(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 August 2004 (12.08.2004)

PCT

(10) International Publication Number
WO 2004/068223 A1

(51) International Patent Classification[7]: G02F 1/1335

(21) International Application Number: PCT/KR2004/000131

(22) International Filing Date: 27 January 2004 (27.01.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10-2003-0005466 28 January 2003 (28.01.2003) KR

(71) Applicant (*for all designated States except US*): **LG CHEM, LTD** [KR/KR]; LG Twin Towers, East Tower, 20, Yeouido-dong, Yeongdeungpo-gu, Seoul 150-721 (KR).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **JEON, Byoung-kun** [KR/KR]; #203 LG Sataik Shinyonrip, Doryong-dong Yuseong-gu, Daejeon 305-740 (KR). **BELYAEV, Sergey** [RU/KR]; 6-201 LG Sataik, Doryong-dong Yuseong-gu, Daejeon 305-740 (KR). **YU, Jeong Su** [KR/KR]; 107-1501 Hanwool APT, Sinseong-dong Yuseong-gu, Daejeon 305-345 (KR).

(74) Agent: **CHO, In-jae**; NewKorea Int'l Patent & Law Office, 3rd Fl., Janghyun Bldg., 637-23, Yeoksam-dong Gangnam-gu, Seoul 135-909 (KR).

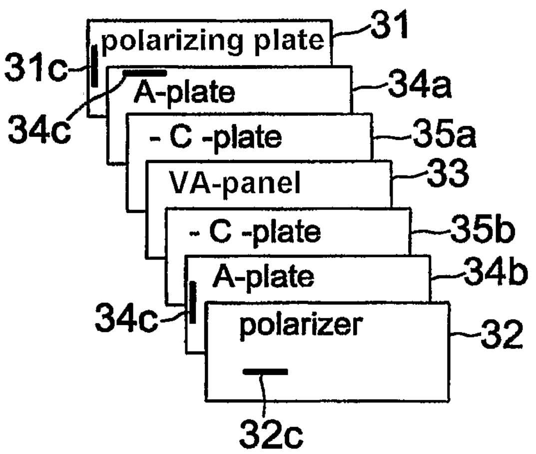
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: VERTICALLY ALIGNED LIQUID CRYSTAL DISPLAY HAVING POSITIVE COMPENSATION FILM



(57) Abstract: The present invention relates to a vertically aligned LCD (VA-LCD) comprising a positive compensation film including one or more of a first retardation film (+A-plate) satisfying the condition of $n_x > n_y = n_z$ and a second retardation film (-C-plate) satisfying the condition of $n_x = n_y > n_z$, wherein the first retardation film is arranged such that its optical axis is perpendicular to an optical absorption axis of a neighboring polarizing plate, and a total thickness retardation ($R_{-C}+R_{VA}$) including the thickness retardation of the second retardation film and the thickness retardation of a VA-panel has a positive value in then range of 50~150nm. The VA-LCD in accordance with the present invention improves contrast characteristics on a front surface and at a tilt angle and minimizes coloring in a black state according to the tilt angle.

WO 2004/068223 A1

VERTICALLY ALIGNED LIQUID CRYSTAL DISPLAY HAVING POSITIVE COMPENSATION FILM

TECHNICAL FIELD

The present invention relates to a vertically aligned liquid crystal display (hereinafter, referred to as a "VA-LCD") using a compensation film having a positive retardation value so as to improve viewing angle characteristics.

BACKGROUND ART

As well known to those skilled in the art, a -C-plate compensation film and an A-plate compensation film have been used to compensate for a black state of a VA-LCD under the condition that small drive voltage is applied. U.S. Patent Serial No. 4,889,412 discloses a conventional VA-LCD using the -C-plate compensation film.

However, the conventional VA-LCD using the -C-plate compensation film does not completely compensate for a black state, thus having a disadvantage such as a leakage of light at a viewing angle.

Further, U.S. Patent Serial No. 6,141,075 discloses a conventional VA-LCD comprising both the -C-plate compensation film and the A-plate compensation film.

The above VA-LCD comprising both the -C-plate compensation film and the A-plate compensation film more completely achieves compensation of a black state under the condition that small drive voltage is applied.

However, the above-described conventional VA-LCDs require improvements of contrast and coloring at a front surface and a tilt angle in order to completely compensate for the black state.

DISCLOSURE OF THE INVENTION

Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide an achromatic VA-LCD comprising a positive compensation film, in which contrast at a front surface and a tilt angle of the VA-LCD filled with liquid crystal having a positive or negative dielectric anisotropy is improved, and coloring at the tilt angle in a black state is minimized, thus improving viewing angle characteristics.

In accordance with the present invention, the above and other objects can be accomplished by the provision of a vertically aligned LCD (VA-LCD) in a multi-domain mode or using a chiral additive, provided with a positive compensation film, in which a vertically aligned panel (VA-panel) is obtained by injecting liquid crystal having a negative dielectric anisotropy ($\Delta\varepsilon < 0$) or a positive dielectric anisotropy ($\Delta\varepsilon > 0$) into a gap between upper and lower glass substrates, upper and lower polarizing plates are arranged above the upper and lower surfaces of the VA-panel so that optical absorption axes of the polarizing plates are perpendicular to each other, and a cell gap in the range of 3μm to 8μm is maintained, comprising: the positive compensation film including one or more of a first retardation film (+A-plate) satisfying the condition of $n_x > n_y = n_z$, and a second retardation film (-C-plate) satisfying the condition of $n_x = n_y > n_z$, for forming a liquid crystal cell, in which the n_x and n_y represent in-plane refractive indexes between the VA-panel and the upper and lower polarizing plates and the n_z represents a thickness refractive index, wherein the first retardation film is arranged such that an optical axis of the first retardation film is perpendicular to an optical absorption axis of the neighboring polarizing plate, and a total thickness retardation ($R_{-C}+R_{VA}$) including the thickness retardation of the second retardation film and the thickness retardation of the VA-panel has a positive value.

In Example 1 according to the present invention, the positive compensation film may include one of a first retardation film (+A-plate) and one of a second retardation film (-C-plate) in which one of the first retardation film and the second retardation film may be selectively arranged between the VA-panel and the upper polarizing plate, and the other one of the second retardation film is arranged between the VA-panel and the lower polarizing plate, or all of the first retardation film and the second retardation film are arranged at one area between the VA-panel and the upper polarizing plate, or between the VA-panel and the lower polarizing plate.

In Example 2 according to the present invention, the positive compensation film may include two of a first retardation film (+A-plate) and one of a second retardation film (-C-plate), in which one of the first retardation film and one of the second retardation film may be arranged at one area between the VA-panel and the upper polarizing plate, or between the VA-panel and the lower polarizing plate, and the other one of the first retardation film is arranged at the other area between the VA-panel and the upper polarizing plate, or between the VA-panel and the lower polarizing plate.

In Example 3 according to the present invention, the positive compensation film may include two of a first retardation film (+A-plate) and two of a second retardation film (-C-plate), in which one of the first retardation film and one of the second retardation film may be arranged between the VA-panel and the upper polarizing plate, and the other one of the first retardation film and the other one of the second retardation film are arranged between the VA-panel and the lower polarizing plate.

In each of the above examples according to the present invention, a first retardation film (+A-plate) may have a reversed wavelength dispersion in which retardation is increased in proportion to the increase of a wavelength in the range of visible rays, and has a retardation in the range of 20～200nm, preferably 130～160nm at a wavelength of 550nm. The ratio ($R_{A,400}/R_{A,550}$) of the in-plane retardations of the first retardation film (A-plate) is in the range of 0.6 to 0.9; and the ratio ($R_{A,700}/R_{A,500}$) of the in-plane retardations of the first retardation film (A-plate) is in the range of 1.1 to 1.5, wherein the $R_{A,400}$, $R_{A,500}$, $R_{A,550}$ and $R_{A,700}$ represent in-plane retardations at wavelengths of 400nm, 500nm, 550nm and 700nm, respectively.

Also, in each of the above examples according to the present invention, a second retardation (-C-Plate) film has a retardation in the range of -100～-400nm at a wavelength of 550nm, and the total thickness retardation ($R_{-C}+R_{VA}$) including the thickness retardation of a second retardation film and the thickness retardation of the VA-panel may be in the range of 50nm to 150nm, being proportional to a wavelength in the range of visible rays, and a relative retardation($R_{-C,400}/R_{-C,550}$) at wavelengths of 400nm and 550nm is larger than that of the VA-panel at the same wavelength and a relative retardation($R_{-C,700}/R_{-C,550}$) at wavelengths of 550nm and 700nm is smaller than that of the VA-panel at the same wavelength. Preferably, the thickness relative retardation($R_{-C,400}/R_{-C,550}$) at 400nm and 550nm of the second retardation film(-C-plate) has in the range of 1.1~1.3, and the thickness relative retardation($R_{-C,700}/R_{-C,550}$) at 550nm and 700nm of the second retardation film(-C-plate) has in the range of 0.8~0.9.

Also, in each of the above examples according to the present invention, directors of liquid crystalline polymers of the VA-panel, under the condition that small voltage is applied to the VA-panel, may have a pretilt angle in the range of 75° to 90° between the upper and lower glass substrates. The pretilt angle is preferably in the range of 87° to 90°, more preferably in the range of 89° to 90°.

Also, in each of the above examples according to the present invention, a liquid crystalline layer formed on the VA-panel may have a retardation at a wavelength of 550nm, in the range of 80nm to 400nm, preferably in the range of 80nm to 300nm. A rubbed direction of the liquid crystals injected into the VA-panel may have an angle of 45° with the optical absorption axes of the polarizing plates.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Figs. 1a to 1d are perspective views of a VA-LCD cell comprising a positive compensation film in accordance with a first embodiment of the present invention;

Figs. 2a and 2b are perspective views of a VA-LCD cell comprising a positive compensation film in accordance with a second embodiment of the present invention;

Fig. 3 is a perspective view of a VA-LCD cell comprising a positive compensation film in accordance with a third embodiment of the present invention;

Fig. 4 is a graph showing a thickness retardation ($R_{VA,550}$) of a VA-LCD at 550nm in relation to the ratio ($R_{-C,400}/R_{-C,550}$) of a thickness retardation of a second film at 400nm and a thickness retardation of a second film at 550nm;

Fig. 5 is a graph showing the results of simulation for wavelength dependability of a thickness retardation of the VA-LCD cell, a thickness retardation of a second retardation film (C-plate), its absolute value, and a total thickness retardation in the VA-LCD cell comprising the positive compensation film of the present invention;

Fig. 6 is a diagram showing the result of simulation for a contrast ratio of the VA-LCD cell comprising a positive compensation film in accordance with Example 1 of the present invention at a tilt angle in the range of 0° to 80° at all azimuth angles, in case that a white ray is applied;

Fig. 7 is a diagram showing the result of simulation for coloring of the VA-LCD cell comprising a positive compensation film in accordance with Example 1 of the present invention in a black state at a tilt angle in the range of 0° to 80°, which is varied by an interval of 2°, at an azimuth angle of 45°, in case that a white ray is applied;

Fig. 8 is a diagram showing the results of simulation for a contrast ratio of the VA-LCD cell comprising a positive compensation film in accordance with Example 2 of the present invention at a tilt angle in the range of 0° to 80° at all azimuth angles, in case that a white ray is applied; and

Fig. 9 is a diagram showing the results of simulation for coloring of the VA-LCD cells in accordance with examples 1 and 2 of the present invention in a black state at a tilt angle in the range of 0° to 80°, which is varied by an interval of 2°, at an azimuth angle of 45°, in case that a white ray is applied.

BEST MODE FOR CARRYING OUT THE INVENTION

Now, preferred embodiments of the present invention will be described in detail with reference to the annexed drawings.

Figs. 1 to 3 respectively illustrate VA-LCD cells comprising a positive compensation film in accordance with each of examples of the present invention.

Figs. 1a to 1d are perspective views of a VA-LCD cell comprising a positive compensation film including one of a first retardation film (+A-plate) and one of a second retardation film (-C-plate), in accordance with Example 1 of the present invention. Figs. 2a and 2b are perspective views of a VA-LCD cell comprising a positive compensation film including two of the first retardation film (+A-plates) and one of the second retardation film (-C-plate), in accordance with Example 2 of the present invention. Fig. 3 is a perspective view of a VA-LCD cell comprising a positive compensation film including two of the first retardation film (+A-plates) and two of the second retardation film (-C-plates), in accordance with Example 3 of the present invention.

Example 1

As shown in Figs. 1a to 1d, a VA-LCD in accordance with Example 1 of the present invention comprises a vertically aligned panel (VA-panel) 13 obtained by injecting liquid crystal having a negative dielectric anisotropy ($\Delta\varepsilon < 0$) or a positive dielectric anisotropy ($\Delta\varepsilon > 0$) into a gap between upper and lower glass substrates, two polarizing plates 11 and 12 arranged above the upper and lower surfaces of the VA-panel 13 so that optical absorption axes 11c and 12c are perpendicular to each other, and a positive compensation film including a first retardation film (+A-plate) 14 and a second retardation film (-C-plate) 15, which are arranged between the VA-panel 13 and the polarizing plates 11 and 12.

In Fig. 1a, a first retardation film (+A-plate) 14 is arranged between the VA-panel 13 and the lower polarizing plate 11, and a second retardation film (-C-plate) 15 is arranged between the VA-panel 13 and the upper polarizing plate 12. Here, the first retardation film (+A-plate) 14 is arranged such that an optical axis 14c of the first retardation film (+A-plate) 14 is perpendicular to the optical absorption axis 11c of the lower polarizing plate 11, thus serving as a compensation film for compensating for retardation.

In Fig. 1b, illustrating a modification of Example 1 shown in Fig. 1a, a first retardation film (+A-plate) 14 is arranged between the VA-panel 13 and the upper polarizing plate 12, and a second retardation film (-C-plate) 15 is arranged between the VA-panel 13 and the lower polarizing plate 11. Here, the first retardation film (+A-plate) 14 is arranged such that the optical axis 14c of the first retardation film (+A-plate) 14 is perpendicular to the optical absorption axis 12c of the upper polarizing plate 12.

In Fig. 1c illustrating another modification of Example 1 shown in Fig. 1a, a first retardation film (+A-plate) 14 and a second retardation film (-C-plate) 15 are arranged between the VA-panel 13 and the upper polarizing plate 12. Here, the first retardation film (+A-plate) 14 is arranged such that the optical axis 14c of the first retardation film (+A-plate) 14 is perpendicular to the optical absorption axis 12c of the upper polarizing plate 12.

In Fig. 1d illustrating yet another modification of Example 1 shown in Fig. 1a, a first retardation film (+A-plate) 14 and a second retardation film (-C-plate) 15 are arranged between the VA-panel 13 and the upper polarizing plate 12. However, the positions of the first retardation film (+A-plate) 14 and the second retardation film (-C-plate) 15 are opposite to the positions of the first retardation film (+A-plate) 14 and the second retardation film (-C-plate) 15 in Fig. 1c. Here, the first retardation film (+A-plate) 14 is arranged such that the optical axis 14c of the first retardation film (+A-plate) 14 is perpendicular to the optical absorption axis 12c of the upper polarizing plate 12.

Example 2

As shown in Figs. 2a and 2b, a VA-LCD in accordance with Example 2 of the present invention comprises two polarizing plates 21 and 22 arranged such that optical absorption axes 21c and 22c are perpendicular to each other, a vertically aligned panel (VA-panel) 23 is interposed between the two polarizing plates 21 and 22, and a positive compensation film including two of the first retardation film (+A-plate) 24a and 24b and one of the second retardation film (-C-plate) 25, which are arranged between the VA-panel 23 and the polarizing plates 21 and 22. One of the first retardation films (+A-plates) 24a and 24b and the second retardation film (-C-plate) 25 are arranged at one area between the VA-panel 23 and the upper polarizing plate 22, or between the VA-panel 23 and the lower polarizing plate 21, and the other one of the first retardation film is arranged at the other area between the VA-panel 23 and the upper polarizing plate 22, or between the VA-panel 23 and the lower polarizing plate 21.

In Fig. 2a, a first retardation film (+A-plate) 24a is arranged between the VA-panel 23 and the lower polarizing plate 21, and a first retardation film (+A-plate) 24b and a second retardation film (-C-plate) 25 are arranged between the VA-panel 23 and the upper polarizing plate 22. Here, the first retardation film (+A-plate) 24a is arranged between the VA-panel 23 and the lower polarizing plate 21 such that an optical axis 24c of the first retardation film (+A-plate) 24a is perpendicular to the optical absorption axis 21c of the lower polarizing plate 21, and the first retardation film (+A-plate) 24b is arranged between the VA-panel 23 and the upper polarizing plate 22 such that an optical axis 24c of the first retardation film (+A-plate) 24b is perpendicular to the optical absorption axis 22c of the upper polarizing plate 22.

In Fig. 2b illustrating a modification of Example 2 shown in Fig. 2a, a first retardation film (+A-plate) 24b is arranged between the VA-panel 23 and the upper polarizing plate 22, and a first retardation film (+A-plate) 24a and a second retardation film (-C-plate) 25 are arranged between the VA-panel 23 and the lower polarizing plate 21. Here, the first retardation film (+A-plate) 24b is arranged between the VA-panel 23 and the upper polarizing plate 22 such that the optical axis 24c of the first retardation film (+A-plate) 24b is perpendicular to the optical absorption axis 22c of the upper polarizing plate 22, and the first retardation film (+A-plate) 24b is arranged between the VA-panel 23 and the lower polarizing plate 21 such that the optical axis 24c of the first retardation film (+A-plate) 24a is perpendicular to the optical absorption axis 21c of the lower polarizing plate 21.

Example 3

As shown in Fig. 3, a VA-LCD in accordance with Example 3 of the present invention comprises two polarizing plates 31 and 32 arranged such that optical absorption axes 31c and 32c are perpendicular to each other, a vertically aligned panel (VA-panel) 33 is interposed between the two polarizing plates 31 and 32, and a positive compensation film including two of a first retardation film (+A-plates) 34a and 34b and two of a second retardation film (-C-plates) 35a and 35b, which are arranged between the VA-panel 33 and the polarizing plates 31 and 32. One of the first retardation films (+A-plates) 34a and 34b and one of the second retardation films (-C-plates) 35a and 35b are arranged at one area between the VA-panel 33 and the upper polarizing plate 32 and between the VA-panel 33 and the lower polarizing plate 31, and the other one of the first retardation films (+A-plates) 34a and 34b and the other one of the second retardation films (-C-plates) 35a and 35b are arranged at the other area between the VA-panel 33 and the upper polarizing plate 32 and between the VA-panel 33 and the lower polarizing plate 31.

In Fig. 3, a first retardation film (+A-plate) 34a and a second retardation film (-C-plate) 35a are arranged between the VA-panel 33 and the lower polarizing plate 31, and a first retardation film (+A-plate) 34b and a second retardation film (-C-plate) 35b are arranged between the VA-panel 33 and the upper polarizing plate 32. Here, the first retardation film (+A-plate) 34a is arranged between the VA-panel 33 and the lower polarizing plate 31 such that an optical axis 34c of the first retardation film (+A-plate) 34a is perpendicular to the optical absorption axis 31c of the lower polarizing plate 31, and the first retardation film (+A-plate) 34b is arranged between the VA-panel 33 and the upper polarizing plate 32 such that an optical axis 34c of the first retardation film (+A-plate) 34b is perpendicular to the optical absorption axis 32c of the upper polarizing plate 32.

The above-described VA-LCD in accordance with each of Example 1 to 3 of the present invention is a multi-domain vertically aligned LCD (MVA-LCD) or a VA-LCD using a chiral additive, which maintains a cell gap in the range of 3μm to 8μm and is obtained by forming the VA-panel by injecting liquid crystal having a negative dielectric anisotropy ($\Delta\varepsilon < 0$) or a positive dielectric anisotropy ($\Delta\varepsilon > 0$) into a gap between upper and lower glass substrates and arranging two polarizing plates above the upper and lower surfaces of the VA-panel so that optical absorption axes of the polarizing plates are perpendicular to each other. Here, since the positive compensation film including at least one of a first retardation film (+A-plate) and at least one of a second retardation film (-C-plate) is arranged between the VA-panel and the upper and lower polarizing plates, the VA-LCD has a characteristic such that a total thickness retardation ($R_{-C}+R_{VA}$) including a retardation of the second retardation film (-C-plate) and a retardation of the VA-panel has a positive value.

A first retardation film (+A-plate), used as the compensation film of the respective embodiments of the present invention, has $n_x>n_y=n_z$ wherein n_x and n_y are a in-plane refractive index and n_z is a thickness refractive index, and have a reversed wavelength dispersion in which retardation is increased in proportion to the increase of a wavelength in the range of visible rays, so that an optical axis of the first retardation film (+A-plate) is perpendicular to the optical absorption axis of the adjacent polarizing plate. Particularly, the first retardation film has a retardation in the range of 20~200nm, preferably 130nm~160nm at a wavelength of 550nm. The ratio ($R_{A,400}/R_{A,550}$) of relative retardations at wavelengths of 400nm and 550nm of the first retardation film (A-plate) is in the range of 0.6~0.9, and the ratio ($R_{A,700}/R_{A,500}$) of relative retardations at wavelengths of 700nm and 500nm thereof is in the range of 1.1~1.5.

A second retardation film (-C-plate), used as the compensation film of the respective embodiments of the present invention, has $n_x=n_y>n_z$, and a retardation in the range of -100~-400nm at a wavelength of 550nm. The total thickness retardation ($R_{-C}+R_{VA}$), including the retardation of a second retardation film (-C-plate) and the retardation of the VA-panel, has a value preferably in the range of 50~150nm in the range of visible rays. In particular, a relative retardation ($R_{-C,400}/R_{-C,550}$) at 400nm and 550nm of the second retardation film is larger than that of the VA-panel at the same wavelength, and a relative retardation ($R_{-C,700}/R_{-C,550}$) at 700nm and 550nm of the second retardation film is smaller than that of the VA-panel at the same wavelength. Preferably, a thickness relative retardation ($R_{-C,400}/R_{-C,550}$) at 400nm and

550nm of the second retardation film(-C-plate) is in the range of 1.1~1.3, and a thickness relative retardation ($R_{-C,700}/R_{-C,550}$) at 700nm and 550nm thereof is in the range of 0.8~0.9.

Under the condition that no voltage is applied to the VA-panel in accordance with each of examples of the present invention, directors of liquid crystalline polymers of the VA-panel have a pretilt angle in the range of 75° to 90° between the upper and lower substrates, preferably in the range of 87° to 90°, and more preferably in the range of 89° to 90°.

Further, a liquid crystalline layer formed on the VA-panel in accordance with each of the embodiments of the present invention has a retardation in the range of 80nm to 400nm at a wavelength of 550nm, and preferably in the range of 80nm to 300nm. A rubbed direction of liquid crystals injected into the VA-panel has an angle of 45° with the optical absorption axis of the polarizing plate.

The polarizing plate applied to each of examples of the present invention includes a TAC (Triacetate Cellulose) protective film having designated thickness retardation, or one of other protective films having no designated thickness retardation.

Effects of the VA-LCD by examples of the present invention are described in the following taken in conjunction with the accompanying drawings.

Fig. 4 is a graph showing a thickness retardation

($R_{VA,550}$) of a VA-LCD at 550nm in relation to the ratio ($R_{-C,400}/R_{-C,550}$) of a thickness retardation of a second film at 400nm and a thickness retardation of a second film at 550nm; and Fig. 5 is a graph showing the results of simulation for wavelength dependability of a thickness retardation ($R_{VA}>0$) 43 of the VA-panel, a thickness retardation ($R_{-C}<0$) 45′ of a second retardation film (-C- plate), its absolute value 45, a total thickness retardation ($R_{VA}+R_{-C}>0$) 46. Here, there is applied an achromatic positive compensation film in which the total thickness retardation ($R_{VA}+R_{-C}>0$) of the retardations of the VA-panel and a second retardation film (-C- plate) has a positive value.

The thickness retardation ($R_{-C,\ 550}$) of a second retardation film (-C- plate), which is required to compensate for the VA-LCD, is obtained by the following equation.

$$R_{VA,\ 550} + R_{-C,\ 550} = 100\text{nm} \sim 130\text{nm (mean value: 115nm)}$$

$$R_{VA,\ 550} = (d \times \Delta n_{550})_{VA}$$

Here, $R_{VA,\ 550}$ represents a thickness retardation of the VA-panel at a wavelength of 550nm, and $R_{-C,\ 550}$ represents a thickness retardation of the second retardation film (-C- plate) at a wavelength of 550nm.

A wavelength dispersion $(\Delta n_{\lambda}/\Delta n_{550})_{-C}$ required by the second retardation film (-C-plate) is calculated by the following equation.

$$(\Delta n_{\lambda}/\Delta n_{550})_{VA} \times R_{VA,550} + (\Delta n_{\lambda}/\Delta n_{550})_{-C} \times R_{-C,550} = 115\text{nm}$$

Here, $(\Delta n_{\lambda}/\Delta n_{550})_{VA}$ represents a wavelength dispersion of the thickness retardation of the VA-LCD, and $(\Delta n_{\lambda}/\Delta n_{550})_{-C}$ represents a wavelength dispersion of the thickness retardation of a second retardation film (-C-plate).

In particular, for any wavelength(λ=400nm),

$$(\Delta n_{400}/\Delta n_{550})_{VA} \times R_{VA,550} + (\Delta n_{400}/\Delta n_{550})_{-C} \times R_{-C,550} = 115\text{nm}$$

The calculated results for a relative value of a thickness retardation ($R_{-C,400}/R_{-C,550} = (\Delta n_{\lambda}/\Delta n_{550})_{VA}$) of a second retardation film(-C-plate) for $R_{VA,550}$ are shown in Fig. 4.

The optimum condition for a in-plane retardation $R_{\lambda}=0.25\times\lambda$ of a first retardation film(A-plate) is an achromatic quarter wave(λ/4) film.

Accordingly, a relative retardation is

$$R_{400}/R_{500} = 400/500 = 0.727,\ R_{700}/R_{550} = 700/500 = 1.273$$

Figs. 6 to 9 show the results of simulation obtained in respective examples of the present invention. Figs. 6 and 8 show the results of simulation for a contrast ratio, using a color coordinate, obtained by the VA-LCD of the respective examples of the present invention at a tilt angle in the range of 0° to 80° at all azimuth angles, in case that a white ray is applied. Figs. 7 and 9 show the results of simulation for coloring in a black state, using a color coordinate, obtained by the VA-LCD of the respective examples of the present invention at a tilt angle in the range of 0° to 80°, which is varied by an interval of 2°, at an azimuth angle of 45°, in case that a white ray is applied.

Hereinafter, experimental examples for testing contrast characteristics of samples selected from the above examples of the present invention will be described. Improvements of the contrast characteristics in the respective examples will be more easily understood by the below experimental examples. The below experimental examples will be disclosed for illustrative purposes, but do not limit the subject matter of the present invention.

Experimental Example 1

A sample employed by Experimental Example 1 was the VA-LCD of Fig. 1(a) prepared by Example 1. The sample include VA-panel having a cell gap of 3μm, wherein a pretilt angle of directors of liquid crystalline polymers is 89°, a dielectric anisotropy (Δε) is -4.9, a refractive anisotropy (Δn) is

0.0979, and a wavelength dispersion ($\Delta n_{400}/\Delta n_{550}$) is 1.0979. Accordingly, a thickness retardation ($R_{VA,550}$) of the VA-panel at a wavelength of 550nm is 297nm.

And the above second retardation film (-C-plate) employed one of the compensation films is made of liquid crystal film, having a retardation ($R_{A,550}$) of 145nm at a in-plane and a wavelength dispersion ($R_{A,400}/R_{A,550}$) of 0.72.

Table 1 comparatively shows contrasts of the sample (hereinafter, referred to as a "first sample") employed by Experimental Example 1 and a sample (hereinafter, referred to as a "second sample") serving as a comparative example. Here, in the first sample, the retardation (R_{VA}) of the VA-panel, the retardation (R_{-C}) of a second retardation film, the total retardation (R_{TOTAL}) and the retardation (R_A) were 297, -47, +250 and 0, respectively. On the other hand, in the second sample, the retardation (R_{VA}) of the VA-panel, the retardation (R_{-C}) of the second retardation film, the total retardation (R_{TOTAL}) and the retardation (R_A) were 297, -500, +203 and 460, respectively. The minimum contrasts of the first and second samples at a tilt angle of 70° were 120 and 5, respectively.

Table 1

	R_{VA}	R_{-C}	R_{TOTAL}	R_A	Minimum contrast (at a tilt angle of 70°)
First sample (Experimental Example)	297	-190	+107	145	120
Second sample (Comparative Example)	297	-47	+250	0	5

In Table 1, the minimum contrasts of the first and second samples at a tilt angle of 70° were 120 and 5. Since the tilt angle of 70° has the minimum contrast, other tilt angles rather than the tilt angle of 70° have contrasts higher than the minimum contrast. Accordingly, the contrasts at other tilt angles rather than the tilt angle of 70° are higher than the minimum contrast.

Experimental Example 2

A sample employed by Example 2 was a VA-LCD of Fig. 1(d) which is one of the modified examples of Example 1.

The VA-LCD of Fig. 1(d) has a cell gap of 4㎛, a pretilt angle of 89°, a dielectric anisotropy (Δε) of -4.9, a refractive anisotropy (Δn) of 0.0979, and a wavelength dispersion ($\Delta n_{400}/\Delta n_{550}$) of 1.0979. Accordingly, the thickness retardation ($R_{VA,550}$) of the VA-panel at a wavelength of 550nm is 396nm.

And a second retardation film (-C-plate), which is employed as one of compensation films, is made of liquid crystal. The second retardation film has a thickness retardation ($R_{-C,550}$) of -279nm and a wavelength dispersion ($R_{-C,400}/R_{-C,550}$) of 1.21.

A first retardation film (A-plate), which is employed as another of compensation films, is made of hardened nematic liquid crystal. The first retardation film has a retardation ($R_{A,550}$) of 147nm at a in-plane and a wavelength dispersion ($R_{A,400}/R_{A,550}$) of 0.72.

As for a liquid crystal cell of Experimental Examples 1 and 2, Fig. 6 shows the result of simulation for contrast ratio of the above VA-LCD at a tilt angle in the range of 0° to 80° at all azimuth angles, and Fig. 7 shows the result of simulation for coloring of the above VA-LCD in a black state at a tilt angle in the range of 0° to 80° at an azimuth angle of 45°.

<u>Experimental Example 3</u>

A sample employed by Example 3 was a VA-LCD of Fig. 2(a).

The sample includes a VA-panel having a cell gap of 3㎛, a pretilt angle of 89°, a dielectric anisotropy ($\Delta\varepsilon$) of -4.9, a refractive anisotropy (Δn) of 0.0979, and a wavelength dispersion ($\Delta n_{400}/\Delta n_{550}$) of 1.0979. Accordingly, the thickness retardation ($R_{VA,550}$) of the VA-panel at a wavelength of 550nm is 297nm.

And a second retardation film (-C-plate), which is employed as one of compensation films, is made of liquid crystal. The second retardation film has a thickness retardation ($R_{-C,550}$) of -130nm and a wavelength dispersion ($R_{-C,400}/R_{-C,550}$) of 1.31.

A first retardation film (A-plate), which is employed as another of compensation films, is made of hardened nematic liquid crystal. The first retardation film has a retardation ($R_{A,550}$) of 90nm at a in-plane and a wavelength dispersion ($R_{A,400}/R_{A,550}$) of 0.72.

Experimental Example 4

A sample employed by Example 4 was a VA-LCD of Fig. 3, which is Example 3. The sample has a cell gap of 3㎛, a pretilt angle of 89°, a dielectric anisotropy ($\Delta\varepsilon$) of -4.9, a refractive anisotropy (Δn) of 0.0979, and a wavelength dispersion ($\Delta n_{400}/\Delta n_{550}$) of 1.0979. Accordingly, the thickness retardation ($R_{VA,550}$) of the VA-panel at a wavelength of 550nm is 297nm.

And a second retardation film (-C-plate), which is employed as one of compensation films, is made of liquid crystal. The second retardation film has a thickness retardation ($R_{-C,550}$) of -65nm and a wavelength dispersion ($R_{-C,400}/R_{-C,550}$) of 1.31.

Two of a first retardation film (A-plate), which is employed as another of compensation films, is made of hardened liquid crystal. The first retardation film has a retardation ($R_{A,550}$) of 90nm at a in-plane and a wavelength dispersion ($R_{A,400}/R_{A,550}$) of 0.72.

As for a liquid crystal cell of Experimental Example 3 and 4, Fig. 8 shows the result of simulation for contrast ratio of the above VA-LCD at a tilt angle in the range of 0° to 80° at all azimuth angles, and Fig. 9 shows the result of simulation for coloring of the above VA-LCD in a black state at a tilt angle in the range of 0° to 80° at an azimuth angle of 45°.

INDUSTRIAL APPLICABILITY

As apparent from the above description, the present invention provides a VA-LCD comprising a positive compensation film including at least one of a first retardation film (A-plate) and at least one of a second retardation film (-C-plate), which compensates for a dark state at a tilt angle of the VA-LCD and minimizes coloring in dark, white and RGB states, thus improving viewing angle characteristics.

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

WHAT IS CLAIMED IS:

1. A vertically aligned LCD (VA-LCD) in a multi-domain mode or using a chiral additive, provided with a positive compensation film, in which a vertically aligned panel (VA-panel) is obtained by injecting liquid crystal having a negative dielectric anisotropy ($\Delta\varepsilon<0$) or a positive dielectric anisotropy ($\Delta\varepsilon>0$) into a gap between upper and lower glass substrates, upper and lower polarizing plates are arranged above the upper and lower surfaces of the VA-panel so that optical absorption axes of the polarizing plates are perpendicular to each other, and a cell gap in the range of 3㎛ to 8㎛ is maintained, comprising:

the positive compensation film including one or more of a first retardation film (+A-plate) satisfying the condition of $n_x > n_y = n_z$, and a second retardation film (-C-plate) satisfying the condition of $n_x = n_y > n_z$, for forming a liquid crystal cell, wherein said n_x and n_y represent in-plane refractive indexes between the VA-panel and the upper and lower polarizing plates, and said n_z represents a thickness refractive index,

wherein said first retardation film is arranged such that an optical axis of said first retardation film is perpendicular to an optical absorption axis of the neighboring polarizing plate, and a total thickness retardation ($R_{-C}+R_{VA}$)

including the thickness retardation of said second retardation film and the thickness retardation of the VA-panel has a positive value.

2. The VA-LCD according to claim 1, wherein

said positive compensation film includes one of said first retardation film (+A-plate) and one of said second retardation film (-C-plate) in which

one of said first retardation film and said second retardation film is selectively arranged between the VA-panel and the upper polarizing plate, and the other one of said second retardation film is arranged between the VA-panel and the lower polarizing plate, or

said first retardation film and said second retardation film are arranged at one area between the VA-panel and the upper polarizing plate, or between the VA-panel and the lower polarizing plate.

3. The VA-LCD according to claim 1, wherein

said positive compensation film includes two of said first retardation film (+A-plate) and one of said second retardation film (-C-plate) in which

one of said first retardation film and one of said second retardation film are arranged at one area between the VA-panel and the upper polarizing plate, or between the VA-panel and the lower polarizing plate, and the other one of said first retardation films is arranged at the other area between the VA-panel and the upper polarizing plate, or between the VA-panel and the lower polarizing plate.

4. The VA-LCD according to claim 1, wherein

said positive compensation film includes two of said first retardation film (+A-plate) and two of said second retardation film (-C-plate) in which

one of said first retardation film and one of said second retardation film are arranged between the VA-panel and the upper polarizing plate, and the other one of said first retardation film and the other one of said second retardation film are arranged between the VA-panel and the lower polarizing plate.

5. The VA-LCD according to claim 1, wherein

said first retardation film (+A-plate) has a reversed wavelength dispersion in which retardation is increased in proportion to the increase of a wavelength in the range of visible rays; and

the total thickness retardation ($R_{-C}+R_{VA}$) including the thickness retardation of said second retardation film and the thickness retardation of the VA-panel is in the range of 50㎚ to 150㎚, being proportional to a wavelength in the range of visible rays.

6. The VA-LCD according to 5, wherein directors of liquid crystalline polymers of the VA-panel, under the condition that small voltage is applied to the VA-panel, have a pretilt angle in the range of 75° to 90° between the upper and lower glass substrates.

7. The VA-LCD according to claim 6, wherein said pretilt angle is in the range of 87° to 90°.

8. The VA-LCD according to claim 6, wherein said pretilt angle is in the range of 89° to 90°.

9. The VA-LCD according to claim 5, wherein a liquid crystalline layer formed on said VA-panel has a retardation in the range of 80nm to 400nm at a wavelength of 550nm.

10. The VA-LCD according to claim 9, wherein a liquid crystalline layer formed on said VA-panel has a retardation in the range of 80nm to 300nm at a wavelength of 550nm.

11. The VA-LCD according to claim 5, wherein a rubbed direction of the liquid crystals injected into said VA-panel has an angle of 45° with the optical absorption axes of said

polarizing plates.

12. The VA-LCD according to claim 5, wherein said first retardation film (A-plate) has a retardation in the range of 20~200nm at a wavelength of 550nm.

13. The VA-LCD according to claim 12, wherein said first retardation film (A-plate) preferably has a retardation in the range of 130~160nm at a wavelength of 550nm.

14. The VA-LCD according to claim 5, wherein the ratio ($R_{A,400}/R_{A,550}$) of a retardation of said first retardation (A-plate) is in the range of 0.6~0.9, and the ratio ($R_{A,700}/R_{A,500}$) of a relative retardation is in the range of 1.1~1.5.

15. The VA-LCD according to claim 5, wherein said second retardation film has a thickness retardation in the range of -100~-400nm at a wavelength of 550nm.

16. The VA-LCD according to claim 5, wherein a relative retardation ($R_{-C,400}/R_{-C,550}$) at 400nm and 550nm of said second retardation film (-C-plate) is larger than that of said VA-panel, and a relative retardation ($R_{-C,700}/R_{-C,550}$) at 700nm and 550nm of said second retardation film (-C-plate) is smaller than that of said VA-panel.

17. The VA-LCD according to claim 16, wherein a thickness relative retardation ($R_{-C,400}/R_{-C,550}$) at 400nm and 550nm of said second retardation film (-C-plate) is in the range of 1.1~1.3, and a thickness relative retardation ($R_{-C,700}/R_{-C,550}$) at 700nm and 550nm thereof is in the range of 0.8~0.9.

FIGURE 1

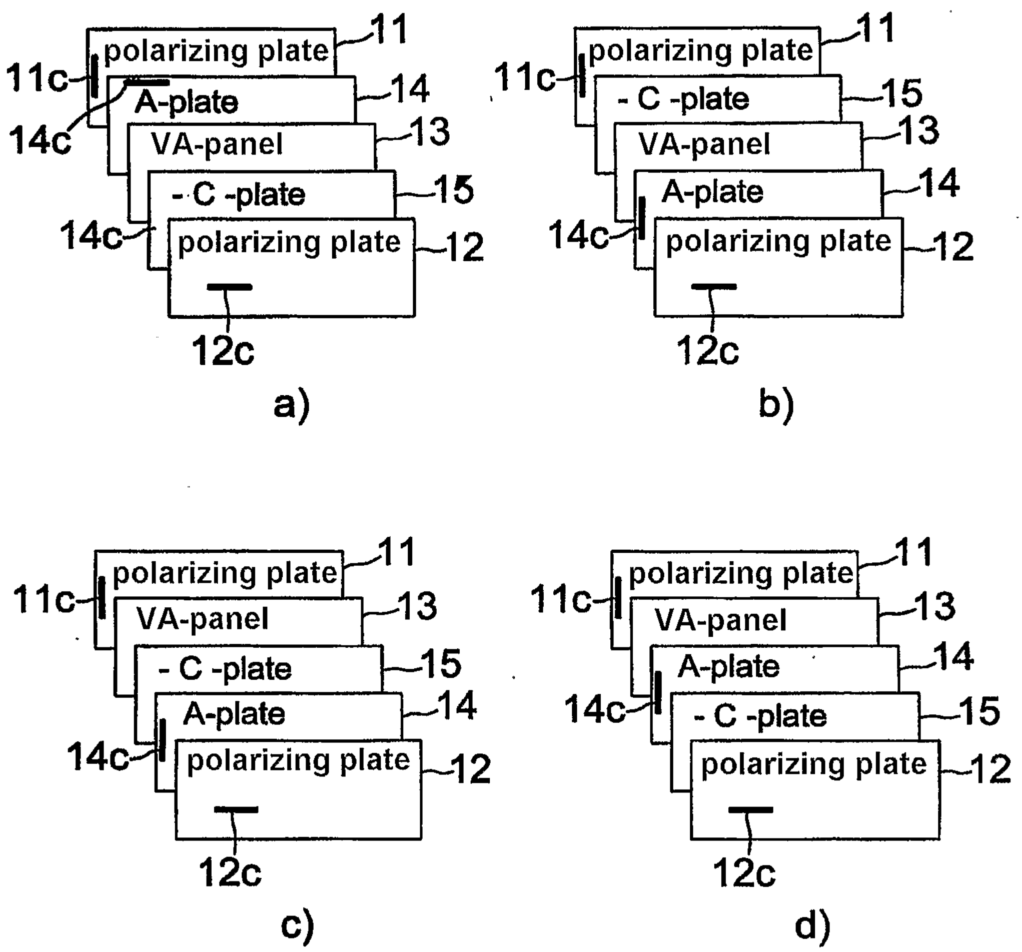
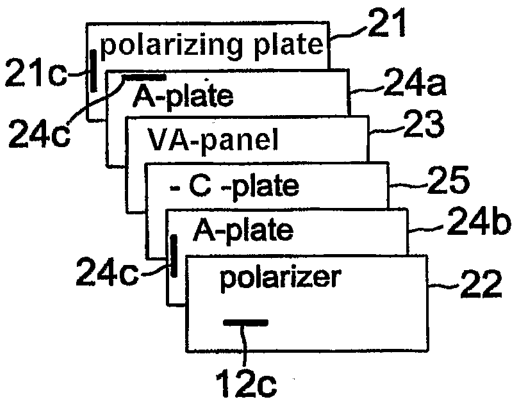
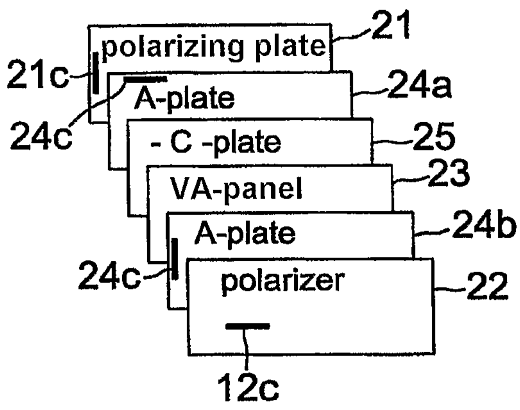

polarizing plate
11
11c
A-plate
14
14c
VA-panel
13
- C -plate
15
14c
polarizing plate
12
12c
a)
polarizing plate
11
11c
- C -plate
15
VA-panel
13
A-plate
14
14c
polarizing plate
12
12c
b)
polarizing plate
11
11c
VA-panel
13
- C -plate
15
A-plate
14
14c
polarizing plate
12
12c
c)
polarizing plate
11
11c
VA-panel
13
A-plate
14
14c
- C -plate
15
polarizing plate
12
12c
d)

FIGURE 2



a)



b)

FIGURE 3

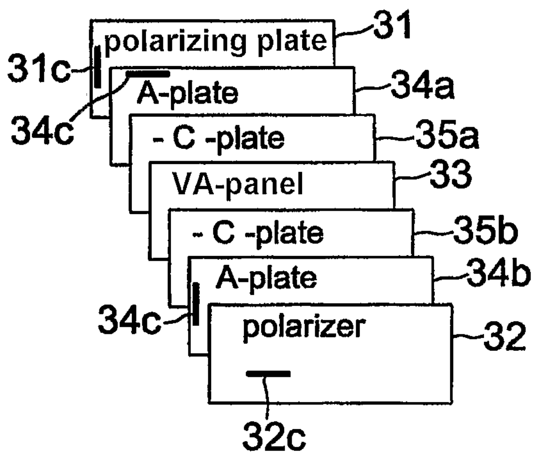
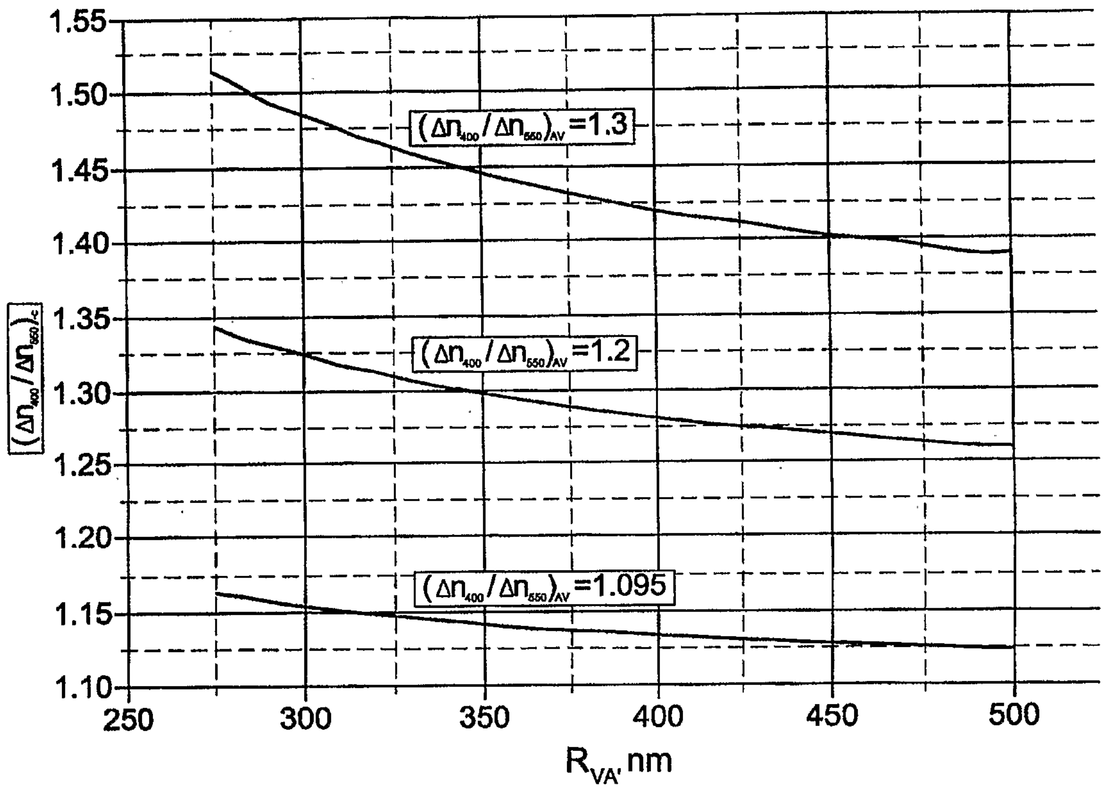


FIGURE 4



1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
$(\Delta n_{400}/\Delta n_{550})_{-c}$
$(\Delta n_{400}/\Delta n_{550})_{AV}=1.3$
$(\Delta n_{400}/\Delta n_{550})_{AV}=1.2$
$(\Delta n_{400}/\Delta n_{550})_{AV}=1.095$
250
300
350
400
450
500
$R_{VA'}$ nm

FIGURE 5

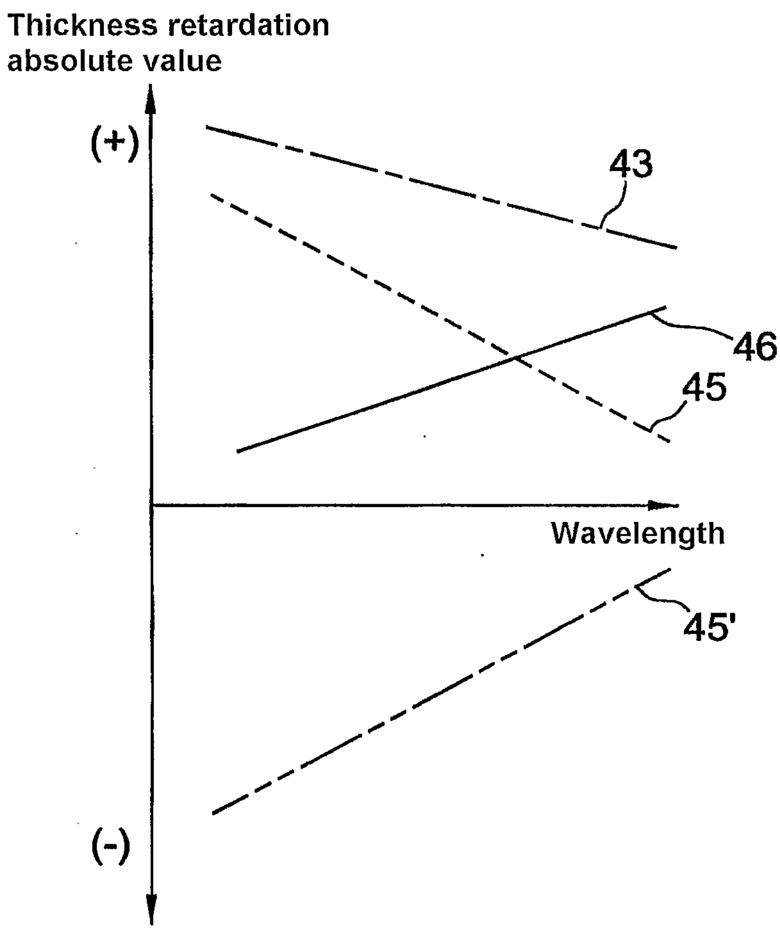

Thickness retardation
absolute value
(+)
43
46
45
Wavelength
45'
(-)

FIGURE 6

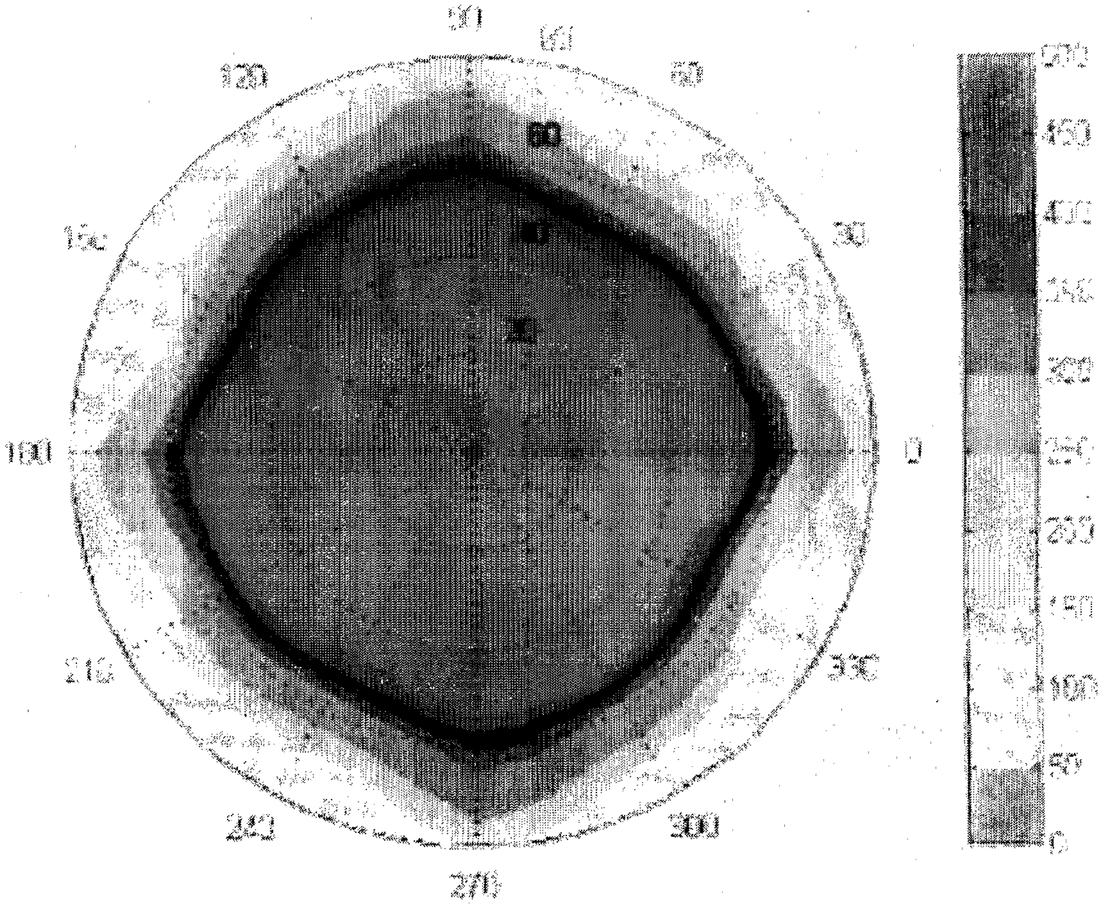


FIGURE 7

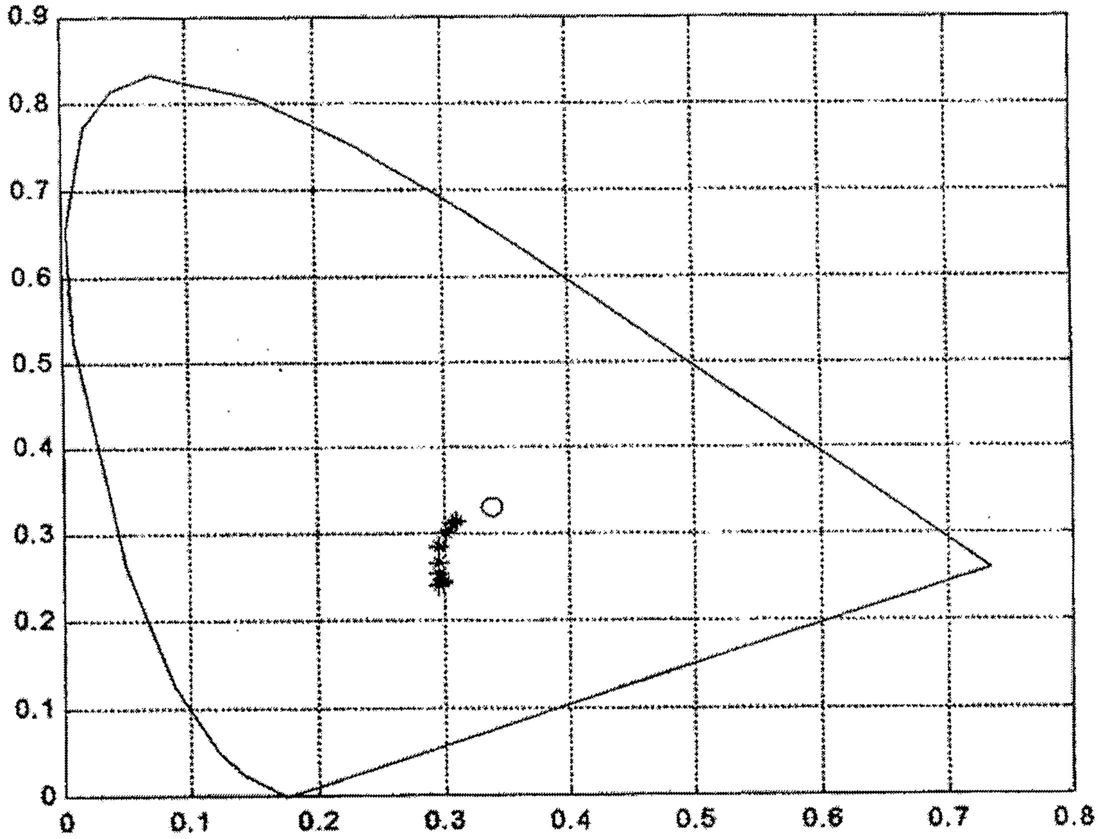


FIGURE 8

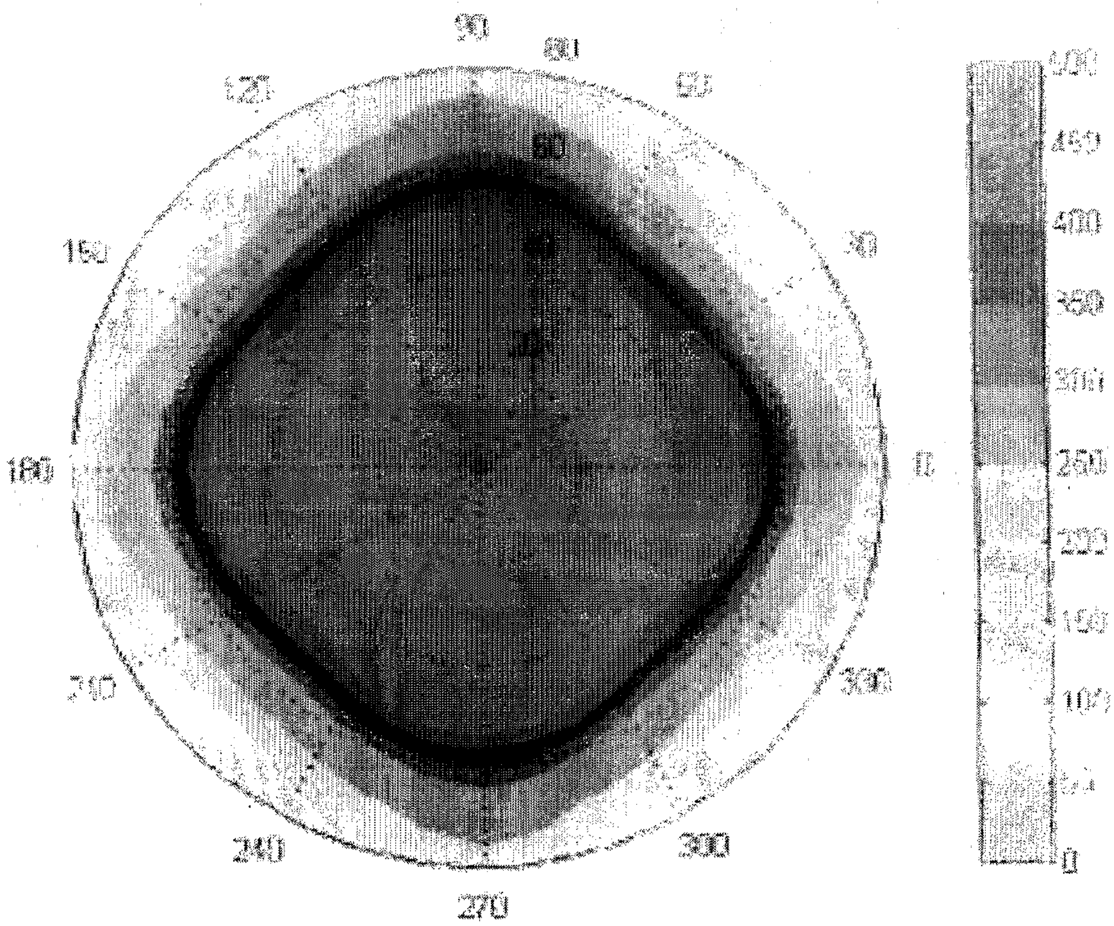
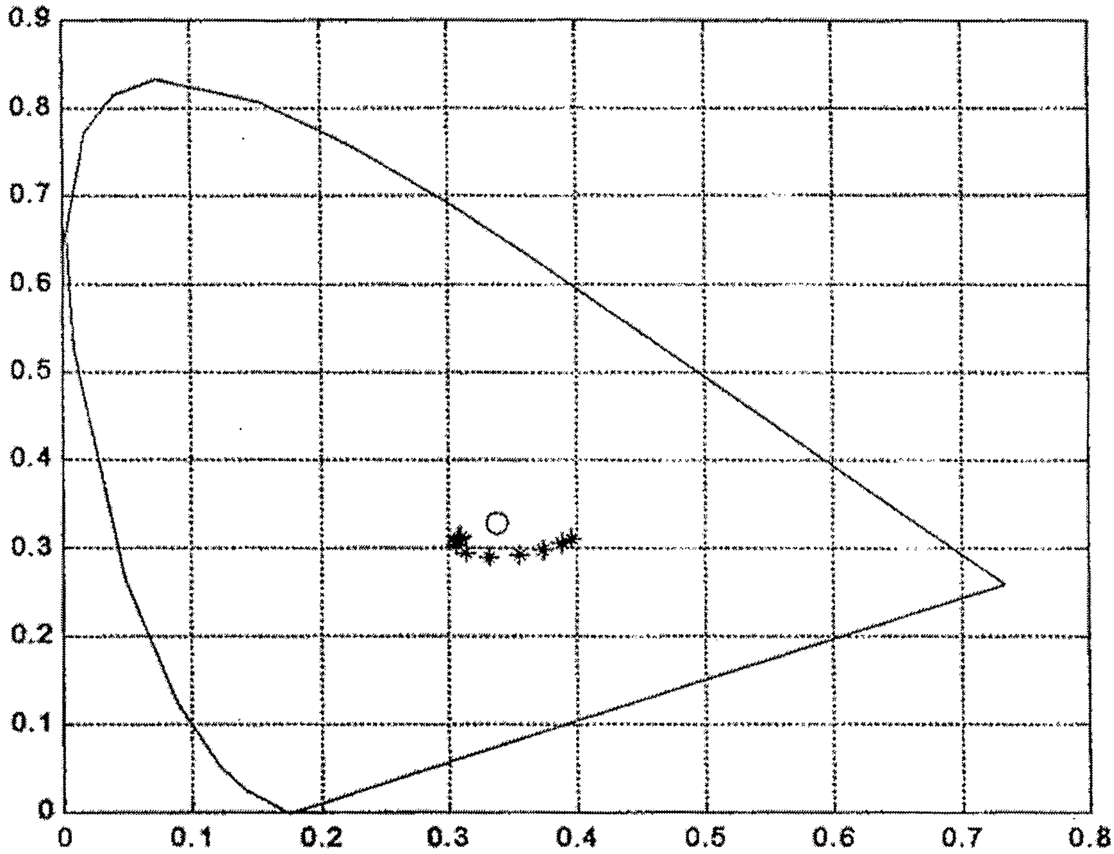

90
60
120
150
30
180
0
210
330
240
300
270
500
450
400
350
300
250
200
150
100
0

FIGURE 9



ıternational application No.
PCT/KR2004/000131

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G02F 1/1335

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
KP JP :IPC as above

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)
KIPO DB
search term:vertically alignend, retardation film

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6141075 A(Fujitsu Limited) 31 OCTOBER 2000 See the abstract See claims	1-17
A	WO 95/00879 A(CASE WESTERN RESERVE UNIVERSITY) 05 JANUARY 1995 See the whole document	1-17
A	US 4889412 A(Commissariat A l'Energie Atomique) 26 DECEMBER 1989 See the whole document	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 APRIL 2004 (28.04.2004)	29 APRIL 2004 (29.04.2004)

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office 920 Dunsan-dong, Seo-gu, Daejeon 302-701, Republic of Korea	YANG, Jae Seok
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-5988

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2004/000131

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6141075 A	31-10-2000	KR 97-0062749 A	12-09-1997
		EP 0793133 A	03-09-1997
		JP 10-123576 A	15-05-1998
WO 95/00879 A	05-01-1995	US 5477358 A	19-12-1995
US 4889412 A	26-12-1989	EP 0239433 A	30-09-1987
		JP 62-210423 A	16-09-1987

专利名称(译)	垂直排列的液晶显示器具有正补偿膜		
公开(公告)号	EP1588212A1	公开(公告)日	2005-10-26
申请号	EP2004705548	申请日	2004-01-27
[标]申请(专利权)人(译)	乐金化学股份有限公司		
申请(专利权)人(译)	LG化学有限公司.		
当前申请(专利权)人(译)	LG化学有限公司.		
[标]发明人	JEON BYOUNG KUN BELYAEV SERGEY YU JEONG SU		
发明人	JEON, BYOUNG-KUN BELYAEV, SERGEY YU, JEONG SU		
IPC分类号	G02F1/1335 G02F1/13363 G02F1/139		
CPC分类号	G02F1/133634 G02F1/1393 G02F2001/133637		
优先权	1020030005466 2003-01-28 KR		
其他公开文献	EP1588212B1 EP1588212A4		
外部链接	Espacenet		

摘要(译)

本发明涉及一种垂直排列的LCD（VA-LCD），包括正补偿膜，该正补偿膜包括满足nx> ny = nz条件的第一延迟膜（+ A-板）和第二延迟膜（ - 中的一个或多个。满足条件nx = ny> nz的C-板，其中第一延迟膜布置成使得其光轴垂直于相邻偏振片的光学吸收轴，以及总厚度延迟（R-C + RVA））包括第二延迟膜的厚度延迟和VA板的厚度延迟在50~150nm的范围内具有正值。根据本发明的VA-LCD改善了前表面上的对比度特性和倾斜角度，并且根据倾斜角度使黑色状态下的着色最小化。