**Title:** A COUPLED POLARIZING PLATE SET AND IN-PLANE SWITCHING MODE LIQUID CRYSTAL DISPLAY INCLUDING THE SAME

**Abstract:** The present invention discloses a coupled polarizing plate set and an in-plane switching mode liquid crystal display including the coupled polarizing plate set. In detail, the present invention discloses a coupled polarizing plate set including compensation films designed to have specific optical properties to minimize color distortion in accordance with viewing directions and ensure a wide viewing angle in an in-plane switching mode, and a liquid crystal display including the coupled polarizing plate set and an in-plane switching mode liquid crystal. According to the liquid crystal display of the present invention, since a degree of distribution of changes in polarization state on a Poincare Sphere is small, color distortion in accordance with viewing directions can be minimized and a wide viewing angle can be ensured. Further, it is possible to ensure a wide viewing angle with only one sheet of compensation film for the upper polarizing plate and lower polarizing plate, such that it is possible to implement mass production of thin liquid crystal displays with high yield (reducing defect ratio due to foreign substances).
Published: without international search report and to be republished upon receipt of that report (Rule 48.2(g))
Description
Title of Invention: A COUPLED POLARIZING PLATE SET AND IN-PLANE SWITCHING MODE LIQUID CRYSTAL DISPLAY INCLUDING THE SAME

Technical Field

[1] The present invention relates to a coupled polarizing plate set capable of minimizing color distortion and ensuring a wide viewing angle when being applied to in-plane switching mode liquid crystal displays, and an in-plane switching mode liquid crystal display including the same.

Background Art

[2] Liquid crystal displays (LCDs), common image displays, are widely used. The narrow viewing angle, however, is pointed out as a defect, despite various excellent characteristics.

[3] The mode of liquid crystal displays is divided by the initial arrangement of the liquid crystal, the structure of the electrodes, and the property of the liquid crystal, and the current commonly-used modes of liquid crystal displays are twisted nematic (TN), vertical arrangement (VA), and in-plane switching (IPS) modes. Further, it falls into normal black and normal white modes in accordance with whether to transmit light without receiving voltage, a VA mode is classified into PVA (Patterned VA), SPVA (Super PVA), and MVA (Multidomain VA) modes, and the IPS mode is classified into S-IPS (Super IPS) or FFS (Fringe Field Switching) modes in accordance with the domain and the initial arrangement of the liquid crystal.

[4] The in-plane switching mode has an arrangement which is uniform and substantially parallel to the surface of a substrate when the liquid crystal molecules are not activated. Therefore, since when the transmission axis of the lower polarizing plate and the fast axis of the liquid crystal molecules are in the same direction in the front surface, the transmission axis and the fast axis of the liquid crystal are in the same direction even in the inclined surface due to the optical properties of the liquid crystal, light does not change in polarization state even if it travels through the liquid crystals after passing through the lower polarizing plate, such that it can penetrate the liquid crystal layer without changes. As a result, it is possible to display a predetermined black state in an inactivation state by arrangement of the polarizing plates on the upper surface and the lower surface of the substrate. Such an in-plane switching mode liquid crystal display can generally implement a wide viewing angle without using an optical film, such that it has an advantage of providing a uniform image and viewing angle over the whole screen while naturally ensuring transmittance. Therefore, the in-plane
switching mode liquid crystal display is mainly used for high-end displays over 18 inches.

[5] Liquid crystal displays using an in-plane switching mode of the related art require a polarizing plate outside the liquid crystal cell including liquid crystals to polarize light and a protection film formed of a TAC (TriAcetyl Cellulose) film is applied on one or both surfaces of the polarizing plate to protect a polarizer. In this configuration, light polarized by the polarizer on the lower plate is elliptically polarized in not the front plane, but the inclined plane by the triacetyl cellulose when the liquid crystal displays a black state, such that the elliptically polarized light increases in polarization in the liquid crystal cell, and as a result, the light is transmitted and has various colors.

[6] Further, in recent years, a wide viewing angle has been required with demands for large image display devices, such as large-sized TVs using an in-plane switching mode. Accordingly, in in-plane switching mode liquid crystal displays, the liquid crystal displays have been manufactured by disposing an isotropic protection layer, instead of a TAC film, between a liquid crystal cell and the PVA of one polarizing plate of the liquid crystal cell, and stacking two or more compensation layers with different optical properties, or disposing one Z-axis alignment (aligned in the thickness direction) film between the liquid crystal cell and the polarizer of the other polarizing plate, in order to ensure a wide viewing angle.

[7] A detailed configuration of in-plane switching mode liquid crystal displays proposed to compensate a viewing angle in the related art is as follows. According to the structure of liquid crystal displays having an in-plane switching mode, when seen from the front, the liquid crystals are vertically (90°) aligned when voltage is not applied, the angle of the absorption axis of the polarizer included in the backlight-sided lower polarizing plate is 90°, and an isotropic protection film is positioned between the polarizing plate and the liquid crystal cell. Further, the angle of the absorption axis of the polarizer included in the display-sided polarizing plate is 0° and, at the liquid crystal cell side, an optical film described below is configured between the polarizer and the liquid crystal cell.

[8] There are a liquid crystal display including a negative C-plate and a positive biaxial plate (Korean Patent Application No. 2008-1 18531); a liquid crystal display including a positive A-plate and a positive biaxial plate (Korean Patent application No. 2008-1 18532); a liquid crystal display including a negative biaxial plate and a positive biaxial plate (Korean Patent Application No. 2008-123002); a liquid crystal display including a positive A-plate and a positive C-plate; a liquid crystal display including a negative biaxial plate and a positive C-plate; a liquid crystal display including a positive C-plate and a negative biaxial plate; a liquid crystal display including a negative A-plate and a negative biaxial plate (Korean Patent Application No.
2008-27107); a liquid crystal display including a positive biaxial plate and a negative biaxial plate (Korean Patent Application No. 2008-43414); a liquid crystal display including a negative A-plate and a negative C-plate (Korean Patent Application No. 2008-2190); a liquid crystal display including a positive biaxial plate and a negative C-plate (Korean Patent Application No. 2008-26831); a liquid crystal display including a Z-axis alignment film and a positive C-plate; and a liquid crystal display including one sheet of Z-axis alignment film.

These configurations can be manufactured by a roll-to-roll method, which is advantageous in mass production.

Liquid crystal displays proposed in the related art, however, use a three compensation film-typed coupled polarizing plate (one lower isotropic film + two upper compensation layers) formed by sacking two layers having different optical properties on one side of the liquid crystal layer, or a Z-axis alignment film that is difficult to have a large area due to low economic efficiency and a necessary contraction process, using a contraction film in the manufacturing process.

Therefore, in the related art, it is difficult to manufacture a thin product due to using a coupled polarizing plate stacked with three compensation films, bending likely occurs by changes in temperature or humidity because both sides of the liquid crystal cell are different in thickness, and the usage is limited to high-cost in-plane switching mode liquid crystal displays due to low price competitiveness by the use of expensive compensation films.

Disclosure of Invention

Technical Problem

The present invention provides a coupled polarizing plate set including compensation films designed to have specific optical properties to minimize color distortion in accordance with any viewing direction and ensure a wide viewing angle in an in-plane switching mode, and an economical thin in-plane switching mode liquid crystal display including the coupled polarizing plate set and providing high-quality images by minimizing color distortion, because a degree of distribution of polarization state on a Poincare Sphere is small, and simultaneously ensuring a wide viewing angle.

Solution to Problem

The present invention provides a coupled polarizing plate set, including: an upper polarizing plate having a protection film, a polarizer and a first compensation film in this sequence from the top; and a lower polarizing plate having a second compensation film, a polarizer and a protection film in this sequence from the top, wherein the first compensation film has an in-plane retardation (RO) of 50 to 200nm and a refractive index ratio (NZ) of -1 to -0.01, with its slow axis parallel to the absorption axis of the
polarizer in the upper polarizing plate, the second compensation film has an in-plane retardation (RO) of 50 to 250nm and a refractive index ratio (NZ) of -2 to -0.5, with its slow axis perpendicular to the absorption axis of the polarizer in the lower polarizing plate, and the sum of the in-plane retardations of the first compensation film and the second compensation film is 200 to 350nm.

In addition, the present invention provides an in-plane switching mode liquid crystal display including the coupled polarizing plate set described above.

Advantageous Effects of Invention

According to a coupled polarizing plate set of the present invention, when it is used for an in-plane switching mode liquid crystal display, it is possible to minimize color distortion in accordance with any viewing direction because degree of distribution of polarization states on a Poincare Sphere is small and ensure a wide viewing angle comparable to the level achieved by using three sheets of compensation film in the related art. Further, it is possible to ensure a wide viewing angle with only one sheet of compensation film for the upper polarizing plate and lower polarizing plate, such that it is possible to implement mass production of thin liquid crystal displays with high yield (reducing defect ratio due to foreign substances or impurities).

Brief Description of Drawings

The above objects, features and advantages of the present invention will become more apparent to those skilled in the related art in conjunction with the accompanying drawings. In the drawings:

FIG. 1 is a perspective view illustrating the structure of an in-plane switching liquid crystal display (IPS-LCD) according to the present invention;

FIG. 2 is a schematic view illustrating refractive index of a compensation film according to the present invention;

FIG. 3 is a schematic view showing an machine direction in a manufacturing process for illustrating an unrolled direction of a compensation film and a polarizing plate;

FIG. 4 is a schematic view illustrating expression of Φ and θ in a coordinate system of the present invention;

FIG. 5 is a view showing change regions in a polarization state on a Poincare Sphere by a first compensation film, a liquid crystal cell, and a second compensation film at a viewing direction of Φ=45° and θ=60° according to the present invention;

FIG. 6 is a view showing the simulation result of transmittance from all viewing directions of an Example 1 of the present invention;

FIG. 7 is a view showing changes in polarization state on a Poincare Sphere at a viewing direction of Φ=45° and θ=60° for the Example 1 of the present invention;

FIG. 8 is a view showing a polarization state for light at wavelength increments of
IOnm within the visible light region ranging from 380nm to 780nm of the Example 1 of the present invention;

[25] FIG. 9 is a view showing color coordinates at all viewing directions in black mode of the Example 1 according to the present invention;

[26] FIG. 10 is a view showing the simulation result of transmittance from all viewing directions of the Example 2 of the present invention;

[27] FIG. 11 is a view showing the range of changes in polarization state at a viewing direction of $\Phi=45^\circ$ and $\Theta=60^\circ$ and a short wavelength of 550nm of the Example 2 of the present invention and the range of polarization state on a Poincare Sphere included in the present invention;

[28] FIG. 12 is a view showing a polarization state of light at wavelength increments of IOnm within the visible light region ranging from 380nm to 780nm of the Example 2 of the present invention;

[29] FIG. 13 is a view showing the simulation result of transmittance from all viewing directions of the Example 3 of the present invention;

[30] FIG. 14 is a view showing the range of changes in polarization state at a viewing direction of $\Phi=45^\circ$ and $\Theta=60^\circ$ and a low wavelength of 550nm of the Example 3 of the present invention and the range of polarization state on a Poincare Sphere included in the present invention;

[31] FIG. 15 is a view showing a polarization state of light at wavelength increments of IOnm within the visible light region ranging from 380nm to 780nm of the Example 3 of the present invention;

[32] FIG. 16 is a view showing the simulation result of transmittance from all viewing directions of the Comparative Example 1 of the present invention;

[33] FIG. 17 is a view showing the range of changes in polarization state at a viewing direction of $\Phi=45^\circ$ and $\Theta=60^\circ$ and a short wavelength of 550nm of the Comparative Example 1 of the present invention and the range of polarization state on a Poincare Sphere included in the present invention;

[34] FIG. 18 is a view showing a polarization state of light at wavelength increments of IOnm within the visible light region ranging from 380nm to 780nm of the Comparative Example 1 of the present invention;

[35] FIG. 19 is a view showing color coordinates at all viewing directions in black mode of the Comparative Example 1 according to the present invention;

[36] FIG. 20 is a view showing the simulation result of transmittance from all viewing directions of the Comparative Example 2 of the present invention;

[37] FIG. 21 is a view showing color coordinates at all viewing directions in black mode of the Comparative Example 2 according to the present invention;

[38] FIG. 22 is a view showing the simulation result of transmittance from all viewing directions of the Example 2 according to the present invention;
rections of the Comparative Example 3 of the present invention; and

FIG. 23 is a view showing the simulation result of transmittance from all viewing directions of the Comparative Example 4 of the present invention.

Best Mode for Carrying out the Invention

The present invention relates to a coupled polarizing plate set including compensation films designed to have specific optical properties to ensure a wide viewing angle and as well as clarity of an image when it is used in an in-plane switching mode liquid crystal display, and an in-plane switching mode liquid crystal display including the coupled polarizing plate.

A coupled polarizing plate set of the present invention includes an upper polarizing plate having a protection film, a polarizer and a first compensation film in this sequence from the top and a lower polarizing plate having a second compensation film, a polarizer and a protection film in this sequence from the top.

The first compensation film has optical properties of an in-plane retardation (RO) of 50 to 200nm and a refractive index ratio (NZ) of -1 to -0.01, the second compensation film has optical properties of an in-plane retardation (RO) of 50 to 250nm and a refractive index ratio of -2 to -0.5, and the sum of the in-plane retardations of the first compensation film and the second compensation film is 200 to 350nm. Further, the first compensation film has a slow axis parallel to the absorption axis of the polarizer in the upper polarizing plate and the second compensation film has a slow axis perpendicular to the absorption axis of the polarizer in the lower polarizing plate.

The optical properties of the compensation films of the present invention are defined by the following Formulae 1 to 3 with respect to all wavelengths within the visible light region.

If the wavelength of a light source is not specifically stated, optical properties at 589nm are described, in which Nx is the refractive index of an axis having the largest refractive index in the in-plane direction, Ny is the refractive index in the perpendicular direction to Nx in the in-plane direction, and Nz is a refractive index in the thickness direction, which are expressed as follows, in FIG. 2:

[Formula 1]

$$R_{th} = [(N_x + N_y)/2 - N_z]xd$$

where Nx and Ny are in-plane refractive indices and Nx\(\geq\)Ny, Nz is a refractive index of light that oscillate in the thickness direction of a film, and d is thickness of the film;

[Formula 2]

$$RO = (N_x - N_y)Xd$$

where Nx and Ny are in-plane refractive indices of compensation films and d is thickness of a film, and Nx\(\geq\)Ny; and
[Formula 3]

\[ N_Z = \frac{(N_x - N_z)}{(N_x - N_y)} = \frac{R_{th}}{R_O} + 0.5 \]

where \( N_x \) and \( N_y \) are in-plane refractive indices and \( N_x \geq N_y \), \( N_z \) is a refractive index of light that oscillate in the thickness direction of a film, and \( d \) is thickness of the film.

Here, \( R_{th} \) is a thickness direction retardation, which shows a phase difference to the in-plane average refractive index in the thickness direction and is not a substantial phase difference, but a reference value, \( R_O \) is an in-plane retardation, which is a substantial phase difference when light has penetrated a film in the normal direction (perpendicular direction).

Further, \( N_Z \) is a refractive index ratio, from which the types of plates of compensation films can be distinguished. The type of the plate of compensation films is referred to as an A-plate have an optical axis (a light propagates direction without a phase difference exists) in the in-plane direction of the film, a C-plate have optical axis in the perpendicular direction to the plane, and a biaxial plate when two optical axes exist.

In detail, the refractive indices satisfy \( N_x > N_y = N_z \) for \( N_Z = 1 \), which is referred to as a positive A-plate, the refractive indices satisfy \( N_x > N_y > N_z \) for \( 1 < N_Z \), which is referred to as a negative biaxial A-plate, the refractive indices have a relationship of \( N_x > N_z > N_y \) for \( 0 < N_Z < 1 \), which is referred to as a Z-axis alignment film, the refractive indices have a relationship of \( N_x = N_z > N_y \) for \( N_Z = 0 \), which is referred to as a negative A-plate, the refractive indices have a relationship of \( N_z > N_x > N_y \) for \( N_Z < 0 \), which is referred to as a positive biaxial A-plate, the refractive indices have a relationship of \( N_x = N_y > N_z \) for \( N_Z = \infty \), which is referred to as a negative C-plate, and the refractive indices have a relationship of \( N_z > N_x = N_y \) for \( N_Z = -\infty \), which is referred to as a positive C-plate.

However, it is impossible to manufacture the A-plate and the C-plate perfectly following the theoretical definition in a real world process. Therefore, in a general process, the A-plate and the C-plate are discriminated by setting an approximate range of a refractive index ratio for the A-plate and a predetermined value within the range of the in-plane retardation for the C-plate. Setting a predetermined value is limited in application to all other materials having different refractive indices dependant upon extension. Therefore, the compensation films included in the upper and lower polarizing plate of the present invention are represented by, \( N_Z \), \( R_O \), and \( R_{th} \) etc. with numerals, which are optical properties of plates, not according to refractive index isotropy.

These compensation films are provided with a phase difference by extension, in which a film having a refractive index increasing in the extension direction has positive (+) refractive index properties and a film having a refractive index decreasing...
in the extension direction has negative (-) refractive index properties. The compensation film having positive (+) refractive index properties can be made of one selected from the group consisting of TAC (TriAcetyl Cellulose), COP (Cyclo-Olefin Polymer), COC (Cyclo-Olefin Copolymer), PET (Polyethylene Terephthalate), PP (Polypropylene), PC (Polycarbonate), PSF (Polysulfone), and PMMA (Poly Methylmethacrylate), and a compensation film having the negative (-) refractive index can be made of, in detail, modified-PS (polystyrene) or modified-PC (Polycarbonate).

Further, the extension method providing a compensation film with optical properties is divided into a fixed-end extension and free-end extension, in which the fixed-end extension is to fix the length other than the extension direction during extension of a film and the free-end extension is to provide a degree of freedom in another direction than the extension direction during extension of a film. In general, a film contracts in another direction than the extension direction in extension, but a Z-axis alignment film requires a specific contraction process rather than extension.

FIG. 3 shows a direction of a rolled raw film, in which the unrolled direction of the rolled film is referred to as an MD (Machine direction) and the direction perpendicular to the MD is referred to as a TD (Transverse direction). Further, in the process, extension of the film in the MD is referred to as free-end extension and extension in the TD is referred to as fixed-end extension.

Summarizing NZ and the type of a plate according to an extension method (when only the first process is applied), the positive A-plate can be manufactured by free-end extending a film having positive (+) refractive index properties, the negative biaxial A-plate by fixed-end extending a film having positive (+) refractive properties, the Z-axis alignment film by free-end extending and then fixed-end contracting a film having positive (+) refractive properties or negative (-) refractive properties, the negative A-plate by free-end extending a film having negative (-) refractive properties, and the positive biaxial A-plate by fixed-end extending a film having negative (-) refractive properties.

It is possible to control the direction of the slow axis, the phase difference, and NZ value by applying an additional process excepting the above processes, and the additional process is one of a number of processes that is generally applied in the field including the present invention and is not particularly limited.

A coupled polarizing plate set of the present invention includes an upper polarizing plate having a protection film, a polarizer and a first compensation film in this sequence from the top; and a lower polarizing plate having a second compensation film, a polarizer and a protection film in this sequence from the top.

The first compensation film has an in-plane retardation (RO) of 50 to 200nm and a refractive index ratio (NZ) of -1 to -0.01, the second compensation film has an in-plane
retardation (RO) of 50 to 250nm and a refractive index ratio (NZ) of -2 to -0.5.

The first and second compensation films according to the present invention should have optical properties in which the polarization state on a Poincare Sphere should change within the region inside the red circle, as shown in FIG. 5, in order to minimize color distortion according to all viewing directions, ensuring a wide viewing angle of an in-plane switching liquid crystal display including the first and second compensation films. In this configuration, the red circle has a radius defined by a distance from a polarization state on a Poincare Sphere when light at a visual angle of $\Phi=45$ and $\theta=60$, and a short wavelength of 550nm has penetrated the polarizer of the lower polarizing plate to a polarization state in which the light is maximally absorbed into the absorption axis of the upper polarizing plate.

Therefore, the first and second compensation films control the polarization state by adjusting optical properties of a compensation film with respect to another compensation film to maintain the region inside the red circle. The present invention selects and uses the first compensation film such that all polarization states are maintained within the region inside the red circle, with respect to the second compensation film.

To be specific, referring to FIG. 5, 50nm, which is the minimum limit of the in-plane retardation (RO) of the second compensation film, is a value where high yield can be accomplished in the manufacturing process of the compensation film, in which the minimum refractive index ratio (NZ) of a liquid crystal display which satisfies the object (red circle) of the present invention is -2 (red circle No.4). Thereinafter, a contact point with the red circle is generated until the refractive index ratio (NZ) increases from -2 and reaches -0.7, in which the maximum in-plane retardation is 250nm (red circle Nos. 3, 2, and 1). Further, when the refractive index ratio (NZ) exceeds -0.7, a contact point with the circle is not generated, but it should be maintained under -0.5 where right-circular polarization does not occur, in order to satisfy compensation conditions with respect to the liquid crystal cell, in which the in-plane retardation should be maintained at 250nm where a polarization state on a Poincare Sphere due to the second compensation film is not in the upper semi-sphere [S3 is positive (+)].

As a result, as shown in FIG. 5, a first compensation film is selected to use in the present invention, of which a polarization state that can satisfy the compensation conditions of the present invention and comes close to the black point F, when passing through the polarization states [red-colored 1, 2, 3, and 4] and the liquid crystal [blue-colored 1, 2, 3, and 4] which are determined by the optical properties of the second compensation film in the maximum change region of the polarization state (red-colored) on a Poincare Sphere. Although anyone having optical properties capable
of coming close to the point F can be used as the first compensation film, it is preferable to maintain the refractive index ratio (NZ) within -1 to -0.01 to easily perform simulation on a Poincare Sphere, and the in-plane retardation (RO) capable of coming close to the point F within the refractive index ratio is 50 to 200nm.

Although anyone satisfying the optical properties described above can be used for the first compensation film and the second compensation film, it is preferable to manufacture the first compensation film by applying one or more fixed-end extension to a film having a negative (-) refractive index, and applying more extension in the TD than the MD such that the slow axis is in the MD. This is for applying it to the roll-to-roll process, in which the absorption axis of the upper polarizing plate is in the MD; therefore, the slow axis of the first compensation film should be maintained in the MD. Further, the second compensation film is manufactured by applying one or more fixed-end extension to a film having a negative (-) refractive index, and applying more extension in the MD than the TD such that the slow axis is in the TD. This is for easily applying it to the roll-to-roll process, in which the absorption axis of the polarizer of the lower polarizing plate is in the MD; such that the slow axis of the second compensation film is maintained in the TD.

The first compensation film is arranged with its slow axis parallel to the absorption axis of the polarizer in the upper polarizing plate and the second compensation film is arranged with the slow axis perpendicular to the absorption axis of the polarizer in the lower polarizing plate.

Meanwhile, most optical systems including a liquid crystal and a compensation film are different in phase difference (radians) according to the wavelengths of a light source, such that a polarization state after passing through the optical systems changes in accordance with the wavelengths. Most optical systems are large in phase difference (radians) at a short wavelength and small in phase difference (radians) at a long wavelength, such that changes in polarization state at the short wavelength are larger than those at a long wavelength, and accordingly, distribution occurs. The distribution causes color distortion in accordance with viewing directions, such that it influences the image quality of a liquid crystal display. The present invention is designed to minimize color distortion by controlling distribution, and the distribution is controlled by changing a polarization state on a Poincare Sphere.

The alignment direction of the liquid crystal and the direction of the slow axis of a compensation film show the change direction of polarization state on the Poincare Sphere. When the alignment direction of the liquid crystal and the direction of the slow axis of a compensation film are horizontal, the polarization states of them cause the same polarization and distribution of light increases, or when they are perpendicular, the polarization states of them cause polarization in the opposite directions, such that
distribution of light is prevented. The increase of distribution implies increase of changes in color in accordance with viewing directions, in which it is advantageous that the distribution is as small as possible because distortion of color is generated. In the present invention, the alignment direction of the liquid crystal is perpendicular to the slow axis of the compensation film, such that their polarization states cause polarization in the opposite direction, and accordingly the distribution is smaller than when the axes are horizontal.

Further, when changes in polarization by the alignment direction of the liquid crystal and the direction of the slow axis of the compensation film are opposite to each other, it is possible to more effectively prevent distribution by maintaining the sum of the in-plane retardations of the first compensation film and the second compensation film within a range similar to the range of the phase difference of the liquid crystal. The in-plane retardation is a factor having an effect on changes of the polarization state at each viewing direction; therefore, it is possible to minimize distribution of light by limiting the range of the in-plane retardation within a range similar to the liquid crystal. In detail, the liquid crystal cell used in the present invention has a phase difference (Δnd) in a range of 300 to 330nm at a wavelength of 589nm, such that distribution is minimized by maintaining the sum of the in-plane retardations of the first compensation film and the second compensation film within the above range of 300 to 330nm. However, since the present invention has an object of minimizing distribution simultaneously with ensuring a wide viewing angle, the sum of the in-plane retardations of the first compensation film and the second compensation film should be 200 to 350nm to simultaneously satisfy the objects.

In general, a compensation film has a phase difference that is different in accordance with the wavelength of incident light. The phase difference is large at a short wavelength and small at a long wavelength, and a compensation film having these properties is referred to as a compensation film having a normal wavelength distribution. Further, a film having a small phase difference at a short wavelength and a large phase difference at a long wavelength is referred to as a compensation film having an inverse wavelength distribution. The distribution of the compensation films are represented by a ratio of a phase difference for a light source of 780nm generally used in this field to a phase difference for a light source of 380nm. For reference, in a compensation film having complete inverse wavelength distribution capable of implementing the same polarization state for all wavelengths, \([R_0(380\text{nm})/R_0(780\text{nm})] = 0.4872\).

Although the present invention can use all compensation films irrespective of the distribution, it is preferable to use a compensation film of \([R_0(380\text{nm})/R_0(780\text{nm})] > 1\) to decrease wavelength dependence of the polarization state right before light penetrates
the polarizer of the upper polarizing plate. In detail, the fact that the wavelength dependence of the polarization state right before light penetrates the polarizer of the upper polarizing plate is small implies that changes in color by viewing directions are small in black mode. Any material satisfying such optical properties can be used in the present invention.

A PVA (Polyvinyl Alcohol) layer that is a polarizer provided with a polarizing function by extension and dyeing is disposed on the polarizers of the upper and lower polarizing plates and a protection film is disposed at the opposite side to the liquid crystal cell on the PVA layer of the lower polarizing plate and the PVA layer of the upper polarizing plate, respectively. The upper and lower polarizing plates can be manufactured by a method generally used in this field, and in detail, a roll-to-roll process and a sheet-to-sheet process can be used. It is preferable to use the roll-to-roll process in consideration of the yield and efficiency in the manufacturing process, and in particular, it is effective because the direction of the absorption axis of the PVA polarizer is always fixed in the MD.

In this configuration, in the protection film of the lower polarizing plate and the protection film of the upper polarizing plate, the optical properties according to a difference in refractive index do not influence the visual angle, such that the refractive index is not particularly limited in the present invention. Materials generally used in this field can be used for the protection films of the upper and lower polarizing plates, in detail, one selected from the group consisting of TAC (TriAcetyl Cellulose), COP (Cyclo-Olefin Polymer), COC (Cyclo-Olefin Copolymer), PET (Polyethylene Terephthalate), PP (Polypropylene), PC (Polycarbonate), PSF (Polysulfone), and PMMA (Poly Methylmethacrylate) can be used.

Further, the present invention relates to an in-plane switching mode liquid crystal display including the coupled polarizing plate set. The absorption axis of the upper polarizing plate is perpendicular to the absorption axis of the polarizer in the lower polarizing plate.

A liquid crystal cell is an in-plane switching liquid crystal when the liquid crystal alignment is 90 without receiving voltage, in which the panel phase difference (Δnxd) determined by the following Formula 4 is 300nm to 330nm at a wavelength of 589nm, and in the configuration of the present invention, it is preferably about 310 to 320nm. This is because the liquid crystal cell phase difference of the IPS-LCD (In-Plane Switching mode Liquid Crystal Display) panel should be half the wavelength of 589nm (monochromatic light that a person feels the most bright) in order that linearly-polarized light in the horizontal direction after penetrating the lower polarizing plate becomes a white state by being linearly-polarized in the vertical direction after penetrating the liquid crystal cell, when voltage is applied to the IPS-LCD panel. In this
case, it can be adjusted to be slightly longer or shorter than the half wavelength to be a white color.

[80] [Formula 4]

\[(\Delta n x d) = (n_e - n_o) x d\]

[82] where \(n_e\) is an extraordinary ray refractive index of liquid crystal, \(n_o\) is an ordinary ray refractive index, \(d\) is a cell gap; \(\Delta n\) and \(d\) are scalars, not vectors.

[83] A liquid crystal display of the present invention has the optical conditions that the maximum transmittance from all light directions in black mode is 0.2% or less, preferably 0.05% or less.

[84] In the present invention, the inclined surface compensation principle can be understood by changing the polarization state on a Poincare Sphere when light passes through each optical layer. FIG. 6 shows polarization states of a liquid crystal display according to the present invention, at a visual angle of \(\Phi=45^\circ\) and \(\Theta=60^\circ\). In detail, it shows changes in polarization state on a Poincare Sphere of light coming out in the front direction when the surface of the \(\Phi\) direction is rotated to the display side by \(\Theta\) about an axis of \(\Phi+90^\circ\) in the front plane. Right-circular polarization appears when the coordinates of the S3 axis are positive (+) on a Poincare Sphere, in which the right-circular polarization, when a certain polarization horizontal component is \(E_x\) and polarization vertical component is \(E_y\), implies that phase delay of light of \(E_x\) component with respect to \(E_y\) component is larger than 0 and smaller than a half wavelength. Further, in the liquid crystal display according to the present invention, each polarization state when light having a short wavelength of 550nm at a visual angle of \(\Phi=45^\circ\) and \(\Theta=60^\circ\) passes through each optical layer on a Poincare Sphere changes in a circle having a radius from a polarization state after the light penetrates the polarizer of the lower polarizing plate to a polarization state where the light is maximally absorbed into the absorption axis of the upper polarizing plate. This is the region inside the red circle shown in FIG. 5, in which when anyone of the polarization states is outside the range, it is possible to implement transmittance from all light directions which is an object of the present invention, but changes in color according to the visual angle are very large, such that color of the liquid crystal display is distorted in the inclined surface.

[85] FIG. 1 is a perspective view illustrating the basic structure of an in-plane switching mode liquid crystal display according to the present invention, which is described hereinafter.

[86] An in-plane switching mode liquid crystal display according to the present invention includes a lower polarizing plate 10, an in-plane switching liquid crystal cell 30, and an upper polarizing plate 20, from a backlight unit 40. The lower polarizing plate 10 has a second compensation film 14, a polarizer 11, and a protection film 13, in this sequence
from the top and the upper polarizing plate 20 has a protection film 23, an polarizer 21, and a first compensation film 24 in this sequence from the top. The absorption axes 12 and 22 of the polarizer 21 of the upper polarizing plate and the polarizer 11 of the lower polarizing plate are perpendicular to each other, and the absorption axis 12 of the polarizer 11 of the lower polarizing plate should be vertically positioned when seen from the front.

[87] In detail, when the absorption axis of the lower polarizing plate close to the backlight unit is in the vertical direction, light penetrating the lower polarizing plate is polarized in the horizontal direction, and the light travels vertically and penetrates the display-sided upper polarizing plate having the absorption axis in the horizontal direction, when the white state is implemented by passing through the liquid crystal cell applied with voltage of a panel. Even a person wearing polarizing sunglasses of which the absorption axis is in the horizontal direction at the display side (the absorption axis of the polarizing sunglasses is in the horizontal direction) can see the light coming from the liquid crystal display. If the absorption axis of the lower polarizing plate close to the backlight unit is in the horizontal direction, the person wearing polarizing sunglasses cannot see the image.

[88] Further, for large-sized liquid crystal displays, in consideration that the main visual angle of a human is wider in the horizontal direction than the vertical direction, common liquid crystal displays, except for specific liquid crystal displays for advertisement etc., are manufactured in a 4:3 or 16:9 type, in order that the image can be shown well from the display side. Therefore, the absorption axis of the lower polarizing plate is positioned in the vertical direction and the absorption axis of the upper polarizing plate is positioned in the horizontal direction when seen from the display-sided front.

[89] A slow axis 25 of the first compensation film 24 and the absorption axis 22 of the polarizer 21 are disposed in parallel to each other in the upper polarizing plate, and a slow axis 15 of the second compensation film 14 and the absorption axis 12 of the polarizer 11 are disposed perpendicular to each other in the lower polarizing plate.

[90] The effect of viewing angle compensation of the present invention can be explained through a Poincare Sphere. The Poincare Sphere is useful to show changes in polarization state at a specific visual angle, such that it can show changes in polarization state when light traveling along a specific visual angle in a liquid crystal display, which displays an image using polarization, passes through each optical element inside the liquid crystal display. The specific visual angle in the present invention is a direction of $\Phi=45^\circ$ and $\theta=60^\circ$ in a hemispherical coordinate system shown in FIG. 4, and it is possible to see wavelength distribution by showing changes in polarization state on a Poincare Sphere of light coming out in this direction with respect to all
Hereafter, in the above configuration, an effect of implementing the black state at all viewing angles when voltage is not applied is described through examples and comparative examples. Although the present invention can be more easily understood through the following embodiments, the following embodiments are provided only as examples of the present invention and do not limit the protective scope of the present invention claimed by the accompanying claims.

EXAMPLES

Wide viewing angle effects were compared through simulation by using TECH WIZ LCD ID (Sanayi System Co., Ltd, Korea), which is an LCD simulation system in the following Examples 1-3 and Comparative Examples 1-4.

EXAMPLE 1

Actually-measured data of each optical film, a liquid crystal cell, and a backlight according to the present invention was used for the TECH WIZ LCD ID (Sanayi System Co., Ltd, Korea) with a stacked structure shown in FIG. 1. The structure of FIG. 1 is described hereinafter.

From the backlight unit 40, a lower polarizing plate 10, an in-plane switching mode liquid crystal cell 30 having a liquid crystal alignment of 90°, when seen from the display-sided front without receiving voltage, and an upper polarizing plate 20 are disposed, in which the lower polarizing plate 10 is formed by stacking a protection film 13, a polarizer 11, and a second compensation film 14 from the backlight unit 40, and the upper polarizing plate 20 is formed by stacking a first compensation film 24, a polarizer 21, and a protection film 23 from the in-plane switching mode liquid crystal cell 30.

The liquid crystal cell is one applied to LC420WU5 being a 42 inch panel produced by LG Display Co., Ltd.

On the other hand, each optical film and the backlight unit used in this example have the following optical properties.

First, the polarizers 11 and 21 of the lower polarizing plate 10 and the upper polarizing plate 20 are provided with polarizing function by dyeing an extended PVA with iodine and the polarizing performance of the polarizers having a 99.9% or more luminance degree of polarization and 41% or more luminance group transmittance within a visible light region of 370 to 780nm. The luminance degree of polarization and the luminance group transmittance are defined by the following Formulae 5 to 9, when transmittance of the transmittance axis according to a wavelength is TD(λ), transmittance of the absorption axis according to a wavelength is MD(λ), and
luminance compensation value defined in JIS Z 8701:1999 is

\[ SW \]

, where \( S(\lambda) \) is light source spectrum and the light source is a C-light source.

\[ T_{\text{TD}} = K \int_{380}^{780} S(\lambda) \tilde{y}(\lambda) TD(\lambda) d\lambda \]

\[ T_{\text{MD}} = K \int_{380}^{780} S(\lambda) \tilde{y}(\lambda) MD(\lambda) d\lambda \]

\[ K = \frac{100}{\int_{380}^{780} S(\lambda) \tilde{y}(\lambda) d\lambda} \]

\[ \text{Degree of polarization} = \sqrt{\frac{T_{\text{TD}}^2 - T_{\text{MD}}^2}{T_{\text{TD}}^2 + T_{\text{MD}}^2}} \]

\[ \text{Group transmittance} = \frac{(T_{\text{TD}} + T_{\text{MD}})}{2} \]

According to optical properties generated by a difference in internal refractive index in the direction of each film, for a light source of 589.3nm, there were used the first compensation film 24 having an in-plane retardation (RO) of 150nm and a refractive index ratio (NZ) of -0.1, and the second compensation film 14 having an in-plane retardation (RO) of 70nm and a refractive index ratio of -1.2. In this case, the absorption axis 22 of the polarizer 21 and the slow axis 25 of the first compensation film 24 are parallel to each other in the upper polarizing plate 20, and the absorption axis 12 of the polarizer 11 and the slow axis 15 of the second compensation film 14 are perpendicular to each other in the lower polarizing plate 10. The sum of the in-plane retardations of
the first compensation film 24 and the second compensation film 14 was 220nm.

The first compensation film 24 and the second compensation film 14 were manufactured by applying triple-coextrusion such that a PS (Polystyrene) layer having a negative refractive index is disposed between two PMMA (Poly Methylmethacrylate) and then sequentially disposing compensation films (I-Film, Optes Inc., Japan) through extension.

Further, TAC (TriAcetyl Cellulose) having an optical property of 50nm Rth with respect to incident light of 589.3nm was used for the outer protection films 13 and 23 as protection layers of the upper and lower polarizing plates 10 and 20. Actually-measured data equipped in a TV LC320WX4 model of 32 inches (LG. PHILIPS LCD Inc.) was used for the backlight unit 40.

FIG. 6 shows a simulation result of transmittance from all light directions after stacking optical components, as shown in FIG. 1. FIG. 6 shows transmittance from all light directions when a black state is displayed on the screen, in which the transmittance is 0% to 0.2%, the portion exceeding 0.02% transmittance is shown by red color and low-transmittance portion is shown by blue color when the black state is shown, in the range of the scale. In this case, it can be seen that the wider the blue portion at the center, the easier it is to ensure a wider viewing angle. This is because the changes in polarization state on a Poincare Sphere are shown in FIG. 7 at a visual angle (Φ=45° and θ=60°) where the most amount of light is transmitted.

In the Example 1, changes in polarization of light having a short wavelength 550nm at a visual angle of Φ=45° and θ=60° is shown in FIG. 7. In FIG. 7, the first polarization state that is the right start point is a polarization state when the light penetrates the polarizer of the lower polarizing plate, the second polarization state is a polarization state when the light penetrates the second compensation film of the lower polarizing plate, the third polarization state is a polarization state when the light penetrates the liquid crystal cell, and the fourth polarization state is a polarization state when the light penetrates the first compensation film of the upper polarizing plate. In the Example 1, all the polarization states of the layers under the above conditions are in the red circle, which is within the scope of the present invention.

EXAMPLE 2

Although it was configured the same as in the Example 1, the first compensation film 24 has an in-plane retardation (RO) of 100nm and a refractive index ratio (NZ) of -0.1 and the second compensation film 14 has an in-plane retardation (RO) of 150nm and a refractive index ratio (NZ) of -0.7. The sum of the in-plane retardations of the first compensation film 24 and the second compensation film 14 was 250nm.

As a simulation result of transmittance from all light directions, the result shown in
FIG. 10 was obtained. FIG. 10 shows transmittance from all light directions distribution when the black state is displayed on the screen, in which the transmittance is 0% to 0.2%, the portion exceeding 0.02% transmittance is shown by red color and low-transmittance portion is shown by blue color when the black state is shown, in the range of the scale. In this case, it can be seen that the wider the blue portion at the center, the easier it is to ensure a wider viewing angle. This is because the changes in polarization state on a Poincare Sphere are shown of FIG. 11 at a visual angle (\(\Phi=45^\circ\) and \(\theta=60^\circ\)) where the most amount of light is transmitted.

In the Example 2, changes in polarization of light having a short wavelength of 550nm at a visual angle of \(\Phi=45^\circ\) and \(\theta=60^\circ\) is shown in FIG. 11. In FIG. 11, the first polarization state that is the right starting point is a polarization state when the light penetrates the polarizer of the lower polarizing plate, the second polarization state is a polarization state when the light penetrates the second compensation film of the lower polarizing plate, the third polarization state is a polarization state when the light penetrates the liquid crystal cell, and the fourth polarization state is a polarization state when the light penetrates the first compensation film of the upper polarizing plate.

Further, in the liquid crystal display of the Example 2, polarization states of light for wavelength increments of 10nm within a range of 380nm to 780nm of visible light are shown in FIG. 12.

It can be seen from the Example 2 that the polarization states at the short wavelength of 550nm, as shown in FIG. 11, should be changed within the circle (red circle) having the range described herein on a Poincare Sphere to implement the effect of the present invention.

In FIGS. 7 and 11 according to the Examples 1 and 2, as the change in polarization state with respect to the light source of 550nm, the optical conditions of the first and second compensation films satisfying when the polarization changes are in the red circle may have a mathematically large number of cases. That is, anyone can be used as long as they satisfy the specific optical properties proposed in the present invention and the changes in polarization state of a liquid crystal display including them is in a circle having a radius defined as a distance from a polarization state after light penetrates the polarizer of the lower polarizing plate to a polarization state where the light can be maximally absorbed into the absorption axis of the upper polarizing plate.

EXAMPLE 3

Although it was configured the same as in the Example 1, the first compensation film 24 has an in-plane retardation (RO) of 50nm and a refractive index ratio NZ of -0.1 and the second compensation film 14 has an in-plane retardation (RO) of 250nm and a refractive index ratio of -0.7. The sum of the in-plane retardations of the first com-
As a simulation result of transmittance from all light directions, the result shown in FIG. 13 was obtained. FIG. 13 shows transmittance from all light directions distribution when the black state is displayed on the screen, in which the transmittance is 0% to 0.2%, the portion exceeding 0.02% transmittance is shown by red color and low-transmittance portion is shown by blue color when the black state is shown, in the range of the scale. In this case, it can be seen that the wider the blue portion at the center, the easier it is to ensure a wider viewing angle. This is because the changes in polarization state on a Poincare Sphere are shown in FIG. 14 at a visual angle (\(\Phi=45^\circ\) and \(\theta=60^\circ\)) where the most amount of light is transmitted.

In the Example 3, changes in polarization of light having a short wavelength 550nm at a visual angle of \(\Phi=45^\circ\) and \(\theta=60^\circ\) is shown in FIG. 14. In FIG. 14, the first polarization state that is the right start point is a polarization state when the light penetrates the polarizer of the lower polarizing plate, the second polarization state is a polarization state when the light penetrates the second compensation film of the lower polarizing plate, the third polarization state is a polarization state when the light penetrates the liquid crystal cell, and the fourth polarization state is a polarization state when the light penetrates the first compensation film of the upper polarizing plate.

Further, in the liquid crystal display of the Example 3, polarization states of light for wavelength increments of 10nm within a range of 380nm to 780nm of visible light are shown in FIG. 15.

It can be seen from the Example 3 that the polarization states at the short wavelength of 550nm, as shown in FIG. 15, should be changed within the circle (red circle) having the range described herein on a Poincare Sphere to implement the effect of the present invention.

**COMPARATIVE EXAMPLE 1**

Although it was configured the same as in the Example 1, a liquid crystal display was manufactured by stacking an upper polarizing plate formed by stacking a positive biaxial A-plate having an in-plane retardation (RO) of 60nm and a refractive index ratio (NZ) of -1.3, a positive uniaxial A-plate having an in-plane retardation (RO) of 70nm and a refractive index ratio (NZ) of 1.7, a polarizer, and a protection film, and a lower polarizing plate formed by stacking an isotropic protection layer having an in-plane retardation (RO) of 0nm and a thickness direction retardation (Rth) of 0nm, a polarizer, and a protection film. In this configuration, the slow axis of each of the positive uniaxial A-plate and the positive biaxial A-plate is parallel to the absorption axis of the polarizer in the polarizing plates.

As a result of transmittance from all light directions simulation of the in-plane
switching mode liquid crystal display, the result shown in FIG. 16 was obtained.

In the first comparative example, changes in polarization of light having a short wavelength 550nm at a visual angle of Φ=45° and θ=60° is shown in FIG. 17. In FIG. 17, the first polarization state that is the right start point is a polarization state when the light penetrates the polarizer of the lower polarizing plate, the second polarization state is a polarization state when the light penetrates the second compensation film of the lower polarizing plate, the third polarization state is a polarization state when the light penetrates the liquid crystal cell, the fourth polarization state is a polarization state when the light penetrates the first compensation film of the upper polarizing plate, and the fifth polarization state is a polarization state when the light penetrates the second first compensation film of the upper polarizing plate.

Further, in the liquid crystal display of the Example 1 and the Comparative Example 1, polarization states of light for wavelength increments of 10nm within a range of 380nm to 780nm of visible light are shown in FIGS 8 and 18. In general, the polarization states right before the light penetrates the polarizer of the upper polarizing plate are the same at each wavelength, such that the liquid crystal display shows less color changes for visual angels, whereby it is possible to expect the color changes from degree of distribution of the polarization states on a Poincare Sphere with respect to all wavelengths within the visible light region. That is, comparing the Example 1 shown in FIG. 8 with the Comparative Example 1 shown in FIG. 18, it can be seen that the degree of distribution of color is small in the Example 1, such that the color change is small.

In order to confirm the color change in detail, color coordinates (CIE 1931, XY) for all viewing directions in black mode in the liquid crystal displays of the Example 1 and the Comparative Example 1 are shown in FIGS. 9 and 19. As shown in FIGS. 9 and 19, it can be seen that the color change of the Example 1 according to the present invention is significantly less than that of the existing in-plane switching liquid crystal display of the Comparative Example 1.

As described above, it can be seen from the Example 1 that, in order to implement the effect of the present invention, the polarization states at the short wavelength of 550nm should be changed within the range (red circle) described herein, as shown in FIG. 7.

COMPARATIVE EXAMPLE 2

Although it was configured the same as in the Example 1, an in-plane switching liquid crystal display was manufactured by using Normal TAC (Triacetyl Cellulose having Rth of 50nm with respect to incident light of 589.3nm) for upper and second compensation film of the lower polarizing plates.
Transmittance from all light directions of the in-plane switching liquid crystal display is shown in FIG. 20 and the color coordinates (CIE 1931, XY) are shown in FIG. 21. As a result, it can be seen that light transmittance is large with respect to an inclined surface and color change is also large, as compared with the Example 1.

COMPARATIVE EXAMPLE 3

Although it was configured the same as in the Example 1, an in-plane switching liquid crystal display was manufactured by using an isotropic protection film (the in-plane retardation (RO) is 0nm and the thickness direction retardation (Rth) is 0nm) for upper and second compensation film of the lower polarizing plates.

Transmittance from all light directions of the in-plane switching liquid crystal display is shown in FIG. 22. As a result, it can be seen that the contrast in an inclined surface is low, such that the image is not clear, as compared with the Example 1.

COMPARATIVE EXAMPLE 4

Although it was configured the same as in the Example 1, the first compensation film 24 had an in-plane retardation (RO) of 150nm and a refractive index ratio (NZ) of -0.1 and the second compensation film 14 had an in-plane retardation (RO) of 250nm and a refractive index ratio of -0.7. The sum of the in-plane retardations of the first compensation film 24 and the second compensation film 14 was 400nm.

Transmittance from all light directions of the in-plane switching liquid crystal display is shown in FIG. 23. As a result, it can be seen that the contrast in an inclined surface is low, such that the image is not clear, as compared with the Example 1.

Industrial Applicability

As described above, an in-plane switching liquid crystal display according to the present invention can be applied to liquid crystal displays requiring high visual angle properties because it can provide excellent image quality for all viewing directions.
Claims

[Claim 1] A coupled polarizing plate set, comprising:
an upper polarizing plate having a protection film, a polarizer and a
first compensation film in this sequence from the top; and
a lower polarizing plate having a second compensation film, a polarizer
and a protection film in this sequence from the top,
wherein the first compensation film has an in-plane retardation (RO) of
50 to 200nm and a refractive index ratio (NZ) of -1 to -0.01, with its
slow axis parallel to the absorption axis of the polarizer in the upper polarizing plate,
the second compensation film has an in-plane retardation (RO) of 50 to
250nm and a refractive index ratio (NZ) of -2 to -0.5, with its slow axis
perpendicular to the absorption axis of the polarizer in the lower polarizing plate, and
the sum of the in-plane retardations of the first compensation film and
the second compensation film is 200 to 350nm.

[Claim 2] The coupled polarizing plate set according to claim 1, wherein the first
compensation film and the second compensation film are independently
made of one selected from the group consisting of TAC (TriAcetyl
Cellulose), COP (Cyclo-Olefin Polymer), COC (Cyclo-Olefin
Copolymer), PET (Polyethylene Terephthalate), PP (Polypropylene),
PC (Polycarbonate), PSF (Polysulfone) and PMMA (Poly Methyl-
methacrylate).

[Claim 3] The coupled polarizing plate set according to claim 1, wherein each of
the first compensation film and the second compensation film includes
PMMA (Poly Methylmethacrylate) layer, PS (Polystyrene) layer and
PMMA (Poly Methylmethacrylate) layer in this sequence.

[Claim 4] An in-plane switching mode liquid crystal display including the
coupled polarizing plate set according to any one of claims 1 to 3.

[Claim 5] The in-plane switching mode liquid crystal display according to claim
4, wherein a liquid crystal cell has a phase difference (Δnxd) in a range
of 300 to 330nm at a wavelength of 589nm.

[Claim 6] The in-plane switching mode liquid crystal display according to claim
4, wherein the oriented direction of liquid crystals is parallel to the ab-
sorption axis of the polarizer in the lower polarizing plate.

[Claim 7] The in-plane switching mode liquid crystal display according to claim
4, wherein the maximum transmittance from all viewing directions in
black mode is 0.2% or less.

[Claim 8] The in-plane switching mode liquid crystal display according to claim 4, wherein each polarization state on a Poincare Sphere, when light having a short wavelength of 550nm at a viewing direction of \( \Phi = 45^\circ \) and \( \theta = 60^\circ \) passes through each optical layer, is in a circle having a radius from a polarization state right after the light penetrates the polarizer in the lower polarizing plate to a polarization state where the light is maximally absorbed into the absorption axis of the polarizer in the upper polarizing plate.
[Fig. 1]

UPPER POLARIZING PLATE (20)

PROTECTION FILM 23
POLARIZER 22
FIRST COMPENSATION FILM 21
IN-PLANE SWITCHING MODE LIQUID CRYSTAL CELL 25
SECOND COMPENSATION FILM 24

LOWER POLARIZING PLATE (10)

POLARIZER 31
SECOND COMPENSATION FILM 30
IN-PLANE SWITCHING MODE LIQUID CRYSTAL CELL 15
SECOND COMPENSATION FILM 14
POLARIZER 12
PROTECTION FILM 11
BACKLIGHT 13

[Fig. 2]

Diagram showing a 3D coordinate system with axes X, Y, and Z.