(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 619 543 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
08.04.2009 Bulletin 2009/15

(51) Int Cl.:
G02F 1/1335 *(2006.01)* ***G02F 1/13363*** *(2006.01)*
G02B 5/30 *(2006.01)*

(21) Application number: **05015191.9**

(22) Date of filing: **13.07.2005**

(54) Phase delay element for transflective type liquid crystal display

Phasenverzögerungselement für transflektive Flüssigkristallanzeige

Elément de retard de phase pour un dispositif d'affichage à cristaux liquides de type transflectif

(84) Designated Contracting States:
DE FI FR GB

(30) Priority: **19.07.2004 KR 2004055827**

(43) Date of publication of application:
25.01.2006 Bulletin 2006/04

(73) Proprietor: **Samsung Electronics Co., Ltd**
Yeongtong-gu
Suwon-city, Gyeonggi-do
442-742 (JP)

(72) Inventors:
- **Hirai, Akira**
Seongnam-si
Gyeonggi-do (KR)
- **Yun, Jin-Hyuk**
Gangnam-gu
Seoul (KR)
- **Uh, Kee-Han**
Yongin-si
Gyeonggi-do (KR)
- **Park, Min-Soo**
Giheung-eup
Yongin-si
Gyeonggi-do (KR)

(74) Representative: **Dr. Weitzel & Partner**
Friedenstrasse 10
89522 Heidenheim (DE)

(56) References cited:
WO-A-03/062872
WO-A-20/05010601
US-A1- 2001 020 990
US-A1- 2002 089 623
US-A1- 2004 066 477

- **PATENT ABSTRACTS OF JAPAN vol. 2003, no. 09, 3 September 2003 (2003-09-03) -& JP 2003 140152 A (SHARP CORP), 14 May 2003 (2003-05-14)**

EP 1 619 543 B1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a phase delay element for a liquid crystal display, and more particularly, to phase delay element for a transmissive and reflective type liquid crystal display in which the display operation is carried out in a reflection mode of a low power consumption at a bright place where a light amount is abundant and the display operation is also carried out in a transmission mode of a high luminance at a dark place where a light amount is deficient

2. Description of the Related Art

[0002] In an information-oriented society these days, the role of an electronic display is getting more important. All kinds of electronic displays are widely used in various industrial fields.

[0003] Generally, the electronic display is an apparatus for visually providing a variety of information to a person. In other words, an electrical information signal output from various electronic devices is converted into a visually recognizable optical information signal at the electronic display. Therefore, the electronic display serves as a bridge for connecting the person and the electronic devices.

[0004] Electronic displays are classified as either an emissive display in which the optical information signal is displayed by a light-emitting way, or a non-emissive display in which the optical information signal is displayed by an optical modulation way such as light-reflecting, dispersing and interfering phenomenon, etc. As the emissive display is known as an active display, for example, they include a CRT (Cathode Ray Tube), a PDP (Plasma Display Panel), an LED (Light Emitting Diode) and an ELD (Eelectroluminescent Display), etc. As the non-emissive display is known as a passive display, they include an LCD (Liquid Crystal Display), an ECD (Electrochemical Display) and an EPID (Electrophoretic Image Display), etc.

[0005] The CRT used in an image display, such as a television receiver and a monitor, for example, has the highest market share in an aspect of displaying quality and economical efficiency, but also has many disadvantages such as heavy weight, large volume and high power consumption.

[0006] Meanwhile, due to rapid developments in semiconductor technology, various kinds of electronic devices are driven by lower voltage and lower power, and thus the electronic equipments became much slimmer and lighter. Therefore, a flat panel type display having the slimmer and lighter characteristic, as well as the lower driving voltage and lower power consumption characteristic, is required according to the new environment.

[0007] The LCD among the various developed flat panel type displays is much slimmer and lighter than any other displays, and has a lower driving voltage and lower power consumption, and also has a display quality similar to that of the CRT. Therefore, the LCD is widely used in various electronic equipments.

[0008] The LCD is classified as either a transmission type LCD for displaying an image using an external light source such as a backlight assembly, a reflection type LCD for displaying an image using natural light, and a transmissive and reflective type LCD in which the display operates in a transmission mode using an internal light source provided in the display itself when indoors or in a dark place where an external light source does not exist and the display operates in a reflection mode to display an image by reflecting an external incident light in a high brightness environment, such as outdoors.

[0009] The reflective type LCD apparatus, in general, displays an image using an external natural light or ambient light that is provided to the LCD apparatus. Therefore, the reflective type LCD apparatus may not display the image when the LCD apparatus is surrounded in darkness.

[0010] The transmissive type LCD apparatus displays an image using an artificial light that is generated from a backlight assembly internal to the LCD apparatus. Therefore, the transmissive type LCD apparatus can display the image when the LCD apparatus is surrounded in darkness. However, the transmissive type LCD apparatus has a larger power consumption than the reflective type LCD apparatus. In addition, the transmissive type LCD apparatus has a battery resulting in a heavier weight than the reflective type LCD apparatus. Therefore, the transmissive type LCD apparatus is not as desirable for use as a portable display apparatus compared with the reflective type LCD apparatus.

[0011] The LCD controls the alignment of liquid crystal molecules using a voltage applied to the liquid crystal layer, and can be classified as either a passive matrix type or an active matrix type, depending on the way the pixels are driven. In the passive matrix type, pixels are driven using a root-mean-square (rms) of a difference between voltages applied to signal lines and scanning lines while a line addressing in which a signal voltage is applied to all of the pixels at the same time is carried out. In the active matrix type, pixels are driven by a switching element such as a metal-insulator-metal (MIN) device or a thin film transistor (TFT).

[0012] FIG. 1 is a cross-sectional view showing a conventional reflective-transmissive type LCD apparatus. A portion of an artificial light, i.e., from a backlight assembly disposed at a rear side of the reflective-transmissive LCD apparatus, is lost.

[0013] Referring to FIG. 1, the reflective-transmissive LCD apparatus includes a lamp 1, a lamp reflecting plate 2, a lower polarizer 3, a retardation film 4, a reflection layer 5, a liquid crystal layer 6, a color filter 7, and an upper polarizer 8.

[0014] The lamp 1 is disposed on a backside of the lower polarizer 3 and intermediate thereof and the lamp reflecting plate 2. Lamp 1 supplies the lower polarizer 3 with an artificial light. The lower polarizer 3 has an absorption axis that is substantially perpendicular to a horizontal direction defining substantially parallel layers with respect to the reflective-transmissive LCD apparatus. When the artificial light generated from the lamp 1 is incident on the lower polarizer 3, a portion of the artificial light vibrating in the horizontal direction passes through the lower polarizer 3 and is emitted towards a viewer's side of the reflective-transmissive LCD apparatus. When the natural light that is provided from the exterior of the LCD apparatus is incident on the lower polarizer 3, a portion of the natural light vibrating in the horizontal direction passes through the lower polarizer 3 and is emitted towards the backside of the reflective-transmissive LCD apparatus.

[0015] The retardation film 4 includes a 1/4 wavelength phase *(λ/4)* retardation film 4. When the artificial light or the natural light passes through the λ*/4* retardation film 4, a phase of the light is delayed by about 1/4 of the wavelength phase or λ/4. The 1/4 wavelength phase retardation film 4 functions to convert a linearly polarized light to a circularly polarized light, or vice versa by causing a phase difference of 1/4 wavelength between two polarization components that are normal to each other and are parallel to optical axes of the 1/4 wavelength phase retardation film 4.

[0016] The reflection layer 5 is disposed under the liquid crystal layer 6 and is intermediate the liquid crystal layer and the 1/4 wavelength phase retardation film 4 as illustrated . When a vertically polarized light is incident on the reflection layer 5, the vertically polarized light is reflected from the reflection layer 5. A luminance of the vertically polarized light is controlled by the liquid crystal layer 6. More specifically, the arrangement of the liquid crystal layer 6 varies in response to an electric field applied thereto, thus allowing a light transmittance of the liquid crystal layer 6 to be changed. A portion of the vertically polarized light that passes through the liquid crystal layer is incident on the color filter 7 and, passes through the color filter 7, dependent on a predetermined wavelength range.

[0017] The upper polarizer 8 includes a vertical polarizing axis allowing a vertically polarized light to pass through the upper polarizer 8. When the vertically polarized light that is provided from the backside is incident on the upper polarizer 8, the vertically polarized light passes through the upper polarizer 8. In addition, when the natural light or a frontal light is incident on the upper polarizer 8, the vertically polarized light passes through the upper polarizer 8 and is incident on the color filter 7.

[0018] The artificial light corresponding to the transmissive mode has a lower efficiency than an efficiency of the natural light corresponding to the reflective mode. When the reflective-transmissive LCD apparatus is in the transmissive mode, the artificial light generated from the lamp 1 is incident on the lower polarizer 3 allowing the linearly polarized light to pass through the lower polarizer 3. The linearly polarized light is incident on the retardation film 4 allowing the right circularly polarized light to be emitted from the retardation film 4. A portion of the right circularly polarized light passes through a transmission window of the liquid crystal layer 6 having a wavelength phase of the light that is changed in response to the electric field applied to the liquid crystal layer 6.

[0019] When the right circularly polarized light passes through the liquid crystal layer 6, either the right circularly polarized light or the vertically polarized light is emitted from the liquid crystal layer 6 dependent on the electric field applied to the liquid crystal layer 6. In addition, it is noted that the vertically polarized light passes through the upper polarizer 8, while the right circularly polarized light may not pass through the upper polarizer 8.

[0020] A remaining portion of the right circularly polarized light that is emitted from the retardation film 4 is reflected from the reflection layer 5 and emitted therefrom as a left circularly polarized light. The left circularly polarized light is incident on the retardation film 4 so that the vertically polarized light is emitted from the retardation film 4 toward the lower polarizer 3. The vertically polarized light is blocked by the lower polarizer 3. Therefore, the remaining portion of the artificial light is lost, thus decreasing the efficiency of the lamp.

[0021] For example, when an effective display area is about 80% and the transmission window is about 30% of the unit pixel, more than about 70% of the unit pixel is therefore lost for transmission of artificial light.

[0022] Accordingly, there is a desire to improve a luminance of a reflective-transmissive LCD apparatus by increasing the efficiency of the artificial light reflected from the reflection layer.

[0023] The concept illustrated in FIG. 2 of enhancing the backlight efficiency in a backlit transflective LCD device by arranging a patterned λ14 plate between the backlight source and the transflector; the pattern of the λ14 plate corresponding to the reflective portions of the transflector, is known from JP 2003/140152 (cf. figure 3b).

BRIEF SUMMARY OF THE INVENTION

[0024] Accordingly, the present invention is to solve the aforementioned problems of the conventional art, and it is an object of the present invention to provide a transflective LCD device capable of simplifying a structure of a liquid crystal cell and decreasing light loss in the transmission mode.

[0025] A transflective LCD device in accordance with the present invention is defined in the appended claims 1-6.

[0026] A method of fabricating a patterned phase retarding film suitable for recycling of backlight in a transflective display device in accordance with the present invention, is defined in appended claims 7-11.

[0027] An LCD apparatus in accordance with the present invention is defined in appended claim 12.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The above and other advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the accompanying drawings, in which:

FIG. 1 is a cross-sectional view showing a conventional reflective-transmissive LCD apparatus;
FIG. 2 is a cross-sectional view showing another conventional transflective LCD apparatus in accordance with JP 2003/14052.
FIG. 3 is a plan view showing a molecular structure of a cholesteric liquid crystal;
FIGS. 4A to 4F are cross-sectional views showing a method of fabricating a patterned phase retarding film in accordance with an exemplary embodiment of the present invention;
FIGS. 5A to 5E are cross-sectional views showing a method of fabricating a patterned phase retarding film in accordance with another exemplary embodiment of the present invention;
FIGS. 6A to 6F are cross-sectional views showing a method of fabricating a patterned phase retarding film in accordance with another exemplary embodiment of the present invention;
FIGS. 7A to 7E are cross-sectional views showing a method of fabricating a patterned phase retarding film in accordance with another exemplary embodiment of the present invention;
FIG. 8 is a cross-sectional view showing an LCD apparatus in accordance with an exemplary embodiment of the present invention;
FIGS. 9A to 9E are cross-sectional views showing a method of manufacturing an array substrate shown in FIG. 8;
FIGS. 10A is a cross-sectional view of a conventional backlight-recycling phase retarding film;
FIGS. 10B to 10D are cross-sectional views each showing a backlight-recycling phase retarding film in accordance with alternative exemplary embodiments of the present invention;
FIG. 11 is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;
FIG. 12 is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention;
FIG. 13 is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention; and
FIG. 14 is a cross-sectional view showing an LCD apparatus in accordance with another exemplary embodiment of the present invention.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0029] It should be understood that the exemplary embodiments of the present invention described below may be varied or modified in many different ways without departing from the scope of the appended claims.

[0030] Referring to FIG. 2, a cross section view of a conventional LCD apparatus is illustrated in accordance with JP 2003/140152. The LCD apparatus includes a lamp 10, a lower polarizer 20, a retardation film 30, a backlight-recycling phase retarding film 40, a reflection layer 50, a lamp reflecting plate 60, a liquid crystal layer 70, a color filter 80 and an upper polarizer 90. The upper polarizer 90 may be an analyzer. A viewer's side of the LCD apparatus corresponds to an upper portion or a top side of the LCD apparatus as illustrated. A backside of the LCD apparatus corresponds to a lower portion of the LCD apparatus as illustrated.

[0031] The lamp 10 is disposed under the lower polarizer 20, as illustrated, or is intermediate the lamp polarizer 20 and the lamp reflecting plate 60. Lamp 10 is configured to generate an artificial light that is a non-polarized light.

[0032] The lower polarizer 20 includes a horizontal polarizing axis indicated generally with arrow 22. When the artificial light is incident on the lower polarizer 20 from the backside, a horizontally polarized light is emitted from the lower polarizer 20 toward the viewer's side indicated generally with double-ended arrows 24. When the horizontally polarized light 24 is incident on the lower polarizer 20 from the viewer's side, the horizontally polarized light 24 is emitted from the lower polarizer 20 toward the backside. In this manner, the horizontally polarized light 24 is allowed to pass through the lower polarizer 20 from either side.

[0033] A phase of a wavelength of light that has passed through the retardation film 30 is delayed by about 1/4 phase or $\lambda/4$. When the horizontally polarized light 24 is incident on the retardation film 30 from the backside, a phase of the horizontally polarized light 24 is delayed by about 1/4 phase ($\lambda/4$), thus emitting a right circularly polarized light indicated generally at 36 from the retardation film 30 towards the viewer's side. When the right circularly polarized light 36 is incident on the retardation film 30 from the viewer's side, the horizontally polarized light 24 is emitted from the retardation film 30 toward the backside.

[0034] A phase of the light that has passes through the backlight-recycling phase retarding film 40 is delayed by about 1/4 phase ($\lambda/4$). When the right circularly polarized light 36 is incident on the backlight-recycling phase retarding film 40 from the backside, a phase of the right circularly polarized 36 light is delayed by about 1/4 phase ($\lambda/4$), thus emitting a vertically polarized light from the backlight-recycling phase retarding film 40 toward the viewer's side indicated generally at 44. When a reflected vertically polarized light 36 that is reflected from the reflection layer 50 is incident on thebacklight-recycling phase retarding film 40 from the viewer's side, a phase of the reflected vertically polarized light is delayed about 1/4 phase ($\lambda/4$) emitting the right circularly polarized light 36 from the backlight-recycling phase retarding film 40 toward the backside.

[0035] The backlight-recycling phase retarding film 40 may include a birefringent film, an alignment film of a liquid crystal polymer, and an alignment layer of the liquid crystal polymer that is fixed using a film, for example. A polymer film may be extended in a predetermined direction to form the birefringent film. The polymer film may include polycarbonate, polyvinylalcohol, polystyrene, polymethylmethacrylate, polypropylene, polyolefin, polyacrylate, polyamide, for example, but is not limited thereto.

[0036] In FIG. 3, the backlight-recycling phase retarding film brightness enhancement layer 40 includes a cholesteric liquid crystal that is an ultraviolet curable liquid crystal polymer. FIG. 3 illustrates a plan view showing a molecular structure of a cholesteric liquid crystal. Directions of molecules 96 of the cholesteric liquid crystal are gradually changed along a spiral axis (not shown) having a pitch (P). The spiral axis corresponds to a direction of the light that passes through the cholesteric liquid crystal. In particular, a portion of a nematic liquid crystal is changed to have a chiral structure that has a spiral shape, thereby forming the liquid crystal. One layer of the cholesteric liquid crystal is substantially identical to a plan view of the nematic liquid crystal, however, the nematic liquid crystal does not have the spiral axis.

[0037] Referring again to FIG.2, the reflection layer 50 is disposed under the liquid crystal layer 70 as illustrated or is intermediate the liquid crystal layer and backlight-recycling phase retarding film 40. When the vertically polarized light 44 is reflected from the reflection layer 70, the phase of the vertically polarized light is not changed.

[0038] The lamp reflecting plate 60 is disposed under the lamp 10 and defmes the backside of the LCD apparatus. When the artificial light generated from lamp 10 or the vertically polarized light 44 from the viewer's side is incident on the lamp reflecting plate 60, the artificial light is reflected from the lamp reflecting plate 60 toward the viewer's side without change to the phase of the artificial light. The reflected vertically polarized light then consequently passes through the backlight-recycling phase retarding film 40, the retardation film 30 and the lower polarizer 20.

[0039] The liquid crystal layer 70 controls the phase of the vertically polarized light 44 that is provided from the backside based on an electric field applied to the liquid crystal layer 70 and emitting a light incident on the color filter 80 having the changed phase. Therefore, a light transmittance of the liquid crystal layer 70 may be changed. A thickness of the liquid crystal layer 70 is referred to as a cell gap. The cell gap of the liquid crystal layer 70 corresponding to the reflection region may be different from the cell gap of the liquid crystal layer 70 corresponding to the transmission region. In this conventional example, the cell gap of the reflection region may be about a half of the cell gap of the transmission region.

[0040] A portion of the vertically polarized light 44 that has passed through the liquid crystal layer 70, which has a predetermined wavelength range, passes through a corresponding portion of the color filter 80. More specifically, the color filter 80 includes a red color filter portion, a green color filter portion and a blue color filter portion. For example, a red light having about 650nm of the wavelength is allowed to pass through the red color filter portion. A green light having about 550nm of the wavelength is allowed to pass through the green color filter portion. A blue light having about 450nm of the wavelength is allowed to pass through the blue color filter portion. The color filter 80 is disposed on the liquid crystal layer 70 as illustrated, or is intermediate the liquid crystal layer 70 and the upper polarizer 90. Alternatively, the color filter 80 may be disposed under the liquid crystal layer 70 being intermediate thereof and the reflection layer 50.

[0041] The upper polarizer 90 includes a vertically polarizing axis 92. When a light is incident on the upper polarizer 90 from the backside, a vertically polarized light is emitted from the upper polarizer 90 toward the viewer's side. When a natural light or a front light is incident on the upper polarizer 90 from the viewer's side, the vertically polarized light is emitted from the upper polarizer 90 and is incident on the color filter 80. The polarizing axis 92 of the upper polarizer 90 is substantially perpendicular to the polarizing axis 22 of the lower polarizer 20. The natural light may include sunlight or an illumination light from a front, for example, but is not limited thereto. Further, the front light may be an artificial light generated from an auxiliary lamp (not shown) disposed on a viewer's side of the LCD apparatus. Still referring to FIG. 2, the overall operation of the backlight-recycling phase retarding film 40 will now be described herein below. When the artificial light generated from the lamp 10 is incident on the lower polarizer 20, the horizontally polarized light 24 is emitted from the lower polarizer 20 toward the retardation film 30. When the horizontally polarized light 24 is incident on the retardation film 30, the right circularly polarized light 36 is emitted from the retardation film 30 toward the backlight-recycling phase retarding film 40. When the right circularly polarized light 36 is incident on the backlight-recycling phase retarding film 40, the vertically polarized light 44 is emitted from the backlight-recycling phase retarding film 40 toward the reflection layer 50. The vertically polarized light 44 is reflected from the reflection layer 50 so that the reflected light is incident on the backlight-recycling phase retarding film 40. The vertically polarized light 44 may be reflected and scattered. The linearly polarized light (e.g., horizontally and vertically polarized lights 24 and 44, respectively) is a P-wave, and the circularly polarized light 36 is a S-wave.

[0042] When the reflected light from the reflection layer 50 is incident on the backlight-recycling phase retarding film 40, the right circularly polarized light 36 is emitted from the backlight-recycling phase retarding film 40 toward the retardation film 30. When the right circularly polarized light 36 is incident on the retardation film 30, the horizontally polarized light 24 is emitted from the retardation film 30. The horizontally polarized light 24 passes through the lower polarizer 20, and the horizontally polarized light 24 is reflected from the lamp reflecting plate 60. The reflected horizontally polarized light is incident on the lower polarizer 20, thus increasing a luminance of the LCD apparatus.

[0043] The backlight-recycling phase retarding film 40 is disposed in the reflection region. Alternatively, the backlight-recycling phase retarding film may be disposed in the reflection region and the transmission region.

[0044] The backlight-recycling phase retarding film 40 may be disposed in the liquid crystal layer 70. The backlight-recycling phase retarding film may also be disposed on a lower substrate of the LCD apparatus using a film.

[0045] The cell gap of the liquid crystal layer 70 is determined by an anisotropy of the reflective index Δn. In this exemplary embodiment, the cell gap of the transmission region of the liquid crystal layer 70 is about 4μm to about 6μm, and the cell gap of the reflection region of the liquid crystal layer 70 is about 2μm to about 3μm. Referring to Figure 2, the backlight-recycling phase retarding film 40 may constitute about 2μm to about 3μm of the 1/4 phase (λ/4) retardation film 30. A polycarbonate is extended in a predetermined direction to form the 1/4 phase (λ/4) retardation film 30. The 1/4 phase (λ/4) retardation film 30 may also be formed by aligning the liquid crystal.

[0046] The 1/4 phase *(λ/4)* retardation film 30 having the extended polycarbonate may have about 0.001 of the anisotropy of the reflective index An. When the anisotropy of the reflective index △n and a reference wavelength are about 0.001 and about 560nm, respectively, the thickness of the 1/4 phase (λ/4) retardation film 30 corresponding to a light having a wavelength of about 140nm may be 140μm.

[0047] The 1/4 phase (λ/4) retardation film 30 having the aligned liquid crystal may have about 0.1 of the anisotropy of the reflective index Δn. When the anisotropy of the reflective index △n and a reference wavelength are about 0.1 and about 560nm, respectively, the thickness of the 1/4 phase (λ/4) retardation film 30 corresponding to a light having a wavelength of about 140nm may be 1.4μm.

[0048] FIGS. 4A to 4F are cross-sectional views illustrating a method of fabricating a patterned phase retarding film 217 in accordance with an exemplary embodiment of the present invention.

[0049] Referring to FIG. 4A, an alignment film 211 is formed on a substrate film 210 for printing. An ultraviolet curable liquid crystal polymer is coated on the alignment film 211 to form an aligned liquid crystal layer 212. The ultraviolet curable liquid crystal polymer may include the cholesteric liquid crystal illustrated in FIG. 3.

[0050] Referring to FIG. 4B, an ultraviolet light indicated generally with rays 200 is irradiated on the aligned liquid crystal layer 212 to form a semi-solid liquid crystal layer 213. The semi-solid liquid crystal layer 213 may be a biaxial film or a uniaxial film. For example, a polarized ultraviolet light may be irradiated on the cholesteric liquid crystal to form the biaxial film. A non-polarized ultraviolet light may be irradiated on the cholesteric liquid crystal to form a C-plate. A "C-plate" denotes a birefringent optical element, such as, for example, a plate or film, with a principle optical axis (often referred to as the "extraordinary axis") substantially perpendicular to the selected surface of the optical element. The principle optical axis corresponds to the axis along which the birefringent optical element has an index of refraction different from the substantially uniform index of refraction along directions normal to the principle optical axis.

[0051] The biaxial film has an x-refractive index (nx), a y-refractive index (ny), and a z-refractive index (nz) that are different from one another. The uniaxial film includes an A-plate and the C-plate. An "A-plate" denotes a birefringent optical element, such as, for example, a plate or film, having its principle optical axis within the x-y plane of the optical element. Positively birefringent a-plates can be fabricated using, for example, uniaxially stretched films of polymers such as, for example, polyvinyl alcohol, or uniaxially aligned films of nematic positive optical anisotropy LCP materials. Negatively birefringent a-plates can be formed using uniaxially aligned films of negative optical anisotropy nematic LCP materials, including for example discotic compounds. A y-refractive index of the A-plate is substantially equal to a z-refractive index of the A-plate, and the y-refractive index of the A-plate is smaller than a z-refractive index of the A-plate. A x-refractive index of the C-plate is substantially equal to a y-refractive index of the C-plate, and the y-refractive index of the C-plate is larger than a z-refractive index of the C-plate.

[0052] Referring to FIG. 4C, the semi-solid liquid crystal layer 213 is disposed on a glass plate 214. The glass plate 214 includes a reflection region or reflection area (RA) and a transmission region or transmission area (TA). The semi-solid liquid crystal layer 213 is heated or compressed to fix the semi-solid liquid crystal layer 213 to the glass plate 214.

[0053] Referring to FIG. 4D, the substrate film 210 for printing is then detached from the alignment film 211 forming the semi-solid liquid crystal layer 213 on the glass plate 214.

[0054] Referring to FIG. 4E, a reticle 218 having a transparent plate 215 and an opaque pattern 216 is aligned over the glass plate 214. The opaque pattern 216 corresponds to the reflection region RA and is aligned therewith. Alternatively, the opaque pattern 216 may correspond to and be aligned with the transmission region TA. When the ultraviolet light 200 is irradiated on the semi-solid liquid crystal layer 213 through the reticle 218 during a developing process, the semi-solid liquid crystal layer 213 is developed. Therefore, a portion of the semi-solid liquid crystal layer 213 corresponding to the reflection region RA is solidified, and a remaining portion of the semi-solid liquid crystal layer 213, corresponding to the transmission region TA, is removed. The alignment film 211 is also removed during the developing process.

[0055] Referring to FIG. 4F, a patterned phase retarding film 217 is illustrated as being an embossed pattern formed on an exposed surface of the solidified liquid crystal layer disposed in the reflection region RA.

[0056] FIGS. 5A to 5E are cross-sectional views illustrating a method of fabricating a patterned phase retarding film 226 in accordance with another exemplary embodiment of the present invention.

[0057] Referring to FIG. 5A, an alignment layer 221 is formed on a photoresist film 220 having an embossed pattern. A liquid crystal layer 222 is formed on the alignment layer 221 such that the alignment layer 221 is intermediate the photoresist film 220 and the liquid crystal layer 222.

[0058] Referring to FIG. 5B, an exposed surface of the liquid crystal layer 222 is then disposed to a glass plate 223. An ultraviolet light 200 is irradiated on the liquid crystal layer 222 to semi-solidify the liquid crystal layer 222, which may be a biaxial film or a uniaxial film. For example, a polarized ultraviolet light may be irradiated on a cholesteric liquid crystal of the liquid crystal layer 222 to form the biaxial film. Alternatively, a non-polarized ultraviolet light may be irradiated on the cholesteric liquid crystal to form a C-plate.

[0059] Referring to FIG. 5C, the photoresist film 220 is illustrated as being removed from the alignment layer 221.

[0060] Referring to FIG. 5D, a reticle 228 having a transparent plate 224 and an opaque pattern 225 is disposed over the alignment layer 221. The opaque pattern 225 corresponds to and is aligned with the reflection region RA. Alternatively, the opaque pattern 225 may correspond to the transmission region TA. When the ultraviolet light 200 is irradiated on the semi-solid liquid crystal layer 222' through the reticle, the semi-solid liquid crystal layer 222' is developed. Therefore, a portion of the semi-solid liquid crystal layer 222' corresponding to the reflection region RA is then solidified, and a remaining portion of the semi-solid liquid crystal layer 222', corresponding to the transmission region TA, is removed. The alignment film 221 is also removed during this developing process.

[0061] FIG. 5E illustrates a completed patterned phase retarding film 226 having the embossed pattern on an exposed surface thereof.

[0062] FIGS. 6A to 6F are cross-sectional views illustrating another method of fabricating a patterned phase retarding film 233 in accordance with another exemplary embodiment of the present invention.

[0063] Referring to FIGS. 6A and 6B, an alignment layer 231 is formed on a plate 230 having a reflection region (RA) and a transmission region (TA). A liquid crystal layer 232 is formed on the alignment layer 231, which is intermediate the liquid crystal layer 232 and the plate 230.

[0064] Referring to FIG. 6C, a reticle 238 having a first transparent plate 234 and an opaque pattern 235 is disposed over the plate 230, as illustrated. The opaque pattern 235 corresponds to and is aligned with the reflection region RA. Alternatively, the opaque pattern 235 may correspond to the transmission region TA. When the ultraviolet light 200 is irradiated on the liquid crystal layer 232 through the reticle, the liquid crystal layer 232 is developed. Therefore, a portion of the liquid crystal layer 232 corresponding to the reflection region RA is solidified, and a remaining portion of the liquid crystal layer 232 corresponding to the transmission region TA is removed. The alignment film 231 may not be removed during this developing process. FIG. 6D illustrates the patterned layer 232 formed through the developing process.

[0065] Referring to FIG. 6E, a reticle 239 having a second transparent plate 236 and a plurality of opaque members 237 is disposed over the plate 230. The opaque members 237 correspond to and are aligned with the reflection region RA. When the ultraviolet light 200 is irradiated on the liquid crystal layer 232 through the reticle 239, the liquid crystal layer 232 is developed. Therefore, an embossed pattern is formed on an exposed surface of the patterned layer 232 forming a completed patterned phase retarding film 233 (see FIG. 6F). FIG. 6F also illustrates an absence of a portion of the alignment film 231 corresponding to and aligned with the transmission region TA that has been removed.

[0066] FIGS. 7A to 7E are cross-sectional views illustrating another method of fabricating a patterned phase retarding film 246 in accordance with another exemplary embodiment of the present invention.

[0067] Referring to FIG. 7A, a photoresist alignment layer 241 is formed on a plate 240 having a reflection region RA and a transmission region TA.

[0068] Referring to FIG. 7B, a reticle 248 having a transparent plate 242 and an opaque pattern 243 is disposed over the plate 240. The opaque pattern 243 corresponds to and is aligned with the transmission region TA. Alternatively, the opaque pattern 243 may correspond to and be aligned with the reflection region RA. When ultraviolet light 200 is irradiated on the photoresist alignment layer 241 through the reticle 248, the photoresist alignment layer 241 is developed. Therefore, a portion of the photoresist alignment layer 241 corresponding to the reflection region RA is removed, and a remaining portion of the photoresist alignment layer 241 corresponding to the transmission region TA is solidified.

[0069] Referring to FIG. 7C, a liquid crystal layer 244 is then formed over the plate 240 having the photoresist alignment layer 241 corresponding to and aligned with the reflection region RA.

[0070] Referring to FIG. 7D, the ultraviolet light 200 is shown selectively irradiated on a portion of the liquid crystal layer 244 in the reflection region RA, thereby developing the liquid crystal layer 244. The ultraviolet light 200 may be irradiated on the liquid crystal layer 244 through a reticle (not shown). After selective irradiation in the reflection region RA, a portion of the liquid crystal layer 244 corresponding to the transmission region TA is removed. A remaining portion of the liquid crystal layer 244 corresponding to the reflection region RA is solidified, thereby forming a patterned layer 245.

[0071] Referring to FIG. 7E, an embossed pattern is formed on an exposed surface of the patterned layer 245 forming a completed patterned phase retarding film 246.

[0072] Referring to FIG. 8 a cross-sectional view of an LCD apparatus in accordance with an exemplary embodiment of the present invention is illustrated. The LCD apparatus includes a reflective-transmissive array substrate having a top transparent conductive oxide such as indium tin oxide (ITO). In this embodiment, a backlight-recycling phase retarding film is formed on an organic insulating layer corresponding to a reflection region.

[0073] The LCD apparatus includes an array substrate 100, a color filter substrate 200, a liquid crystal layer 300 disposed between the array substrate 100 and the color filter substrate 200, a lower film assembly 410 and an upper film assembly 420. The lower film assembly 410 and an upper film assembly 420 are disposed at opposite ends of the LCD apparatus proximate a backside and a topside thereof, respectively.

[0074] The array substrate 100 includes a lower transparent plate 105, a thin film transistor (TFT) disposed on the lower transparent plate 105, an organic insulating layer 140, a backlight-recycling phase retarding film 150, a pixel electrode 160 and a reflection layer 170, disposed in ascending order as illustrated. The TFT includes a gate electrode 110 formed on the lower transparent plate 105, a gate insulating layer 112 formed on the lower transparent plate 105 having the gate electrode 110, a semiconductor layer 114, an ohmic contact layer 116, a source electrode 120, and a drain electrode 130. The organic insulating layer 140 is disposed over the TFT. The drain electrode 130 and the gate insulating layer 112 corresponding to the reflection region are partially exposed through a contact hole 141 and an opening of the organic insulating layer 140, respectively.

[0075] The backlight-recycling phase retarding film 150 is formed on the organic insulating layer 140 and has an uneven thickness due to a non-planar surface. In one embodiment, convex and concave portions may be formed along a length on the organic insulating layer 140 defining the uneven thickness and non-planar surface. In the exemplary embodiment illustrated in FIG. 8, the backlight-recycling phase retarding film 150 has an embossed pattern. Therefore, when a light that passes through the backlight-recycling phase retarding film 150 is reflected from the reflection layer 170 and passes through the backlight-recycling phase retarding film 150 toward the backside of the LCD apparatus, the light passes through various light paths as a result of the uneven backlight-recycling phase retarding film 150 having various optical characteristics Δnd. The various optical characteristics Δnd is a product of a refractive anisotropy Δn and a thickness d of the backlight-recycling phase retarding film.

[0076] The pixel electrode 160 is formed over the backlight-recycling phase retarding film 150 such that a portion of the pixel electrode 160 enhancement layer is exposed through the opening of the backlight-recycling phase retarding film 150, the organic insulating layer 140, and the contact hole 141 allowing electrical connection between the pixel electrode 160 and the drain electrode 130 of the TFT. In this exemplary embodiment, the pixel electrode 160 is electrically connected to the drain electrode 130 of the TFT through the contact hole 141. The reflection layer 170 is formed on the pixel electrode 160 and corresponds to the reflection region. A transmission window is defined by an absence of the reflection layer 170.

[0077] The pixel electrode 160 is a transparent electrode that includes a conductive oxide film such as indium tin oxide (ITO), tin oxide (TO), indium zinc oxide (IZO), zinc oxide (ZO), and the like, for example. A capacitor line (not shown) may be formed between the organic insulating layer 140 and the pixel electrode 160 in a region spaced apart from the TFT so that the capacitor line and a portion of the pixel electrode 160 form a storage capacitor C_{st}. In this exemplary embodiment illustrated in FIG. 8, the reflection layer 170 is formed on the pixel electrode 160. In an alternative embodiment, an insulating layer may be disposed between the reflection layer 170 and the pixel electrode 160.

[0078] The color filter substrate 200 intermediate the liquid crystal layer 300 and the upper film assembly 420 includes an upper transparent plate 205, a black matrix 210, a color filter 220, a surface protection layer 230 and a common electrode 240 disposed in descending order, as illustrated. The black matrix 210 is formed on the upper transparent plate 205 to define a red pixel region, a green pixel region and a blue pixel region (e.g., for preventing a light from being leaked between pixels). The color filter 220 includes a red color filter portion disposed in the red pixel region, a green color filter portion disposed in the green pixel region and a blue color filter portion disposed in the blue pixel region. The surface protection layer 230 is formed on the upper transparent plate 205 having the black matrix 210 and the color filter 220 to protect the black matrix 210 and the color filter 220. The common electrode 240 is formed on the surface protection layer 230. In an alternative embodiment, at least two of the red, green and blue color filter portions are overlapped to form the black matrix 210.

[0079] The liquid crystal layer 300 disposed between the array substrate 100 and the color filter substrate 200 is configured to vary an arrangement of liquid crystal in the liquid crystal layer 300 in response to an electric field applied thereto. The electric field is formed by a voltage difference between the pixel electrode 160 of the array substrate 100 and the common electrode 240 of the color filter substrate 200 disposed on either side of the liquid crystal layer 300. In this manner, the liquid crystal layer 300 allows a front light to pass through the color filter substrate 200 or a backside light to pass through the transmission window defined by the absence of reflection layer 170.

[0080] A portion of the liquid crystal layer 300 corresponding to the contact hole 141 in the reflection region, a portion of the liquid crystal layer 300 corresponding to a remaining region of the reflection region, and a portion of the liquid crystal layer 300 corresponding to the transmission window all have different cell gaps relative to one another. A first cell gap d1 of the liquid crystal layer 300 corresponding to the contact hole 141 is larger than a second cell gap d2 of the liquid crystal layer 300 corresponding to the remaining region of the reflection region. A third cell gap d3 of the liquid crystal layer 300 corresponding to the transmission window is no smaller than the first cell gap d1 of the liquid crystal layer 300 corresponding to the contact hole 141.

[0081] It will be recognized that an optical characteristic $\Delta nd1$ of the liquid crystal layer 300 corresponding to the contact hole 141 is substantially equal to an anisotropy of a reflective index $\triangle n$ multiplied by the first cell gap d1. Likewise, optical characteristics $\Delta nd2$ and $\Delta nd3$ of the liquid crystal layer 300 corresponding to the remaining region of the reflection region and transmission window are substantially equal to the anisotropy of the reflective index $\triangle n$ multiplied by the second cell gap d2 and the third cell gap d3, respectively.

[0082] The first to third cell gaps d1 and d3, respectively, are determined in response to a liquid crystal of the liquid crystal layer 300, an optical condition of the array substrate, or an optical condition of the color filter substrate 200. In this exemplary embodiment, the second cell gap d2 corresponding to the reflection region is no more than about 1.7μm, and the third cell gap d3 corresponding to the transmission region is no more than about 3.3μm. The liquid crystal layer 300 may have a homogeneous alignment mode so that a twist angle of the liquid crystal layer 300 is about zero degrees.

[0083] In this exemplary embodiment, a lower alignment layer (not shown) of the array substrate 100 is rubbed in a first direction, and an upper alignment layer (also not shown) of the color filter substrate 200 is rubbed in a second direction that is substantially opposite to the first direction.

[0084] In this exemplary embodiment, voltages are applied to the pixel electrode 160 of the array substrate 100 and the common electrode 240 of the color filter substrate 200 forming an electric field that is applied to the liquid crystal layer 300. In an alternative embodiment, the array substrate 100 may include both the pixel electrode 160 and the common electrode 240 in place of forming the common electrode 240 on the color filter substrate.

[0085] The lower film assembly 410 includes a lower $\lambda/4$ retardation film 412 and a lower polarizer 414: The lower $\lambda/4$ retardation film 412 is disposed intermediate the array substrate 100 and the lower polarizer 414. The lower polarizer 414 is disposed under the lower $\lambda/4$ retardation film 412 and defines a bottom of the LCD apparatus as illustrated in FIG. 8.

[0086] When a horizontally polarized light is incident on the lower $\lambda/4$ retardation film 412 from a topside of the LCD apparatus, a phase of the horizontally polarized light is delayed by about 1/4 phase ($\lambda/4$) so that a right circularly polarized light is emitted from the lower $\lambda/4$ retardation film 412 toward the lower polarizer 414. When the right circularly polarized light is incident on the lower retardation film 412 from a topside of the LCD apparatus, a phase of the right circularly polarized light is delayed by about 1/4 phase ($\lambda/4$) so that the horizontally polarized light is emitted from the lower retardation film 412 toward the lower polarizer 414.

[0087] The lower polarizer 414 includes a first polarizing axis allowing a light that is polarized in the first polarizing axis to pass through the lower polarizer 414 toward the lower $\lambda/4$ retardation film 412 or the backside. For example, when the first polarizing axis is substantially parallel with the horizontal direction defining each of the plurality of layers of the LCD apparatus, the horizontally polarized light passes through the lower polarizer 414 from the backside so that the horizontally polarized light is incident on the lower $\lambda/4$ retardation film 412. In addition, the horizontally polarized light may pass through the lower polarizer 414 from the lower $\lambda/4$ retardation film 412 so that the horizontally polarized light is emitted from the lower polarizer 414 toward the backside.

[0088] The upper film assembly 420 is disposed on the color filter substrate 200 and includes an upper $\lambda/4$ retardation film 422 and an upper polarizer 424. The upper $\lambda/4$ retardation film 422 is disposed intermediate the upper polarizer 424 and the color filter substrate.

[0089] When a light from the color filter substrate 200 is incident on the upper $\lambda/4$ retardation film 422, a phase of the light is delayed by about 1/4 phase ($\lambda/4$) so that the light having the delayed phase is emitted from the upper $\lambda/4$ retardation film 422 toward a viewer's side. When a light is incident on the upper $\lambda/4$ retardation film 422 from the viewer's side, a phase of the light is delayed by about 1/4 phase ($\lambda/4$) so that the light having the delayed phase is emitted from the upper $\lambda/4$ retardation film 422 toward color filter substrate 200.

[0090] The upper polarizer 424 includes a second polarizing axis allowing a light that is polarized in the second polarizing axis to pass through the upper polarizer 424 toward the upper $\lambda/4$ retardation film 422 from the viewer's side. For example, when the second polarizing axis is substantially parallel with a vertical direction or normal to the layers defining the LCD apparatus, the vertically polarized light passes through the upper polarizer 424 from the viewer's side so that the vertically polarized light is incident on the upper $\lambda/4$ retardation film 422. In addition, the vertically polarized light may pass through the upper polarizer 424 from the upper $\lambda/4$ retardation film 422 so that the vertically polarized light is emitted from the upper polarizer 424 toward the viewer's side.

[0091] In operation, when an artificial light generated from a lamp (not shown) is incident on the lower polarizer 414, a linearly polarized light that is a P wave is emitted from the lower polarizer 414 toward the viewer's side. When the linearly polarized light is incident on the lower λ/4 retardation film 412, an elliptically polarized light is emitted from the lower λ/4 retardation film 412 toward the viewer's side. When the elliptically polarized light is incident on the backlight-recycling phase retarding film 150, a substantially linearly polarized light that is a S-wave is emitted from the backlight-recycling phase retarding film 150 toward the viewer's side. The substantially linearly polarized light is reflected and scattered from the reflection layer 170 toward the backside. The linearly polarized light may be diffused from the reflection layer 170.

[0092] When the reflected light is incident on the backlight-recycling phase retarding film 150 from the viewer's side, the elliptically polarized light is emitted from the backlight-recycling phase retarding film 150 toward the backside. When the elliptically polarized light is incident on the lower λ/4 retardation film 412, the linearly polarized light (the P-wave) is emitted from the lower λ/4 retardation film 412 through the lower polarizer 414 toward the backside.

[0093] The linearly polarized light that passes through the lower polarizer 414 is then reflected from a lamp reflecting plate 60 (see Figure 2) so that the reflected light is emitted from the lamp reflecting plate (not shown) toward the reflection layer 170 and out through the transmission window corresponding with an absence of the reflection layer 170. Therefore, a portion of the light generated from the lamp is recycled to improve a luminance of the LCD apparatus. In addition, a luminance of the LCD apparatus in a transmission mode is improved although a power consumption of the LCD apparatus need not be increased.

[0094] FIGS. 9A to 9E are cross-sectional views illustrating a method of manufacturing an array substrate 100 shown in FIG. 8.

[0095] Referring to FIG. 9A, a metal is deposited on the lower transparent plate 105. The metal may include tantalum (Ta), titanium (Ti), molybdenum (Mo), aluminum (Al), chromium (Cr), copper (Cu), or tungsten-(W), for example, but is not limited thereto. The lower transparent plate 105 includes an insulating material, such as glass, ceramic, quartz, for example. The deposited metal is patterned to form a plurality of gate lines (not shown) and a plurality of the gate electrodes 110. The gate lines (not shown) are extended in a longitudinal direction with respect to the lower transparent plate 105, and aligned in a horizontal direction that is substantially perpendicular to the longitudinal direction. Each of the gate lines (not shown) is electrically connected to a portion of the gate electrodes 110 as recognized by those skilled in the pertinent art. A storage electrode (not shown) line may be formed together with the gate electrode 110.

[0096] A silicon nitride is deposited over the lower transparent plate 105 having the gate electrode 110 using a plasma chemical vapor deposition to form the gate insulating layer 112. An amorphous silicon layer is deposited on the gate insulating layer 112, and an n+ amorphous silicon layer is formed by implanting impurities on the amorphous silicon layer in-situ. The n+ amorphous silicon layer and the amorphous silicon layer are patterned to form the semiconductor layer 114 and the ohmic contact layer 116 disposed on the semiconductor layer 114.

[0097] A metal, for example, such as tantalum (Ta), titanium (Ti), molybdenum (Mo), aluminum (Al), chromium (Cr), copper (Cu), or tungsten (W), for example, is deposited on the gate insulating layer 112 having the semiconductor layer 114 and the ohmic contact layer 116. The deposited metal is then patterned to form a plurality of source lines (not shown), a plurality of the source electrodes 120 and a plurality of the drain electrodes 130. The source lines (not shown) are extended in the horizontal direction. Each of the source lines (not shown) is electrically connected to a portion of the source electrodes 120 as recognized by those skilled in the pertinent art. Each of the drain electrodes 130 is spaced apart from each of the source electrodes 120. In an alternative embodiment, a passivation layer may be formed over the gate insulating layer 112 having the semiconductor layer 114, the ohmic contact layer 116, the source electrode 120 and the drain electrode 130.

[0098] Referring to FIG. 9B, the organic insulating layer 140 is formed by coating a photoresist on the gate insulating layer 112 having the semiconductor layer 114, the ohmic contact layer 116, the source electrode 120, and the drain electrode 130 through a spin coating process. Portions of the organic insulating layer 140 are removed to form the contact hole 141, through which the drain electrode 130 is partially exposed, and the opening, through which the gate insulating layer 112 corresponding to the transmission window is exposed. The organic insulating layer 140 includes an acrylic resin and a positive photoresist. The contact hole 141 and the opening are formed through a photo process having an exposure step and a developing step. When an ultraviolet light is irradiated on a portion of the positive photoresist, the portion of the positive photoresist is removed during the developing step, and a remaining portion of the positive photoresist remains.

[0099] Referring to FIG. 9C, an ultraviolet curable liquid crystal polymer is coated and aligned on the organic insulating layer 140. The ultraviolet curable liquid crystal polymer may be a cholesteric liquid crystal illustrated in FIG. 3. An ultraviolet light is irradiated on the aligned ultraviolet curable liquid crystal polymer to fix the ultraviolet curable liquid crystal, thereby forming the backlight-recycling phase retarding film 150. The backlight-recycling phase retarding film 150 has an uneven surface. The uneven surface may include an embossed pattern. The backlight-recycling phase retarding film 150 may be a biaxial film or a uniaxial film dependent on the polarization of the ultraviolet light irradiated thereon. When a polarized ultraviolet light is irradiated on the aligned ultraviolet curable liquid crystal polymer, the backlight-recycling phase retarding film 150 has the uniaxial film. When a non-polarized ultraviolet light is irradiated on the aligned ultraviolet curable liquid crystal polymer, the backlight-recycling phase retarding film 150 may be a C-plate.

[0100] Referring to FIG. 9D, the pixel electrode 160 is illustrated as being formed on the lower transparent plate 105 via the backlight-recycling phase retarding film 150 corresponding to each of the pixel regions. The pixel electrode 160 may be formed through a patterning or a selective deposition.

[0101] Referring to FIG. 9E, the reflection layer 170 is illustrated as being formed on the lower transparent plate 105 via the pixel electrode 160 corresponding to the reflection region. In an alternative embodiment, the lower alignment layer (not shown) may be formed on the transparent plate 105 having the reflection layer 170.

[0102] To complete manufacture of the LCD apparatus as illustrated in FIG. 8, the array substrate 100 is combined with the color filter substrate 200 with the liquid crystal layer 300 being formed between the array substrate 100 and the color filter substrate 200.

[0103] FIG. 10A is a cross-sectional view illustrating a conventional backlight-recycling phase retarding film.

[0104] FIGS. 10B to 10D are cross-sectional views illustrating backlight-recycling phase retarding films in accordance with other exemplary embodiments of the present invention. It will be recognized that the brightness enhancement layers of FIGS. 10B to 10D are defined with varying thicknesses due to uneven surfaces along a length thereof.

[0105] Referring to FIG. 10A, the backlight-recycling phase retarding film is defined with a uniform thickness d1 along a length thereof, thus a scattering portion is absent therefrom. A reflection layer may be disposed on the backlight-recycling phase retarding film in this conventional example. A light path of the backlight-recycling phase retarding film is about 2×d1, and an optical characteristic of the backlight-recycling phase retarding film is about 2×Δnd1.

[0106] Referring to FIG. 10B, the backlight-recycling phase retarding film is defined with a plurality of convex and concave portions along a length thereof. Each of the convex portions has a first thickness d1, and each of the concave portions has a second thickness d2. In this embodiment, a reflection layer is disposed on the backlight-recycling phase retarding film.

[0107] A first light path of each of the convex portions is about 2×d1, and a second light path of each of the concave portion is about 2×d2. An optical characteristic of each of the convex portions is about 2×Δnd1, while an optical characteristic of each of the concave portions is about 2×△nd2.

[0108] Referring to FIG. 10C, the backlight-recycling phase retarding film is defined with a plurality of convex portions and a plurality of concave portions along a length thereof. Thicknesses d1 and d3 of the convex portions are different from one another, as well as the thicknesses d2 and d4 of the concave portions. In this embodiment, a reflection layer is disposed on the backlight-recycling phase retarding film.

[0109] The convex portions provide various light paths of about 2×d1 and 2×d3, while the concave portions also provide various light paths of about 2×d2 and 2×d4, respectively. Optical characteristics of the convex portions are about 2×△nd1 and 2×△nd3, respectively, and optical characteristics of the concave portions are about 2×△nd2 and 2×△nd4, respectively.

[0110] Referring to FIG. 10D, the backlight-recycling phase retarding film is defined with a plurality of convex portions and a plurality of flat portions intermediate adjacent convex portions. Thicknesses d1 and d4 of the convex portions are different from one another, while each of the flat portions has a fifth thickness d5. In this embodiment, a reflection layer is disposed on the backlight-recycling phase retarding film.

[0111] The convex portions provide various light paths of about 2×d1 and 2×d4, while a light path of each of the flat portions is about 2×d5. Optical characteristics of the convex portions are about 2×△nd1 and 2×And4, respectively, and an optical characteristic of each of the flat portions is about 2×And5.

[0112] FIG. 11 is a cross-sectional view illustrating an LCD apparatus in accordance with another exemplary embodiment of the present invention. A backlight-recycling phase retarding film 550 is disposed intermediate a lower transparent plate 505 and a TFT of an array substrate 500. The LCD apparatus of FIG. 11 is the same as in FIG. 8 except for the location of the backlight-recycling phase retarding film 550. Thus, the same reference numerals will be used to refer to the same or like parts as those described in FIG. 8 and any further explanation will be omitted.

[0113] The LCD apparatus includes the array substrate 500, a color filter substrate 200, a liquid crystal layer 300 disposed between the array substrate 500 and the color filter substrate 200, a lower film assembly 410 and an upper film assembly 420. The lower film assembly 410 and the upper film assembly 420 define outboard layers of the LCD apparatus as illustrated.

[0114] The array substrate 500 includes, disposed in ascending order as illustrated, the lower transparent plate 505, the backlight-recycling phase retarding film 550, the TFT, an organic insulating layer 540, a pixel electrode 560, and a reflection layer 570. The backlight-recycling phase retarding film 550 is disposed on the lower transparent plate 505 and below a gate insulating layer 512 formed on an opposite surface defining the lower transparent plate 505. The TFT includes a gate electrode 510 formed on the lower transparent plate 505, the gate insulating layer 512 formed on the lower transparent plate 505, a semiconductor layer 514, an ohmic contact layer 516, a source electrode 520, and a drain electrode 530. The organic insulating layer 540 is disposed over the TFT. The drain electrode 530 and the gate insulating layer 512 correspond to a reflection region and are partially exposed through a contact hole 541 and an opening of the organic insulating layer 540, respectively.

[0115] The lower transparent plate 505 includes the reflection region and a transmission window. The backlight-recycling phase retarding film 550 is disposed on the lower transparent plate 505 corresponding to the reflection region. The backlight-recycling phase retarding film 550 is defined having an uneven surface facing the lower transparent plate 505 . Convex and concave portions may be formed on the backlight-recycling phase retarding film 550 defining the uneven thickness. Therefore, when a light that has passed through thebacklight-recycling phase retarding film 550 is reflected from the reflection layer 570 and passes through the backlight-recycling phase retarding film 550 toward a backside of the LCD apparatus (e.g., toward the lower film assembly 410), the light passes through various light paths corresponding to the uneven surface defining the backlight-recycling phase retarding film 550 having various optical characteristics Δnd.

[0116] The pixel electrode 560 is formed over the gate insulating layer 512 that is exposed through the opening of the backlight-recycling phase retarding film 550, the organic insulating layer 540 and the contact hole 541 so that the pixel electrode 560 is electrically connected to the drain electrode 530 of the TFT. The reflection layer 570 is formed on the pixel electrode 560 and corresponds to the reflection region. A transmission window is defined by the absence of the reflection layer 570 on the pixel electrode 560. A capacitor line is optionally be formed intermediate the organic insulating layer 540 and the pixel electrode 560 in a region spaced apart from the TFT so that the capacitor line and a portion of the pixel electrode 560 form a storage capacitor C_{st}. In the exemplary embodiment of FIG. 11, the reflection layer 570 is formed on the pixel electrode 560, alternatively, an insulating layer may be disposed between the reflection layer 570 and the pixel electrode 560.

[0117] Therefore, a portion of the light generated from a lamp (not shown) is recycled to improve a luminance of the LCD apparatus. Furthermore, since the light from the lamp may not be incident on the TFT that partially absorbs the light, a luminance of a transmission mode of the LCD apparatus is improved.

[0118] FIG. 12 is a cross-sectional view illustrating an LCD apparatus in accordance with another exemplary embodiment of the present invention. In this embodiment, a backlight-recycling phase retarding film 650 is formed on a TFT. The LCD apparatus of FIG. 12 is the same as in FIG. 8 except for the location of the backlight-recycling phase retarding film 650. Thus, the same reference numerals will be used to refer to the same or like parts as those described in FIG. 8 and any further explanation will be omitted.

[0119] The LCD apparatus includes an array substrate 600, a color filter substrate 200, a liquid crystal layer 300 disposed intermediate the array substrate 600 and the color filter substrate 200, a lower film assembly 410, and an upper film assembly 420. The lower film assembly 410 and the upper film assembly 420 define outboard layers of the LCD apparatus as illustrated.

[0120] The array substrate 600 includes, disposed in ascending order as illustrated, a lower transparent plate 605, a TFT, the backlight-recycling phase retarding film 650, an organic insulating layer 640, a pixel electrode 660, and a reflection layer 670. The TFT includes a gate electrode 610 formed on the lower transparent plate 605, a gate insulating layer 612 formed on the lower transparent plate 605 having the gate electrode 610, a semiconductor layer 614, an ohmic contact layer 616, a source electrode 620, and a drain electrode 630. In this embodiment, it will be recognized that the backlight-recycling phase retarding film 650 is disposed on the TFT. Further, the organic insulating layer 640 is disposed over the gate insulating layer 612 having the backlight-recycling phase retarding film 650 thereon. The drain electrode 630 and the gate insulating layer 612 corresponding to a reflection region and a transmission window are partially exposed through a contact hole 641 and an opening of the organic insulating layer 640, respectively. The contact hole 641 and the opening are formed in the organic insulating layer 640 and the backlight-recycling phase retarding film 650.

[0121] The lower transparent plate 605 includes the reflection region and a transmission window. The backlight-recycling phase retarding film 650 is disposed on the source electrode 620, the drain electrode 630, the gate insulating layer 612, the semiconductor layer 614, and the lower transparent plate 605 corresponding to the reflection region. The backlight-recycling phase retarding film 650 is defined with an uneven surface facing the organic insulating layer 640. The uneven thickness may be defined by convex and concave portions along a length of the backlight-recycling phase retarding film 650. Therefore, when a light that has passed through the backlight-recycling phase retarding film 650 is reflected from the reflection layer 670 and passes through the backlight-recycling phase retarding film 650 toward a backside of the LCD apparatus (e.g., toward the lower film assembly 410), the light passes through various light paths corresponding to the uneven backlight-recycling phase retarding film 650 having various optical characteristics Δnd.

[0122] The pixel electrode 660 is formed over the gate insulating layer 612 that is exposed through the opening of the backlight-recycling phase retarding film 650, the organic insulating layer 640, and the contact hole 641 so that the pixel electrode 660 is electrically connected to the drain electrode 630 of the TFT. The reflection layer 670 is formed on the pixel electrode 660 corresponding to the reflection region. A transmission window is defined by the absence of the reflection layer 670 on the pixel electrode 660. A capacitor line is optionally be formed intermediate the organic insulating layer 640 and the pixel electrode 660 in a region spaced apart from the TFT so that the capacitor line and a portion of the pixel electrode 660 may form a storage capacitor C_{st}. It will be recognized that in this exemplary embodiment, the reflection layer 670 is formed on the pixel electrode 660. Alternatively, an insulating layer may be disposed between the reflection layer 670 and the pixel electrode 660.

[0123] FIG. 13 is a cross-sectional view illustrating an LCD apparatus in accordance with another exemplary embodiment of the present invention. In this embodiment, a backlight-recycling phase retarding film 710 is formed under a color filter 730.

[0124] The LCD apparatus includes a color filter substrate 700, an array substrate 800, a liquid crystal layer 300 disposed intermediate the array substrate 800 and the color filter substrate 700, a lower film assembly 410 and an upper film assembly 420. The lower film assembly 410 and the upper film assembly 420 define outboard layers of the LCD apparatus as illustrated, while the color filter substrate 700 is disposed under the array substrate 800 and intermediate the liquid crystal layer 300 and the lower film assembly 410.

[0125] The color filter substrate 700 includes, disposed in ascending order as illustrated in FIG. 13, a lower transparent plate 705, a backlight-recycling phase retarding film 710, a reflection layer 720, a color filter 730, a surface protection layer 740 and a common electrode 750. The backlight-recycling phase retarding film 710 is disposed on the reflection layer 720 corresponding the reflection region. The color filter 730 includes a red color filter portion, a green color filter portion and a blue color filter portion. The red color filter portion is disposed in a red pixel region, the green color filter portion is disposed in a green pixel region, and the blue color filter portion is disposed in a blue pixel region. The surface protection layer 740 is disposed on the lower transparent plate 705 having the backlight-recycling phase retarding film 710 and the reflection layer 720. The backlight-recycling phase retarding film 710 is defined with an uneven surface. The uneven surface may be defined by convex and concave portions formed along a length of the backlight-recycling phase retarding film 710. In this embodiment, as illustrated, convex and concave portions of the backlight-recycling phase retarding film face the reflection layer 720.

[0126] The lower transparent plate 705 includes the reflection region and a transmission window. The reflection layer 720 corresponds to the reflection region, while a transmission window is defined by an absence of the reflection layer 720 and on the lower transparent plate 705.

[0127] When a light that has passed through the backlight-recycling phase retarding film 750 is reflected from the reflection layer 720 and passes through the backlight-recycling phase retarding film 710 toward a backside of the LCD apparatus (e.g., toward the lower film assembly 410), the light passes through various light paths corresponding to the uneven backlight-recycling phase retarding film 710 having various optical characteristics Δnd.

[0128] The array substrate 800 includes, disposed in descending order as illustrated in FIG. 13, an upper transparent plate 805, a TFT, an organic insulating layer 840, and a pixel electrode 850. The TFT includes a gate electrode 810 disposed under the upper transparent plate 805, a gate insulating layer 812 disposed under the upper transparent plate 805 having the gate electrode 810, a semiconductor layer 814, an ohmic contact layer 816, a source electrode 820, and a drain electrode 830. The organic insulating layer 840 is disposed under the upper transparent plate 805 having the TFT. The drain electrode 830 is partially exposed through a contact hole 841.

[0129] The pixel electrode 850 is formed intermediate the organic insulating layer 840 and the liquid crystal layer 300. In particular, the pixel electrode 850 is formed under the organic insulating layer 840 and the contact hole 841 allowing the pixel electrode 850 to be electrically connected to the drain electrode 830 of the TFT.

[0130] The pixel electrode 850 is a transparent electrode that includes indium tin oxide (ITO), tin oxide (TO), indium zinc oxide (IZO), and zinc oxide (ZO), for example, but is not limited thereto. A capacitor line is optionally formed intermediate the organic insulating layer 840 and the pixel electrode 850 in a region spaced apart from the TFT so that the capacitor line and a portion of the pixel electrode 850 may form a storage capacitor C_{st}.

[0131] The liquid crystal layer 300 is disposed between the array substrate 800 and the color filter substrate 700 to vary an arrangement of the liquid crystal in response to an electric field applied to the liquid crystal layer 300. The electric field is formed by a voltage difference between the pixel electrode 850 of the array substrate 800 and the common electrode 750 of the color filter substrate 700. Therefore, a front light that has passed through the array substrate 800 or a backside light that has passed through the transmission window defined by the reflection layer 720 is dependent on the electric field formed by a voltage difference between the pixel electrode 850 and the common electrode 750.

[0132] A portion of the liquid crystal layer 300 corresponding to a contact hole 841 in the reflection region, a portion of the liquid crystal layer 300 corresponding to a remaining region of the reflection region, and a portion of the liquid crystal layer 300 corresponding to the transmission window have different cell gaps relative to one another. As described above, the pixel electrode 850 is electrically connected to the drain electrode 830 of the TFT through the contact hole 841. A first cell gap d1 of the liquid crystal layer 300 corresponding to the contact hole 841 is larger than a second cell gap d2 of the liquid crystal layer 300 corresponding to the remaining region of the reflection region. A third cell gap d3 of the liquid crystal layer 300 corresponding to the transmission window is less than the first cell gap d1 of the liquid crystal layer 300 corresponding to the contact hole 841 but is greater than the second cell gap d2 of the liquid crystal layer 300 corresponding to the remaining region of the reflection region.

[0133] An optical characteristic $\Delta nd1$ of the liquid crystal layer 300 corresponding to the contact hole 841 is substantially equal to an anisotropy of a reflective index

△n multiplied by the first cell gap d1. Likewise, optical characteristics Δnd2 and Δnd3 of the liquid crystal layer 300 corresponding to the remaining region of the reflection region and the transmission region are substantially equal to the anisotropy of the reflective index △n multiplied by the second cell gap d2 and the third cell gap d3, respectively. The surface protection layer 730 is defined having a stepped portion corresponding to an interface between the reflection region and the transmission window so that a height of the color filter substrate 700 corresponding to the reflection region is larger than a height of the color filter substrate 700 corresponding to the transmission window. This feature is also exemplified by cell gap d3 being larger than cell gap d2 in FIG. 13.

[0134] The first, second and third cell gaps are determined in response to a liquid crystal of the liquid crystal layer 300, an optical condition of the array substrate, or an optical condition of the color filter substrate. In this exemplary embodiment, the second cell gap d2 corresponding to the reflection region is no more than about 1.7μm, while the third cell gap d3 corresponding to the transmission region is no more than about 3.3μm.

[0135] The liquid crystal layer 300 may have a homogeneous alignment mode so that a twist angle of the liquid crystal layer 300 is about zero degrees.

[0136] In this exemplary embodiment, an upper alignment layer (not shown) of the array substrate 800 is rubbed in a first direction, and a lower alignment layer (not shown) of the color filter substrate 700 is rubbed in a second direction substantially opposite to the first direction.

[0137] In this exemplary embodiment, when a voltage is applied to the pixel electrode 850 of the array substrate 800 and the common electrode 750 of the color filter substrate 700, the electric field formed by the voltage is applied to the liquid crystal layer 300. In an alternative embodiment, the array substrate 800 may include the pixel electrode 850 and the common electrode 750.

[0138] The lower film assembly 410 includes a lower λ/4 retardation film 412 and a lower polarizer 414. The lower λ/4 retardation film 412 is disposed under the array substrate 800 and intermediate the lower transparent plate 705 and the lower polarizer 414, as illustrated in FIG. 13. The lower polarizer 414 is disposed under the lower λ/4 retardation film 412 and defines the backside of the LCD apparatus.

[0139] When a horizontally polarized light is incident on the lower λ/4 retardation film 412, a phase of the horizontally polarized light is delayed by about 1/4 phase (λ/4) so that a right circularly polarized light is emitted from the lower λ/4 retardation film 412 toward the lower polarizer 414. When the right circularly polarized light is incident on the lower retardation film 412, a phase of the right circularly polarized light is delayed by about 1/4 phase (λ/4) so that the horizontally polarized light is emitted from the lower retardation film 412 toward the lower polarizer 414.

[0140] The lower polarizer 414 includes a first polarizing axis allowing a light that is polarized in the first polarizing axis to pass through the lower polarizer 414 toward the lower λ/4 retardation film 412 or the backside of the LCD apparatus. For example, when the first polarizing axis is substantially parallel with the horizontal direction relative to the LCD apparatus having layers extending in the same direction, the horizontally polarized light passes through the lower polarizer 414 from the backside so that the horizontally polarized light is incident on the lower λ/4 retardation film 412. In addition, the horizontally polarized light may pass through the lower polarizer 414 from the lower λ/4 retardation film 412 allowing the horizontally polarized light to be emitted from the lower polarizer 414 toward the backside.

[0141] The upper film assembly 420 includes an upper λ/4 retardation film 422 and an upper polarizer 424. The upper λ/4 retardation film 422 is disposed on the upper transparent plate 805 of the array substrate 800. The upper polarizer 424 is disposed on the upper λ/4 retardation film 422, which is intermediate the upper λ/4 retardation film 422 and the upper λ/4 retardation film 422.

[0142] When a light is incident on the upper λ/4 retardation film 422 from the array substrate 800, a phase of the wavelength of the light is delayed by about 1/4 phase (λ/4) so that the light having the delayed phase is emitted from the upper λ/4 retardation film 422 toward the upper λ/4 retardation film 422 corresponding to a viewer's side. When a light is incident on the upper λ/4 retardation film 422 from the viewer's side, a phase of the light is delayed by about 1/4 phase (λ/4) so that the light having the delayed phase is emitted from the upper λ/4 retardation film 422 toward the array substrate 800.

[0143] The upper polarizer 424 includes a second polarizing axis allowing a light that is polarized in the second polarizing axis to pass through the upper polarizer 424 toward the upper λ/4 retardation film 422 from the viewer's side. For example, when the second polarizing axis is substantially parallel with a vertical direction relative to stacking layers defining the LCD apparatus, the vertically polarized light passes through the upper polarizer 424 from the viewer's side allowing the vertically polarized light to be incident on the upper λ/4 retardation film 422. In addition, the vertically polarized light may pass through the upper polarizer 424 from the upper λ/4 retardation film 422 allowing the vertically polarized light to be emitted from the upper polarizer 424 toward the viewer's side.

[0144] FIG. 14 is a cross-sectional view illustrating an LCD apparatus in accordance with another exemplary embodiment of the present invention. In this embodiment, a backlight-recycling phase retarding film 180 is disposed under a lower transparent plate 105 corresponding to a reflection region. The LCD apparatus of FIG. 14 is the same as in FIG. 8 except for the location of the backlight-recycling phase retarding film 180. Thus, the same reference numerals will be used to refer to the same or like parts as those described in FIG. 8 and any further explanation will be omitted.

[0145] The LCD apparatus includes an array substrate 100, a color filter substrate 200, a liquid crystal layer 300 disposed intermediate the array substrate 100 and the color filter substrate 200, a lower film assembly 410 and an upper film assembly 420. The lower film assembly 410 and the upper film assembly 420 define outboard layers of the LCD apparatus as illustrated.

[0146] The backlight-recycling phase retarding film 180 is disposed under the array substrate 100 and disposed intermediate the lower transparent plate 105 and the lower film assembly 410, as illustrated. In this exemplary embodiment, the backlight-recycling phase retarding film 180 is integrally formed under the array substrate 100. Alternatively, the backlight-recycling phase retarding film 180 may be integrally formed on the lower film assembly 410.The backlight-recycling phase retarding film 180 is defined having an uneven thickness. The uneven thickness may include convex and concave portions formed on the backlight-recycling phase retarding film 180. In the embodiment illustrated in FIG. 14, convex and concave portions define a surface of the backlight-recycling phase retarding film 180 facing the lower film assembly 410 along a length thereof. Therefore, when a light that has passed through the backlight-recycling phase retarding film 180 is reflected from a reflection layer 170 and passes through the backlight-recycling phase retarding film 180 toward a backside of the LCD apparatus, the light passes through various light paths corresponding to the uneven backlight-recycling phase retarding film 180 having various optical characteristics Δnd.

[0147] Therefore, a portion of the light generated from a lamp (not shown) is recycled to improve a luminance of the LCD apparatus. In addition, the light may not be incident on the TFT that partially absorbs the light so that a luminance of the LCD apparatus in a transmission mode is improved.

[0148] According to the present invention, an uneven backlight-recycling phase retarding film is formed corresponding to a reflection region of an array substrate so that at least a portion of light generated from a lamp is recycled. More specifically, the backlight-recycling phase retarding film allows a portion of the light that is reflected from a reflection layer to be recycled to improve a luminance of an LCD apparatus. Furthermore, the addition of the backlight-recycling phase retarding film allows a decrease in power consumption of the LCD apparatus.

[0149] While this invention has been described with reference to the exemplary embodiments disclosed herein, it is evident, however, that many alternative modifications and variations will be apparent to those having skill in the art in light of the foregoing description. Accordingly, the present invention embraces all such alternative modifications and variations falling within the scope of the appended claims.

Claims

1. A transflective liquid crystal display device comprsing
a first (105,505,605,705) and
a second substrate (205, 805) with a liquid crystal layer (300) and a transflective layer (160,170,560,570,660,670,850,720) having reflective (RA,170,570,670,720) and transmissive portions (TA) arranged between the opposed inner surfaces of the first substrate (105,505,605,705) and the second substrate (205,805);
the display device further comprising a circular polariser (410) and a backlight source arranged in this order on the outer surface of the first substrate (105,505,605,705);
said circular polariser (410) being composed of a quarterwave plate (412) and a linear polariser (414) with the linear polariser (414) facing the backlight source;
the display device further comprising a patterned backlight-recycling phase retarding film (150,550,650,710,180) arranged between the transflective layer (160,170,560,570,770,670,850,720) and the quarterwave plate (412), the pattern of the backlight-recycling phase retarding film (150,550,650,710,180) corresponding to the reflective portions (RA,170,570,670,720) of the transflective layer (160,170,560,570,770,670,850,720);
characterised in that
the backlight-recycling phase retarding film (150,550,650,710,180) has an uneven surface relief resulting in a spatially varing thickness of the backlight-recycling phase retarding film (150,550,650,710,180).

2. The transflective liquid crystal display device of claim 1, wherein the backlight-recycling phase retarding film (150,550,650,710,180) is constituted by a birefringent solidified liquid crystal polymer layer (217,226) or a birefringent solidified liquid crystal polymer layer (223,246) arranged on a liquid crystal alignment film (231,241).

3. The transflective liquid crystal display device of claim 2, wherein the backlight-recyling phase retardingfilm (150,550,650,710,180) includes a cholesteric liquid crystal that is an ultraviolet curable liquid crystal polymer,

4. The transflective liquid crystal display device of claim 2, wherein the backlight-recycling phase retarding film (150,550,650,710,180) includes a solidified cholesteric liquid crystal.

5. The transflective liquid crystal display device of claim 1, wherein the backlight-recycling phase retarding film (150,550,650,710,180) is defined by a first sur-

face and an opposite second surface and delays incident light by about 1/4 phase, the first surface being disposed facing the reflective portions (RA, 170,570,670,720) of the transflective layer (160,170,560,570,660,670,850,720).

6. The transflective liquid crystal display device of claim 5, wherein the second surface and the first surface of the backlight-recycling phase retarding film (150,550,650,710,180) are constituted by surfaces of a solidified cholesteric liquid crystal layer (217,226,233,246).

7. A method of fabricating a patterned phase retarding film suitable for recycling of backlight in a transflective display device, said method including the steps of

forming a liquid crystal layer (232,244,212,222) on an alignment film (231,241,211,221) disposed on a substrate (230,240) or disposed on a printing film (210) or disposed on a photoresist film (220) having an embossed surface;

solidifying local portions (RA) of the liquid crystal layer (232,244,212,222) and removing the remaining portions (TA) of the liquid crystal layer (232,244,212,222) to form a patterned solidified liquid crystal layer; and

forming an uneven surface relief on the liquid crystal layer (232,244,212,222) resulting in a patterned phase retarding film (217,226,233 246) with a spatially varying thickness.

8. The method of claim 7 further including the steps of aligning the liquid crystal layer (212) containing a photoresist imparting agent on an alignment film (211) disposed on a printing film (210);

irradiating ultraviolet light (200) on the aligned liquid crystal layer (212) to semi-solidify the liquid crystal layer (212);

disposing the semi-solidified liquid crystal layer (213) with the alignment film (211) and the printing film (210) upside down on a substrate (214);

removing the printing film (211) from the liquid crystal layer (213), patterning and solidifying the semi-solidified liquid crystal layer (213) accompanied by removing the aligment film (211), and embossing the liquid crystal layer (213) in order to form the backlight-recycling phase retarding film (217).

9. The method of claim 7 further including the steps of aligning the liquid crystal layer (222) on an alignment layer (221) formed on a photoresist film (220) having an embossed surface;

disposing a substrate (223) on the exposed surface of the liquid crystal layer (232); and

irradiating ultraviolet light (220) on the liquid crystal layer (222) in order to semi-solidify the liquid crystal layer (222)

removing the photoresist film (220) from the semi-solidified liquid crystal layer (222'), patterning and solidifying semi-solidified liquid crystal layer (222') accompanied by removing the alignment film (221) in order to form the backlight-recycling phase retarding film (226).

10. The method of claim 7 wherein forming the liquid crystal layer (244) on the alignment layer (241) disposed on the substrate (240) comprises:

depositing a photoresist aligning material (241) on the whole substrate surface (240), wherein the photoresist aligning material (241) is solidified in a first region (RA) and removed in the remaining second region (TA) as to form an alignment layer (241) only in the first region (RA);

disposing thereafter the liquid crystal layer (244) on the substrate (240) being aligned and solidified only in said first region (RA) while being removed in the second region (TA), embossing the solidified patterned liquid crystal layer (245) thereby forming the patterned backlight-recycling phase retarding film (246)

11. The method of either of claims 7 to 10, wherein said substrate (230,240,214,223) is one of a transparent substrate and a glass substrate.

12. A liquid crystal display apparatus comprising a transflective liquid crystal display device of one of the claims 1 to 6.

Patentansprüche

1. Transflexive Flüssigkristall-Display-Vorrichtung, die Folgendes umfasst:

ein erstes Substrat (105, 505, 605, 705) und ein zweites Substrat (205, 805) mit einer Flüssigkristallschicht (300) und einer transflexiven Schicht (160, 170, 560, 570, 660, 670, 850, 720) mit reflexiven (RA, 170, 570, 670, 720) und transmissiven (durchlässigen) Abschnitten (TA), die zwischen den gegenüber angeordneten Innenflächen des ersten Substrats (105, 505, 605, 705) und des zweiten Substrats (205, 805) angeordnet sind,

wobei die Display-Vorrichtung ferner ein zirkulares Polarisationsfilter (410) und eine Gegenlichtquelle umfasst, die in dieser Reihenfolge an der Außenfläche des ersten Substrats (105, 505, 605, 705) angeordnet sind,

wobei das zirkulare Polarisationsfilter (410) aus einem Lambdaviertelplättchen (412) und einem linearen Polarisationsfilter (414) zusammengesetzt ist, wobei das lineare Polarisationsfilter (414) der Gegenlichtquelle zugewandt ist, wobei die Display-Vorrichtung ferner einen gerasterten Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) umfasst, der zwischen der transflexiven Schicht (160, 170, 560, 570, 660, 670, 850, 720) und dem Lambdaviertelplättchen (412) angeordnet ist, wobei der gerasterte Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) den reflexiven Abschnitten (RA, 170, 570, 670, 720) der transflexiven Schicht (160, 170, 560, 570, 660, 670, 850, 720) entspricht;

dadurch gekennzeichnet, dass
der Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) ein ungleichmäßiges Oberflächenrelief aufweist, woraus sich eine räumlich variable Dicke des Gegenlicht-Recycling-Phasenverzögerungsfilms (150, 550, 650, 710, 180) ergibt.

2. Transflexive Flüssigkristall-Display-Vorrichtung gemäß Anspruch 1, worin der Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) aus einer doppelbrechenden verfestigten Flüssigkristallpolymerschicht (217, 226) oder einer doppelbrechenden verfestigten Flüssigkristallpolymerschicht (233, 246) zusammengesetzt ist, die auf einem Flüssigkristall-Ausrichtungsfilm (231, 241) angeordnet ist.

3. Transflexive Flüssigkristall-Display-Vorrichtung gemäß Anspruch 2, worin der Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) einen cholesterischen Flüssigkristall umfasst, der ein UV-härtbarer Flüssigkristall-Polymer ist.

4. Transflexive Flüssigkristall-Display-Vorrichtung gemäß Anspruch 2, worin der Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) einen verfestigten cholesterischen Flüssigkristall umfasst.

5. Transflexive Flüssigkristall-Display-Vorrichtung gemäß Anspruch 1, worin der Gegenlicht-Recycling-Phasenverzögerungsfilm (150, 550, 650, 710, 180) durch eine erste Oberfläche und eine gegenüber liegende zweite Oberfläche begrenzt ist und einfallendes Licht um etwa ¼ Phase verzögert, wobei die erste Oberfläche so angeordnet ist, dass sie den reflexiven Abschnitten (RA, 170, 570, 670, 720) der transflexiven Schicht (160, 170, 560, 570, 660, 670, 850, 720) zugewandt ist.

6. Transflexive Flüssigkristall-Display-Vorrichtung gemäß Anspruch 5, worin die zweite Oberfläche und die erste Oberfläche des Gegenlicht-Recycling-Phasenverzögerungsfilms (150, 550, 650, 710, 180) aus Oberflächen einer verfestigten cholesterischen Flüssigkristallschicht (217, 226, 233, 246) zusammengesetzt sind.

7. Verfahren zur Herstellung eines gerasterten Phasenverzögerungsfilms, der für das Recycling von Gegenlicht in einer transflexiven Display-Vorrichtung geeignet ist, wobei das Verfahren folgende Schritte umfasst:

Ausbildung einer Flüssigkristallschicht (232, 244, 212, 222) auf einem Ausrichtungsfilm (231, 241, 211, 221), der auf einem Substrat (230, 240) oder auf einem Druckfilm (210) oder auf einem Photoresist-Film (220) mit einer geprägten Oberfläche aufgebracht ist;
Verfestigen lokaler Abschnitte (RA) der Flüssigkristallschicht (232, 244, 212, 222) und Entfernen der restlichen Abschnitte (TA) der Flüssigkristallschicht (232, 244, 212, 222) zur Ausbildung einer gerasterten verfestigten Flüssigkristallschicht; und
Ausbilden eines ungleichmäßigen Oberflächenreliefs auf der Flüssigkristallschicht (232, 244, 212, 222), woraus sich ein gerasteter Phasenverzögerungsfilm (217, 226, 233, 246) mit räumlich variierender Dicke ergibt.

8. Verfahren gemäß Anspruch 7, das ferner folgende Schritte umfasst:

Ausrichten der Flüssigkristallschicht (212), die ein Photoresist-Vermittlungsmittel enthält, auf einem Ausrichtungsfilm (211), der auf einem Druckfilm (210) angeordnet ist,
Abstrahlen von UV-Licht (200) auf der ausgerichteten Flüssigkristallschicht (212) zur Halbverfestigung der Flüssigkristallschicht (212);
Aufbringen der halbverfestigten Flüssigkristallschicht (213) mit dem umgekehrten Ausrichtungsfilm (211) und Druckfilm (210) auf einem Substrat (214);
Entfernen des Druckfilms (211) von der Flüssigkristallschicht (213), Rastern und Verfestigen der halbverfestigten Flüssigkristallschicht (213), begleitet von der Entfernung des Ausrichtungsfilms (211), und
Prägen der Flüssigkristallschicht (213), um den Gegenlicht- Recycling- Phasenverzögerungsfilm (217) zu bilden.

9. Verfahren gemäß Anspruch 7, das ferner Folgende Schritte umfasst:

Ausrichten der Flüssigkristallschicht (222) auf einer Ausrichtungsschicht (221), die auf einem Photoresistfilm (220) mit einer geprägten Oberfläche gebildet ist;
Anordnen eines Substrats (223) auf der exponierten Oberfläche der Flüssigkristallschicht

(232) und Abstrahlen von UV-Licht (220) auf die Flüssigkristallschicht (222), um die Flüssigkristallschicht (222) zu halbverfestigen;
Entfernen des Photoresistfilms (220) von der halbverfestigten Flüssigkristallschicht (222), Rastern und Verfestigen der halbverfestigten Flüssigkristallschicht (222), begleitet vom Entfernen des Ausrichtungsfilms (221), um den Gegenlicht- Recycling- Phasenverzögerungsfilm (226) zu bilden.

10. Verfahren gemäß Anspruch 7, worin das Formen der Flüssigkristallschicht (244) auf der auf dem Substrat (240) angeordneten Ausrichtungsschicht (241) Folgendes umfasst:

Aufbringen eines Photoresist-Ausrichtungsmaterials (241) auf der gesamten Substratoberfläche (240), wobei das Photoresist-Ausrichtungsmaterial (241) in einem ersten Bereich (RA) verfestigt und im verbleibenden zweiten Bereich (TA) entfernt wird, um eine Ausrichtungsschicht (241) nur im ersten Bereich (RA) zu bilden;
danach Aufbringen der Flüssigkristallschicht (244) auf das Substrat (240), das nur im ersten Bereich (RA) ausgerichtet und verfestigt ist, während es im zweiten Bereich (TA) entfernt ist;
Prägen der verfestigten, gerasterten Flüssigkristallschicht (245) und dadurch Ausbildung des gerasterten Gegenlicht-Recycling-Phasenverzögerungsfilms (246).

11. Verfahren gemäß einem der Ansprüche 7 bis 10, wobei das Substrat (230, 240, 214, 223) entweder ein transparentes Substrat oder ein Glassubstrat ist.

12. Flüssigkristall-Display-Apparat, der eine transflexive Flüssigkristall-Display-Vorrichtung eines der Ansprüche 1 bis 6 umfasst.

Revendications

1. Dispositif d'affichage à cristaux liquides transflectif comprenant
un premier substrat (105, 505, 605, 705) et
un second (205, 805) avec une couche de cristaux liquides (300) et une couche transflective (160, 170, 560, 570, 660, 670, 850, 720) ayant des parties réflectives (RA, 170, 570, 670,720) et transmissives (TA) disposées entre les surfaces intérieures opposées du premier substrat (105, 505, 605, 705) et du second substrat (205, 805) ;
le dispositif d'affichage comprend en outre un polariseur circulaire (410) et une source de rétro-éclairage disposés dans cet ordre sur une surface extérieure du premier substrat (105, 505, 605, 705) ;
ledit polariseur circulaire (410) étant composé d'une platine quart d'onde (412) et d'un polariseur linéaire (414), lequel polariseur linéaire (414) fait face à la source de rétro-éclairage ;
le dispositif d'affichage comprenant en outre un film texturé à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) disposé entre la couche transflective (160, 170, 560, 570, 660, 670, 850, 720) et la platine quart d'onde (412), la texture du film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) correspondant aux parties réfléchissantes (RA, 170, 570, 670, 720) de la couche transflective (160, 170, 560, 570, 660, 670, 850, 720) ;
caractérisé en ce que le film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) possède un relief de surface irrégulier donnant une variation spatiale de l'épaisseur du film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180).

2. Dispositif d'affichage à cristaux liquides transflectif selon la revendication 1, dans lequel le film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) est constitué par une couche de polymère de cristaux liquides solidifiée biréfringente (217, 226) ou une couche de polymère de cristaux liquides solidifiée biréfringente (233, 246) disposée sur un film d'alignement des cristaux liquides (231, 241).

3. Dispositif d'affichage à cristaux liquides transflectif selon la revendication 2, dans lequel le film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) comprend un cristal liquide cholestérique qui est un polymère de cristaux liquides polymérisable aux ultraviolets.

4. Dispositif d'affichage à cristaux liquides transflectif selon la revendication 2, dans lequel le film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) comprend un cristal liquide cholestérique solidifié.

5. Dispositif d'affichage à cristaux liquides transflectif selon la revendication 1, dans lequel le film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) est défini par une première surface et une seconde surface opposée et retarde la lumière incidente d'environ un quart de phase, la première surface étant disposée face aux parties réfléchissantes (RA, 170, 570, 670, 720) de la couche transflective (160, 170, 560, 570, 660, 670, 850, 720).

6. Dispositif d'affichage à cristaux liquides transflectif selon la revendication 5, dans lequel la seconde surface et la première surface du film à retard de phase recyclant la lumière de rétro-éclairage (150, 550, 650, 710, 180) sont constituées par des surfaces d'une couche de cristaux liquides cholestériques solidifiés (217, 226, 233, 246).

7. Procédé de fabrication d'un film structuré à retard de phase capable de recycler la lumière de rétro-éclairage dans un dispositif d'affichage transflectif, lequel procédé comprend les étapes de :

formation d'une couche de cristaux liquides (232, 244, 212, 222) sur un film d'alignement (231, 241, 211, 221) disposé sur un substrat (230, 244) ou disposé sur un film d'impression (210) ou disposé sur un film de réserve photosensible (220) ayant une surface gaufrée,
solidification de parties locales (RA) de la couche de cristaux liquides (232, 244, 212, 222) et retrait des parties restantes (TA) de la couche de cristaux liquides (232, 244, 21 2 , 222) pour former une couche de cristaux liquides solidifiée structurée et
formation d'un relief de surface irrégulier sur la couche de cristaux liquides (232, 244, 212 , 222) pour former un film à retard de phase structuré (217, 226, 233, 246) dont l'épaisseur varie dans l'espace.

8. Procédé selon la revendication 7, comprenant en outre les étapes d'alignement de la couche de cristaux liquides (212) contenant un agent de création d'une réserve photosensible sur un film d'alignement (211) disposé sur un film d'impression (210) ;
exposition à de la lumière ultraviolette (200) de la couche de cristaux liquides (212) alignée pour solidifier à demi la couche de cristaux liquides (212) ;
disposition de la couche de cristaux liquides à demi solidifiée (213) avec le film d'alignement (211) et le film d'impression (210) à l'envers sur un substrat (214) ;
retrait du film d'impression (211) de la couche de cristaux liquides (213), structuration et solidification de la couche de cristaux liquides (213) à demi solidifiée accompagnées du retrait du film d'alignement (211), et gaufrage de la couche de cristaux liquides (213) de façon à former le film à retard de phase recyclant la lumière de rétro-éclairage (217).

9. Procédé selon la revendication 7, comprenant en outre les étapes d'alignement de la couche de cristaux liquides (222) sur une couche d'alignement (221) formée sur un film de réserve photosensible (220) ayant une surface gaufrée ;
disposition d'un substrat (223) sur la surface exposée de la couche de cristaux liquides (232) et exposition à de la lumière ultraviolette (220) de la couche de cristaux liquides (222) afin de solidifier à demi la couche de cristaux liquides (222) ;
retrait du film de réserve photosensible (220) de la couche de cristaux liquides (222') à demi solidifiée, structuration et solidification de la couche de cristaux liquides à demi solidifiée (222') accompagnées du retrait du film d'alignement (221) afin de former le film à retard de phase recyclant la lumière de rétro-éclairage (226).

10. Procédé selon la revendication 7, dans lequel la formation de la couche de cristaux liquides (244) sur la couche d'alignement (241) disposée sur le substrat (240) comprend :

le dépôt d'un matériau d'alignement de réserve photosensible (241) sur toute la surface du substrat (240), le matériau d'alignement de réserve photosensible (241) étant solidifié dans une première région (RA) et retiré dans la seconde région (TA) restante pour former une couche d'alignement (241) dans la première région (RA) seulement ;
disposition subséquente de la couche de cristaux liquides (244) sur le substrat (240) aligné et solidifié seulement dans ladite première région (RA) tout en l'éliminant dans la seconde région (TA),
gaufrage de la couche de cristaux liquides structurée solidifiée (245) pour former ainsi le film structuré à retard de phase recyclant la lumière de rétro-éclairage (246).

11. Procédé selon l'une des revendications 7 à 10, dans lequel ledit substrat (230, 240, 214, 223) est soit un substrat transparent, soit un substrat en verre.

12. Appareil d'affichage à cristaux liquides comprenant un dispositif d'affichage à cristaux liquides transflectif selon l'une des revendications 1 à 6.

FIG. 1

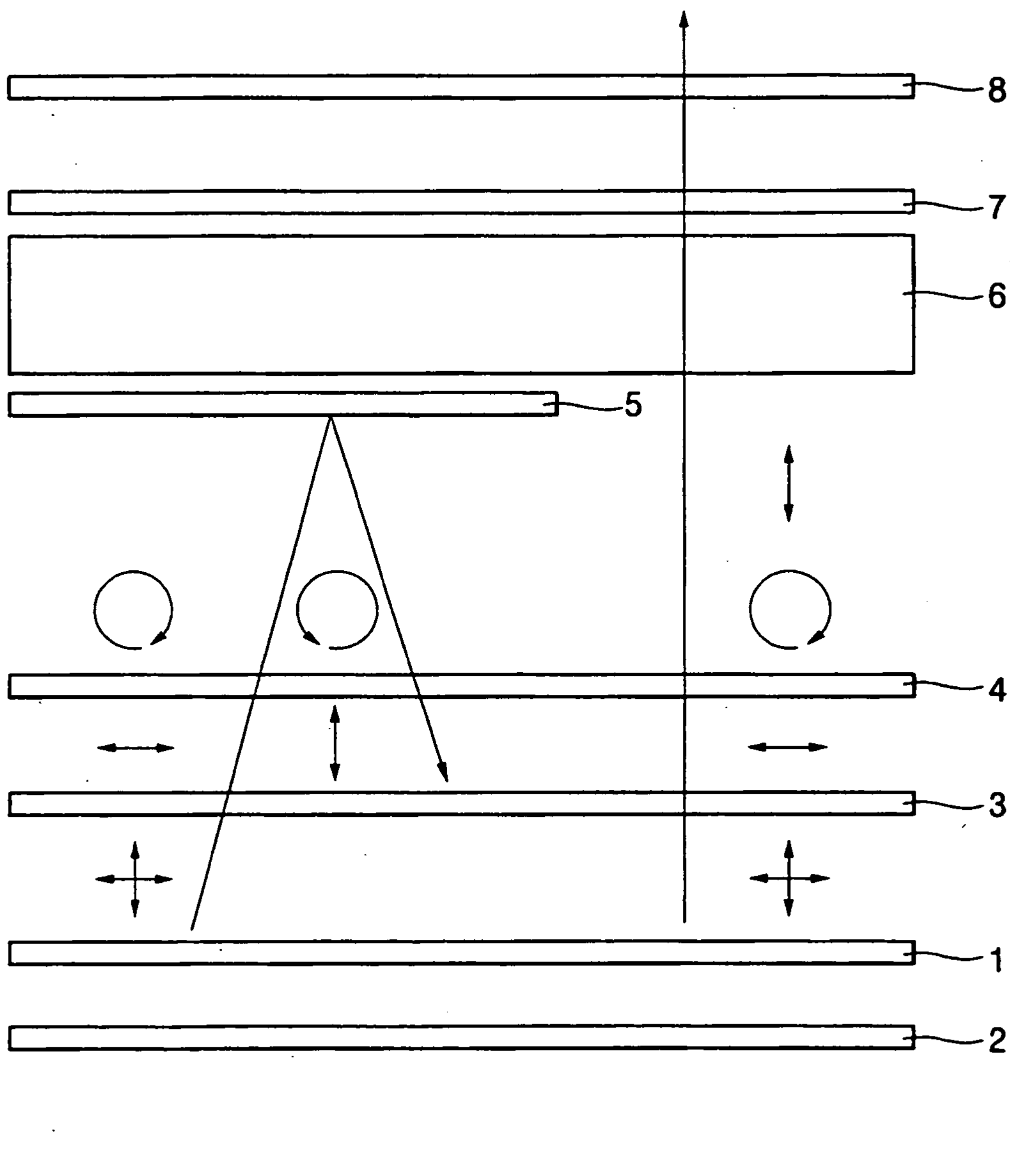


FIG. 2

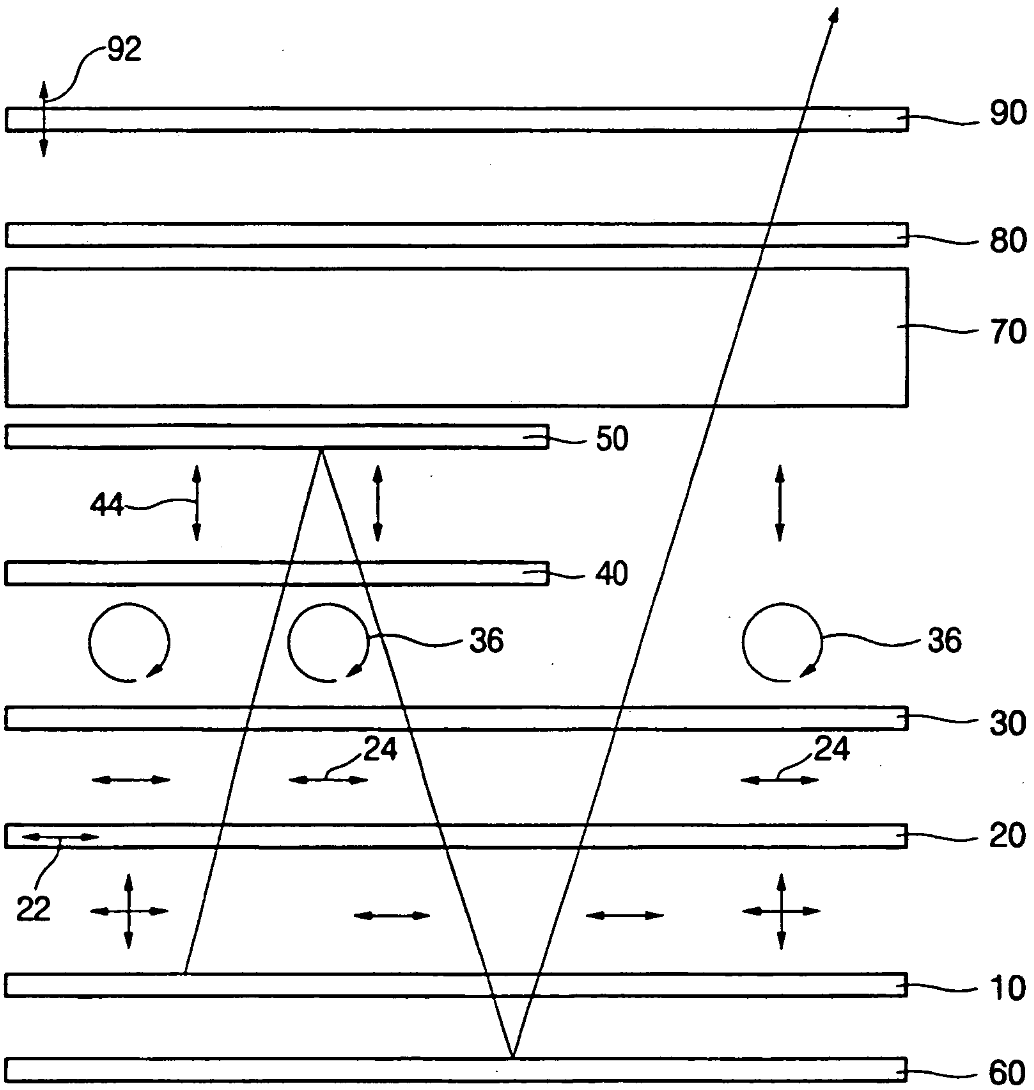


FIG. 3

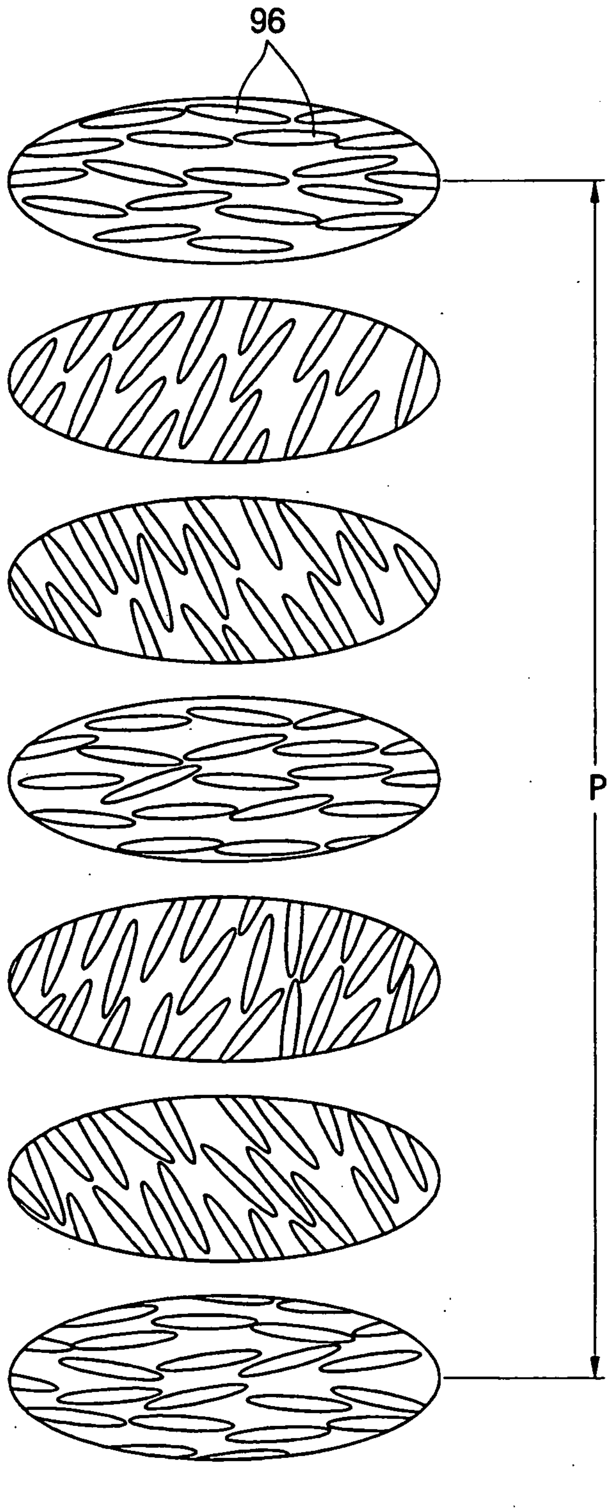


FIG. 4A

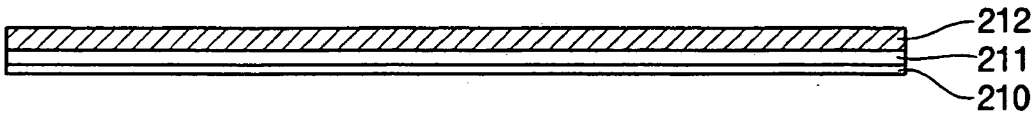


FIG. 4B

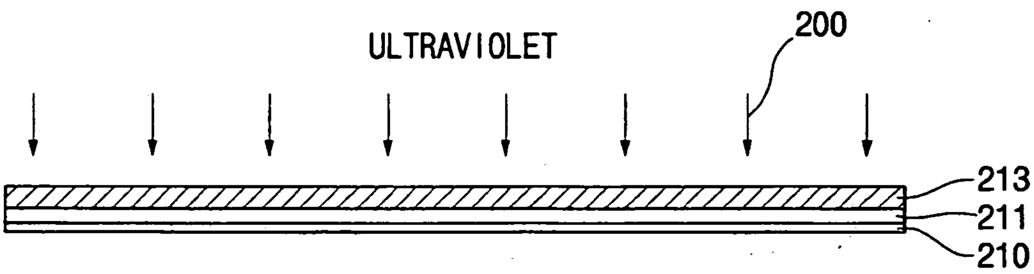


FIG. 4C

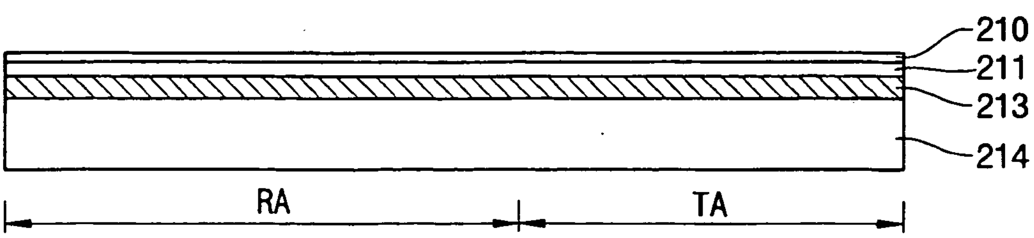


FIG. 4D

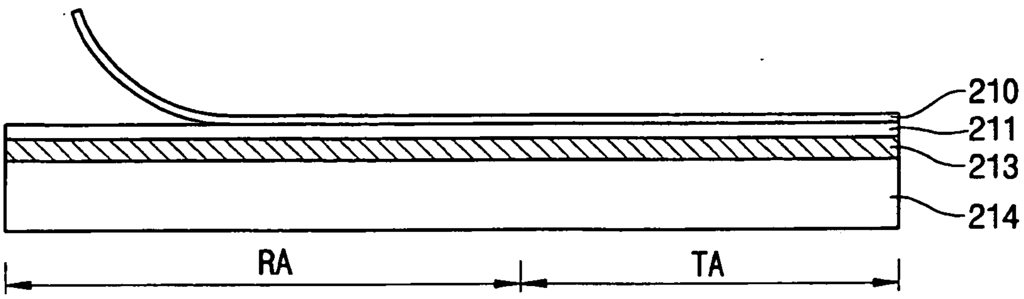


FIG. 4E

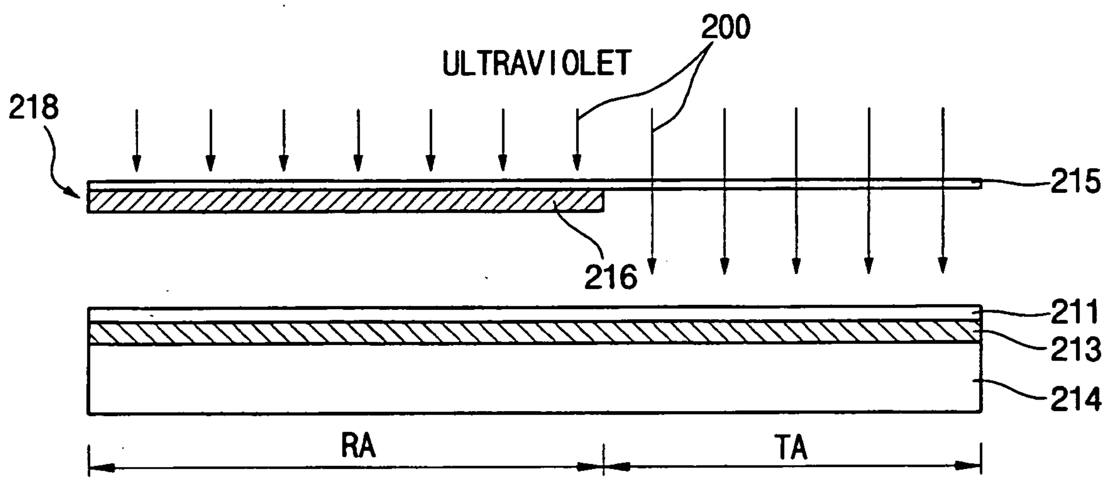


FIG. 4F

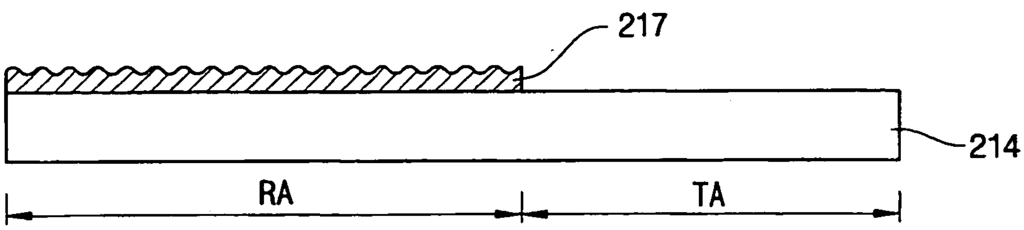


FIG. 5A

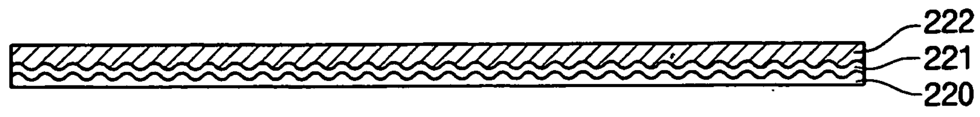


FIG. 5B

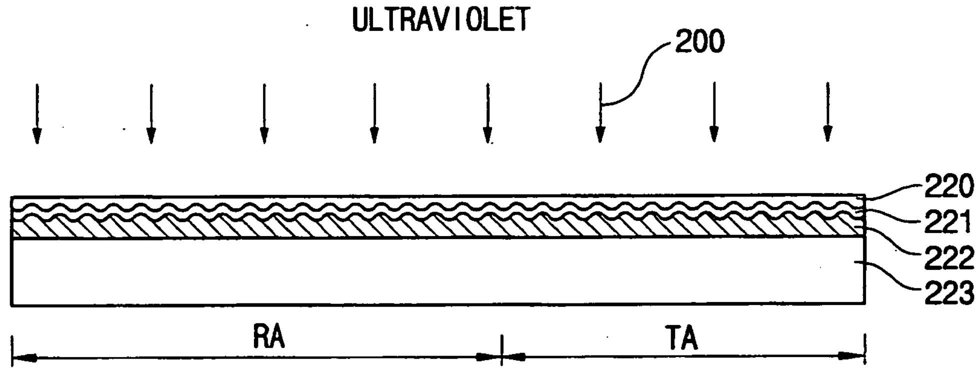


FIG. 5C

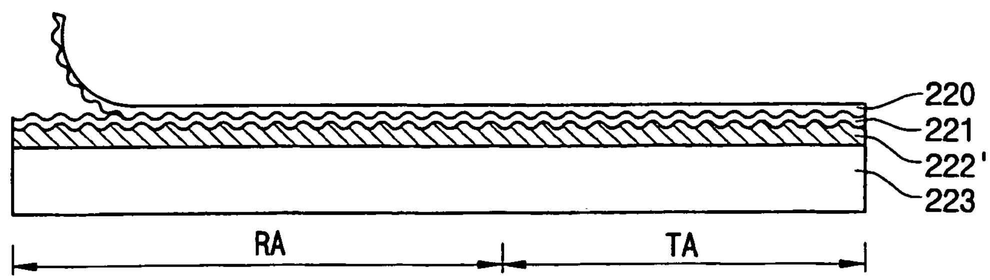


FIG. 5D

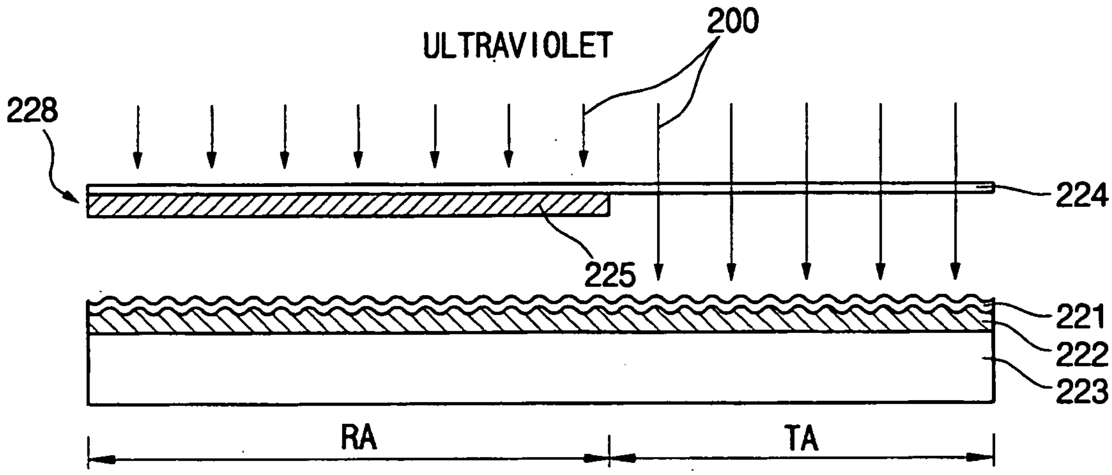


FIG. 5E

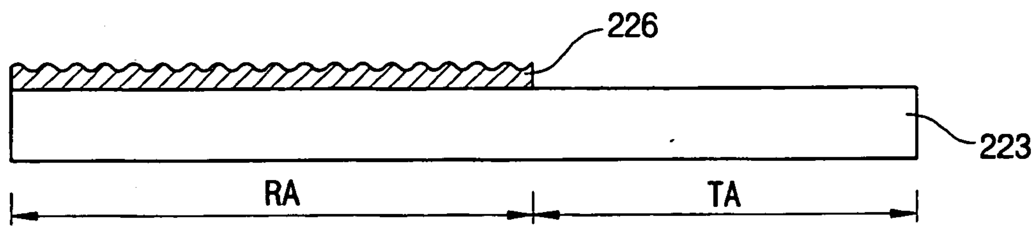


FIG. 6A

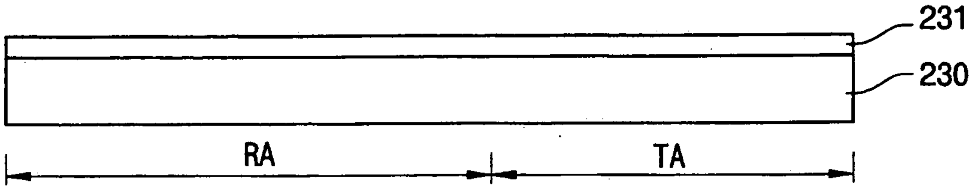


FIG. 6B

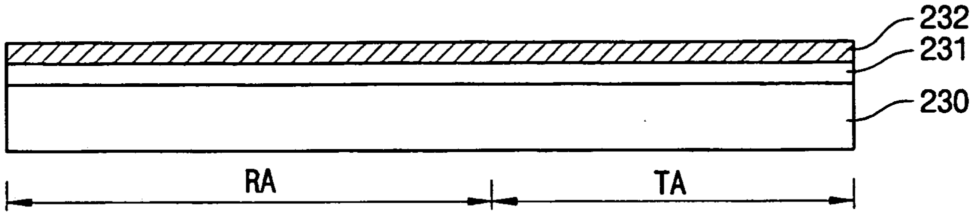


FIG. 6C

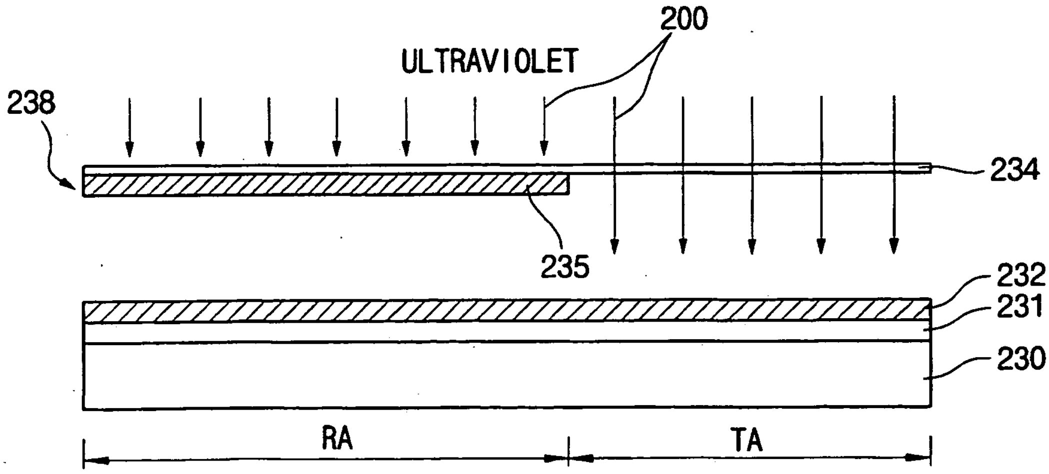


FIG. 6D

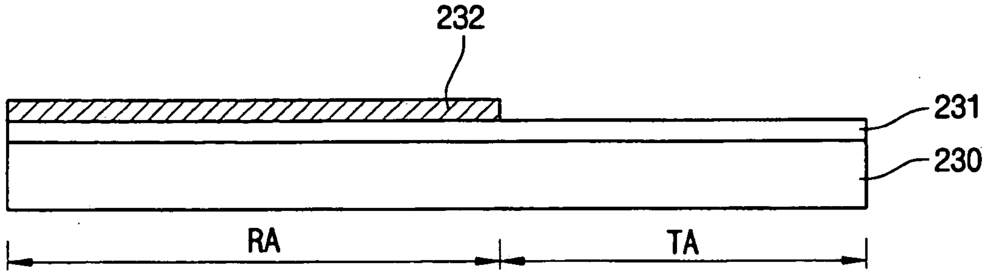


FIG. 6E

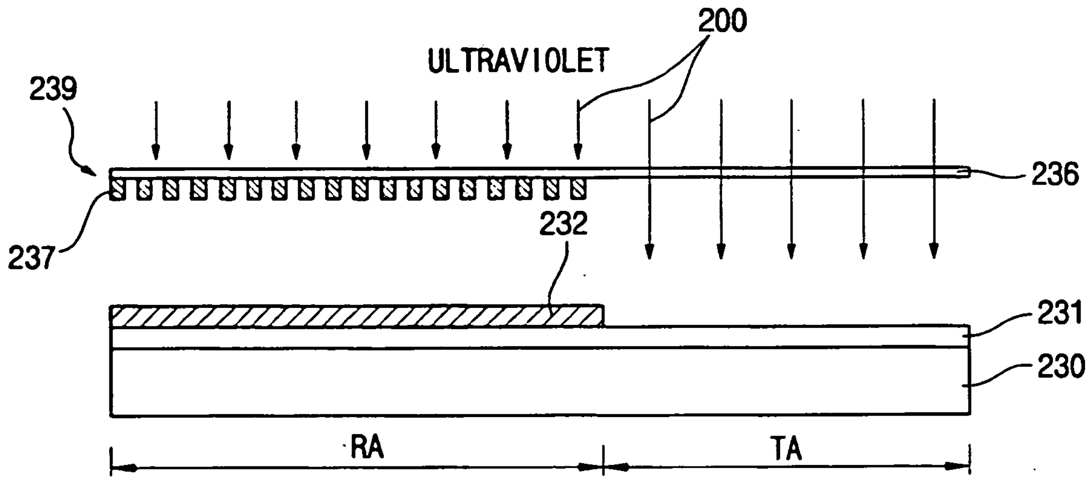


FIG. 6F

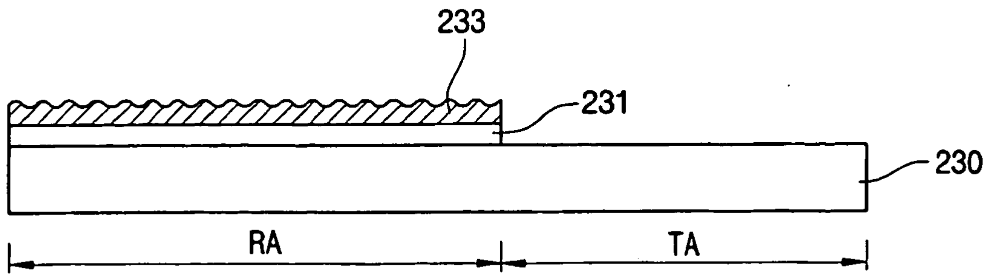


FIG. 7A

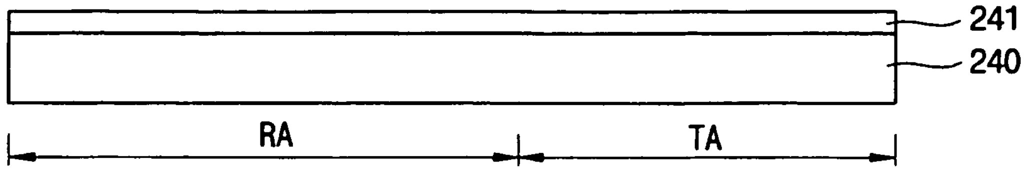


FIG. 7B

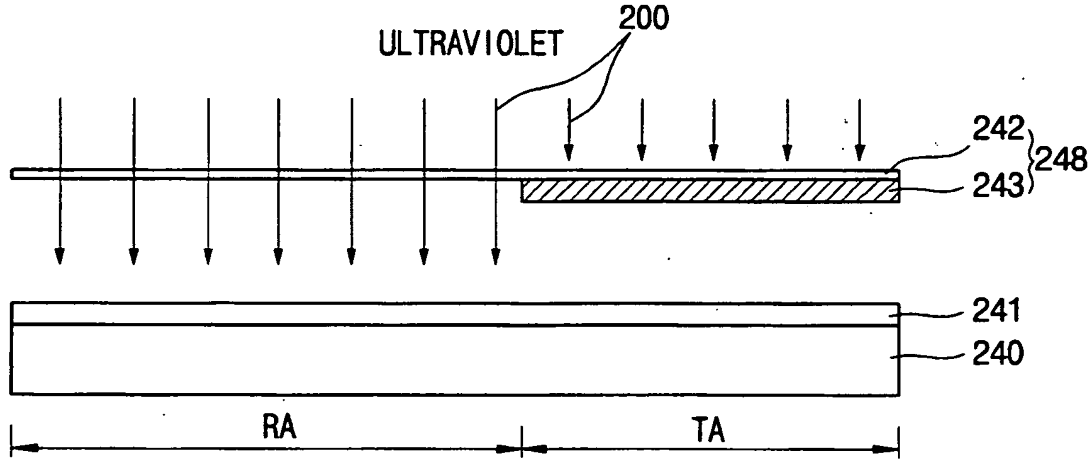


FIG. 7C

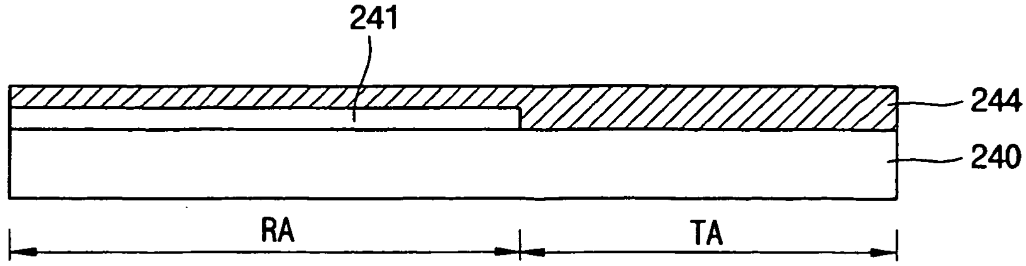


FIG. 7D

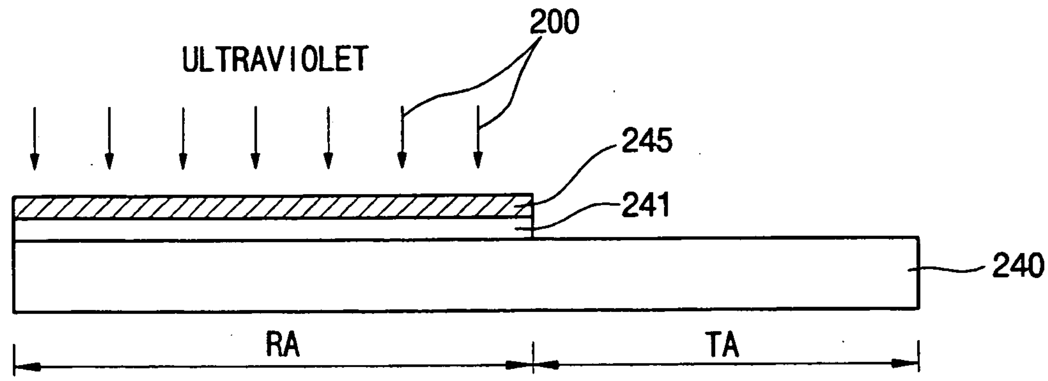


FIG. 7E

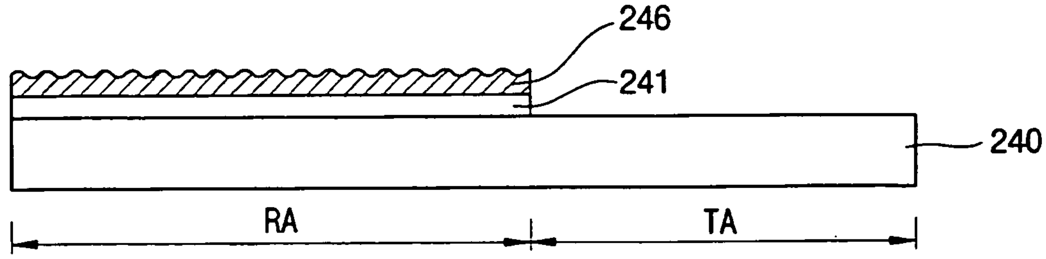


FIG. 8

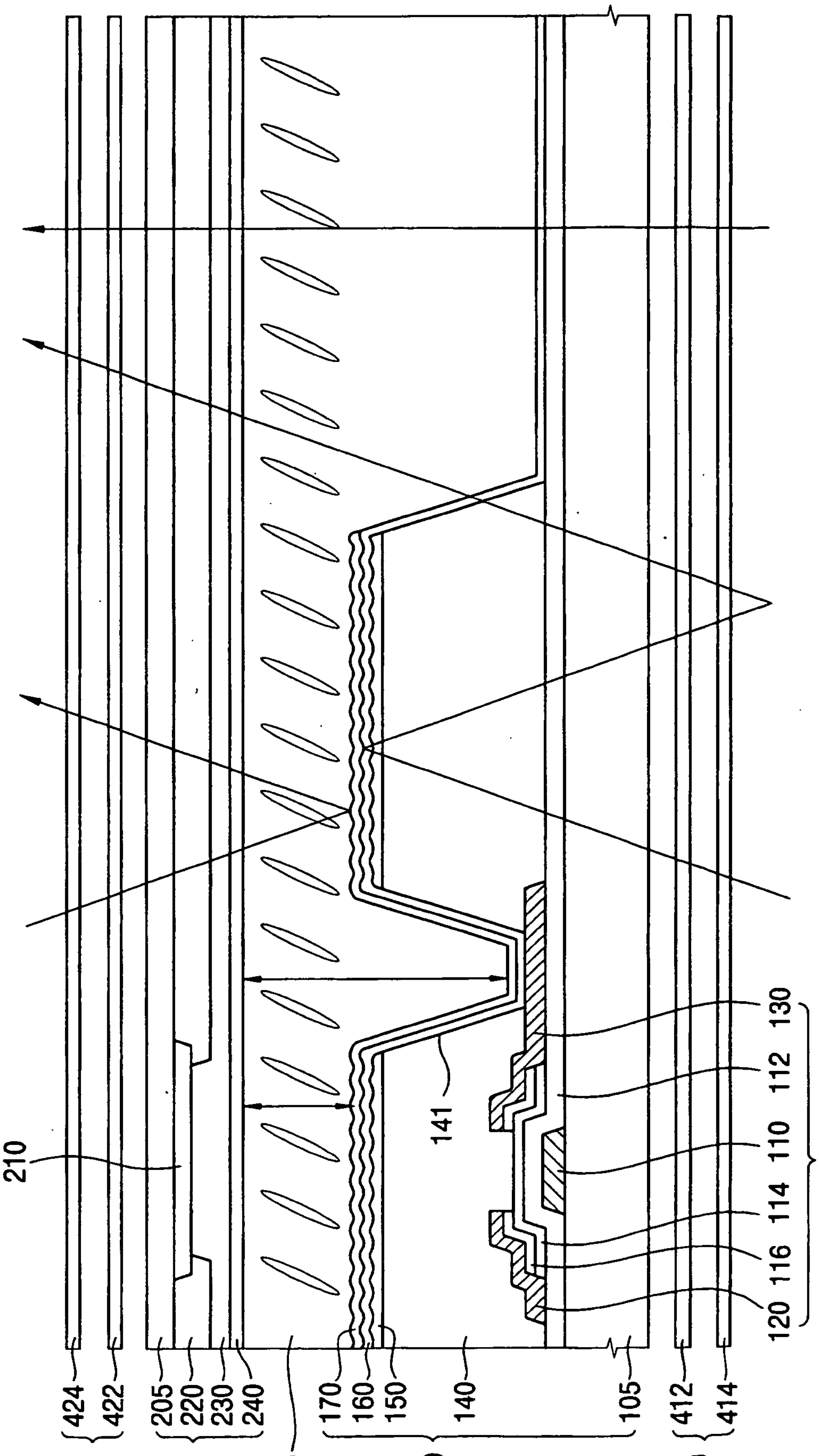

210
141
130
112
110
114
116
120
TFT
424
422
420
205
220
230
240
200
300
170
160
150
140
105
100
412
414
410

FIG. 9A

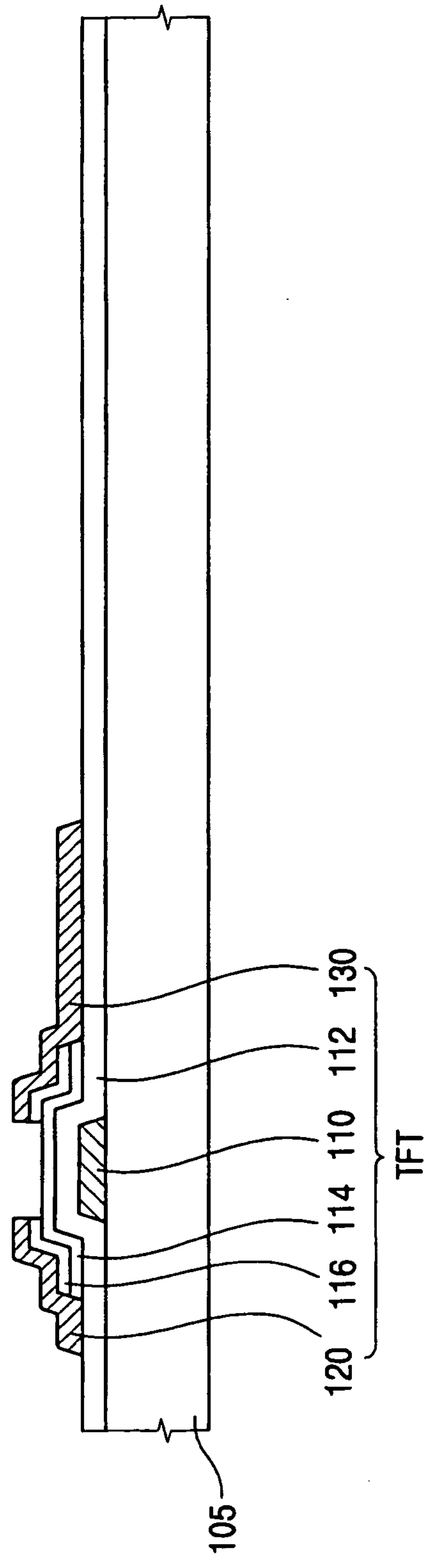


FIG. 9B

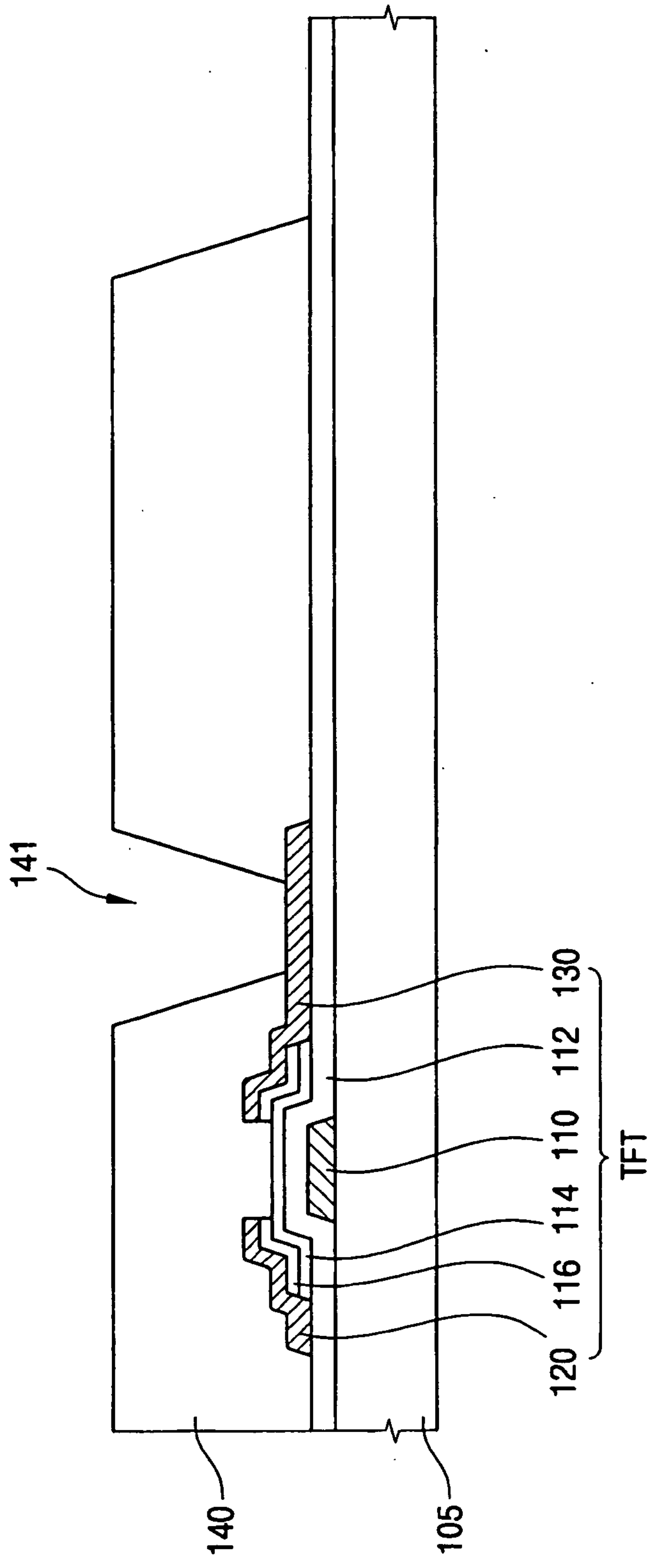


FIG. 9C

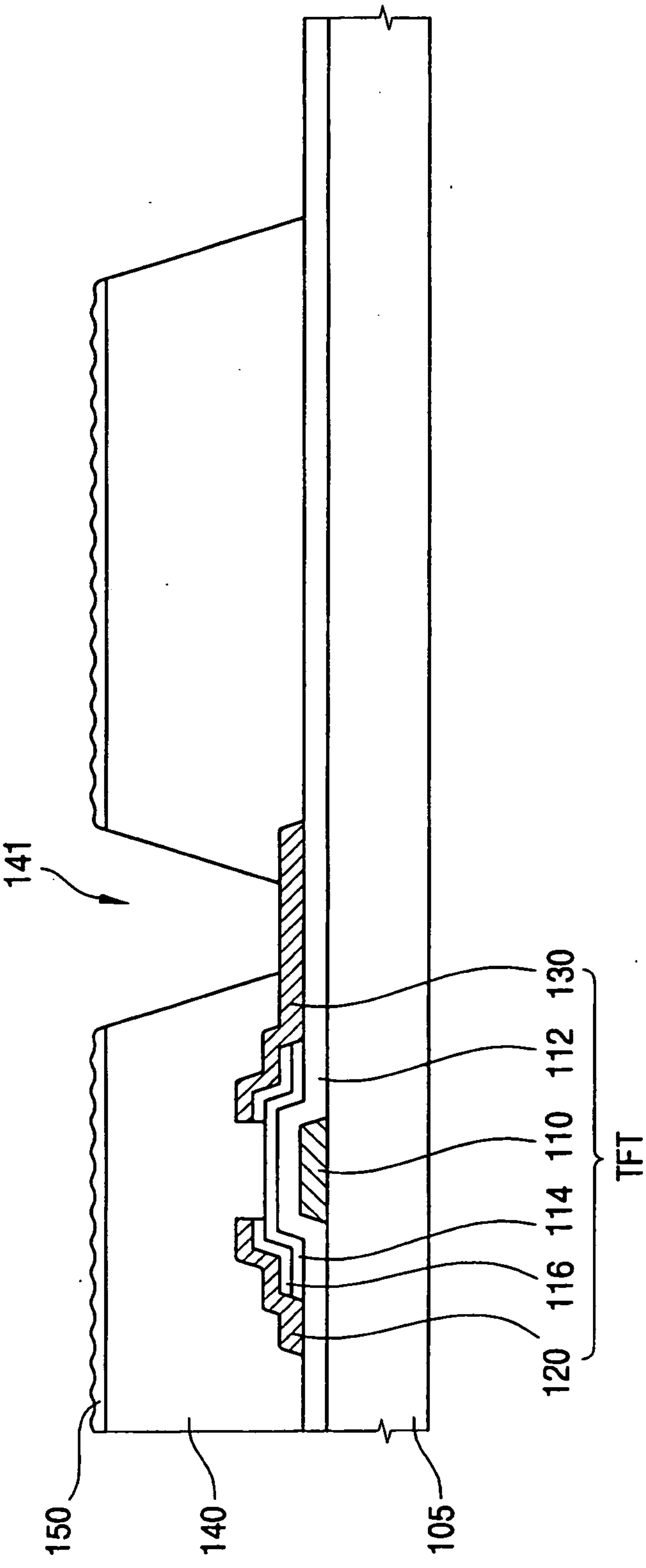


FIG. 9D

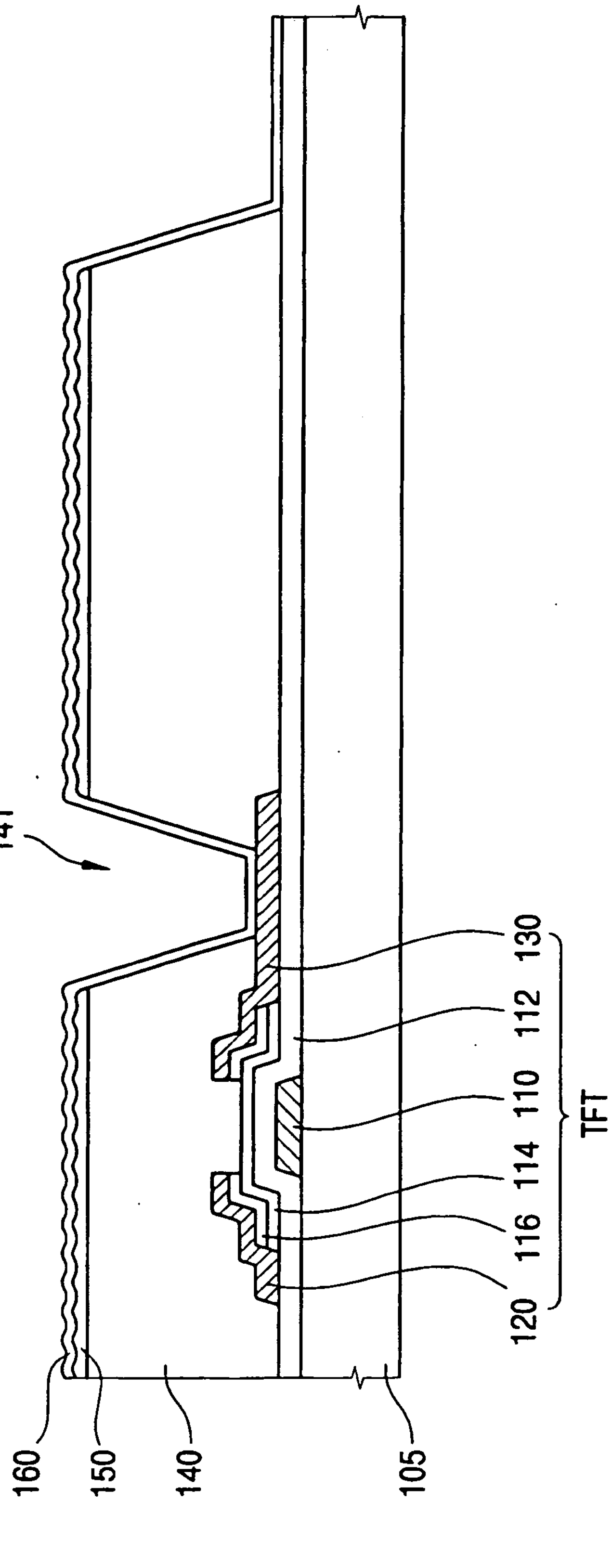


FIG. 9E

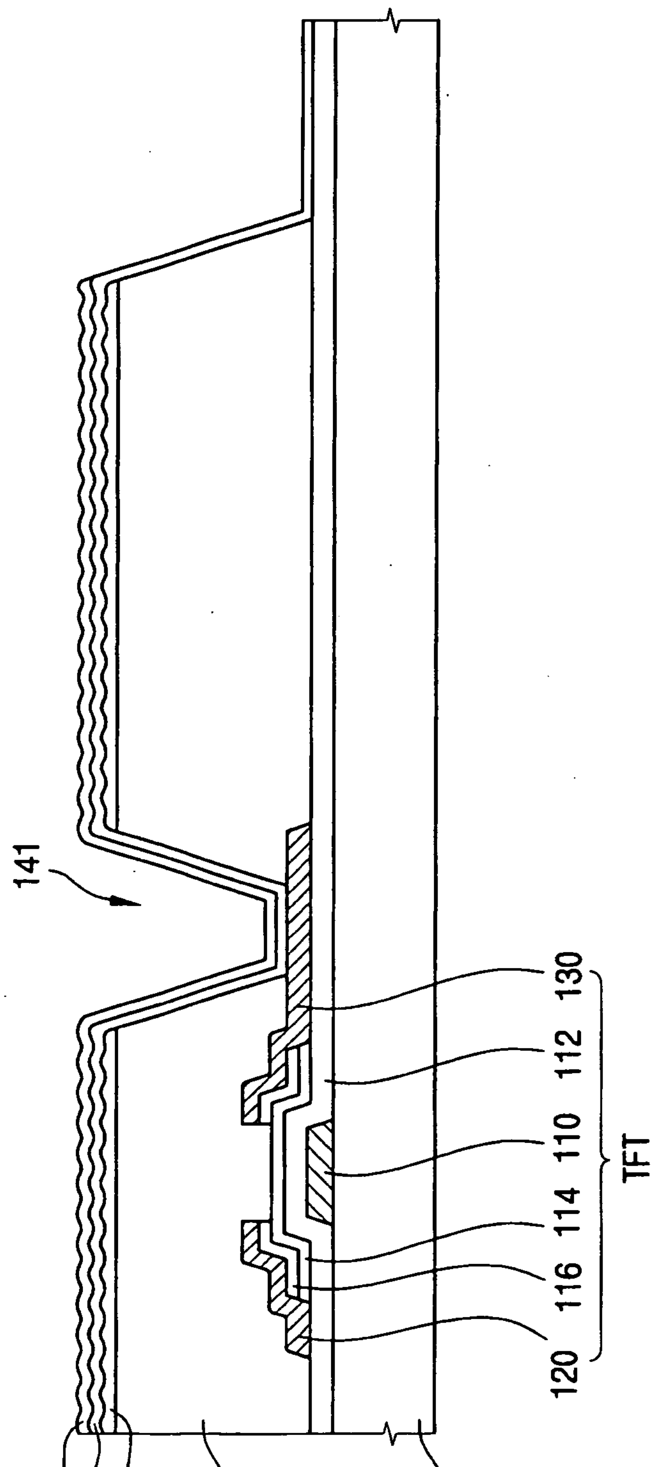


FIG. 10A

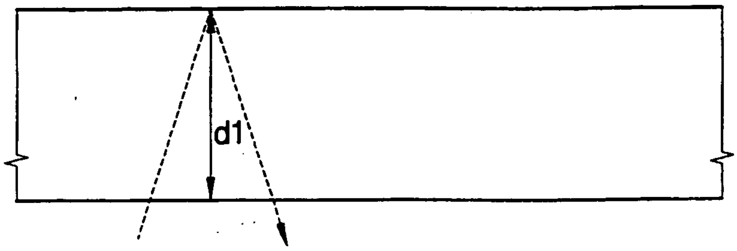


FIG. 10B

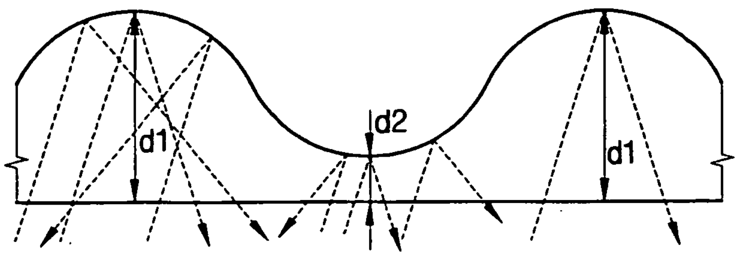


FIG. 10C

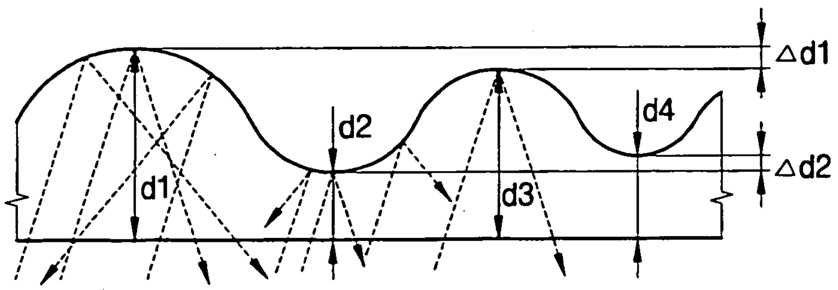


FIG. 10D

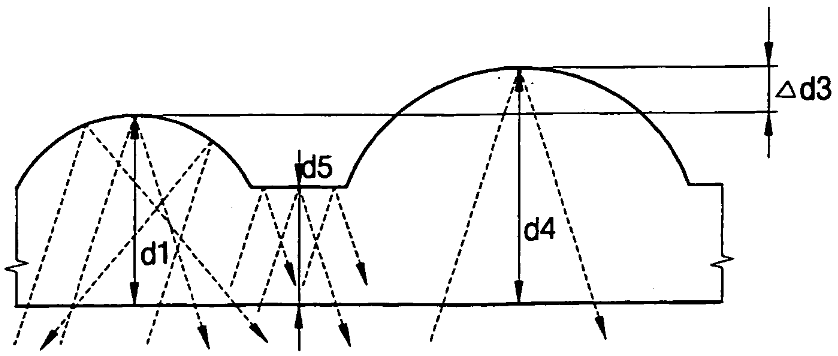


FIG. 11

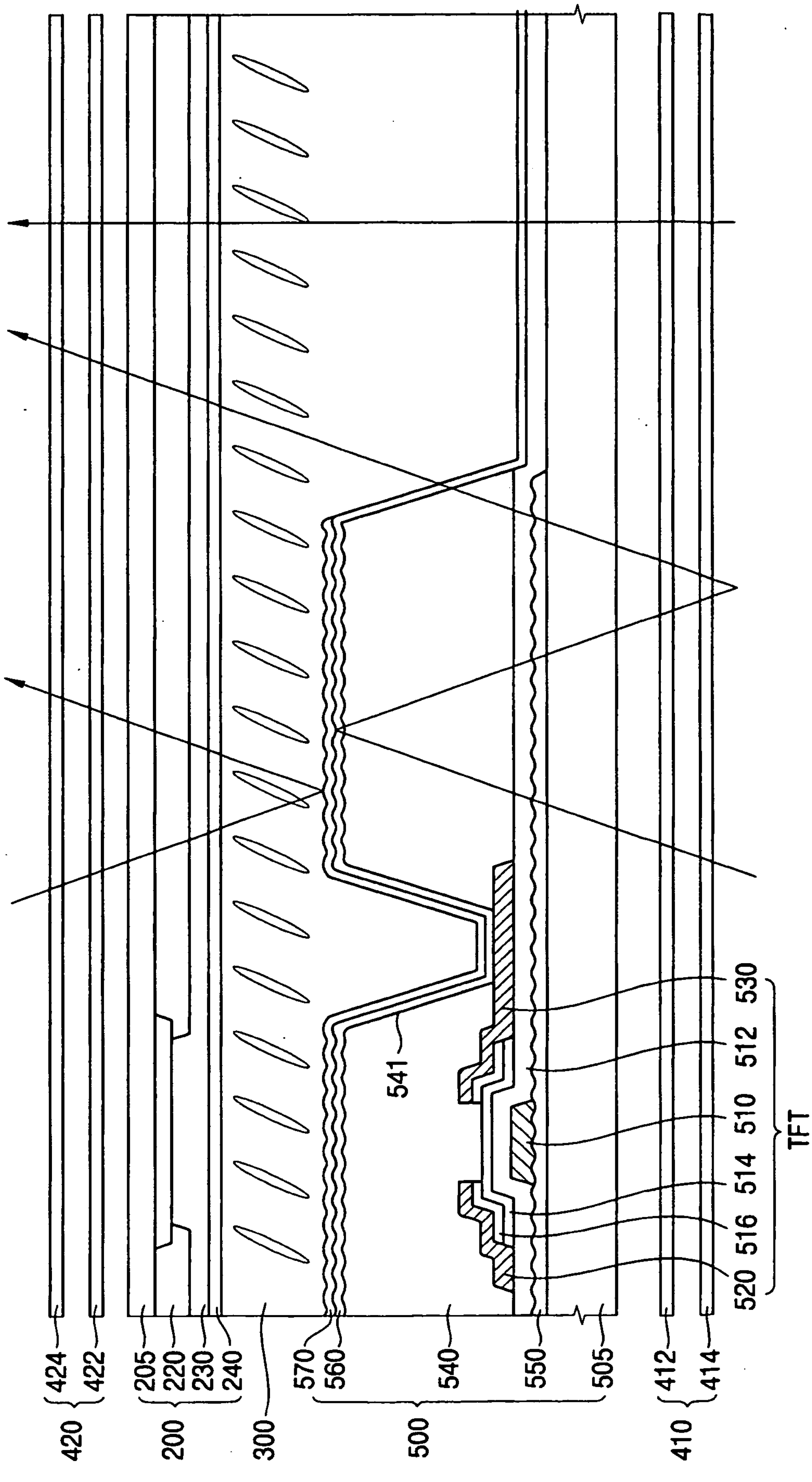

420
424
422
200
205
220
230
240
300
500
570
560
540
550
505
410
412
414
541
530
512
510
514
516
520
TFT

FIG. 12

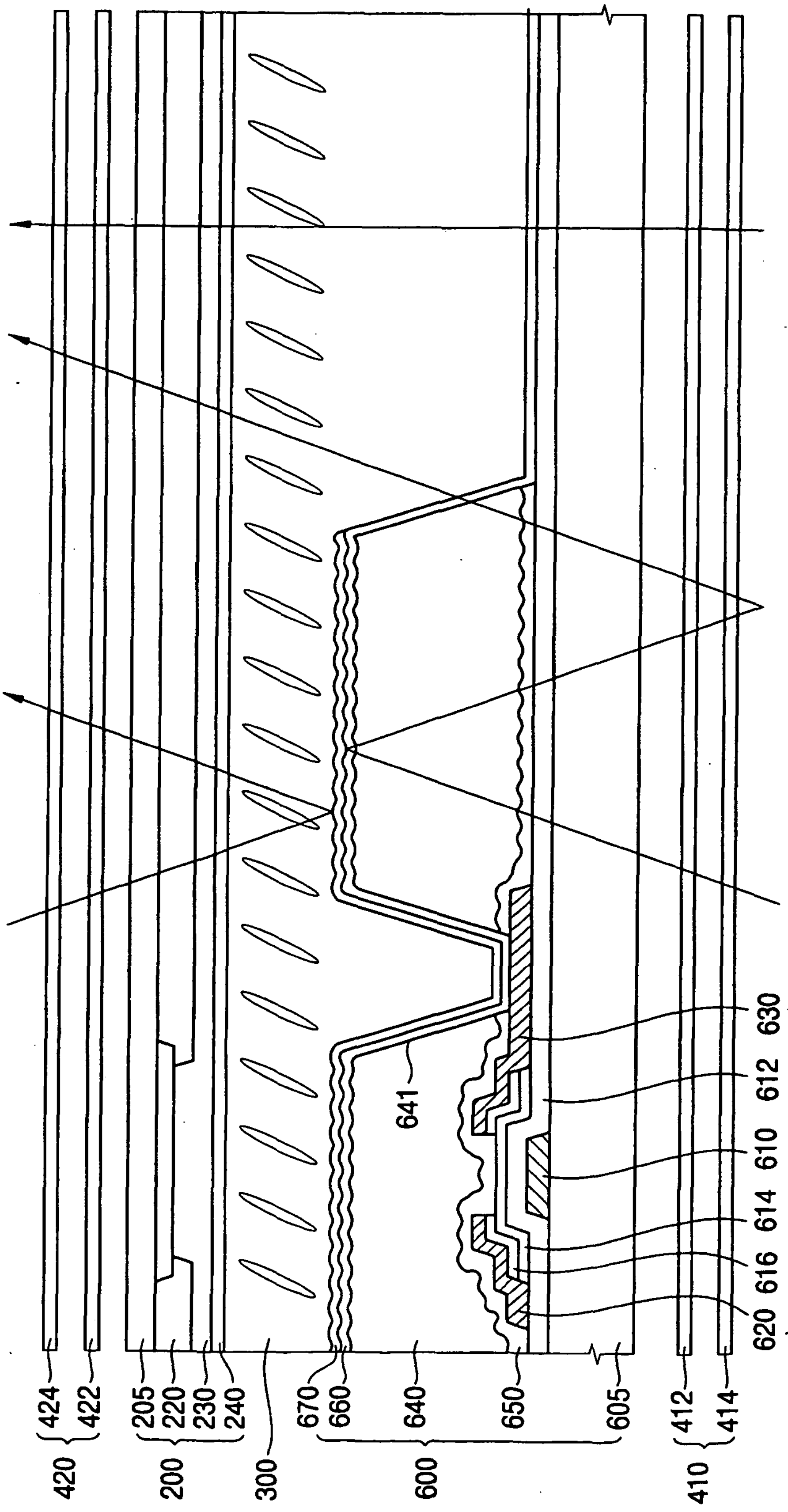

424
422
420
205
220
230
240
200
300
670
660
640
650
605
600
641
630
612
610
614
616
620
TFT
412
414
410

FIG. 13

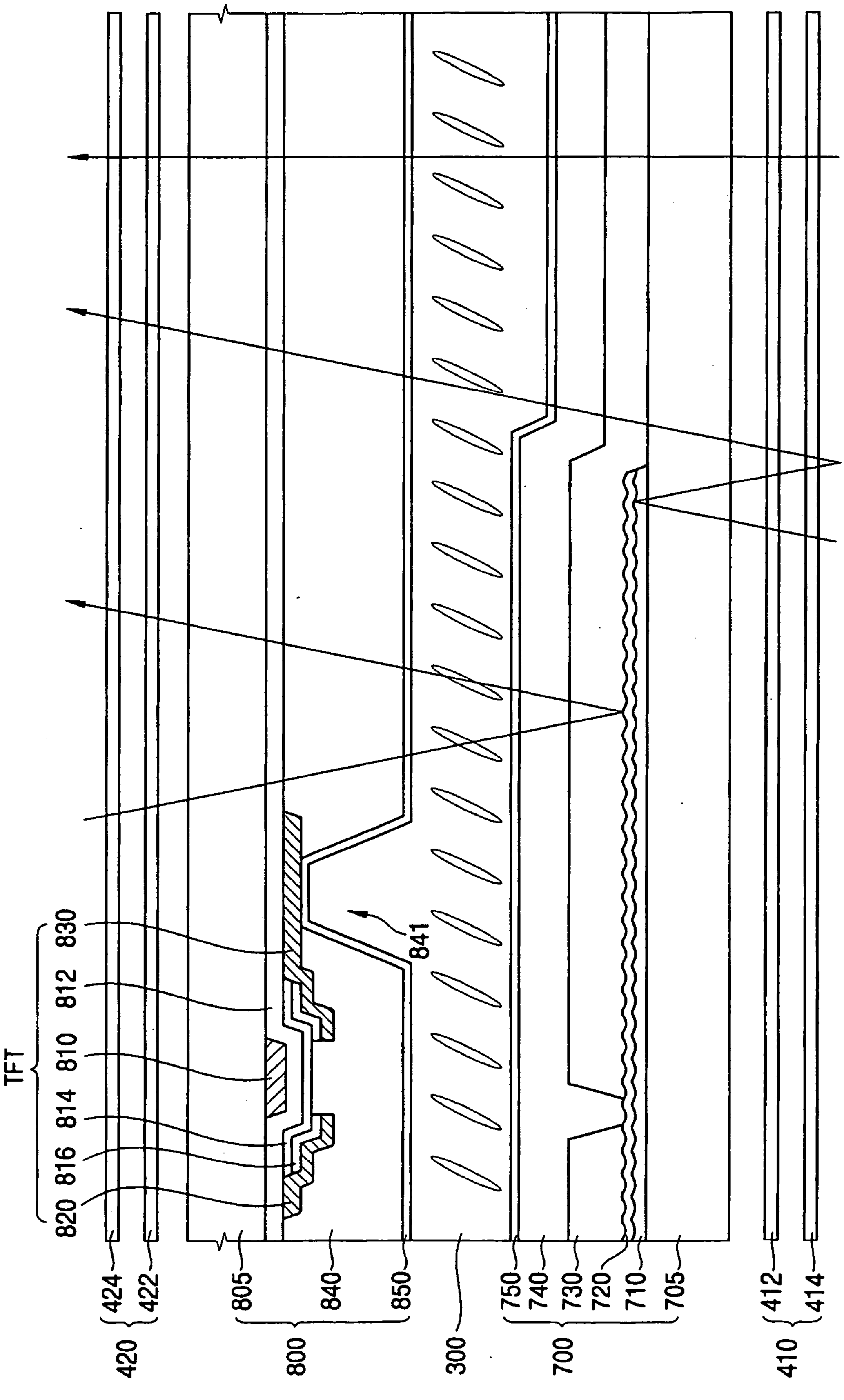
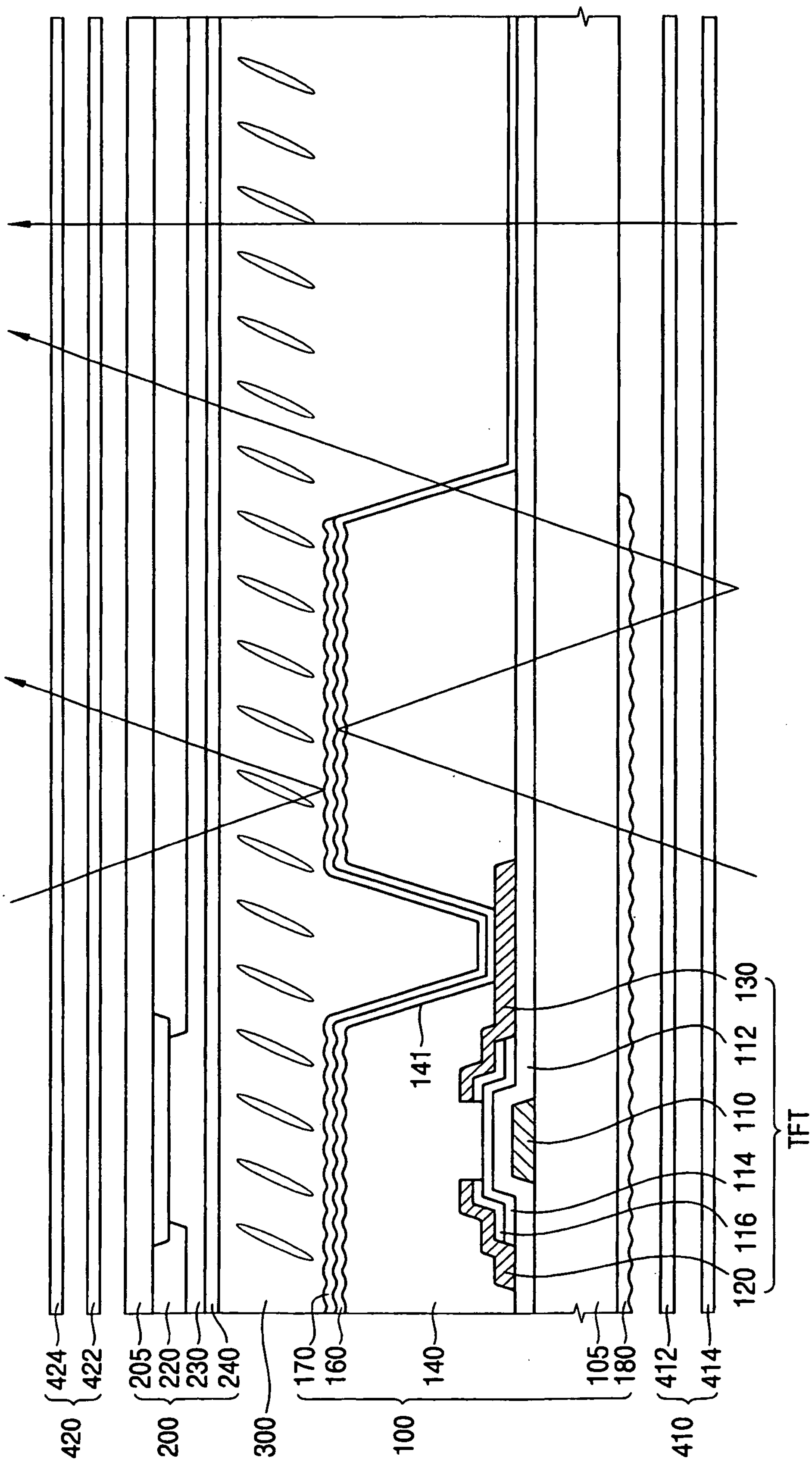

TFT
820
816
814
810
812
830
841
424
422
805
840
850
300
750
740
730
720
710
705
412
414
420
800
700
410

FIG. 14



424
422
420
205
220
230
240
200
300
170
160
140
100
105
180
412
414
410
141
130
112
110
114
116
120
TFT

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2003140152 A **[0023] [0031]**
- JP 2003014052 A **[0029]**

专利名称(译)	用于半透半反型液晶显示器的相位延迟元件		
公开(公告)号	EP1619543B1	公开(公告)日	2009-04-08
申请号	EP2005015191	申请日	2005-07-13
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	三星电子有限公司		
当前申请(专利权)人(译)	三星电子有限公司		
[标]发明人	HIRAI AKIRA YUN JIN HYUK UH KEE HAN PARK MIN SOO		
发明人	HIRAI, AKIRA YUN, JIN-HYUK UH, KEE-HAN PARK, MIN-SOO		
IPC分类号	G02F1/1335 G02F1/13363 G02B5/30		
CPC分类号	G02F1/13363 G02F1/133526 G02F2001/133638 G02F2413/02		
代理机构(译)	DR.威猛和合作伙伴		
优先权	1020040055827 2004-07-19 KR		
其他公开文献	EP1619543A2 EP1619543A3		
外部链接	Espacenet		

摘要(译)

相位延迟元件包括在反射层（50）和人造光（10）之间的亮度增强层（40）。亮度增强层（40）由第一表面和相对的第二表面限定。第一表面面向反射层（50）。来自人造光的第一光入射在第二表面上。第一光的相位延迟1/4相位（λ/4），使得第二光从第一表面朝向反射层（50）发射。第二光从反射层反射，使得第三光从反射层（50）朝向第一表面发射。第三光的相位延迟1/4相位（λ/4），从而从第二表面发射第四光。因此，从反射层（50）反射的一部分人造光被再循环以改善LCD装置的亮度。

FIG. 1