Rxy of the first and second phase difference films is set to be in a range from 85% to 115% of the parameter α, and the retardation Rz of the first and second phase difference films is set to be in a range from 85% to 115% of the parameter β.

19. The liquid crystal display device according to claim **18**, wherein:

the retardation Rxy is set to be the parameter α, and the retardation Rz is set to be the parameter β.

20. The liquid crystal display device according to claim **18**, wherein the liquid crystal has a negative dielectric anisotropy.

21. The liquid crystal display device according to claim **18**, wherein the liquid crystal cell is a multi-domain vertical alignment liquid crystal cell.

22. The liquid crystal display device according to claim **1**, wherein the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller than 110% of the parameter β.

23. The liquid crystal display device according to claim **5**, wherein the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller than 110% of the parameter β.

24. The liquid crystal display device according to claim **9**, wherein the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller than 110% of the parameter β.

25. The liquid crystal display device according to claim **14**, wherein the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller than 110% of the parameter β.

26. The liquid crystal display device according to claim **18**, wherein the retardation Rp is set to be greater than 90% but smaller than 110% of the parameter α, and the retardation Rn is set to be greater than 90% but smaller than 110% of the parameter β.

* * * * *

专利名称(译)	液晶显示装置		
公开(公告)号	US7176999	公开(公告)日	2007-02-13
申请号	US10/377660	申请日	2003-03-04
[标]申请(专利权)人(译)	MIYACHI KOICHI		
申请(专利权)人(译)	MIYACHI KOICHI		
当前申请(专利权)人(译)	夏普株式会社		
[标]发明人	MIYACHI KOICHI		
发明人	MIYACHI, KOICHI		
IPC分类号	G02F1/13 G02B5/30 G02F1/13363 G02F1/1337 G02F1/139		
CPC分类号	G02F1/1393 G02F1/133634		
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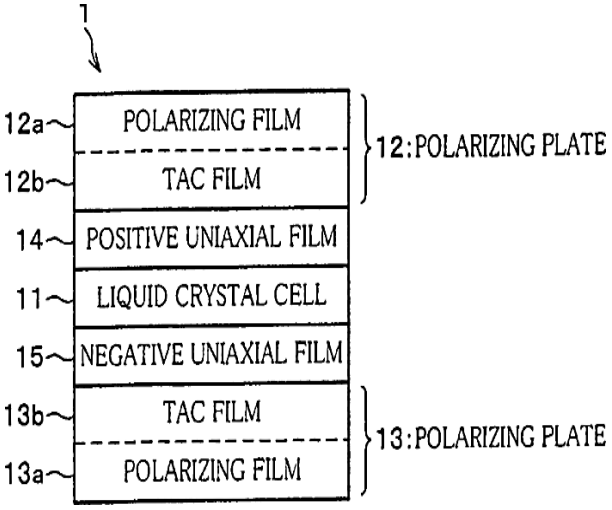
摘要(译)

在垂直取向模式液晶单元11和偏振板12之间提供具有在面内方向上的延迟Rp [nm]的正单轴膜14，以及具有Rn [nm]的延迟的负单轴膜15在液晶单元11和偏振板13之间设置厚度方向。另外，当相对于Rp的参数α1[nm]为：α1= 135-0.7×Rtac;相对于Rn的参数β1[nm]为：β1= Rlc-65-1.4×Rtac，其中Rtac [nm]是偏振片12和13的各个三乙酰纤维素膜12b和13b在厚度方向上的延迟，相对于参数α1和β1，延迟Rp和Rn分别设定为大于90％但小于110％的值。这使得可以可靠地提供一种垂直配向模式液晶显示装置，当从倾斜方向观察时，该液晶显示装置能够保持高对比度。