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(54) **IN-PLANE SWITCHING LIQUID CRYSTAL DISPLAY COMPRISING COMPENSATION FILM FOR ANGULAR FIELD OF VIEW USING +A-PLATE AND +C-PLATE**

IN-PLANE-UMSCHALT-FLÜSSIGKRISTALLANZEIGE MIT KOMPENSATIONSFILM FÜR WINKELSICHTFELD UNTER VERWENDUNG EINER +A-PLATTE UND EINER +C-PLATTE

DISPOSITIF D'AFFICHAGE A CRISTAUX LIQUIDES A MODE DE COMMUTATION DANS LE PLAN COMPRENANT UN FILM DE COMPENSATION POUR UN CHAMP DE VISION ANGULAIRE AU MOYEN D'UNE PLAQUE A+ ET D'UNE PLAQUE C+

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EP 1 676 170 B1

Description

Technical Field

[0001] The present invention relates to a liquid crystal display (LCD), and more particularly to an in-plane switching liquid crystal display (IPS-LCD) including a compensation film using a +A-plate(s) and a +C-plate(s) in order to improve a viewing angle characteristic of the in-plane switching liquid crystal display filled with liquid crystal of positive dielectric anisotropy ($\Delta\ \varepsilon>0$).

Background Art

[0002] An IPS-LCD is disclosed in U.S. Patent No. 3,807,831. However, the IPS-LCD disclosed in U.S. Patent No. 3,807,831 does not use a compensation film. Accordingly, the above IPS-LCD represents a low contrast ratio at a predetermined inclination angle due to a relatively great amount of light leakage in the black state of the IPS-LCD.

[0003] U.S. Patent No. 5,189,538 discloses an LCD including a viewing angle compensation film using an A-plate and a positive biaxial retardation film.

[0004] In addition, U.S. Patent No. 6,115,095 discloses an IPS-LCD including a compensation film using a +C-plate and an A-plate. Characteristics of the IPS-LCD disclosed in U.S. Patent No. 6,115,095 are as follows:

1) A liquid crystal layer is horizontally aligned between two substrates in such a manner that an electric field is supplied in parallel to the liquid crystal layer by means of electrodes.
2) At least one A-plate and C-plate is sandwiched between two polarizer plate.
3) A main optical axis of an A-plate is perpendicular to a main optical axis of a liquid crystal layer.
4) A retardation value of a liquid crystal layer R_{LC}, a retardation value of a + C-plate R_{+C}, and a retardation value of an A-plate R_{+A} are determined such that they satisfy the following equation.

$$R_{LC}:R_{+C}:R_{+A} \fallingdotseq 1:0.5:0.25$$

5) A relationship between retardation values of the A-plate and C-plate and a thickness retardation value of a polarizer plate protective film (TAC, COP and PNB) is not disclosed.

[0005] A main object of using the A-plate and C-plate in U.S. Patent No. 6,115,095 is to compensate for a color shift of the IPS-LCD in a white state(a bright state). In this case, although the color shift of the IPS-LCD in the white state can be reduced, a great amount of light leakage may occur at a predetermined inclination angle of the IPS-LCD in a black state. For this reason, the IPS-LCD represents a relatively low contrast ratio at the predetermined inclination angle.

[0006] Recently, various methods of reducing the color shift in the white state has been proposed and used. For example, a two-domain liquid crystal alignment using a zig-zag type electrode structure has been suggested in order to minimize the color shift in the white state.

Brief Description of the Drawings

[0007]

FIG. 1 is a view illustrating a basic structure of an IPS-LCD.

FIG. 2 is a view illustrating an alignment of an absorption axis of a polarizer plate and an optical axis of liquid crystal in IPS-LCD panel of Fig. 1.

FIG. 3 is a view illustrating a refractive index of a retardation film.

FIGS. 4 and 5 are views illustrating structures of IPS-LCDs including a viewing angle compensation film according to one embodiment of the present invention, in which FIG. 4 is a first IPS-LCD structure, and FIG. 5 is a second IPS-LCD structure.

FIGS. 10 and 11 are graphs representing simulation results for a contrast characteristic at inclination angles of 0° to 80° in all azimuthal angles when a white light is used in a structure of an IPS-LCD including a viewing angle compensation film according to one embodiment of the present invention, in which FIG. 10 is a simulation result of a first IPS-LCD structure, and FIG. 11 is a simulation result of a second IPS-LCD structure.

FIGS. 19 to 22 are views illustrating structures of IPS-LCDs including a viewing angle compensation film according to one embodiment of the present invention, in which FIG. 19 is an eleventh IPS-LCD structure, FIG. 20 is a twelfth

IPS-LCD structure, FIG. 21 is a thirteenth IPS-LCD structure, and FIG. 22 is a fourteenth IPS-LCD structure.
FIGS. 29 and 30 are graphs representing simulation results for a contrast characteristic at inclination angles of 0° to 80° in all azimuthal angles when a white light is used in a structure of an IPS-LCD including a viewing angle compensation film according to one embodiment of the present invention, in which FIG. 29 is simulation results of eleventh and twelfth IPS-LCD structures, and FIG. 30 is simulation results of thirteenth and fourteenth IPS-LCD structures.

[0008] There are no Figs. 6-9,12-18 and 23-28.)

Disclosure of the Invention

[0009] It is an object of the present invention to provide an IPS-LCD representing a superior contrast characteristic and a low color shift at a front and at a predetermined inclination angle of the IPS-LCD by minimizing light leakage in a black state at the predetermined inclination angle.

[0010] The viewing angle characteristic of the IPS-LCD may be lowered due to a dependency of a perpendicularity between the absorption axes of two polarizer plates), to the viewing angle and a dependency of a birefringence of an IPS-LCD-panel to the viewing angle.

[0011] The present inventors have found that a +A-plate and a +C-plate are necessary to compensate for the above problems lowering the viewing angle characteristic of the IPS-LCD. Accordingly, the present inventors have designed two type retardation films of the +A-plate and +C-plate, thereby obtaining a wide viewing angle characteristic.

[0012] In addition, the present inventors have found that an optical axis direction of the +A-plate must be properly determined in match with an alignment order of the +A-plate and +C-plate positioned between a polarizer plate and an IPS-LCD panel. The present invention has been suggested on the basis of the above concepts.

[0013] Accordingly, the present invention provides an in-plane switching liquid crystal display (IPS-LCD) capable of solving the above-mentioned problems by using +A-plate and +C-plate, as defined in claims 1, 2, 5 and 6.

[0014] In detail, the present invention provides an in-plane switching liquid crystal display comprising: a first polarizer plate; a liquid crystal cell, which is horizontally aligned and filled with liquid crystal of positive dielectric anisotropy ($\Delta\varepsilon>0$), an optical axis of the liquid crystal filled in the liquid crystal cell being aligned in-plane in parallel to first polarizer plate; and a second polarizer plate, wherein an absorption axis of the first polarizer plate is perpendicular to an absorption axis of the second polarizer plate, and the optical axis of the liquid crystal filled in the liquid crystal cell is parallel to the absorption axis of the first polarizer plate,

[0015] According to the present invention, a pair of compensation films including the +A-plate and the +C-plate are aligned between the second polarizer plate (2) and the liquid crystal cell; and the optical axis of the +A-plate is aligned perpendicularly to an absorption axis (5) of the second polarizer plate if the +A-plate is adjacent to the second polarizer plate. In addition, the optical axis of the +A-plate aligned between the first polarizer plate (1) and the liquid crystal cell (3) can be aligned in parallel to or in perpendicular to an absorption axis of the first polarizer plate.

[0016] When the IPS-LCD exclusively uses the polarizer plates, a contrast ratio at the inclination angle of 70° is equal to or less than 10:1. However, the IPS-LCD of the present invention using the +A-plate and the +C-plate may represent a minimum contrast ratio above 20:1, preferably 50:1, at the inclination angle of 70°.

[0017] Reference will now be made in detail to the preferred embodiments of the present invention.

[0018] FIG. 1 is a view illustrating a basic structure of an IPS-LCD.

[0019] The IPS-LCD includes a first polarizer plate 1, a second polarizer plate 2 and an IPS-LCD panel 3. An absorption axis 4 of the first polarizer plate 1 is aligned in perpendicular to the an absorption axis 5 of the second polarizer plate 2 and the absorption axis 4 of the first polarizer plate 1 is parallel to an optical axis 6 of the IPS-LCD panel 3. In FIG. 2, two absorption axes 4 and 5 of two polarizer plates and one optical axis 6 of one IPS-LCD panel are shown.

[0020] That is, the liquid crystal display using a compensation film according to the present invention includes the first polarizer plate 1, the IPS-LCD panel 3, which is horizontally aligned between two glass substrates 15 and 16 and includes a liquid crystal cell filled with liquid crystal of positive dielectric anisotropy ($\Delta\varepsilon>0$), and the second polarizer plate 2. The optical axis 6 of the liquid crystal filled in the liquid crystal cell is aligned in-plane in parallel to the first and second polarizer plates 1 and 2. The absorption axis 4 of the first polarizer plate 1 is aligned in perpendicular to the absorption axis 5 of the second polarizer plate 2 and the absorption axis 4 of the first polarizer plate 1 is parallel to the optical axis 6 of the liquid crystal filled in the liquid crystal cell of the IPS-LCD panel 3. In addition, one of first and second substrates 15 and 16 includes an active matrix drive electrode having a pair of electrodes, which is formed on a surface of the substrate adjacent to a liquid crystal layer.

[0021] A retardation value of the liquid crystal cell of the IPS-LCD according to the present invention is preferably 200nm to 450nm at a wavelength of 550nm.

[0022] A white state of the IPS-LCD can be obtained by (1) linearly polarizing light radiated from a backlight unit at an angle of 0° after passing through one polarizer plate, (2) rotating the 0°-linearly polarized light into the 90°-linearly polarized light after passing through a liquid crystal cell, and then (3) transmitting the 90°-linearly polarized light through the other polarizer plate. In order to allow the 0°-polarized light to be converted into the 90°-polarized light, the liquid crystal cell must have a retardation value corresponding to a half of a wavelength of an incident light. In addition, it is also possible to use a waveguide characteristic of a liquid crystal layer of a liquid crystal cell in a reverse-TN (twisted nematic) IPS-LCD, in which the retardation value of the liquid crystal cell is set to 400nm. The retardation value of the liquid crystal cell may vary depending on modes of the IPS-LCD.

[0023] The LCD according to the present invention may align the liquid crystal in multi-directions, or the liquid crystal may be divided into multi-regions by voltage applied thereto.

[0024] The LCDs can be classified into IPS (In-Plain Switching) LCDs, S-IPS (Super-In-Plan Switching) LCDs and FFS (Fringe Field Switching) LCDs according to modes of the active matrix drive electrode including a pair of electrodes. In the present invention, the IPS-LCD may include the S-IPS LCD, the FFS LCD, and a reverse TN IPS LCD.

[0025] According to the present invention, the IPS-LCD uses a +A-plate and a +C plate in order to compensate for a viewing angle thereof. When IPS-LCD uses the +A-plate combined with the +C plate in order to compensate for the viewing angle of the IPS-LCD, a wide viewing angle characteristic can be obtained.

[0026] FIG. 3 illustrates a refractive index of a retardation film used for compensating for a viewing angle of the IPS-LCD. Referring to FIG. 3, an in-plane refractive index in an x-axis direction is n_x(8), an in-plane refractive index in a y-axis direction is n_y(9), and a thickness refractive index in a z-axis direction is n_z(10). In addition, the characteristic of the retardation film depends on the refractive index.

[0027] A uniaxial retardation film represents mutually different refractive indexes in two-axis directions among x-axis, y-axis and z-axis directions. The uniaxial retardation film is defined as follows:

(1) The +A-plate satisfies an equation of $n_x > n_y = n_z$, and an in-plane retardation value thereof can be defined as following Equation 1 by using a difference between two in-plane refractive indexes and a thickness of a film.

Equation 1

$$R_{in} = d \times (n_x - n_y),$$

, wherein d is a thickness of a film. Tha +A-plate has a thickness reardation value of almost 0 and a positive in-plane etardation value.

(2) The +C-plate satisfies an equation of $n_x = n_y < n_z$, and a thickness retardation value thereof can be defined as following Equation 2 by using a thickness of a film and a difference between an in-plane refractive index and a thickness refractive index.

Equation 2

$$R_{th} = d \times (n_z - n_y),$$

, wherein d is a thickness of a film.

[0028] The +C-plate 11 has an in-plane retardation value of almost 0 and a positive thickness retardation value.

[0029] In order to compensate for the viewing angle of the IPS-LCD, the +A-plate preferably has an in-plane retardation value of 30nm to 500nm at a wavelength of 550nm, and the +C-plate preferably has a thickness retardation value of 30nm to 500nm at a wavelength of 550nm.

[0030] Light leakage may occur in the black state of the IPS-LCD mainly because of a polarizer plate and partially because of an IPS-LCD panel. Therefore, a range of the retardation value required for compensating for the IPS-LCD can be obtained by slightly expanding the retardation value such that the light leakage of the polarizer plate can be compensated. That is, the range of the retardation values for the +A-plate and the +C-plate required for minimizing the light leakage generated from two polarizer plates with the absorption axes thereof aligned perpendicularly to each other, is 50nm to 300nm, respectively. In addition, when taking the IPS-LCD panel into consideration, the above range can be slightly expanded. For this reason, the range of the retardation values for the +A-plate and the +C-plate required for compensating for the viewing angle of the IPS-LCD is 30nm to 500nm, respectively.

[0031] The wavelength dispersion characteristic of the retardation film includes normal wavelength dispersion, flat wavelength dispersion, and reverse wavelength dispersion.

[0032] FIGS. 4 and 5, and 19 to 22 illustrate structures of a viewing angle compensation film including a +C-plate 11 and a +A-plate 12 used in an IPS-LCD according to the present invention.

[0033] An IPS-LCD panel 3 is interposed between polarizer plates, wherein liquid crystal molecules 7 are aligned in parallel to IPS-LCD panel substrates 15 and 16 and in a rubbing direction, which is formed on the substrates by surface-treating the substrates such that liquid crystal molecules are aligned in one direction. In order to obtain the viewing angle compensation function, retardation films must be interposed between the IPS-LCD panel 3 and polarizer plates 1 and 2. An optical axis (or slow axis) 13 of the retardation film is aligned in perpendicular to or parallel to an absorption axis 5 of an adjacent polarizer plate. Since an optical axis of the +C-plate is perpendicular to the polarizer plate, it may not directly relate to the viewing angle characteristic. That is, only an angle formed between the optical axis of the +A-plate and the absorption axis of the polarizer plate may exert an influence upon the viewing angle characteristic.

[0034] The optical axis direction of the +A-plate is determined according to an alignment order of the retardation films.

[0035] When designing a viewing angle compensation film of the IPS-LCD, the present invention considers that an internal protective film of a polarizer plate has a function of the retardation film while taking a case in which the internal protective film has a thickness retardation value and a case in which the internal protective film has no thickness retardation value into consideration. Design values of the +A-plate and +C-plate with the internal protective film of the polarizer plate having the thickness retardation value are different from those of the +A-plate and +C-plate with the internal protective film having no thickness retardation value. Tables 1 to 10 show a variation in the design values of the +A-plate and +C-plate according to the internal protective films.

[0036] According to a first embodiment of the present invention, there is provided an LCD including a first polarizer plate 1, an IPS panel liquid crystal cell 3, a +C-plate 11, an A-plate 12, and a second polarizer plate, which are sequentially aligned and in which an optical axis 13 of the A-plate is perpendicular to an absorption axis 5 of the second polarizer plate.

[0037] When the A-plate is adjacent to the polarizer plate and the +C-plate is positioned next to the A-plate, the viewing angle can be compensated only when the optical axis of the A-plate is perpendicular to the absorption axis of the adjacent polarizer plate. That is, the viewing angle characteristic may be lowered if the optical axis of the A-plate is aligned in parallel to the absorption axis of the adjacent polarizer plate.

[0038] At this time, the A-plate 12 preferably has an in-plane retardation value in a range of 30nm to 500nm at a wavelength of 550nm, and the +C-plate 11 preferably has a thickness retardation value in a range of 30nm to 500nm at a wavelength of 550nm.

[0039] FIG. 4 shows a first IPS-LCD structure including a compensation film according to the first embodiment of the present invention and FIG. 5 shows a second IPS-LCD structure including a compensation film according to the first embodiment of the present invention.

[0040] The first and second IPS-LCD structures shown in FIGS. 4 and 5 are substantially identical to each other, except for light sources thereof, which are aligned in opposition to each other. The first and second IPS-LCD structures shown in FIGS. 4 and 5 represent the same viewing angle characteristics.

[0041] FIG. 10 and Table 1 show a simulation result when practical design values of a retardation film are applied to the IPS-LCD structure shown in FIG. 4.

Table 1

Internal protective film of 1st polarizer plate	IPS-LCD	Retardation value of +C- plate (nm)	Retardation value of A- plate (nm)	Internal protective film of 2nd polarizer plate	Minimum contrast ratio value at inclination angle of 70°
COP	290nm	94	150	COP	167
		99	-	A-COP R_{in}=140nm	167
		99	110	40μmTAC	170
		116	80	80μmTAC	150
		174	53	PNB R_{th}=-130nm	100
40μmTAC		54	132	COP	75
		70	110	40μmTAC	75
		100	90	80μmTAC	60
80μmTAC		35	137	COP	33
		35	100	40μmTAC	33
		50	70	80μmTAC	30

[0042] Table 1 shows the contrast ratio value (contrast ratio value of the white state to the black state) in the IPS-LCD structure obtained through the simulation at the inclination angle of 70°.

[0043] The contrast ratio value is an index representing a degree of definition for an image, and a higher contrast ratio value allows a higher definition image. The simulation is carried out at the inclination angle of 70° because the contrast characteristic of the IPS-LCD is greatly degraded at the inclination angle of 70°. When the IPS-LCD does not use the viewing angle compensation film, the minimum contrast ratio value of the IPS-LCD is identical to or less than 10:1. Accordingly, Table 1 shows an improved minimum contrast ratio value of the IPS-LCD at the inclination angle of 70°, which means that the contrast characteristic of the IPS-LCD may be improved at all viewing angles.

[0044] FIG. 11 shows a simulation result for the contrast characteristic when practical design values of a retardation film are applied to the IPS-LCD structure shown in FIG. 5.

[0045] Although the first embodiment of the present invention illustrates that the A-plate and the +C-plate are interposed between the second polarizer plate and the IPS-LCD liquid cell, it is also possible to further align the A-plate and/or the +C-plate between the first polarizer plate and the IPS-LCD liquid cell as represented in third to ninth embodiments of the present invention.

[0046] In the IPS-LCD structure according to the present invention, a relative position between two polarizer plates and liquid crystal is only important, regardless of the relative positions of an observer and a backlight unit.

[0047] According to the sixth embodiment of the present invention, there is provided an LCD including a first polarizer plate 1, a first +A-plate 11, a first +C-plate 16, an IPS panel liquid crystal cell 3, a second +C-plate 15, a second +A-plate 13, and a second polarizer plate, which are sequentially aligned and in which an optical axis 12 of the first A-plate is parallel to an absorption axis 4 of the first polarizer plate and an optical axis 14 of the second A-plate is perpendicular to an absorption axis 6 of the second polarizer plate.

[0048] In this case, the first +C-plate 16 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm and the second +C-plate 15 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm.

[0049] In addition, the first A-plate 11 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm and the second A-plate 13 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm

[0050] FIG. 19 shows an eleventh IPS-LCD structure including a compensation film according to the sixth embodiment of the present invention and FIG. 20 shows a twelfth IPS-LCD structure including a compensation film according to the sixth embodiment of the present invention. The eleventh and twelfth IPS-LCD structures shown in FIGS. 19 and 20 are substantially identical to each other, except for light sources thereof, which are aligned in opposition to each other. The eleventh and twelfth IPS-LCD structures shown in FIGS. 19 and 20 represent the same viewing angle characteristics.

[0051] FIG. 29 and Table 7 show a simulation result for the contrast characteristic when practical design values of a retardation film are applied to the IPS-LCD structures shown in FIGS. 19 and 20.

Table 7

Internal protective film of 1st polarizer plate	A-plate	+C-plate	IPS-LCD	+C-plate	A-plate	Internal protective film of 2nd polarizer plate	Minimum contrast ratio value at inclination angle of 70°
80μmTAC	110	110	310nm	210	40	80μmTAC	24:1
40μmTAC	110	110		210	100		75:1
Isotropic COP	0	110		210	110		59:1
80μmTAC	30	110		150	110	40μmTAC	133:1
40μmTAC	20	110		170	130		109:1
Isotropic COP	0	110		200	130		64:1
80μmTAC	0	110		190	160	Isotropic COP	62:1
40μmTAC	180	120		240	130		30:1
Isotropic COP	180	120		200	160		98:1

[0052] According to the seventh embodiment of the present invention, there is provided an LCD including a first polarizer plate 1, a first +C-plate 16, a first +A-plate 11, an IPS panel liquid crystal cell 3, a second +C-plate 15, a second +A-plate 13, and a second polarizer plate, which are sequentially aligned and in which an optical axis 12 of the first A-plate is parallel to an absorption axis 4 of the first polarizer plate and an optical axis 14 of the second A-plate is perpendicular to an absorption axis 6 of the second polarizer plate.

[0053] In this case, the first +C-plate 16 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm and the second +C-plate 15 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm.

[0054] In addition, the first A-plate 11 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm and the second A-plate 13 preferably has a retardation value in a range of 1nm to 500nm at a wavelength of 550nm.

[0055] FIG. 21 shows a thirteenth IPS-LCD structure including a compensation film according to the seventh embodiment of the present invention and FIG. 22 shows a fourteenth IPS-LCD structure including a compensation film according to the seventh embodiment of the present invention. The thirteenth and fourteenth IPS-LCD structures shown in FIGS. 21 and 22 are substantially identical to each other, except for light sources thereof, which are aligned in opposition to each other. The thirteenth and fourteenth IPS-LCD structures shown in FIGS. 21 and 22 represent the same viewing angle characteristics.

[0056] FIG. 30 and Table 8 show a simulation result for the contrast characteristic when practical design values of a retardation film are applied to the IPS-LCD structures shown in FIGS. 21 and 22.

Table 8

Internal protective film of 1st polarizer plate	C-plate	A-plate	IPS-LCD	+C-plate	A-plate	Internal protective film of 1st polarizer plate	Minimum contrast ratio value at inclination angle of 70°
80μmTAC	100	200	310nm	70	100	80μmTAC	90:1
40μmTAC	60	230		60	100		25:1
	0	90		110	80		99:1
80μmTAC	50	70		80	90	90μmTAC	63:1
40μmTAC	20	70		90	100		94:1
	10	90		100	120		117:1
80μmTAC	50	40		80	120	Isotropic COP	95:1
40μmTAC	50	60		100	150		133:1
	50	40		110	180		69:1

[0057] A diagonal direction represents a direction forming an angle of 45° with regard to the absorption axis of the polarizer plate, causing the worst viewing angle characteristic of the IPS-LCD. When two type retardation films are used as viewing angle compensation films of the IPS-LCD, the viewing angle characteristic in the diagonal direction may be improved (see contrast characteristics illustrated in FIGS. 10, 11 and 29 to 30) .

[0058] Protective films used for protecting the polarizer plates may exert an influence upon the viewing angle compensation characteristic of the IPS-LCD. In general, the polarizer plate is made from stretched PVA (polyvinyl alcohol) doped with iodine, and the protective film used for the polarizer plate can be made from a TAC (triacetate cellulose) film having a thickness retardation value, PNB (polynobonene) or a non-oriented COP (cyclo olefin without stretching) film having no thickness retardation value. If the protective film having the thickness retardation value, such as the TAC film, is used for the polarizer plate, the viewing angle compensation characteristic may be deteriorated.. However, if an isotropic film, such as the non-oriented COP film(COP without stretching), is used as the protective film for the polarizer plate, a superior viewing angle characteristic can be obtained.

[0059] Preferably, the internal protective film for the first and second polarizer plates is one selected from the group consisting of non-stretched COP (cyclo olefin), 40μm TAC (triacetate cellulose), 80μm TAC (triacetate cellulose), and PNB (polynobonene). Particularly, the internal protective film for the first polarizer plate 1 is preferably made from COP having a thickness retardation value of 0 or 40μm TAC.

[0060] If the internal protective film made from COP is used for the first polarizer plate, that is, when the internal protective film has the thickness retardation value of 0, the best contrast characteristic can be obtained. Contrast characteristics of the IPS-LCD at the inclination angle of 70° represented when the COP film or the TAC film is used as the internal protective film for the first polarizer plate are illustrated in Tables 1 to 10. As illustrated in Tables 1 to 10, the IPS-LCD represents the best contrast characteristic when the COP film or the 40μm TAC film is used as the internal protective film for the polarizer plate.

[0061] The retardation film used for the A-plate 12 includes a uniaxially stretched polycarbonate film, a uniaxially stretched COP, a nematic liquid crystal film or a discotic liquid crystal film. In addition, a film used for the C-plate 11 includes a homeotropically aligned liquid crystal film or a biaxially stretched polycarbonate film. The +C plate can be fabricated by using a polymer film or a UV curable liquid crystal film.

[0062] Meanwhile, the polarizer plate includes an external protective film, PVA-I (stretched PVA doped with iodine), and an internal protective film. Although the TAC film is mainly used as the internal protective film for the polarizer plate, a +A-plate film or a +C-plate film can be used instead of the internal protective film.

Advanced Effect

[0063] As described above, the in-plane switching liquid crystal display according to the present invention can improve the contrast characteristic at a front and at a predetermined inclination angle thereof by using the +A-plate and the +C-plate while minimizing a color shift according to viewing angles in the black state.

Embodiments

[0064] Hereinafter, preferred embodiments of the present invention will be described. However, it is noted that the preferred embodiments described below are used for illustrative purpose and the present invention is not limited thereto.

Embodiment 1

[0065] The IPS-LCD shown in FIG. 4 includes an IPS liquid crystal cell filled with liquid crystal having a cell gap of 2.9μm, a pretilt angle of 3°, dielectric anisotropy of $\Delta\varepsilon$ = +7, and a birefringence of Δn = 0.1. The +C-plate 11 is fabricated by using an UV curable and homeotropically aligned liquid crystal film and has a thickness retardation value R_{th} = 174nm at a wavelength of 550nm. The A-plate 12 is fabricated by using a stretched polycarbonate film and has an in-plane retardation value R_{in} = 53nm. The internal protective film for the first polarizer plate 1 is made from an isotropic COP film, and the internal protective film for the second polarizer plate 2 is made from a PNB (polynobonene) film having a thickness retardation value R_{th} = -130nm. When a white light is used, the contrast characteristic of the IPS-LCD at an inclination angle of 0° to 80° in all azimuthal angles is illustrated in FIG. 10.

[0066] Referring to FIG. 10, a center of a circle corresponds to an inclination angle of 0, and the inclination angle increases as a radius of the circle becomes enlarged. Numerals 20, 40, 60 and 80 marked along the radius of the circle in FIG. 10 represent the inclination angles.

[0067] In addition, numerals 0 to 330 marked along a circumference of the circle represent the azimuthal angles. FIG. 10 shows the contrast characteristic in all viewing directions (inclination angles of 0° to 80° and azimuthal angles of 0° to 360°) when an upper polarizer plate is aligned in a direction of an azimuthal angle of 0°, and a lower polarizer plate is aligned in a direction of an azimuthal angle of 90°. An IPS-LCD, which exclusively uses a polarizer plate, may represent a contrast ratio equal to or less than 10:1 at an inclination angle of 80°. However, the IPS-LCD of the present invention represents a contrast ratio above 100:1 at an inclination angle of 80° as shown in FIG. 10.

Embodiment 2

[0068] The IPS-LCD shown in FIG. 5 includes an IPS liquid crystal cell filled with liquid crystal having a cell gap of 2.9μm, a pretilt angle of 3°, dielectric anisotropy of $\Delta\varepsilon$ = +7, and a birefringence of Δn = 0.1. The +C-plate 11 is fabricated by using an UV curable and homeotropically aligned liquid crystal film and has a thickness retardation value R_{th} = 70nm at a wavelength of 550nm. The A-plate 12 is fabricated by using a stretched polycarbonate film and has an in-plane retardation value R_{in} = 110. The internal protective film for the first and second polarizer plates 1 and 2 is made from a 40μm TAC film having a thickness retardation value R_{th} = - 32nm.

[0069] When a white light is used, the contrast characteristic of the IPS-LCD at an inclination angle of 0° to 80° in all azimuthal angles is illustrated in FIG. 11. Referring to FIG. 11, the IPS-LCD represents the superior contrast characteristic above 50:1 at an inclination angle of 80°.

Embodiment 8

[0070] The IPS-LCD shown in FIGS. 19 and 20 includes an IPS liquid crystal cell filled with liquid crystal having a cell gap of 3.1μm, a pretilt angle of 1°, dielectric anisotropy of $\Delta\varepsilon = +7$, and a birefringence of $\Delta n = 0.1$. The first A-plate 11 is fabricated by using a stretched COP film and has an in-plane retardation value R_{in} = 20nm. The first +C-plate 16 is fabricated by using an UV curable and homeotropically aligned liquid crystal film and has a thickness retardation value R_{th} = 110nm at a wavelength of 550nm. The second A-plate 13 is fabricated by using a stretched COP film and has an in-plane retardation value R_{in} = 130nm. The second +C-plate 15 is fabricated by using an UV curable and homeotropically aligned liquid crystal film and has a thickness retardation value R_{th} = 170nm at a wavelength of 550nm. The internal protective film for the first and second polarizer plates 1 and 2 is made from a 40μm TAC film having a thickness retardation value R_{th} = -30nm. When a white light is used, the contrast characteristic of the IPS-LCD at an inclination angle of 0° to 80° in all azimuthal angles is illustrated in FIG. 29.

Embodiment 9

[0071] The IPS-LCD shown in FIGS. 21 and 22 includes an IPS liquid crystal cell filled with liquid crystal having a cell gap of 3.1μm, a pretilt angle of 1°, dielectric anisotropy of $\Delta \varepsilon = +7$, and a birefringence of $\Delta n = 0.1$. The first A-plate 11 is fabricated by using a stretched COP film and has an in-plane retardation value R_{in} = 70nm. The first +C-plate 16 is fabricated by using an UV curable and homeotropically aligned liquid crystal film and has a thickness retardation value R_{th} = 50nm at a wavelength of 550nm. The second A-plate 13 is fabricated by using a stretched COP film and has an in-plane retardation value R_{in} = 90nm. The second +C-plate 15 is fabricated by using an UV curable and homeotropically aligned liquid crystal film and has a thickness retardation value R_{tn} = 80nm at a wavelength of 550nm. The internal protective film for the first polarizer plate 1 is made from a 80μm TAC film having a thickness retardation value R_{th} = -50nm, and the internal protective film for the second polarizer plate 2 is made from a 40μm TAC film having a thickness retardation value R_{th} = -30nm. When a white light is used, the contrast characteristic of the IPS-LCD at an inclination angle of 0° to 80° in all azimuthal angles is illustrated in FIG. 30.

Claims

1. An in-plane switching liquid crystal display comprising:

a first polarizer plate (1);
a liquid crystal cell (3), which is filled with horizontally aligned liquid crystal of positive dielectric anisotropy, $\Delta\varepsilon>0$, the optical axis of the liquid crystal filled in the liquid crystal cell being aligned in-plane parallel to the first polarizer plate; and
a second polarizer plate (2), and
a pair of compensation films including an +A-plate, $n_x > n_y = n_z$, and a +C-plate, $n_x = n_y < n_z$, are aligned between the second polarizer plate (2) and the liquid crystal cell (3),
in which n_x and n_y represent in-plane refractive indices, n_z represents the refractive index in the thickness direction the A-plate has an in-plane retardation value of $R_{in} = d \times (n_x - n_y)$, and the +C-plate has a thickness retardation value of $R_{in} = d \times (n_z - n_y)$, wherein d is the thickness of the respective retardation film
wherein the absorption axis (4) of the first polarizer plate (1) is perpendicular to the absorption axis (5) of the second polarizer plate (2), and the optical axis (6) of the liquid crystal (3) filled in the liquid crystal cell is parallel to the absorption axis (4) of the first polarizer plate (1),
characterized in that
the +A-plate is adjacent to the second polarizer plate and the optical axis of the +A-plate is aligned perpendicularly to the absorption axis of the second polarizer plate
and

2. The in-plane switching liquid crystal display as claimed in claim 1, wherein the +A-plate has an in-plane retardation value in a range of 30nm to 500nm at a wavelength of 550nm.

3. The in-plane switching liquid crystal display as claimed in claim 1, wherein the +C-plate has a thickness retardation value in a range of 30nm to 500nm at a wavelength of 550nm.

4. An in-plane switching liquid crystal display as claimed in claim 1, wherein
the first polarizer plate (1), a further +A-plate (11), a further +C-plate (16), the liquid crystal cell (3), said +C-plate

(15), said +A-plate (13), and the second polarizer plate (2) are sequentially aligned, in which the optical axis (12) of the further +A-plate (11) is parallel to the absorption axis (4) of the first polarizer plate (1).

5. An in-plane switching liquid crystal display as claimed in claim 1, wherein
the first polarizer plate (1), a further +C-plate (16), a further +A-plate (11), the liquid crystal cell (3), said +C-plate (15), said +A-plate (14), and the second polarizer plate (2) are sequentially aligned, in which the optical axis (12) of the further +A-plate (11) is parallel to the absorption axis (4) of the first polarizer plate (1).

6. The in-plane switching liquid crystal display as claimed in any one of claims 4 and 5, wherein both +A-plates have a retardation value in a range of 1 nm to 500 nm at a wavelength of 550 nm, respectively.

7. The in-plane switching liquid crystal display as claimed in any one of claims 4 and 5, wherein both +C-plates have a retardation value in a range of 1nm to 500nm at a wavelength of 550nm, respectively.

8. The in-plane switching liquid crystal display as claimed in any one of claims 1, 4 and 5, wherein at least one the first and second polarizer plates have an internal protective film having a retardation value of 0 or a negative thickness retardation value.

9. The in-plane switching liquid crystal display as claimed in any one of claims 1, 4 and 5, wherein an +A-plate is used as an internal protective film for at least one polarizer plate.

10. The in-plane switching liquid crystal display as claimed in any one of claims 1, 4 and 5, wherein a +C-plate is used as an internal protective film for at least one polarizer plate.

Patentansprüche

1. In der Ebene schaltende Flüssigkristallanzeige mit:

einer ersten Polarisationsplatte (1),
einer Flüssigkristallzelle (3), die mit horizontal ausgerichtetem Flüssigkristall positiver dielektrischer Anisotropie, $\Delta\varepsilon>0$, gefüllt ist, wobei die optische Achse des in die Flüssigkristallzelle gefüllten Flüssigkristalls in der Ebene parallel zur ersten Polarisationsplatte ausgerichtet ist, und
einer zweiten Polarisationsplatte (2) und
einem Paar Kompensationsfilme, die eine positive A-Platte, $n_x > n_y = n_z$, und eine positive C-Platte, $n_x = n_y < n_z$, aufweisen und zwischen der zweiten Polarisationsplatte (2) und der Flüssigkristallzelle (3) ausgerichtet sind, wobei n_x und n_y Brechungsindizes in der Ebene darstellen, n_z den Brechungsindex in der Dickenrichtung darstellt, die A-Platte einen Verzögerungswert in der Ebene von $R_{in} = d \times (n_x - n_y)$ hat und die positive C-Platte einen Dickenverzögerungswert von $R_{in} = d \times (n_z - n_y)$ hat, wobei d die Dicke des jeweiligen Verzögerungsfilms ist, wobei die Absorptionsachse (4) der ersten Polarisationsplatte (1) senkrecht zur Absorptionsachse (5) der zweiten Polarisationsplatte (2) ist und die optische Achse (6) des in die Flüssigkristallzelle gefüllten Flüssigkristalls (3) parallel zur Absorptionsachse (4) der ersten Polarisationsplatte (1) ist,
dadurch gekennzeichnet, dass
die positive A-Platte an die zweite Polarisationsplatte angrenzt und die optische Achse der positiven A-Platte senkrecht zur Absorptionsachse der zweiten Polarisationsplatte ausgerichtet ist.

2. In der Ebene schaltende Flüssigkristallanzeige nach Anspruch 1, bei der die positive A-Platte einen Verzögerungswert in der Ebene in einem Bereich von 30 nm bis 500 nm bei einer Wellenlänge von 550 nm hat.

3. In der Ebene schaltende Flüssigkristallanzeige nach Anspruch 1, bei der die positive C-Platte einen Dickenverzögerungswert in einem Bereich von 30 nm bis 500 nm bei einer Wellenlänge von 550 nm hat.

4. In der Ebene schaltende Flüssigkristallanzeige nach Anspruch 1, bei der die erste Polarisationsplatte (1), eine weitere positive A-Platte (11), eine weitere positive C-Platte (16), die Flüssigkristallzelle (3), die positive C-Platte (15), die positive A-Platte (13) und die zweite Polarisationsplatte (2) sequentiell ausgerichtet sind, wobei die optische Achse (12) der weiteren positiven A-Platte (11) parallel zur Absorptionsachse (4) der ersten Polarisationsplatte (1) ist.

5. In der Ebene schaltende Flüssigkristallanzeige nach Anspruch 1, bei der die erste Polarisationsplatte (1), eine

weitere positive C-Platte (16), eine weitere positive A-Platte (11), die Flüssigkristallzelle (3), die positive C-Platte (15), die positive A-Platte (14) und die zweite Polarisationsplatte (2) sequentiell ausgerichtet sind, wobei die optische Achse (12) der weiteren positiven A-Platte (11) parallel zur Absorptionsachse (4) der ersten Polarisationsplatte (1) ist.

6. In der Ebene schaltende Flüssigkristallanzeige nach einem der Ansprüche 4 und 5, bei der beide positiven A-Platten jeweils einen Verzögerungswert in einem Bereich von 1 nm bis 500 nm bei einer Wellenlänge von 550 nm haben.

7. In der Ebene schaltende Flüssigkristallanzeige nach einem der Ansprüche 4 und 5, bei der beide positiven C-Platten jeweils einen Verzögerungswert in einem Bereich von 1 nm bis 500 nm bei einer Wellenlänge von 550 nm haben.

8. In der Ebene schaltende Flüssigkristallanzeige nach einem der Ansprüche 1, 4 und 5, bei der die erste und/oder die zweite Polarisationsplatte einen inneren Schutzfilm mit einem Verzögerungswert von 0 oder einem negativen Dickenverzögerungswert aufweisen.

9. In der Ebene schaltende Flüssigkristallanzeige nach einem der Ansprüche 1, 4 und 5, bei der eine positive A-Platte als innerer Schutzfilm für wenigstens eine Polarisationsplatte verwendet wird.

10. In der Ebene schaltende Flüssigkristallanzeige nach einem der Ansprüche 1, 4 und 5, bei der eine positive C-Platte als innerer Schutzfilm für wenigstens eine Polarisationsplatte verwendet wird.

Revendications

1. Ecran à cristaux liquides à commutation dans le plan, comportant :

une première plaque de polarisation (1),
une cellule à cristaux liquides (3) remplie de cristaux liquides alignés horizontalement et présentant une anisotropie diélectrique positive, $\Delta\varepsilon>0$, l'axe optique des cristaux liquides remplis dans la cellule à cristaux liquides étant aligné dans le plan parallèlement à la première plaque de polarisation, et
une deuxième plaque de polarisation (2), et
une paire de films de compensation qui présentent une plaque +A, $n_x > n_y = n_z$, et une plaque +C, $n_x = n_y < n_z$, et qui sont alignés entre la deuxième plaque de polarisation (2) et la cellule à cristaux liquides (3),
n_x et n_y représentant des indices de réfraction dans le plan, n_z représentant l'indice de réfraction dans le sens de l'épaisseur, la plaque +A présentant une valeur de retard dans le plan de $R_{in} = d \times (n_x - n_y)$, et la plaque +C présentant une valeur de retard en épaisseur de $R_{in} = d \times (n_z - n_y)$, d étant l'épaisseur du film de retard respectif,
l'axe d'absorption (4) de la première plaque de polarisation (1) étant perpendiculaire à l'axe d'absorption (5) de la deuxième plaque de polarisation (2), et l'axe optique (6) des cristaux liquides (3) remplis dans la cellule à cristaux liquides étant parallèle à l'axe d'absorption (4) de la première plaque de polarisation (1),
caractérisé en ce que
la plaque +A est adjacente à la deuxième plaque de polarisation et l'axe optique de la plaque +A est aligné perpendiculairement à l'axe d'absorption de la deuxième plaque de polarisation.

2. Ecran à cristaux liquides à commutation dans le plan selon la revendication 1, dans lequel la plaque +A présente une valeur de retard dans le plan dans une plage de 30 nm à 500 nm à une longueur d'onde de 550 nm.

3. Ecran à cristaux liquides à commutation dans le plan selon la revendication 1, dans lequel la plaque +C présente une valeur de retard en épaisseur dans une plage de 30 nm à 500 nm à une longueur d'onde de 550 nm.

4. Ecran à cristaux liquides à commutation dans le plan selon la revendication 1, dans lequel la première plaque de polarisation (1), une plaque +A additionnelle (11), une plaque +C additionnelle (16), la cellule à cristaux liquides (3), ladite plaque +C (15), ladite plaque +A (13) et la deuxième plaque de polarisation (2) sont alignés de manière séquentielle, l'axe optique (12) de la plaque +A additionnelle (11) étant parallèle à l'axe d'absorption (4) de la première plaque de polarisation (1).

5. Ecran à cristaux liquides à commutation dans le plan selon la revendication 1, dans lequel la première plaque de polarisation (1), une plaque +C additionnelle (16), une plaque +A additionnelle (11), la cellule à cristaux liquides (3), ladite plaque +C (15), ladite plaque +A (14) et la deuxième plaque de polarisation (2) sont alignés de manière séquentielle, l'axe optique (12) de la plaque +A additionnelle (11) étant parallèle à l'axe d'absorption (4) de la première plaque de polarisation (1).

6. Ecran à cristaux liquides à commutation dans le plan selon l'une des revendications 4 et 5, dans lequel les deux plaques +A ont respectivement une valeur de retard dans une plage de 1 nm à 500 nm à une longueur d'onde de 550 nm.

7. Ecran à cristaux liquides à commutation dans le plan selon l'une des revendications 4 et 5, dans lequel les deux plaques +C ont respectivement une valeur de retard dans une plage de 1 nm à 500 nm à une longueur d'onde de 550 nm.

8. Ecran à cristaux liquides à commutation dans le plan selon l'une des revendications 1, 4 et 5, dans lequel la première et/ou la deuxième plaque de polarisation a/ont un film de protection interne présentant une valeur de retard de 0 ou une valeur négative de retard en épaisseur.

9. Ecran à cristaux liquides à commutation dans le plan selon l'une des revendications 1, 4 et 5, dans lequel une plaque +A est utilisée comme film de protection interne pour au moins une plaque de polarisation.

10. Ecran à cristaux liquides à commutation dans le plan selon l'une des revendications 1, 4 et 5, dans lequel une plaque +C est utilisée comme film de protection interne pour au moins une plaque de polarisation.

Fig. 1

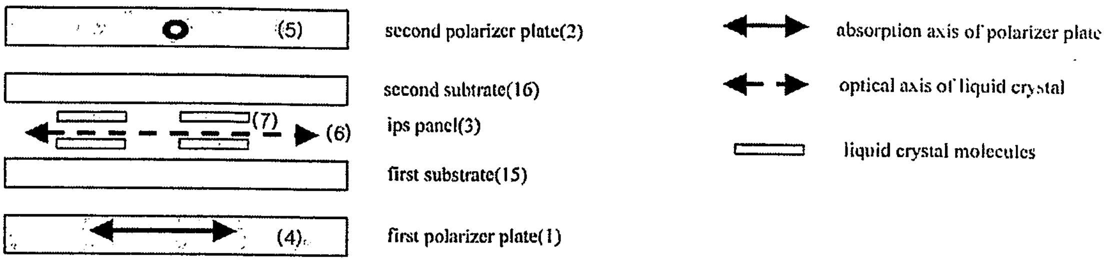


Fig. 2

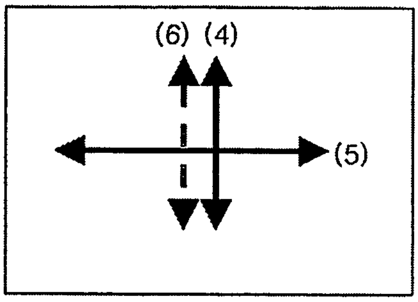


Fig. 3

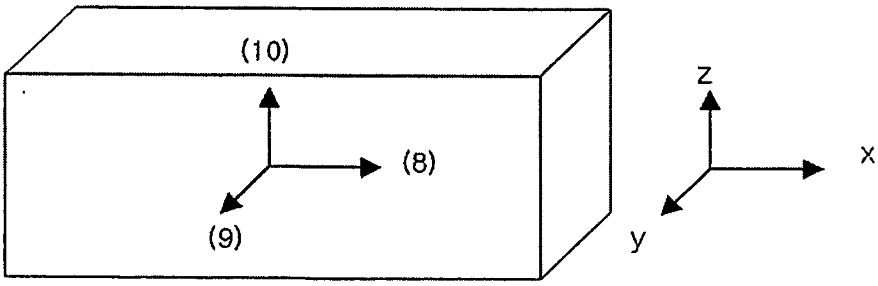
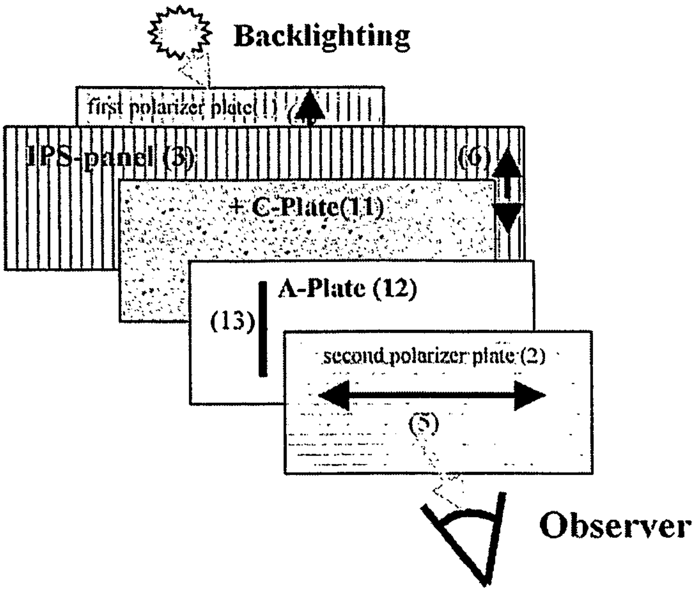


Fig. 4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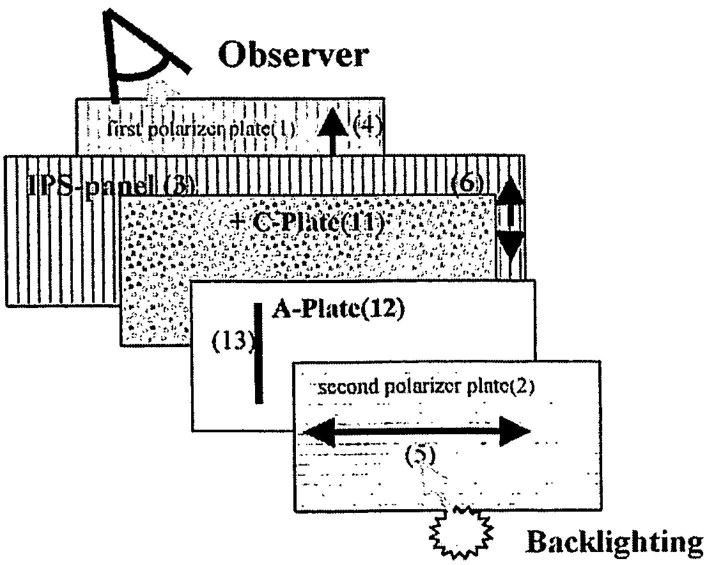
(6)
+ C-Plate(11)
A-Plate (12)
(13)
second polarizer plate (2)
(5)
Observer

Fig. 5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IPS-panel (3)
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+ C-Plate(11)
A-Plate(12)
(13)
second polarizer plate(2)
(5)
Backlighting

Fig. 10

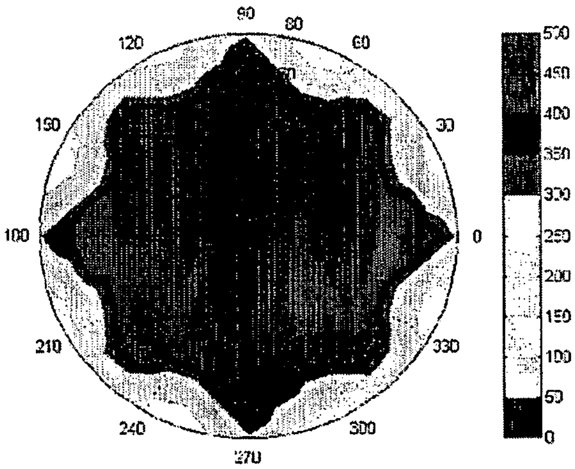
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Fig. 11

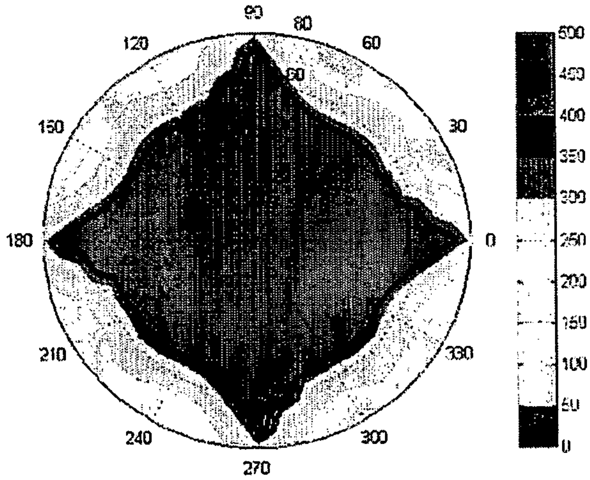
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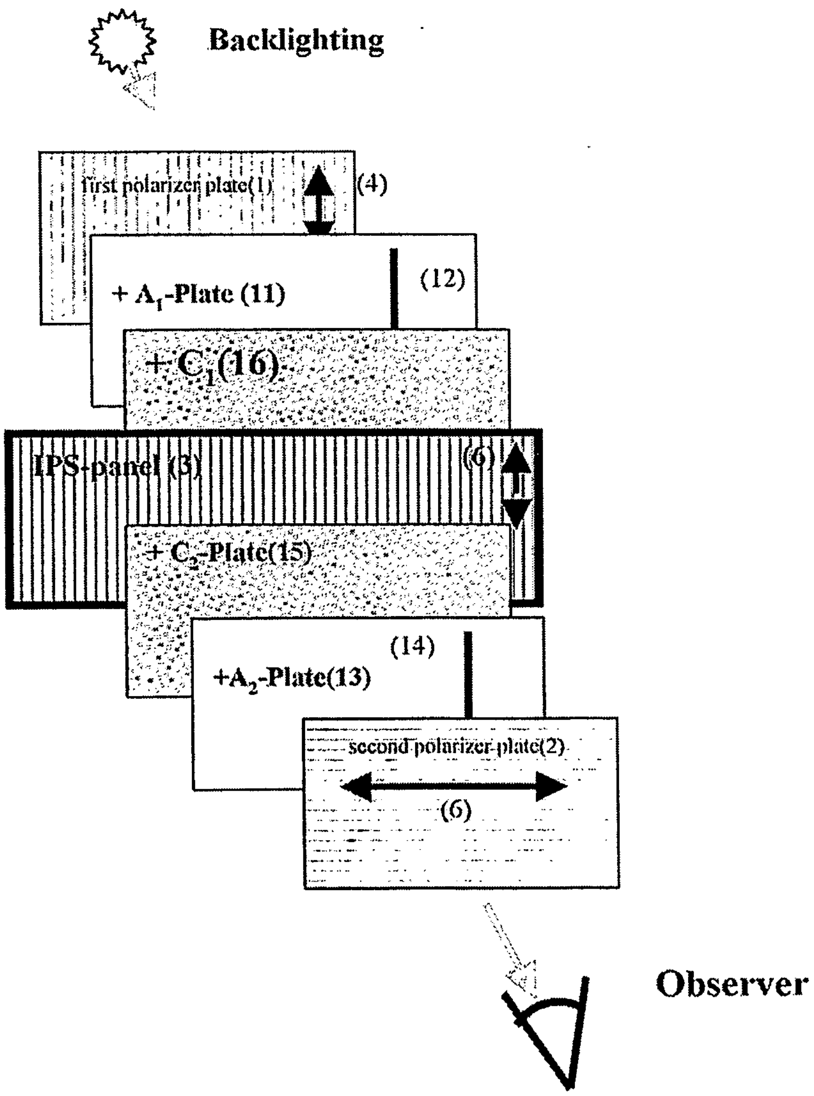
Fig. 19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(12)
+ C_1(16)
IPS-panel (3)
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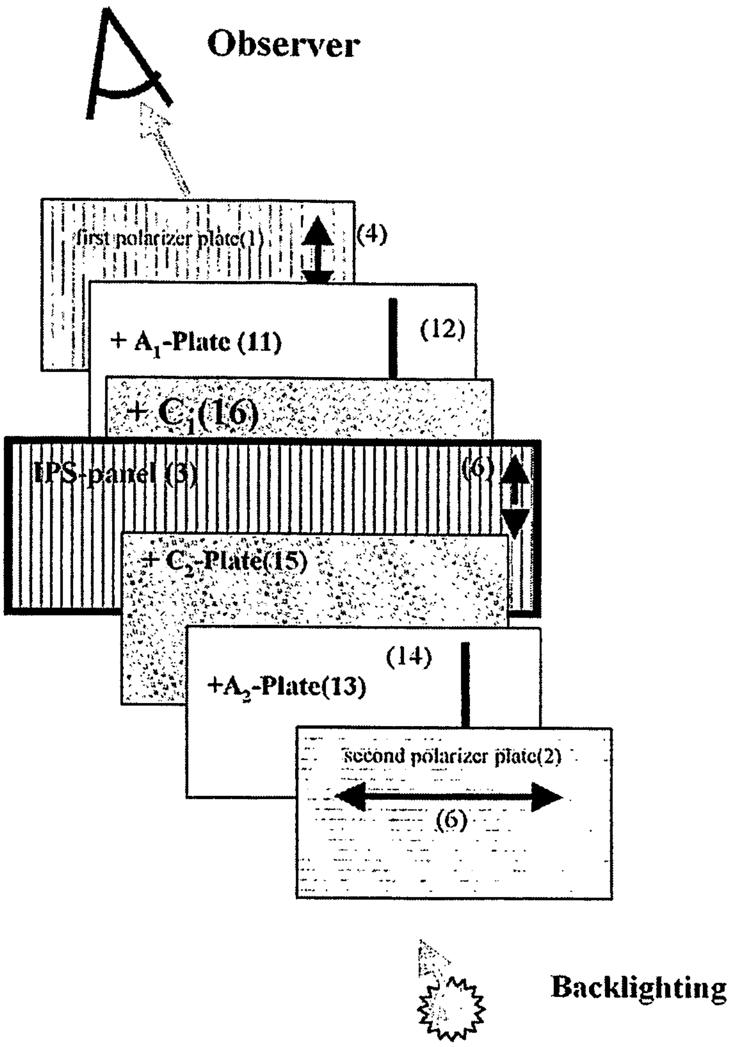
+ C_2-Plate(15)
(14)
+A_2-Plate(13)
second polarizer plate(2)
(6)
Observer

Fig. 20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+ C_1(16)
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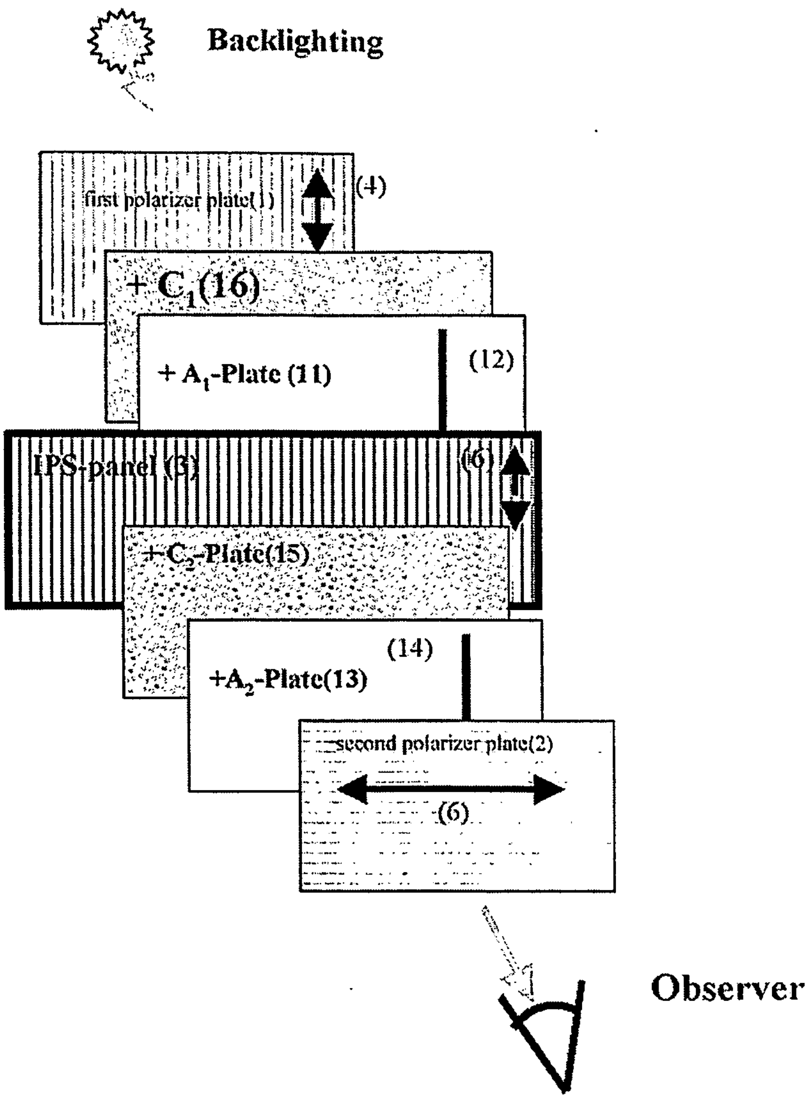
+ C_2-Plate(15)
(14)
+A_2-Plate(13)
second polarizer plate(2)
(6)
Backlighting

Fig. 21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+ A1-Plate (11)
(12)
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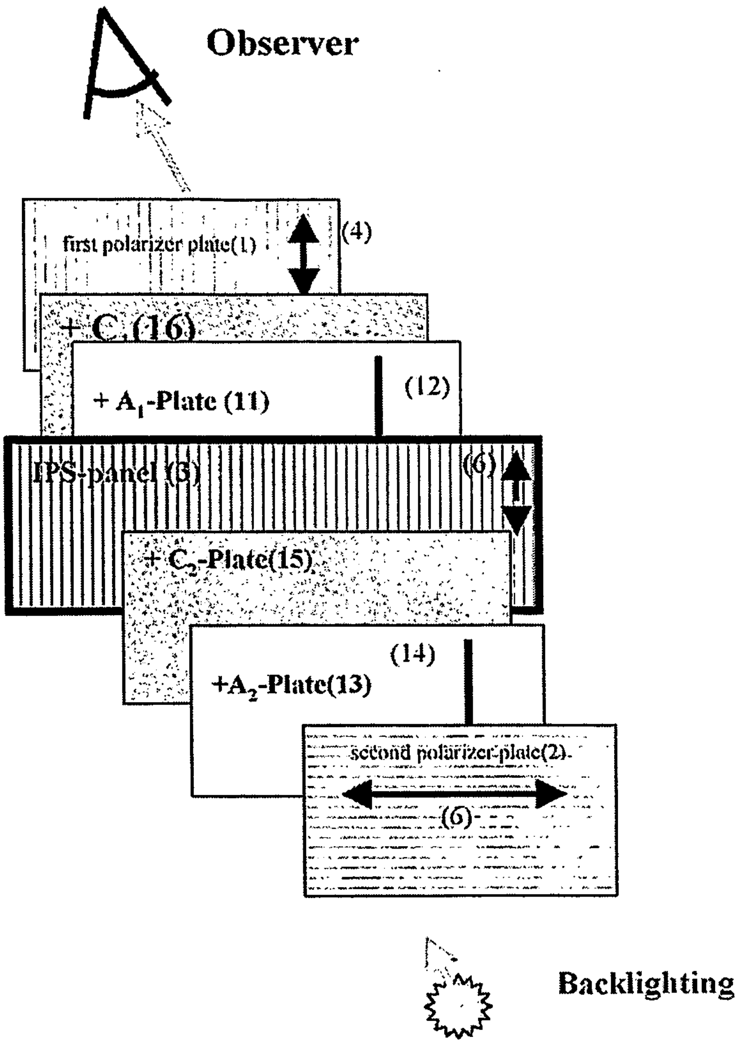
(14)
+A2-Plate(13)
second polarizer plate(2)
(6)
Observer

Fig. 22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+ A_1-Plate (11)
(12)
IPS-panel (3)
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+A_2-Plate(13)
second polarizer plate(2)
(6)
Backlighting

Fig. 29

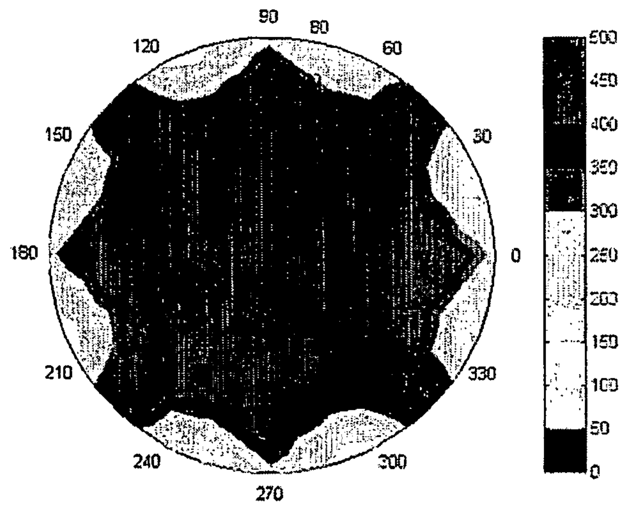
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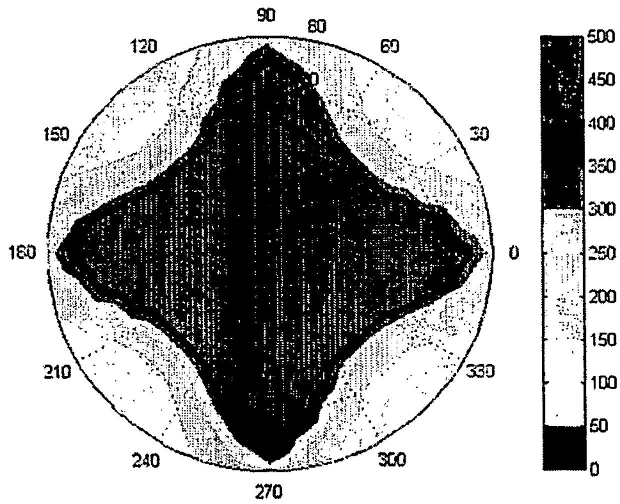
Fig. 30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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 3807831 A **[0002]**
- US 5189538 A **[0003]**
- US 6115095 A **[0004] [0005]**

专利名称(译)	面内切换液晶显示器，包括使用+ a-板和+ c-板的用于角视场的补偿膜
公开(公告)号	EP1676170B1
公开(公告)日	2011-08-24
申请号	EP2004793559
申请日	2004-10-22
[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 MALIMONENKO NIKOLAY
发明人	JEON, BYOUNG-KUN BELYAEV, SERGEY YU, JEONG-SU MALIMONENKO, NIKOLAY
IPC分类号	G02F1/1335 G02F1/13363 G02F1/1343
CPC分类号	G02F1/133634 G02F1/13363 G02F1/134363 G02F2413/06 G02F2413/08 G02F2413/11 G02F2413/13
优先权	1020030073792 2003-10-22 KR
其他公开文献	EP1676170A1 EP1676170A4
外部链接	Espacenet

摘要(译)

公开了一种面内切换液晶显示器。面内切换液晶显示器通过使用+ A-板和+ C-板改善其正面和预定倾斜角的对比度特性，同时根据黑色状态下的视角最小化色移。

$$R_{+C}:R_{+C}:R_{+A} = 1:0.5:0.25$$