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Moon et al.

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(54) **LIQUID CRYSTAL DISPLAY DEVICE HAVING WIDE VIEWING ANGLE**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
G02F 1/1335 (2006.01)

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

(58) **Field of Classification Search** 349/119
See application file for complete search history.

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(57) **ABSTRACT**

Disclosed is a liquid crystal display device having a wide viewing angle, in which compensation films are disposed between a liquid crystal display panel and polarizers to change a polarized state of light, which is incident on the liquid crystal display panel and output therefrom through the polarizers, thereby preventing light from being leaked in a diagonal direction of the liquid crystal display device in a normally black mode.

21 Claims, 13 Drawing Sheets

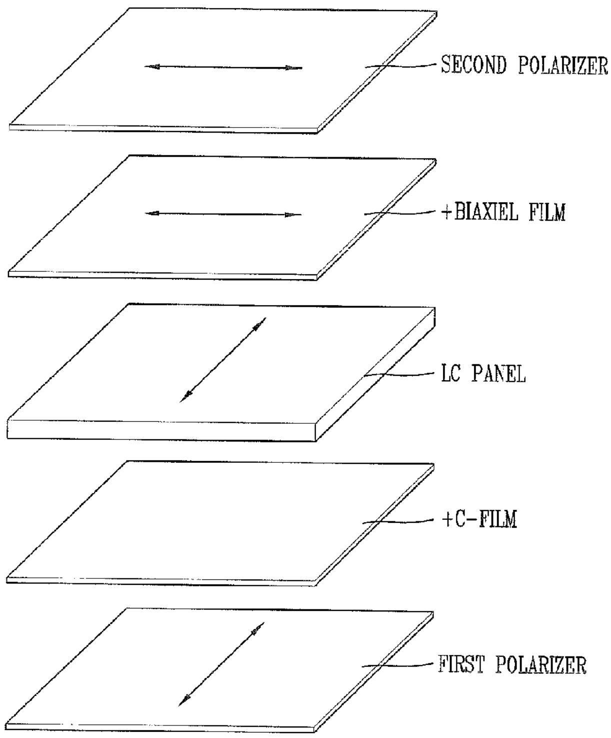


FIG. 1A
PRIOR ART

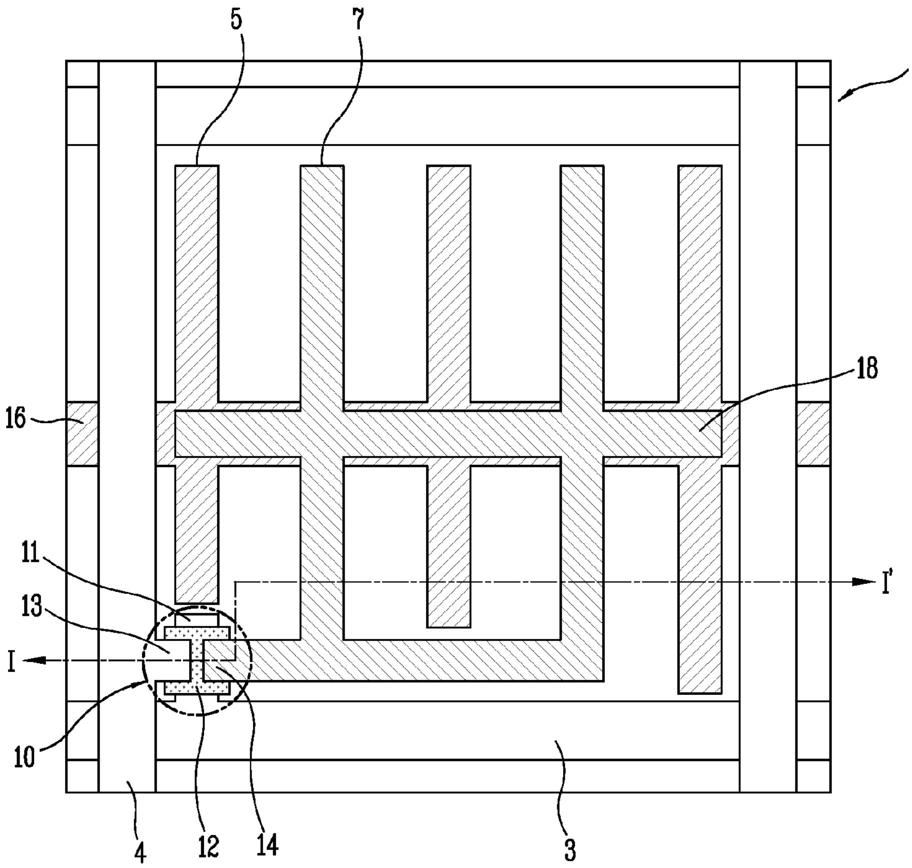


FIG. 1B
PRIOR ART

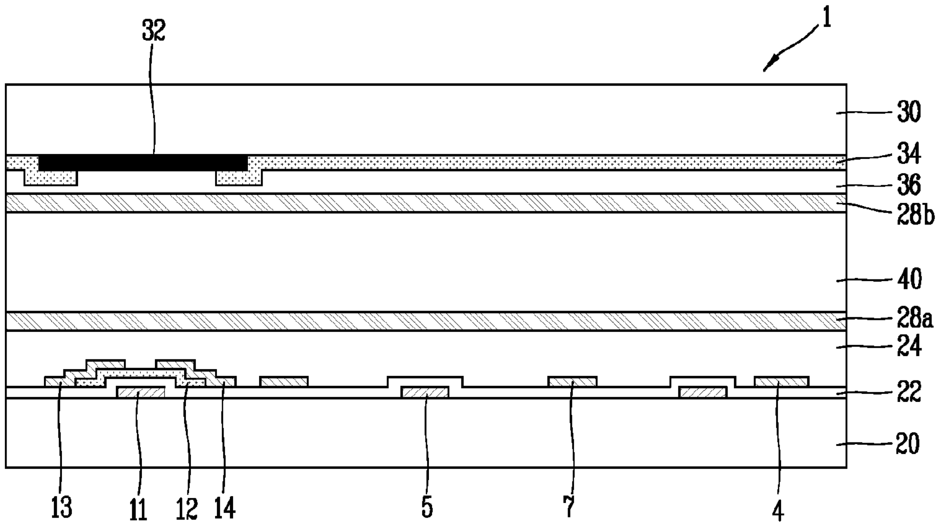


FIG. 2
PRIOR ART

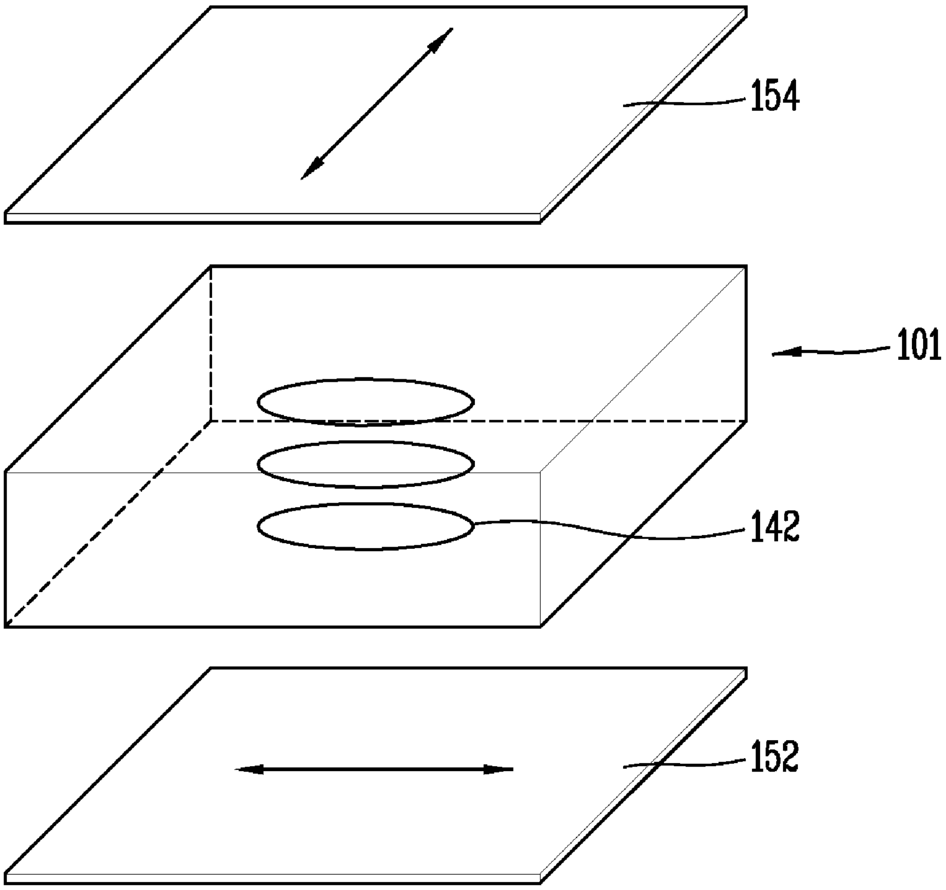


FIG. 3A

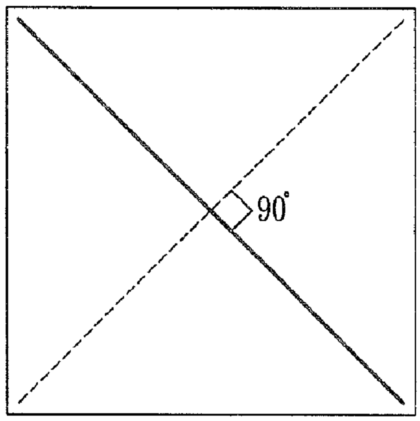


FIG. 3B

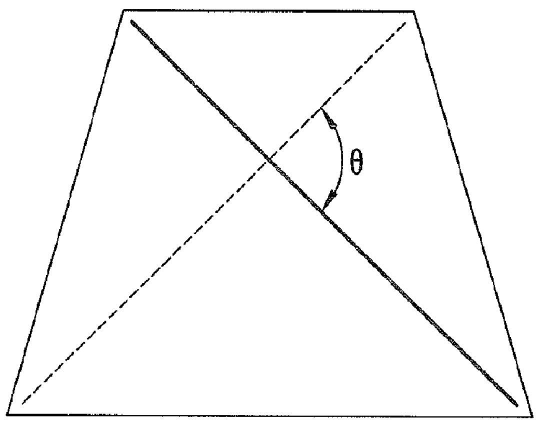
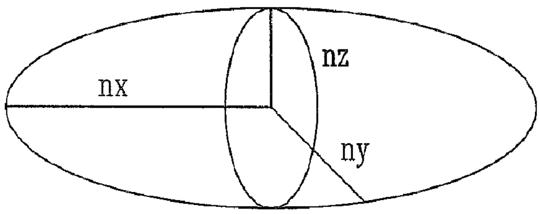
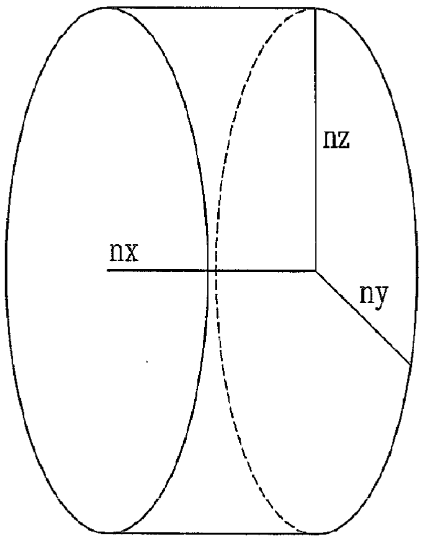


FIG. 4A



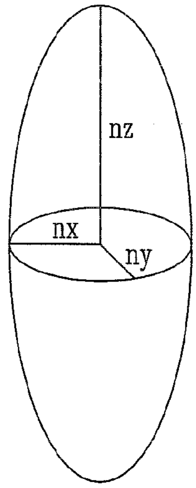
nx>ny=nz

FIG. 4B



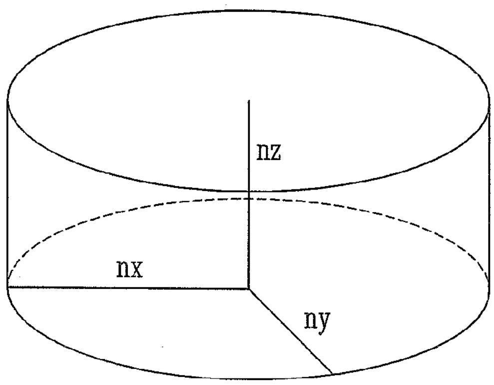
nx<ny=nz

FIG. 5A



nx=ny<nz

FIG. 5B



nx=ny>nz

FIG. 6

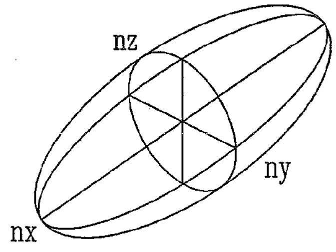


FIG. 7A

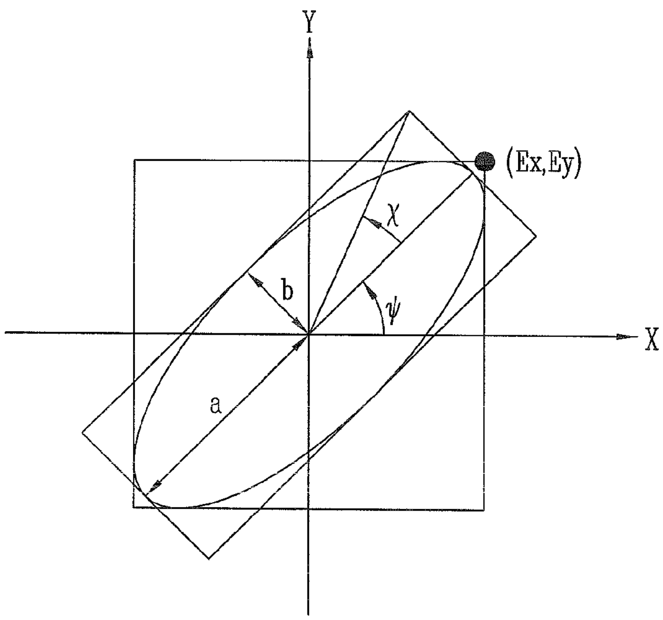


FIG. 7B

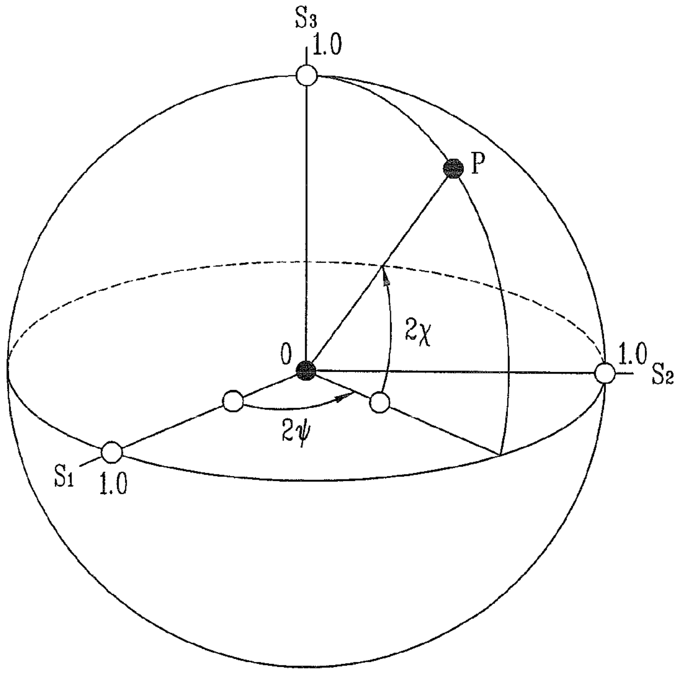


FIG. 8

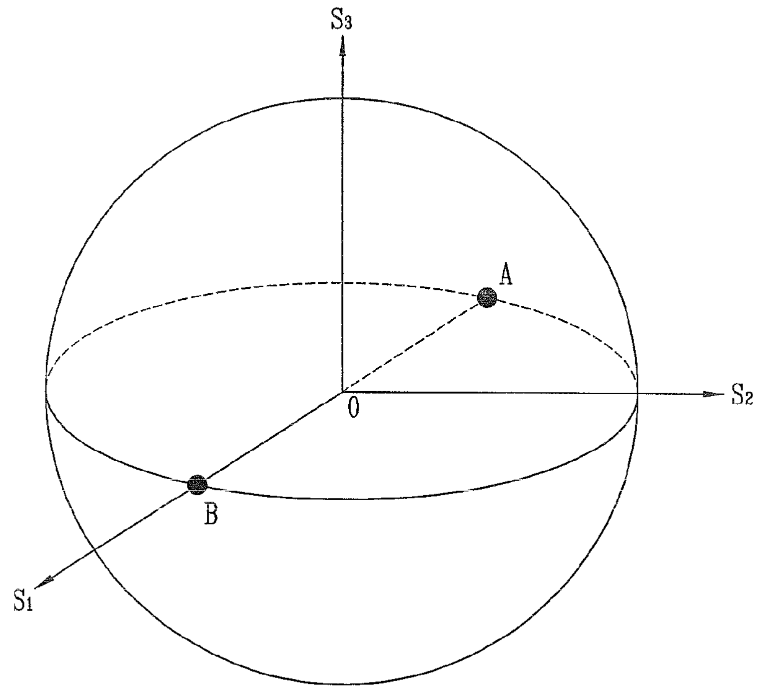


FIG. 9

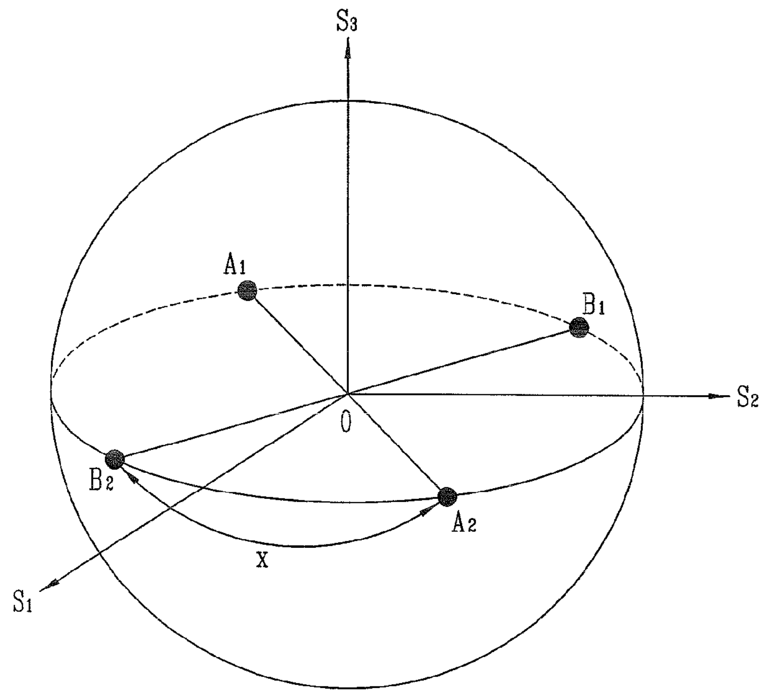


FIG. 10

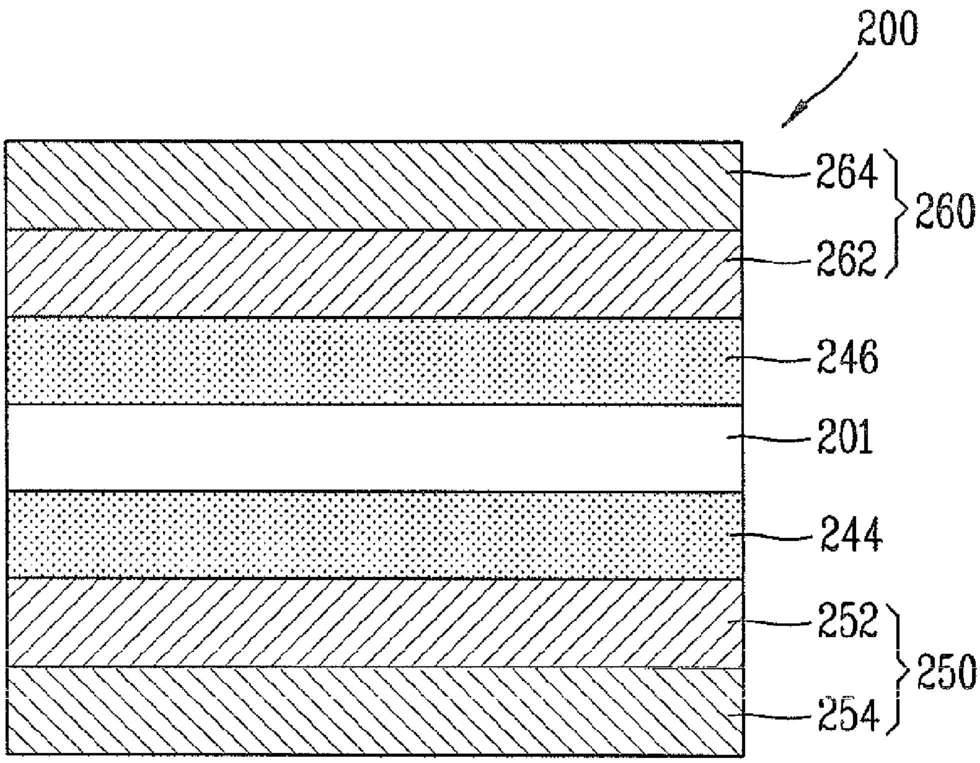
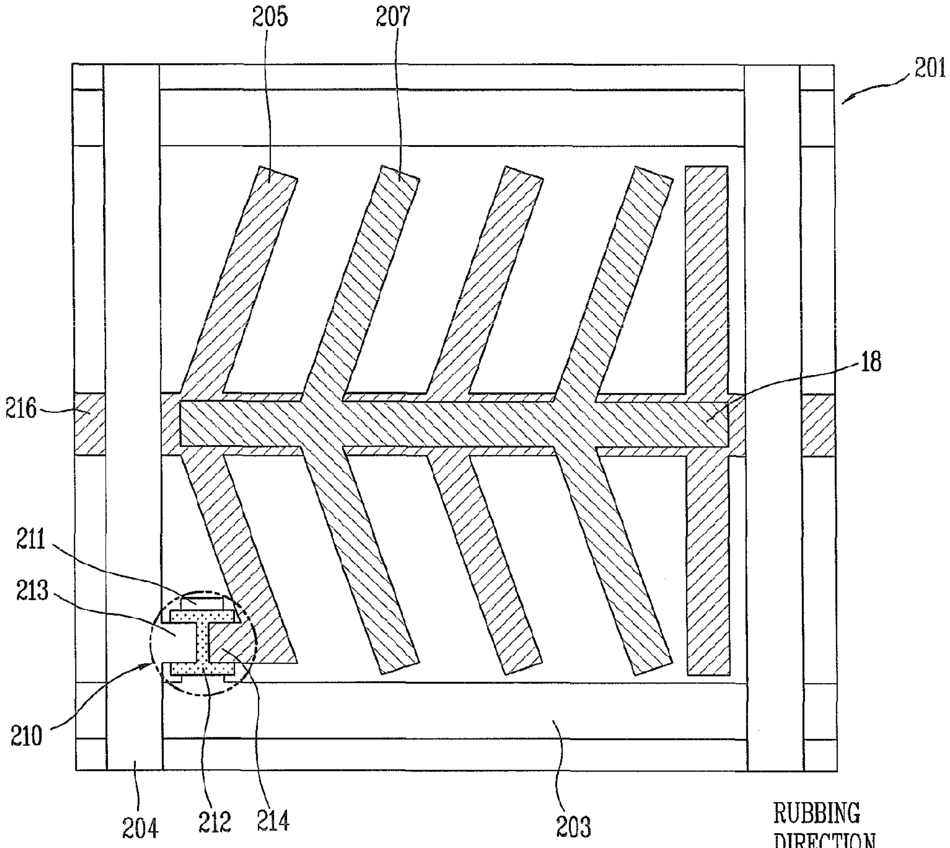


FIG. 11


205
207
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18
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211
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214
203

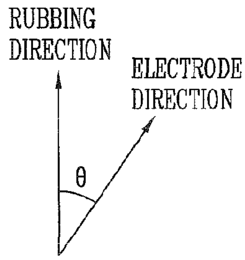

RUBBING DIRECTION
ELECTRODE DIRECTION
θ

FIG. 12A

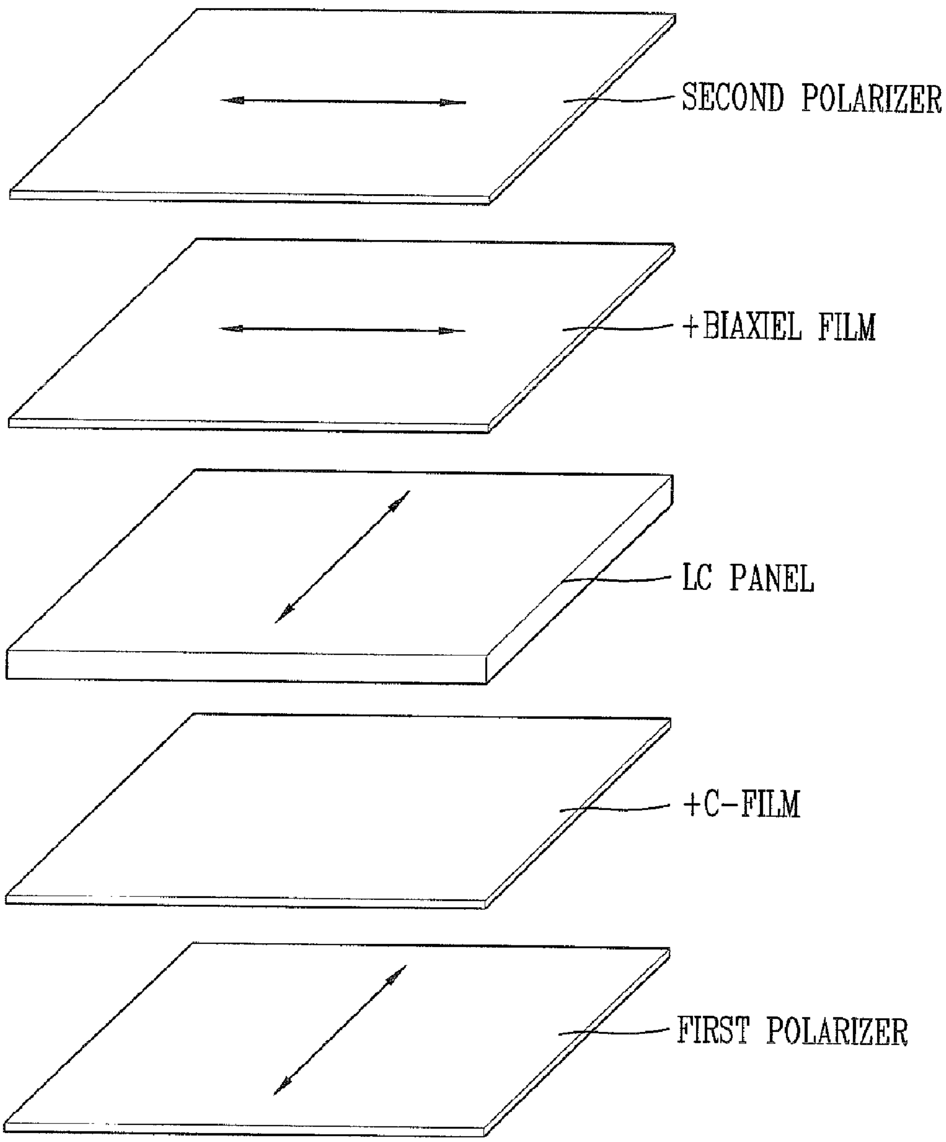

SECOND POLARIZER
+BIAXIEL FILM
LC PANEL
+C-FILM
FIRST POLARIZER

FIG. 12B

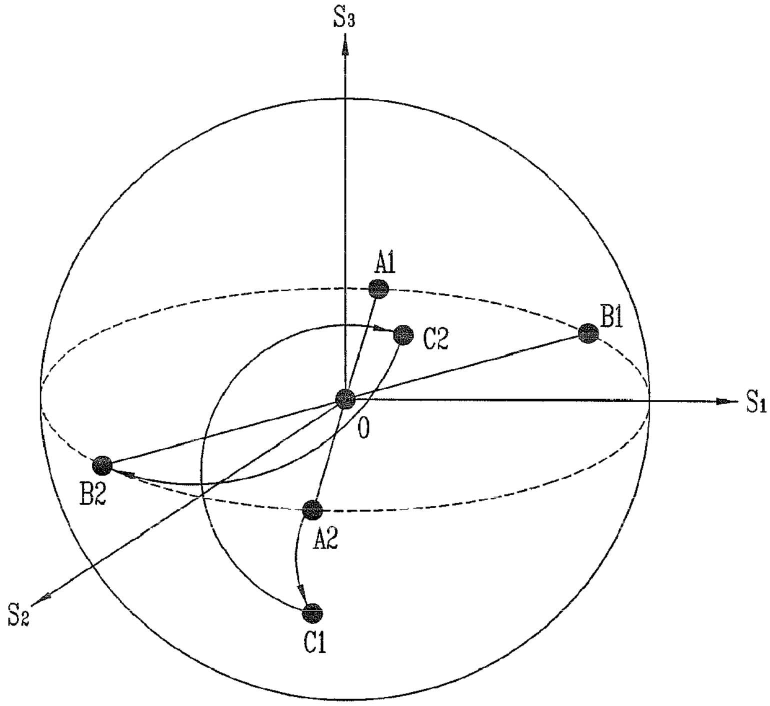


FIG. 12C

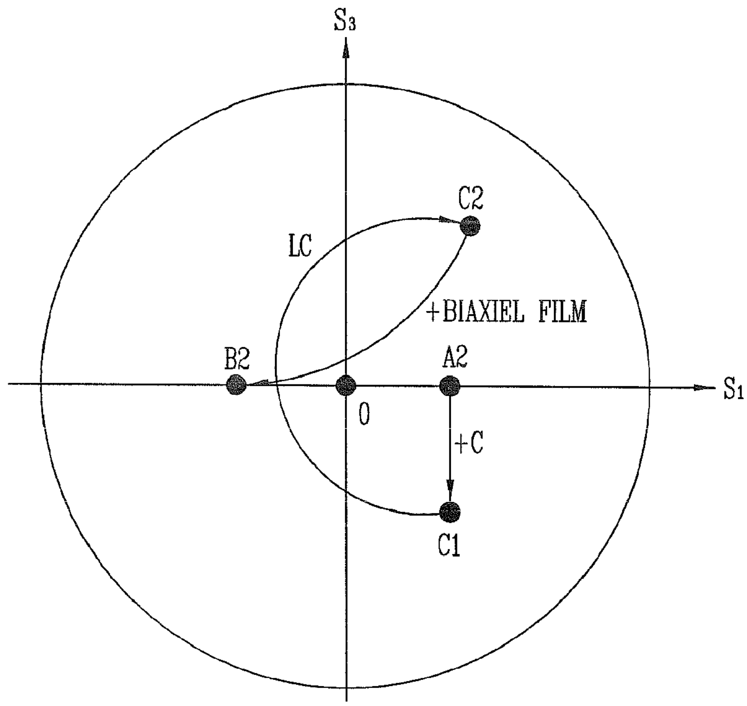


FIG. 13

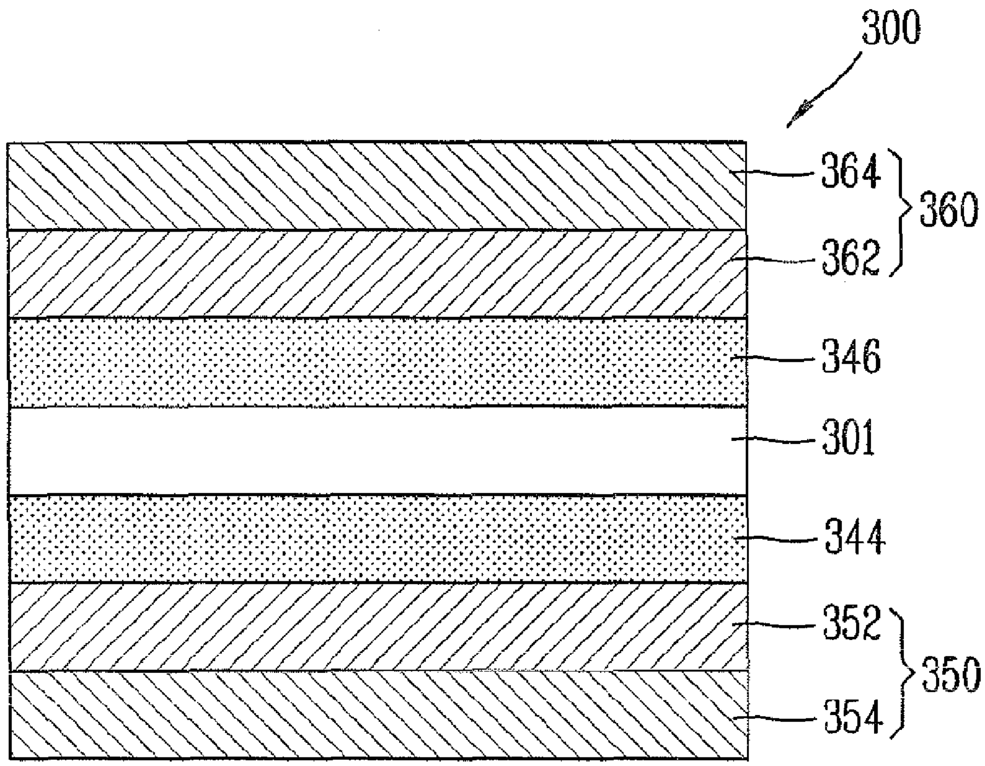
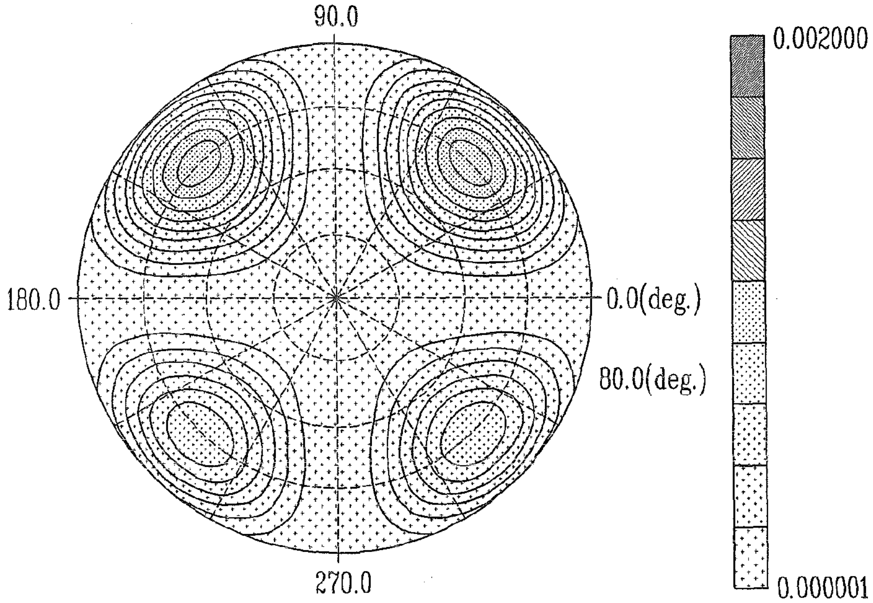
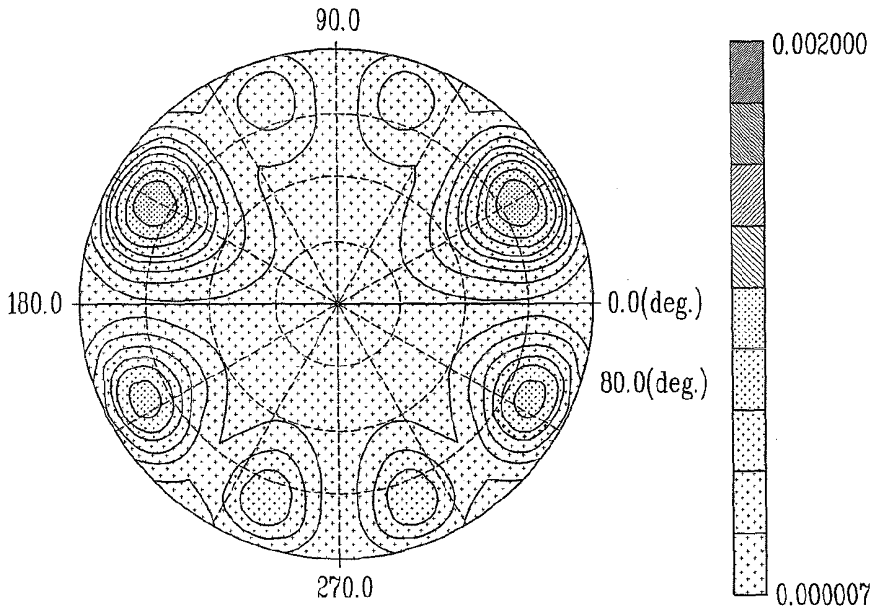


FIG. 14A



BRIGHTNESS CONTOUR LINE

FIG. 14B



LIQUID CRYSTAL DISPLAY DEVICE HAVING WIDE VIEWING ANGLE

CROSS-REFERENCE TO RELATED APPLICATION

Pursuant to 35 U.S.C. §119(a), this application claims the benefit of earlier filing date and right of priority to Korean Application No. 10-2008-0138699, filed on Dec. 31, 2008, the contents of which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a liquid crystal display (LCD) device, and particularly, to an LCD device capable of improving a viewing angle characteristic by employing a plurality of biaxial optical films.

2. Background of the Invention

Recently, the development of various types of portable electric equipment, such as mobile phones, personal digital assistants (PDAs), and note book computers, is increasing the demands on flat panel display devices which are applicable to those equipment and small in size, light in weight and power-efficient. Examples of the flat panel display device are a liquid crystal display (LCD) device, a plasma display panel (PDP) device, a field emission display (FED) device, a vacuum fluorescent display (VFD) device and the like. Studies on those devices are actively conducted. Among others, the LCD device is currently in the limelight in view of its mass production technology, facilitation of driving scheme and implementation of high color rendering property.

Such LCD device implements various display modes according to alignment of liquid crystal molecules. However, TN mode LCD device is usually used in recent time by virtue of facilitation of white and black color rendering, fast response speed and low driving voltage. In the TN mode LCD device, when a voltage is applied, liquid crystal molecules having aligned parallel with a substrate are re-aligned almost perpendicularly to the substrate, which occurs a problem that a viewing angle becomes narrower when a voltage is applied due to a refractive anisotropy of the liquid crystal molecules.

To overcome the problem of the viewing angle, various modes of LCD devices having a wide viewing angle characteristic have been introduced in recent time. Among others, an In-Plane Switching (IPS) Mode LCD device has actually undergone for mass-production. The IPS-mode LCD device is configured such that at least a pair of electrodes aligned parallel with each other are formed in each pixel so as to create a transversal field actually parallel with a substrate, thus aligning liquid crystal molecules on a plane surface.

FIG. **1** is a view showing an IPS-mode LCD device according to the related art, wherein FIG. **1**A is a plane view thereof and FIG. **1**B is a sectional view taken along the line I-I' of FIG. **1**A.

As shown in FIG. **1**A, pixels of a liquid crystal display panel **1** are defined by gate lines **3** and data lines **4** arranged in horizontal and vertical directions. The drawings merely show $(n,m)^{th}$ pixel; however, n gate lines **3** and m data lines **4** are actually arranged on the liquid crystal display panel **1** so as to define n×m pixels on the whole liquid crystal display panel **1**. A thin film transistor (TFT) **10** is formed at an intersection between the gate line **3** and the data line **4** in each pixel. The TFT **10** includes a gate electrode **11** to which a scan signal is applied via the gate line **3**, a semiconductor layer **12** formed on the gate electrode **11** and activated responsive to the applied scan signal so as to form a channel layer, and a source electrode **13** and a drain electrode **14** formed on the semiconductor layer **12** and to which an image signal is applied via the data line **4**. The thusly-constructed TFT **10** applies the image signal input from the exterior into a liquid crystal layer.

A plurality of common electrodes **5** and pixel electrodes **7** arranged to be substantially parallel with the data lines **4**. Also, a common line **16** connected to the common electrodes **5** is disposed at the center of each pixel. A pixel electrode line **18** connected to the pixel electrodes **7** is disposed on the common line **16** so as to overlap the common line **16**. As the common line **16** and the pixel electrode line **18** overlap each other, a storage capacitance is generated in the IPS-mode LCD device.

As such, in the IPS-mode LCD device having such construction, liquid crystal molecules are aligned to be substantially parallel with the common electrodes **5** and the pixel electrodes **7**. When a signal is applied to the pixel electrodes **7** in cooperation with the TFTs **10** being driven, a transversal field substantially parallel with the liquid crystal display panel **1** is generated between the common electrodes **5** and the pixel electrodes **7**. The liquid crystal molecules rotate on the same level along the transversal field, thereby preventing a gray scale inversion due to the refractive anisotropy thereof.

Hereinafter, the related art IPS-mode LCD device having such construction will be described in more detail with reference to FIG. **1**B.

As shown in FIG. **1**B, the gate electrode **11** is formed on a first substrate **20**. A gate insulating layer **22** is laminated all over the first substrate **20**. A semiconductor layer **12** is formed on the gate insulating layer **22**, and the source electrode **13** and the drain electrode **14** are formed on the semiconductor layer **12**. A passivation layer **24** is formed all over the first substrate **20**. A first alignment layer **28***a* having a decided alignment direction for aligning liquid crystal molecules by a rubbing or the like, is formed on the passivation layer **24**.

Further, a plurality of common electrodes **5** are formed on the first substrates **20**, and the pixel electrode **7** and the data line **4** are formed on the gate insulating layer **22**, thereby generating a transversal field E between the common electrode **5** and the pixel electrode **7**.

A black matrix **32** and a color filter layer **34** are formed on a second substrate **30**. The black matrix **32** serves to prevent light leakage into an area in which liquid crystal molecules are not operated. As shown in the drawings, the black matrix **32** is usually formed at a region of the TFT **10** and between pixels (that is, a region of gate line and data line). The color filter layer **34** is provided to render actual colors with red (R), green (G) and blue (B) colors. An overcoat layer **36** for protecting the color filter layer **34** and improving flatness of a substrate is formed on the color filter layer **34**, and a second alignment layer **28***b* having decided alignment direction is formed on the overcoat layer **36**.

A liquid crystal layer **40** is formed between the first substrate **20** and the second substrate **30**, so as to completely form the liquid crystal display panel **1**.

As aforementioned, in the IPS-mode LCD device, the transversal field is generated within the liquid crystal layer **40** by the common electrodes **5** and the pixel electrodes **7** respectively formed on the first substrate **20** and the gate insulating layer **22**, accordingly the liquid crystal molecules within the liquid crystal layer **40** are rotated on the same level, thereby preventing the gray scale inversion due to the refractive anisotropy of the liquid crystal molecules.

However, the IPS-mode LCD device has the following problems. That is, in the IPS-mode LCD device, the liquid crystal molecules are rotated on the same level along the transversal field, so as to prevent the gray scale inversion due to the refractive anisotropy of the liquid crystal molecules and thusly improve a viewing angle characteristic in a vertical (up-and-down) direction or a horizontal (right-and-left) direction whereas not improving the viewing angle characteristic in a diagonal direction of a screen.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide an LCD device capable of improving a viewing angle characteristic in a diagonal direction, by changing polarization property of light transmitted through the LCD device by use of a positive C-film and a positive biaxial film.

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, there is provided a liquid crystal display (LCD) device including, a liquid crystal display panel having a liquid crystal layer, a first polarizer and a second polarizer respectively located at upper and lower portions of the liquid crystal display panel to polarize incident light, a positive C-film disposed between the first polarizer and the liquid crystal display panel to change a polarized state of light, the positive C-film having a retardation value of Re=0 nm in a horizontal direction and a retardation value of Rth=−50~−200 nm in a thickness direction, and a positive biaxial film disposed between the liquid crystal display panel and the second polarizer to change a polarized state of light, the positive biaxial film having a retardation value of Re=80~160 nm in a horizontal direction and a retardation value of Rth=−24~−160 nm in a thickness direction, wherein $Re=(n_x-n_y)d$ and $Rth=(n_x-n_z)d$, where n_x, n_y and n_z respectively denote a refractive index in x-axial direction, a refractive index in y-axial direction and a refractive index in z-axial direction.

According to the present invention, the positive C-film and the positive biaxial film is disposed between the polarizers and the liquid crystal display panel so as to change polarization property of a polarized light incident on the liquid crystal display panel. The change in the polarization property allows an optical axis of light incident on the second polarizer to match with an absorption axis of the second polarizer, resulting in improvement of a viewing angle characteristic in a diagonal direction.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

In the drawings:

FIGS. **1**A and **1**B are views showing a structure of a typical IPS-mode LCD device;

FIG. **2** is a perspective view briefly showing the structure of the related art LCD device;

FIG. **3**A is a view showing absorption axes of upper and lower polarizers when viewing an LCD device from a front side;

FIG. **3**B is a view showing the absorption axes of the upper and lower polarizers when viewing the LCD device in a diagonal direction;

FIGS. **4**A and **4**B are views showing the relation of refractive indexed of A-compensation film in x, y and z-axial directions;

FIGS. **5***a* and **5**B are views showing the relation of refractive indexed of C-compensation film in x, y and z-axial directions;

FIG. **6** is a view showing the relation of refractive indexed of a biaxial compensation film in x, y and z-axial directions;

FIGS. **7**A and **7**B are an elliptical polarization of each light and corresponding Poincare vectors;

FIG. **8** is a view showing polarized states of light in Poincare sphere when viewing the LCD device from a front side;

FIG. **9** is a view showing polarized states of light in Poincare sphere when viewing the LCD device in a diagonal direction;

FIG. **10** is a view showing a structure of an LCD device in accordance with a first embodiment of the present invention;

FIG. **11** is a sectional view showing a structure of an LC panel in accordance with the present invention;

FIG. **12**A is a view showing optical axes of the LCD device in accordance with the first embodiment of the present invention;

FIG. **12**B is a view of the Poincare sphere representing polarized states of light in the LCD device in accordance with the first embodiment of the present invention;

FIG. **12**C is a projected view of FIG. **12**B;

FIG. **13** is a view showing a structure of an LCD device in accordance with a second embodiment of the present invention; and

FIGS. **14**A and **14**B are views respectively showing viewing angle characteristics when viewing the related art LCD device and the LCD device according to the present invention in a diagonal direction.

DETAILED DESCRIPTION OF THE INVENTION

Description will now be given in detail of the present invention, with reference to the accompanying drawings.

A lowering of a viewing angle characteristic when viewing an LCD device in a diagonal direction is caused by light leakage in the diagonal direction of the LCD device, which will be described in detail, hereinafter.

As shown in FIG. **2**, a first polarizer **152** and a second polarizer **154** are attached onto upper and lower portions of a liquid crystal (LC) panel **101** of a typical IPS-mode LCD device, so as to linearly polarize input and output light of the LC panel **101**.

In a normally black mode, polarization axes of the first and second polarizers **152** and **154** attached onto the upper and lower substrates are perpendicular to each other. Hence, light transmitted through the first polarizer **152** is linearly polarized in an x-axial direction to be input into the LCD device. When no signal is applied to the LC panel **101**, liquid crystal molecules **142** of the LC panel **101** are aligned toward the x-axial direction, accordingly light incident on the LC panel **101** is transmitted through the LC panel **101** in the linearly polarized state in the x-axial direction. Meanwhile, a polarization axis of the second polarizer **154** attached onto the upper substrate is perpendicular to a polarizing direction of light transmitted through a liquid crystal layer. Accordingly, light is all absorbed by the polarizer **154** of the upper substrate such that no light is output out of the second polarizer **152**, resulting in rendering a screen entirely black.

However, when viewing the LCD device in a diagonal direction, the polarization directions of the first and second polarizers **152** and **154** are not disposed substantially perpendicular to each other. That is, the first and second polarizers **152** and **154** are perpendicular to each other when viewing the LCD device from a front side, while not being perpendicular when viewing the same in the diagonal direction.

FIG. **3**A shows that polarization axes of the first and second polarizers **152** and **154** arranged when viewing the LCD device from a front side, namely, on a path of light transmitted perpendicular to a screen of the LCD device, and FIG. **3**B shows polarization axes of the first and second polarizers **152** and **154** arranged when viewing the LCD device in a diagonal direction, namely, on a path of light transmitted through the screen of the LCD device at a polar angle and at a azimuthal angle. Here, in the drawing, the dotted line denotes a direction of a polarization axis (i.e., light absorption axis) on the first polarizer **152** and a solid line denotes a direction of a light absorption axis on the second polarizer **154**.

As shown in FIG. **3**A, when viewing the LCD device from the front side (i.e., when light is perpendicularly transmitted through the screen of the LCD device), the polarization axes of the first and second polarizers **152** and **154** are perpendicular to each other. However, as shown in FIG. **3**B, when viewing the LCD device in the diagonal direction (i.e., when light is transmitted through the screen of the LCD device at a preset polar angle and at a preset azimuthal angle, the polarization axes of the first and second polarizers **152** and **154** are not perpendicular to each other but disposed with a preset angle θ therebetween.

As such, when viewing the LCD device in the diagonal direction, since the polarization directions of the first and second polarizers **152** and **154** are not perpendicular to each other, light which has been linearly polarized at the first polarizer **152** and transmitted through the LC panel **101** is rather partially transmitted through the second polarizer **154** without being completely absorbed by the second polarizer **154**. Therefore, even in the normally black state, when viewing the LCD device in the diagonal direction, light is partially leaked out, which makes it impossible to maintain a completely black state.

Thus, when viewing the LCD device in the diagonal direction, since the polarization directions of the first and second polarizers **152** and **154** are not perpendicular to each other and thereby the light polarized at the first polarizer **152** is partially leaked out without being completely absorbed by the second polarizer **154**, a viewing angle characteristic is lowered. Hence, in order to improve the viewing angle characteristic when viewing the LCD device in the diagonal direction, light polarized at the first polarizer **152** should be completely absorbed by the second polarizer **154**. To this end, in the present invention, a compensation film is used to change the polarization direction of light transmitted through the LC panel **101** so as to match optical axis of light incident on the second polarizer **154** with the polarization direction (i.e., light absorption layer) of the second polarizer **154**.

The compensation film may be categorized into a uniaxial film and a biaxial film. The uniaxial film is an anisotropic birefringence film having a single optical axis, and the biaxial film is an anisotropic birefringence film having two optical axes. Of the compensation films, the uniaxial film may be divided into A-compensation film and C-compensation film according to direction and size of the optical axis. Refractive index characteristics of the A-compensation film and C-compensation film are shown in FIGS. **4** and **5**.

FIGS. **4**A and **4**B respectively show a positive A-compensation film and a negative A-compensation film. As shown in FIGS. **4**A and **4**B, the A-compensation film is characterized in that a refractive index n_y in y-axial direction is the same to a refractive index n_z in z-axial direction (i.e., $n_y=n_z$) and a refractive index n_x in x-axial direction is different from the refractive indexes n_y and n_z in the y-axial direction and the z-axial direction (i.e., $n_x \neq n_y = n_z$). As shown in FIG. **4**A, if the refractive index n_x in the x-axial direction is greater than the refractive index n_y in the y-axial direction, it is a positive A-compensation film. To the contrary, if the refractive index n_x in the x-axial direction is smaller than the refractive index n_y in the y-axial direction, it is a negative A-compensation film. The positive A-compensation film and the negative A-compensation film can be defined according to Equation 1 as follows.

$$n_x > n_y = n_z$$

$$n_x < n_y = n_z \qquad \text{[Equation 1]}$$

In the meantime, FIGS. **5**A and **5**B respectively show a positive C-compensation film and a negative C-compensation film. As shown in FIGS. **5**A and **5**B, the C-compensation film is characterized in that a refractive index n_x in x-axial direction is the same to a refractive index n_y in y-axial direction ($n_x=n_y$) and a refractive index n_z in z-axial direction is different from the refractive indexes n_x and n_y in the x-axial direction and the y-axial direction (i.e., $n_z \neq n_x = n_y$). As shown in FIG. **5**A, if the refractive index n_x in the x-axial direction and the refractive index n_y in the y-axial direction are smaller than the refractive index n_z in the z-axial direction, it is a positive C-compensation film. To the contrary, if the refractive index n_x in the x-axial direction and the refractive index n_y in the y-axial direction are greater than the refractive index n_z in the z-axial direction, it is a negative C-compensation film. The positive C-compensation film and the negative C-compensation film can be defined according to Equation 2 as follows.

$$n_x = n_y < n_z$$

$$n_x = n_y > n_z \qquad \text{[Equation 2]}$$

Also, retardation by the compensation films is determined according to the refractive index n_x in the x-axial direction, the refractive index n_y in the y-axial direction and the refractive index n_z in the z-axial direction, the relation between the retardation and the refractive indexes n_x, n_y and n_z may be defined according to Equation 3.

$$Re=(n_x-n_y)d$$

$$Rth=(n_x-n_z)d \qquad \text{[Equation 3]}$$

where Re denotes a retardation value in a horizontal direction, and Rth denotes a retardation value in a thickness direction. Also, d denotes a thickness of a compensation film.

Examples of the A-compensation film and the C-compensation film may usually include cycloolefin polymer film, polycarbonate film, UV-curable horizontal or horizontally-aligned liquid crystal film, polystyrene resin and polyethylene terephthalate.

The biaxial film may be categorized into a positive biaxial film, a negative biaxial film, and z-axis-stretched biaxial film. FIG. **6** shows refractive index n_x in x-axial direction, refractive index n_y in y-axial direction and refractive index n_z in z-axial direction of the biaxial film. The biaxial film may be classified into a positive biaxial film, a negative biaxial film and a z-axis-stretched biaxial film according to the ratio of the refractive indexes n_x, n_y and n_z in the x, y and z-axial directions. The positive biaxial film, the negative biaxial film and the z-axis-stretched biaxial film can respectively be defined by Equation 4.

$$n_z>n_x>n_y$$

$$n_x>n_y>n_z$$

$$n_x>n_z>n_y \quad \text{[Equation 4]}$$

Also, Biaxiality of the biaxial film can be expressed according to Equation 5 as follows.

$$Nz=Rth/Re \quad \text{[Equation 5]}$$

As defined in Equation 3, Re denotes a retardation value in a horizontal direction, Rth denotes a retardation value in a thickness direction, and d denotes a thickness of a compensation film.

According to the definitions of Equations 4 and 5, the negative biaxial film is Nz>1, the positive biaxial film is Nz<0, and the z-axis-stretched biaxial film is 0<Nz<1.

In the present invention, the use of the compensation films allows light linearly polarized at the first polarizer **152** to be phase-transformed such that the polarization direction of the light can completely be perpendicular to the polarization direction of the second polarizer **154**, thereby enabling complete absorption of light incident on the second polarizer **154**.

The light polarized state can be analyzed by the Jones Matrix. According to the Jones calculation, since light reflection at a boundary surface is ignored, the Jones matrix exhibiting polarization transmission characteristics of transparent media is a unitary matrix, which can be expressed by the Poincare sphere.

The Jones vector can merely exhibit complete polarization. Thus, in order to exhibit partial polarization, strokes parameters defined according to the following Equation 6 should be used.

$$S_0=<|E_x|^2>+<|E_y|^2>$$

$$S_1=<|E_x|^2>-<|E_y|^2>$$

$$S_2=2|E_x||E_y|<\cos(\Phi_x-\Phi_y)>$$

$$S_3=2|E_x||E_y|<\sin(\Phi_x-\Phi_y)> \quad \text{[Equation 6]}$$

where < > denotes time average, and E_x and E_x denote magnetic field components in x-axial and y-axial directions. Here, an inequality of $S_0^2ES_1^2+S_2^2+S_3^2$ is established among those four variables. This inequality is satisfied only for a complete polarization. That is, for the complete polarization, Equation 7 will be defined among standardized variables s1, s2 and s3, which are obtained by dividing S1, S2 and S3 by light brightness S0.

$$S_1^2+S_2^2+S_3^2+1 \quad \text{[Equation 7]}$$

This is an equation of the Poincare sphere having a radius of 1 in a three-dimensional space, wherein (s1, s2, s3) denote points of orthogonal coordinates of Poincare sphere.

Here, in the Poincare sphere, all points on the equator represent a linear polarized state, and the arctic corresponds to right-handed circular polarization and the Antarctic corresponds to left-handed circular polarization. Also, all points of the Northern hemisphere correspond to right-handed elliptical polarization, and all points of the Southern hemisphere correspond to left-handed elliptical polarization.

FIGS. **7**A and **7**B are views showing an arbitrary elliptical polarization in an orthogonal coordinate system and corresponding Poincare vector.

As shown in FIGS. **7**A and **7**B, for the Poincare vector P, corresponding to an elliptical polarization in which an azimuthal angle of a long axis thereof is Ψ and an elliptical angle is x, a latitude angle is 2x, an azimuthal angle is 2Ψ and orthogonal coordinates are (cons(2Ψ)cons(2x),sin(2Ψ)cos(2x),sin(2x)). If this point is located on the Northern hemisphere, an electric field vector is rotated in a clockwise direction, and if the point is located on the Southern hemisphere, the electric field vector is rotated in a counterclockwise direction. Here, antipodes on the Poincare sphere represent an orthogonally polarized state.

Further, the unitary Jones matrix representing the change in the polarized state when light passes through a transparent medium can be analyzed by a rotation conversion on the Poincare sphere.

FIG. **8** shows the Poincare sphere representing the polarized states of the first and second polarizers **152** and **154** when viewing the IPS-mode LCD device from a front side as shown in FIG. **3**A.

Since the antipodes on the Poincare sphere represent the orthogonally polarized state, point A indicates a light absorption axis of the first polarizer **152** and a light transmission axis of the second polarizer **154**, and point B indicates a light transmission axis of the first polarizer **152** and a light absorption axis of the second polarizer **154**. As shown in FIG. **8**, when viewing the IPS-mode LCD device from the front side, the light transmission axis of the first polarizer **152** maintains the same linearly polarized state to the light absorption axis of the second polarizer **154**. Thus, since the light absorption axis of the first polarizer **152** is perpendicular to the light absorption axis of the second polarizer **154** when viewing the IPS-mode LCD device from the front side, the light transmission axis of the first polarizer **152** and the light absorption axis of the second polarizer **154** are parallel to each other.

As such, since the light transmission axis of the first polarizer **152** and the light absorption axis of the second polarizer **154** are parallel to each other and accordingly the light transmission axis of the first polarizer **152** and the light absorption axis of the second polarizer **154** are located at the same point, the linearly polarized light transmitted through the first polarizer **152** is all absorbed by the second polarizer **154** such that no light is externally transmitted through the second polarizer **154**. Accordingly, in the normally black mode, when viewing the IPS-mode LCD device from the front side, the completely black state can be maintained.

In the meantime, FIG. **9** shows the Poincare sphere representing the polarized state of light when viewing the IPS-mode LCD device in a diagonal direction.

In FIG. **9**, point A**1** indicates a light absorption axis of the first polarizer **152** and the corresponding antipodal point A**2** indicates a light transmission axis of the first polarizer **152** orthogonal to the light absorption axis. Also, point B**1** indicates a light transmission axis of the second polarizer **154** and point B**2** indicates a light absorption axis of the second polarizer **154**. As shown in FIG. **3**B, when viewing the IPS-mode LCD device in the diagonal direction, the polarization directions of the first polarizer **152** and the second polarizer **154** form a preset angle θ without being perpendicular to each other. Accordingly, the point A**2** as the light transmission axis of the first polarizer **152** and the point B**2** as the light absorption axis of the second polarizer **154** do not match but has an interval by x. The interval x indicates an angle between the light transmission axis of the first polarizer **152** and the light absorption axis of the second polarizer **154**. Light as much as corresponding to the angle between the light transmission axis of the first polarizer **152** and the light absorption axis of the second polarizer **154** is transmitted through the second polarizer **154**. Therefore, in order to prevent light leakage in the diagonal direction of the IPS-mode LCD device, the point

A2 and the point B2 should match each other such that the light transmission axis of the first polarizer **152** is parallel to the light absorption axis of the second polarizer **154**, whereby light polarized at the first polarizer **152** can completely be absorbed at the second polarizer **154**.

In the present invention, the polarized state of light, which was linearly polarized at the first polarizer **152** is changed by use of the compensation films so as to match the point A2 with the point B2 in the Poincare sphere (i.e., the light transmission axis of the first polarizer **152** is allowed to be parallel to the light absorption axis of the second polarizer **154**), thereby preventing the light leakage which may be caused due to light being transmitted through the second polarizer **154**.

Hereinafter, detailed embodiments of the present invention will be described. Here, the polarized state of the LCD device in accordance with the embodiments of the present invention will be described by use of the Poincare sphere. As described above, the present invention is configured to change the polarized state of light by using the biaxial films so as to prevent the light leakage in the diagonal direction of the LCD device.

FIG. **10** shows a structure of an LCD device in accordance with a first embodiment of the present invention.

As shown in FIG. **10**, an LCD device **200** in accordance with a first embodiment of the present invention may include an LC panel **201** for implementing images, a first compensation film **244** and a second compensation film **246** attached onto upper and lower portions of the LC panel **201**, respectively, a first polarizer **250** attached onto a lower portion of the first compensation film **244**, and a second polarizer **260** attached onto an upper portion of the second compensation film **246**.

Although not shown in the drawing in detail, the LC panel **201** may include a first substrate, a second substrate and a liquid crystal layer interposed between the first and second substrates. TFTs, patterns of gate lines and data lines and various electrodes may be formed on the first substrate, and a color filter layer rendering actual colors and a black matrix for preventing deterioration of image quality due to light leakage into an image non-display region may be formed on the second substrate.

Especially, the LC panel **201** according to the preset invention is an IPS-mode LC panel. Therefore, common electrodes and the pixel electrodes are disposed parallel to each other on the first substrate, thus to apply to the liquid crystal layer a magnetic field parallel to the surface of the substrate. Alternatively, a fringe field switching (FFS) mode LC panel may also be used as the LC panel **201** of the present invention. For the LC panel **201**, a nematic liquid crystal having a retardation value of about 250~350 nm may be employed.

The first polarizer **250** may be provided with a first polarizing body **252** and a first supporting body **254**. The first polarizing body **252** is a film which may convert natural light into an arbitrary polarized light. Here, the first polarizing body **252** may be one having a function that when dividing incident light into two orthogonal polarization components, one polarization component of the two is allowed to be transmitted and another one is absorbed, reflected or dispersed. Although there is not any specific limit to an optical film used in the first polarizing body **252**, examples of the optical film may include a polymer film having as a main component a polyvinyl alcohol (PVA) based resin containing iodine or dichromatic dye, O-type polarizing body in which a liquid crystalline composition containing a dichromatic material and a liquid crystalline compound is aligned in a preset direction, E-type polarizing body in which lyotropic liquid crystal is aligned in a preset direction, and the like. The first supporting body **254** is to protect the first polarizer **252**, and usually uses a typical protection film without retardation. Any can be used as the protection film, but usually triacetylcellulose (TAC) is used.

Also, the second polarizer **260** may be provided with a second polarizing body **262** and a second supporting body **264**. The second polarizing body **262** may be made of the polyvinyl alcohol (PVA) based resin, similar to the first polarizing body **252**. For the second supporting body **264**, triacetylcellulose (TAC) is used as a transparent protection film

The first compensation film **244** attached onto the lower portion of the LC panel **201** is a positive C-film as well as a uniaxial compensation film. Here, the C-film may usually be a UV-curable perpendicularly-aligned liquid crystal film, a biaxially-stretched polymer film or the like. Here, a retardation value Rth in the thickness direction of the positive C-film is Rth=−50 nm~−200 nm (Re=0).

Furthermore, the second compensation film **246** is a positive biaxial compensation film. A retardation value Re in a horizontal direction thereof is Re=80~160 nm and a retardation value Rth in a thickness direction thereof is Rth=−24~−160 nm. Therefore, biaxiality of the biaxial film of the second compensation film **246** becomes $-2.0<Nz<0$ based upon Equation 5. Typically, when the biaxiality Nz of the biaxial film is $Nz<0$, the biaxial film is a positive biaxial film and the ratio of refractive indexes n_x n_y and n_z thereof in x, y and z-axial directions is $n_z>n_x>n_y$. Also, when the biaxiality Nz of the biaxial film is $0<Nz<1$, the biaxial film is a z-axis-stretched biaxial film and the ratio of refractive indexes n_x n_y and n_z thereof in x, y and z-axial directions is $n_x>n_z>n_y$. The first compensation film **246** is a positive biaxial film having biaxiality Nz of $Nz<0$.

Examples of the second compensation film **246**, namely, the positive biaxial film may include UV-curable liquid crystal film polycarbonate, polyethylene terephthalate, polystyrene, uniaxially-stretched TAC, uniaxially-stretched polynorbonene (PNB), biaxially-stretched polycarbonate (PC), biaxially-stretched COP, biaxial LC film and the like. Also, the second compensation film **246** may have various characteristics of normal wavelength dispersion, flat wavelength dispersion and reverse wavelength dispersion.

An absorption axis of the first polarizer **250** is disposed at an angle of 90° and an absorption axis of the second polarizer **260** is disposed at an angle of 0°. Also, nx-axis of the second compensation film **246** is disposed at an angle of 0° and a rubbing direction of the LC panel **201** also forms an angle of 90°.

Liquid crystal molecules of the LC panel **201** are disposed along the rubbing direction of an alignment layer upon an off-state of the LC panel **201**. Accordingly, an optical axis of the liquid crystal molecules also forms an angle of 90°. Thus, the reason why the LC panel **201** has a rubbing direction of 90° is described as follows.

Typically, common electrodes and pixel electrodes creating a lateral magnetic field in the IPS-mode LCD device are arranged along data lines, accordingly the rubbing direction of an alignment layer forms an angle of about 15°~45°.

However, as shown in FIG. **11**, in the present invention, common electrodes **205** and pixel electrodes **207** of the IPS-mode LC panel **201** are curved at least once by a preset angle within a pixel defined by gate lines **203** and data lines **204**, and a rubbing of an alignment layer is executed in a data line direction, namely, at an angle of 90°. That is, the direction of the electrodes **205** and **207** and the alignment direction form a preset angle θ.

As such, curving the common electrodes **205** and the pixel electrodes **207** is to form a plurality of domains having different main viewing angles within one pixel, thereby improving a viewing angle characteristic of the LCD device. The common electrode **205** and the pixel electrodes **207** are formed at a preset angle with the data line **204** and the rubbing of the alignment layer is executed in the data line direction. Accordingly, the rubbing direction of the common electrodes **205** and the pixel electrodes **207** forms a preset angle (for example, approximately, θ=15°~45°.

The present invention will not be limited to the IPS-mode LCD device having the above structure, but may be applicable to a FFS-mode LCD device having a rubbing direction of 90° and forming a preset angle between the disposed direction of electrodes and the rubbing direction.

Polarized states of the LCD device in accordance with the first embodiment having such structure will be described with reference to FIGS. **12**A to **12**C. Here, FIG. **12**A shows a polarized state of each component of the LCD device according to the present invention, FIG. **12**B shows the Poincare sphere representing the polarized states in the LCD device according to the present invention, and FIG. **12**C is a two-dimensional view of FIG. **12**B, namely, a protected view of the Poincare sphere.

As shown in FIG. **12**A, the first compensation film **244** implemented as a positive C-film is disposed between the first polarizer **250** and the LC panel **201**. Also, the second polarizer **260** is disposed at an upper portion of the LC panel **201**. Here, a light absorption axis of the second polarizer **260** is perpendicular to a rubbing direction of the LC panel **201** (i.e., the light absorption axis of the second polarizer **260** is formed at an angle of 0°). Also, the second compensation film **246** implemented as a positive biaxial film is disposed between the LC panel **201** and the second polarizer **260**. Here, nx-axis of the second compensation film **246** is perpendicular to the rubbing direction of the LC panel **201**, and parallel to the light absorption axis of the second polarizer **260** (i.e., the nx-axis forms an angle of 0°).

As shown in FIG. **12**B, if non-polarized light is incident on the first polarizer **250** from a backlight of the LC panel **201**, such light is linearly polarized. Most of the linearly polarized light is absorbed at the absorption axis (point A**1**) of the first polarizer **250** and the polarized state of the light transmitted through the first polarizer **250** is located at the point A**2**. That is, the transmission axis of the first polarizer **250** is located at the point A**2**. Here, the absorption axis of the second polarizer **260** is located at the point B**2** so as to be spaced apart from the transmission axis of the first polarizer **250** by a preset distance.

If the light linearly polarized at the first polarizer **250** is transmitted through the first compensation film **244** implemented as the positive-C-film, the polarized state is rotated in a counterclockwise direction centering on axis S**1** so as to be moved from the point A**2** to a point C**1**. Here, the point C**1** is located on the fourth quadrant of the Poincare sphere, thereby maintaining an elliptically polarized state.

The light transmitted through the positive C-film **246** becomes an elliptically polarized state. If the elliptically polarized light is transmitted through the LC panel **201**, the polarized state of the LC panel **201** is located at the point A**1** because the alignment layer is rubbed at an angle of 90°. Therefore, the polarized state is rotated in the counterclockwise direction centering on axis A**20** so as to be moved from the point C**1** to a point C**2**. Here, since the retardation value of the liquid crystal layer of the LC panel **201** is about 280 nm~350 nm, the light transmitted through the LC panel **201** is rotated in a clockwise direction at an angle of about 183°~229° centering around the axis A**20**. Here, the polarized state of the light maintains the elliptically polarized state, which is located at the first quadrant of the Poincare sphere.

If light transmitted through the LC panel **201** is then transmitted through the second compensation film **246** implemented as the positive biaxial film, the polarized state is rotated from the point C**2** to the point B**2**. Here, since the second compensation film **246** is the positive biaxial film, an optical axis exists between n_y-axis and n_z-axis. Accordingly, the polarized state of the light is rotated based upon the optical axis between n_y-axis and n_z-axis, so that the polarized state is moved from the point C**2** and the point B**2**. Consequently, the light transmitted through the second compensation film **246** is changed into linearly polarized light with the same polarization axis to the absorption axis of the second polarizer **260**. This polarized light is all absorbed by the second polarizer **260**, resulting in preventing the light from being transmitted through the second polarizer **260**.

As shown in FIG. **12**C, the polarized state (corresponding to the point A**2**) of the linearly polarized light at the first polarizer **250** is changed by the positive C-film **244** and the LC panel **201** and finally matches with the point B**2** by the positive biaxial film **246**. Accordingly, the optical axis of the light incident on the second polarizer **260** matches with the absorption axis of the second polarizer **260** such that light polarized at the first polarizer **250** is all absorbed by the second polarizer **260**, thereby preventing light leakage in the diagonal direction.

FIG. **13** is a view showing a structure of an LCD device **300** in accordance with a second embodiment of the present invention, wherein the structure shown in this embodiment is similar to the structure of the LCD device shown in FIG. **10**.

That is, an LCD device **300** according to the second embodiment may include an LC panel **301** for implementing images, a first compensation film **344** implemented as a positive C-film attached onto a lower portion of the LC panel **301**, a second compensation film **346** implemented as a positive biaxial film attached onto an upper portion of the LC panel **301**, a first polarizer **350** attached onto a lower portion of the first compensation film **344**, and a second polarizer **360** attached onto an upper portion of the second compensation film **346**.

That is, the LCD device according to the first embodiment and the LCD device according to the second embodiment are substantially the same in the structure excluding the optical axes. That is, the LCD device according to the first embodiment is configured such that an absorption axis of the first polarizer **250** is 90° and an absorption axis of the second polarizer **260** is 0°, while the LCD device according to the second embodiment is configured such that an absorption axis of the first polarizer **350** is 0° and the absorption axis of the second polarizer **360** is 90°. Also, nx-axis of the second compensation film **246** is 0° in the first embodiment while nx-axis of the second compensation film **346** is 90° in the second embodiment.

Even regarding the LCD device according to the second embodiment having such configuration, as light is transmitted, a polarized state of light is changed by the positive C-film **344** and the LC panel **301** in the Poincare sphere shown in FIG. **12**B, and finally an optical axis of the light matches with an absorption axis of the second polarizer **360** due to the positive biaxial film **346**. Consequently, light polarized at the first polarizer **350** is all absorbed by the second polarizer **360**, thereby preventing light leakage in the diagonal direction.

FIG. **14**A shows the result of simulating a viewing angle characteristic in a normally black mode in a direction of a diagonal viewing angle of the related art LCD device, and FIG. **14**B shows the result of simulating a viewing angle characteristic in a normally black mode in a direction of a diagonal viewing angle of the LCD device according to the present invention.

Here, the lower polarizer and the upper polarizer are disposed such that optical axes thereof can be orthogonal to each other, and an optical axis of the liquid crystal layer is parallel with a light transmission axis of the lower polarizer. Here, FIGS. **14**A and **14**B are results of simulating contrast characteristics, at an inclination angle in the range of 0~80° with respect to all radius vector angles (or azimuthal angles) when using white-tone light, for the related art LCD device and an LCD device having an optical compensation film according to the present invention. In FIGS. **14**A and **14**B, a center of a circle may have an inclination angle of 0°. As a radius of the circle increases, the inclination angle becomes larger. Also, the numerals represented along a circumference denote radius vector angles.

Comparing the contrast characteristic of the related art LCD device shown in FIG. **14**A with that of the LCD device according to the present invention shown in FIG. **14**B, it can be observed in the normally black mode that light leakage has been remarkably reduced at angles of 45°, 135°, 225° and 315° corresponding to the diagonal direction of the LC panel. Here, a maximum transmittancy Tmax is Tmax=0.00192 in the diagonal viewing angle direction of the related art LCD device, whereas the maximum transmittancy Tmax is Tmax=0.000188 in the diagonal viewing angle direction of the LCD device of the present invention having the positive C-film and the positive biaxial film. Therefore, it can be noticed that the transmittancy in the diagonal viewing angle direction of the LCD device according to the present invention has been remarkably reduced as compared to the related art LCD device.

The foregoing embodiments and advantages are merely exemplary and are not to be construed as limiting the present disclosure. The present teachings can be readily applied to other types of apparatuses. This description is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art. The features, structures, methods, and other characteristics of the exemplary embodiments described herein may be combined in various ways to obtain additional and/or alternative exemplary embodiments.

As the present features may be embodied in several forms without departing from the characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

What is claimed is:

1. A liquid crystal display (LCD) device comprising:

a liquid crystal display panel having a liquid crystal layer;

a first polarizer and a second polarizer respectively disposed at upper and lower portions of the liquid crystal display panel to polarize light;

a positive C-film disposed between the first polarizer and the liquid crystal display panel to change a polarized state of light, the positive C-film having a retardation value of Re=0 nm in a horizontal direction and a retardation value of Rth=−50~−200 nm in a thickness direction; and

a positive biaxial film disposed between the liquid crystal display panel and the second polarizer to change a polarized state of light, the positive biaxial film having a retardation value Re=80~160 nm in a horizontal direction and a retardation value of Rth=−24~−160 nm in a thickness direction,

wherein $Re=(n_x-n_y)d$ and $Rth=(n_x-n_z)d$, where n_x, n_y and n_z respectively denote a refractive index in x-axial direction, a refractive index in y-axial direction and a refractive index in z-axial direction.

2. The device of claim **1**, wherein absorption axes of the first polarizer and the second polarizer are perpendicular to each other.

3. The device of claim **1**, wherein the first polarizer comprises:

a first supporting body; and

a first polarizing body having one surface attached onto the first supporting body.

4. The device of claim **3**, wherein the first supporting body is formed of a transparent protection film.

5. The device of claim **4**, wherein the transparent protection film is formed of triacetylcellulose.

6. The device of claim **3**, wherein the first polarizer is formed of a polyvinyl alcohol (PVA) based resin.

7. The device of claim **3**, wherein the first polarizer comprises:

a first polarizing body; and

a first supporting body disposed between the first polarizer and the positive C-film, the first supporting body being formed of triacetylcellulose without retardation Rth.

8. The device of claim **1**, wherein the second polarizer comprises:

a second supporting body; and

a second polarizing body having one surface attached onto the second supporting body.

9. The device of claim **8**, wherein the second supporting body is formed of a transparent protection film.

10. The device of claim **9**, wherein the transparent protection film is formed of triacetylcellulose.

11. The device of claim **8**, wherein the second polarizer is formed of a polyvinyl alcohol (PVA) based resin.

12. The device of claim **1**, wherein the positive C-film is formed of a UV-curable perpendicularly-aligned liquid crystal film or a biaxially-stretched polymer film.

13. The device of claim **1**, wherein the positive biaxial film is formed of a material selected from a group consisting of UV-curable liquid crystal film polycarbonate, polyethylene terephthalate, polystyrene, uniaxially-stretched TAC, uniaxially-stretched polynorbonene (PNB), biaxially-stretched polycarbonate (PC), biaxially-stretched COP, and biaxial LC film.

14. The device of claim **1**, wherein nx-axis of the positive biaxial film is parallel to a light absorption axis of the second polarizer.

15. The device of claim **1**, wherein the rubbing direction of the liquid crystal display panel is parallel to a light absorption axis of the first polarizer.

16. The device of claim **1**, wherein a non-polarized light is incident through the first polarizer.

17. The device of claim **1**, wherein a non-polarized light is incident through the second polarizer.

18. The device of claim **1**, wherein the liquid crystal display panel is either an in-plane switching (IPS) mode liquid crystal display panel or a fringe field switching (FFS) mode liquid crystal display panel.

19. The device of claim **1**, wherein the positive C-film is formed of a UV-curable perpendicularly-aligned liquid crystal film.

20. The device of claim **1**, wherein the positive biaxial film is formed of UV-curable liquid crystal film polycarbonate.

21. The device of claim **1**, wherein the liquid crystal display panel is an in-plane switching (IPS) mode liquid crystal display panel.

* * * * *

专利名称(译)	具有宽视角的液晶显示装置		
公开(公告)号	US8269930	公开(公告)日	2012-09-18
申请号	US12/649868	申请日	2009-12-30
[标]申请(专利权)人(译)	MOON JONG WON 新光勋		
申请(专利权)人(译)	MOON JONG-WON 新光勋		
当前申请(专利权)人(译)	LG DISPLAY CO. , LTD.		
[标]发明人	MOON JONG WON SHIN KWANG HOON		
发明人	MOON, JONG-WON SHIN, KWANG-HOON		
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摘要(译)

本发明公开了一种具有宽视角的液晶显示装置，其中补偿膜设置在液晶显示面板和偏振器之间以改变光的偏振状态，其入射在液晶显示面板上并通过偏振器从其输出。从而防止光在常黑模式下沿液晶显示装置的对角线方向泄漏。