



US 20050219446A1

(19) **United States**(12) **Patent Application Publication**
Hisatake(10) **Pub. No.: US 2005/0219446 A1**(43) **Pub. Date: Oct. 6, 2005**(54) **LIQUID CRYSTAL DISPLAY DEVICE**(52) **U.S. Cl. 349/114**(76) **Inventor: Yuzo Hisatake, Yokohama-shi (JP)**

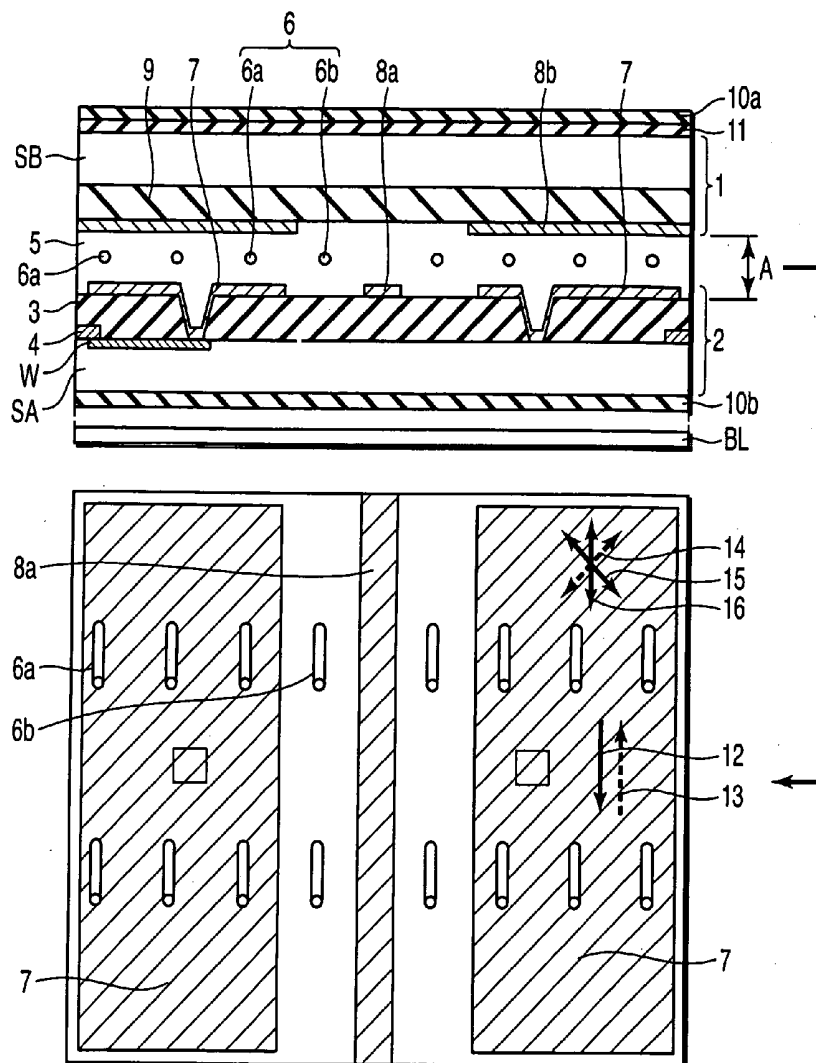
Correspondence Address:

**OBLON, SPIVAK, MCCLELLAND, MAIER &
NEUSTADT, P.C.
1940 DUKE STREET
ALEXANDRIA, VA 22314 (US)**(57) **ABSTRACT**(21) **Appl. No.: 11/097,347**(22) **Filed: Apr. 4, 2005**(30) **Foreign Application Priority Data**

Apr. 5, 2004 (JP) 2004-111129

Publication Classification(51) **Int. Cl.⁷ G02F 1/1335**

A liquid crystal display device includes a TFT substrate, a counter substrate, a liquid crystal layer held between the TFT substrate and the counter substrate and containing a liquid crystal composition, a linear polarizer attached to an outer surface of the TFT substrate, a circular polarizer attached to an outer surface of the counter substrate, a reflective electrode section which is located in an inner surface of the TFT substrate, a counter electrode section which is located in an inner surface of the counter substrate. The reflective electrode section includes a pair of electrodes to apply a lateral electric field to the liquid crystal layer.



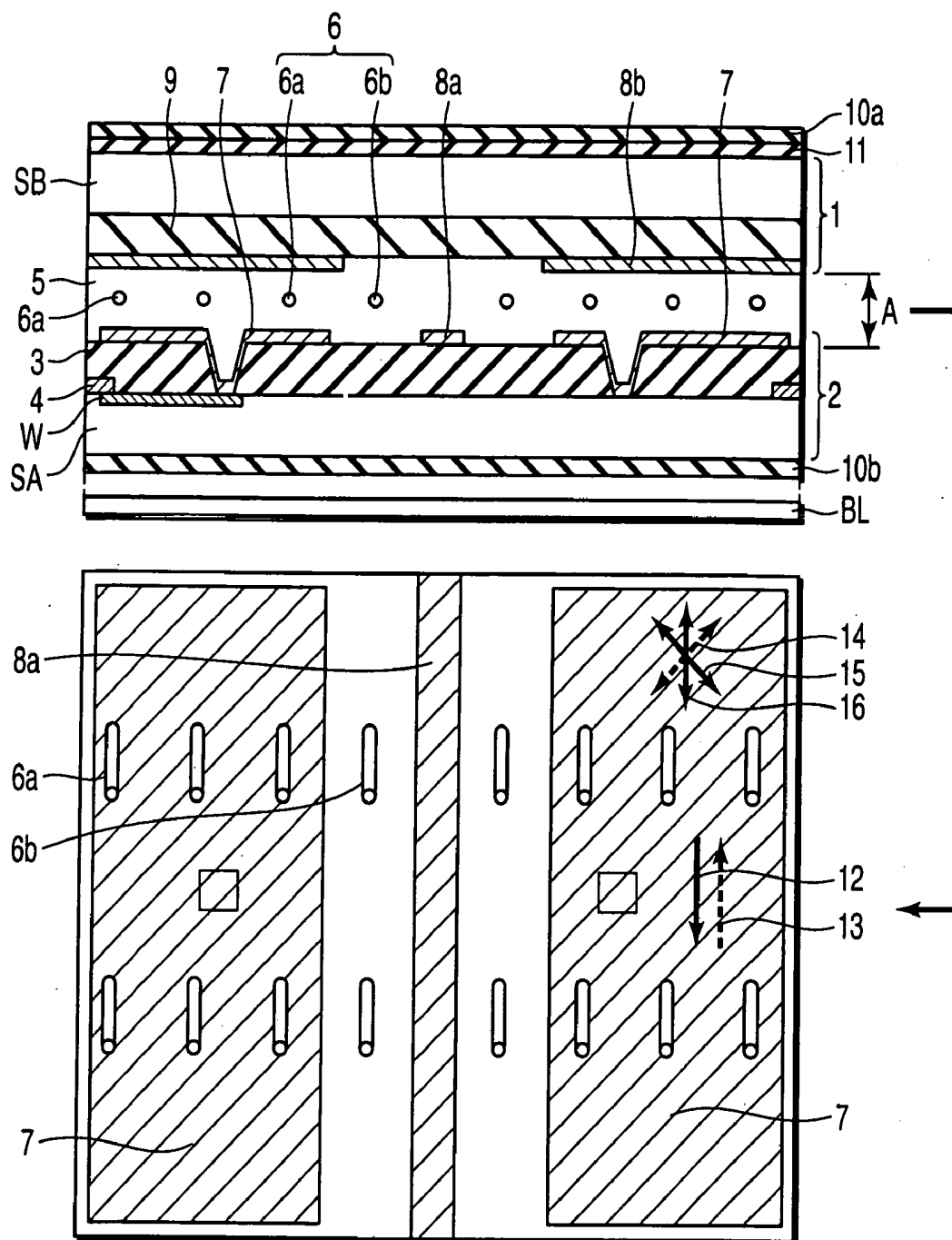


FIG. 1

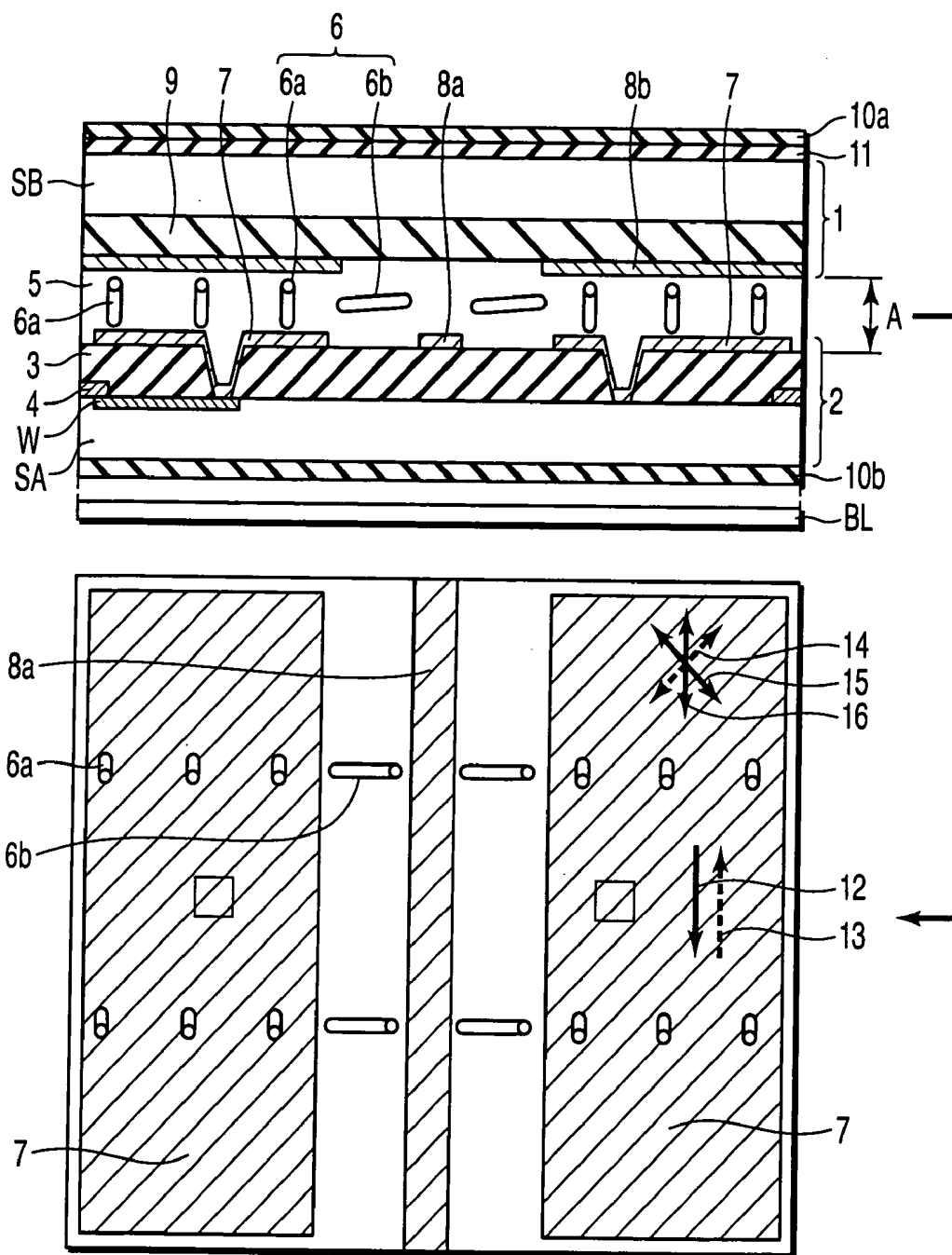


FIG. 2

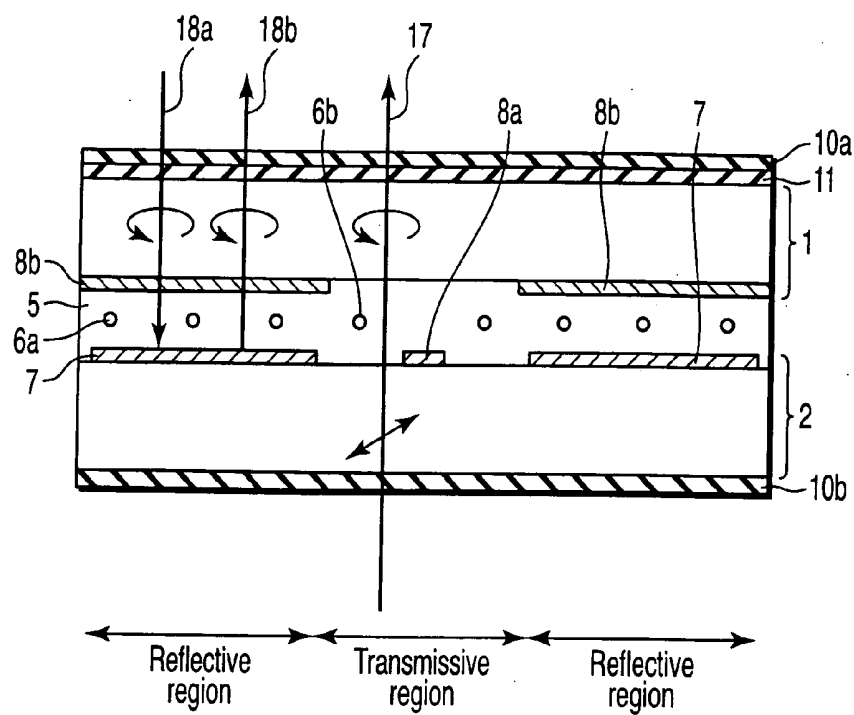


FIG. 3

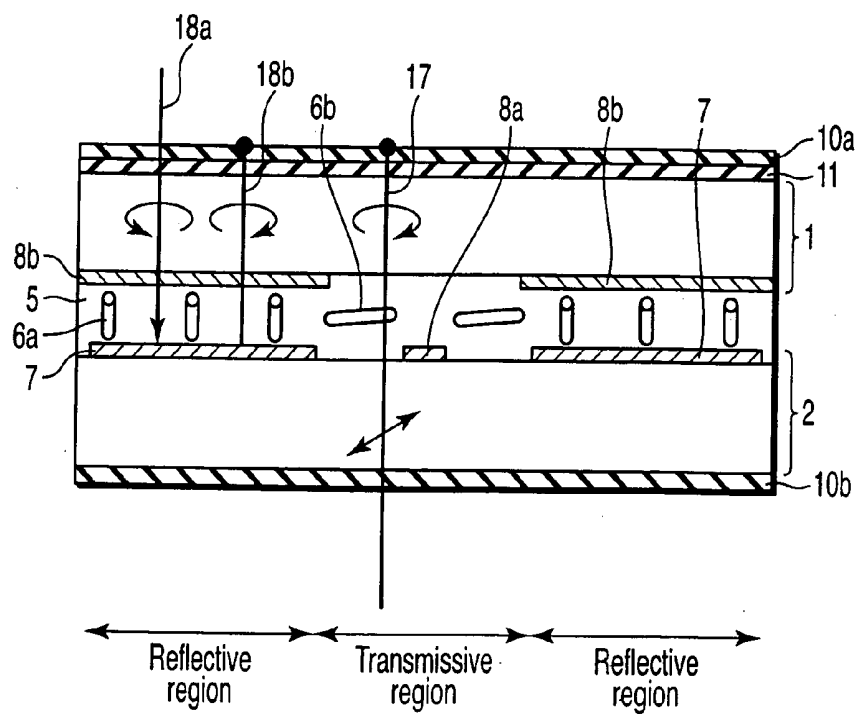


FIG. 4

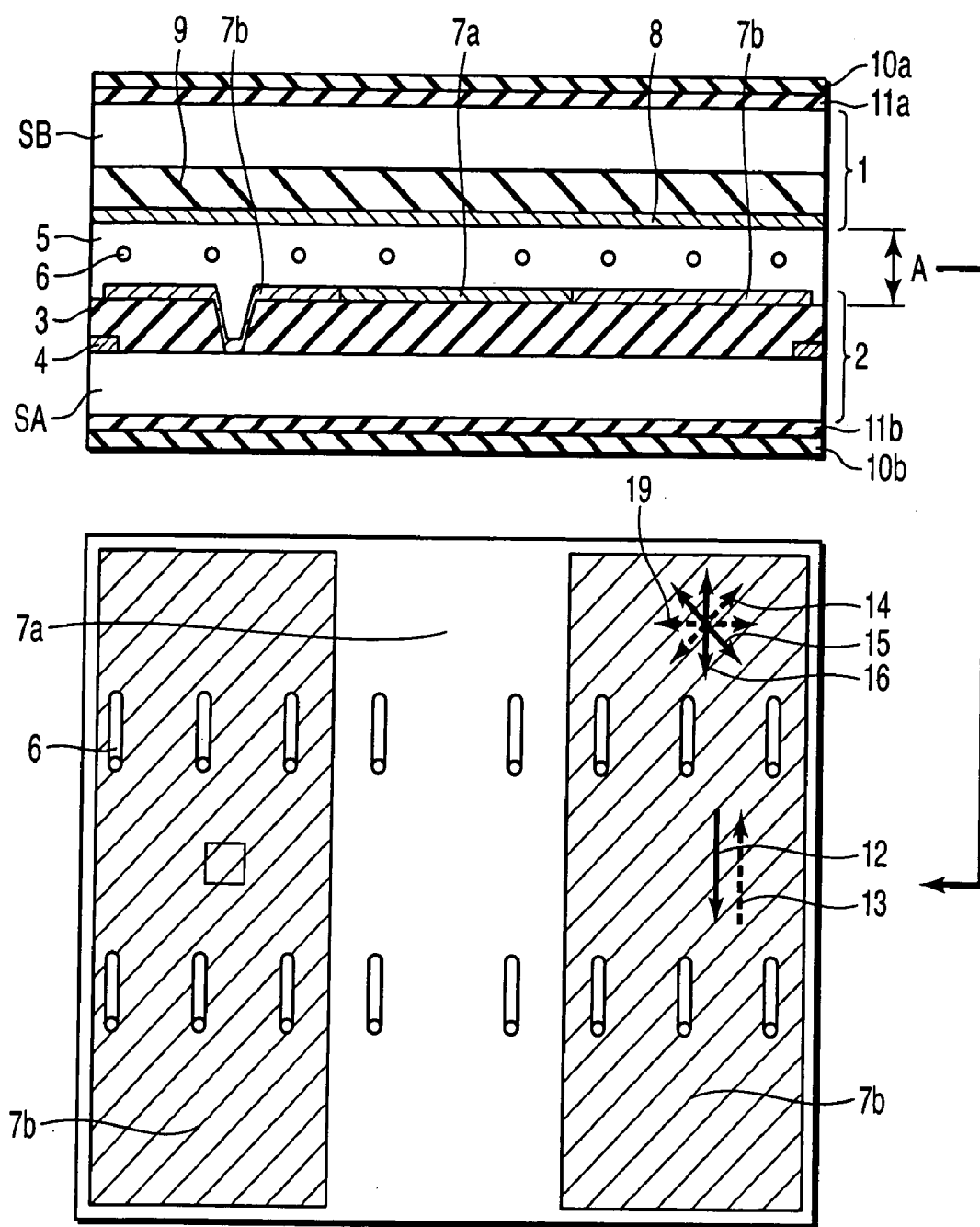


FIG. 5

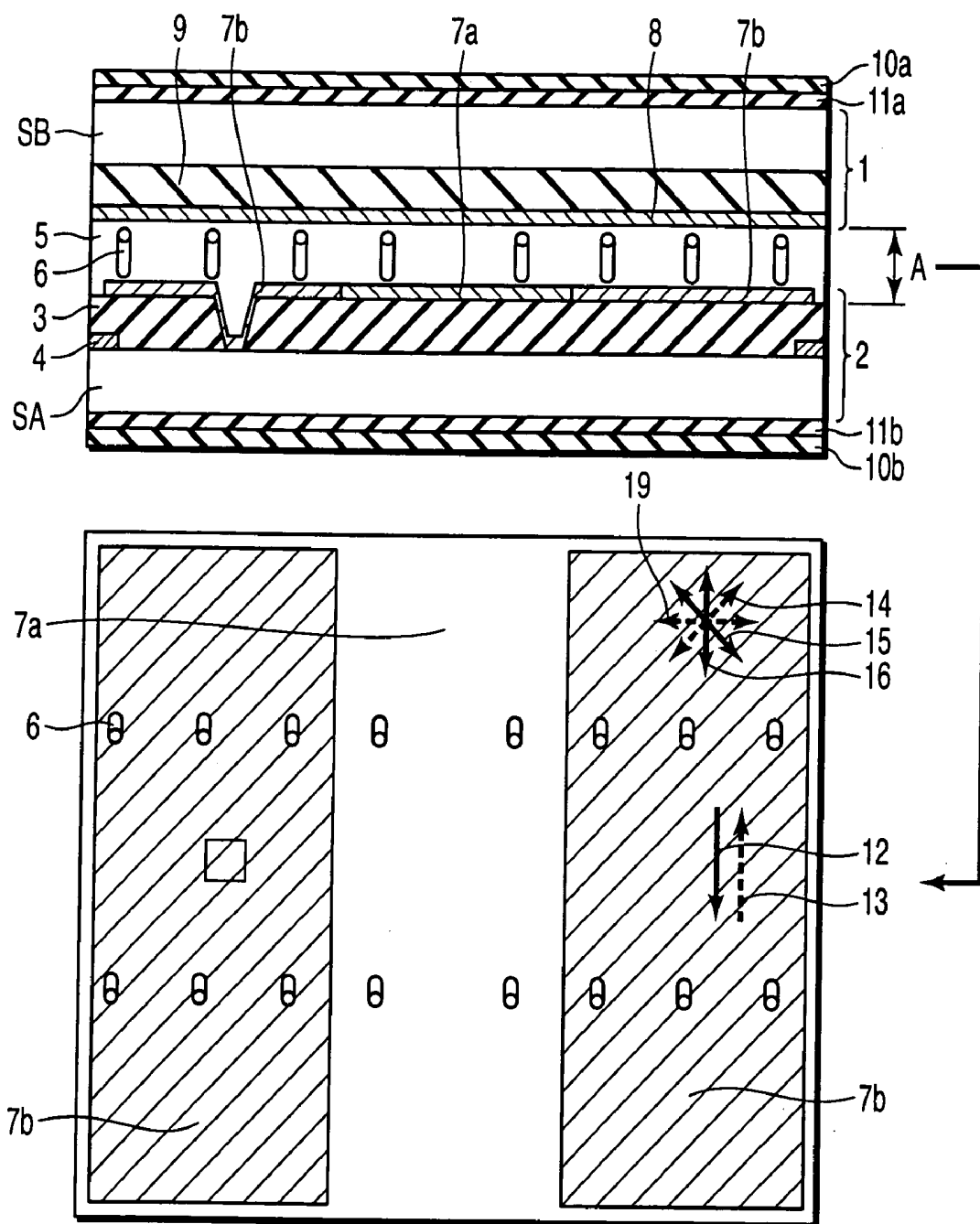


FIG. 6

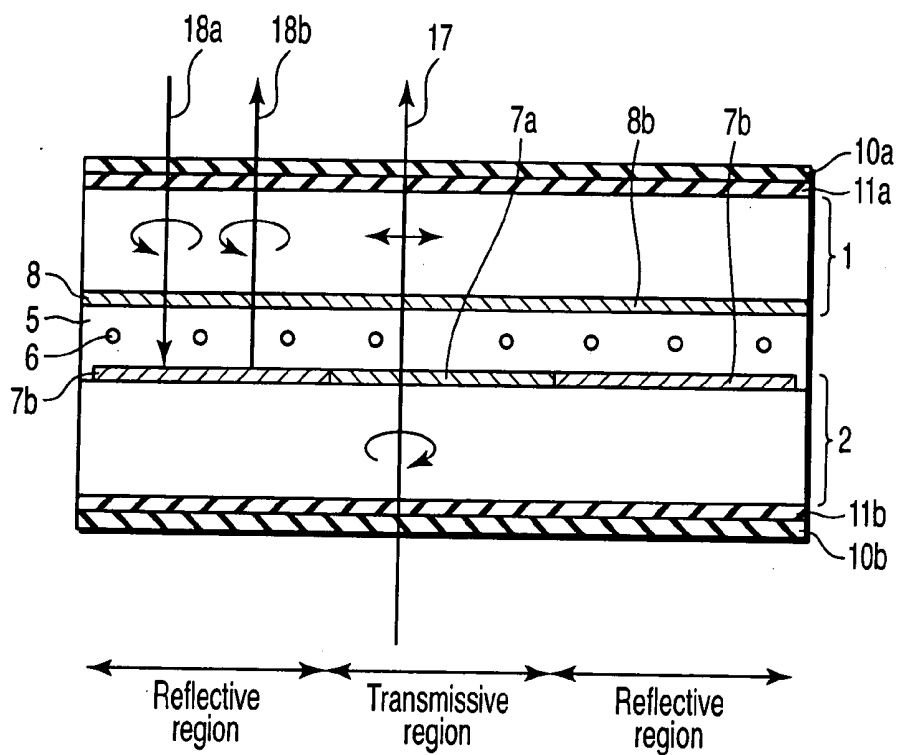


FIG. 7

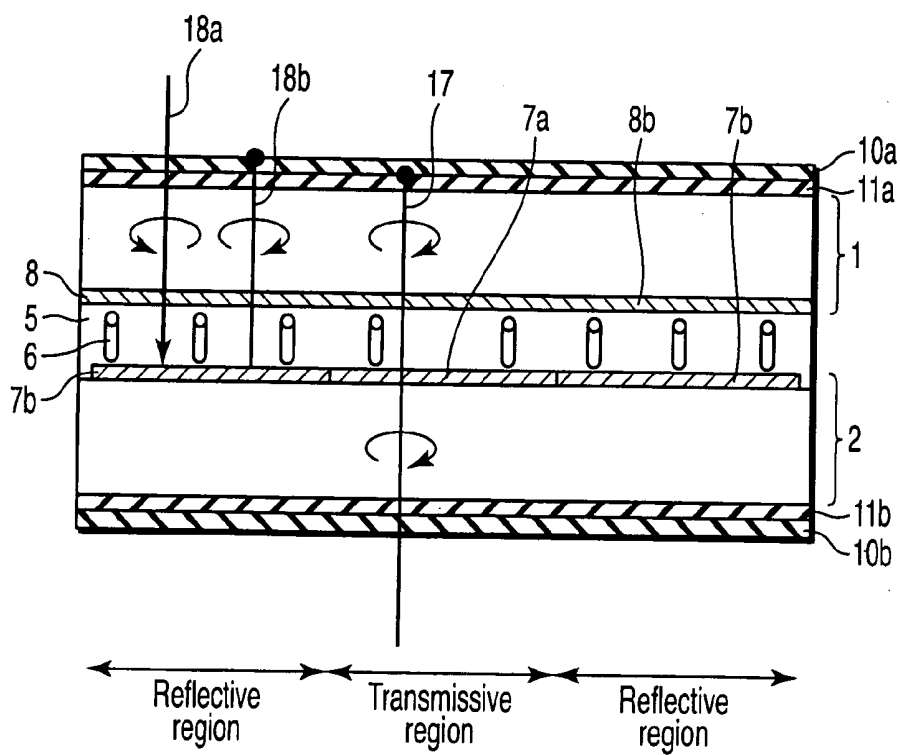


FIG. 8

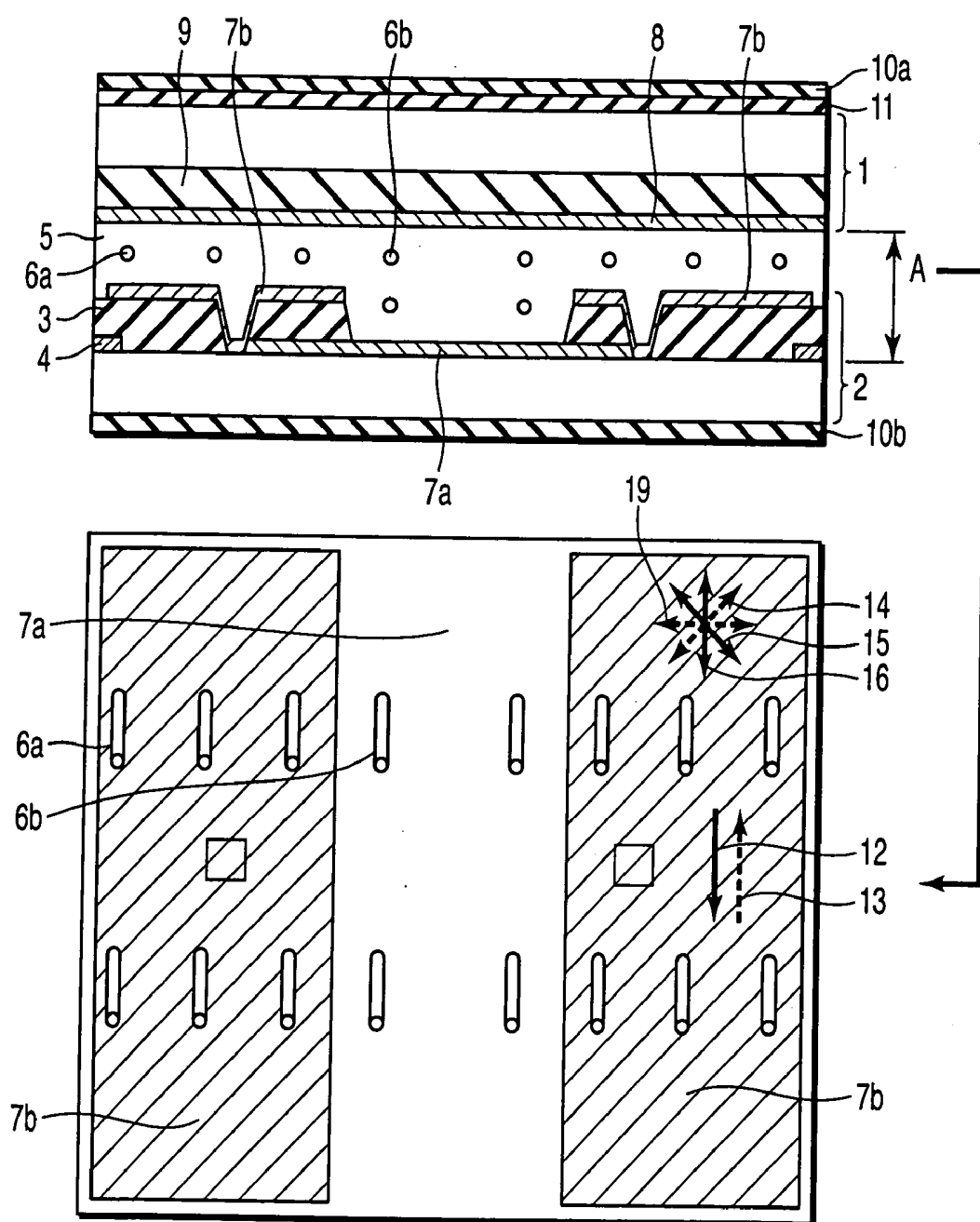


FIG. 9

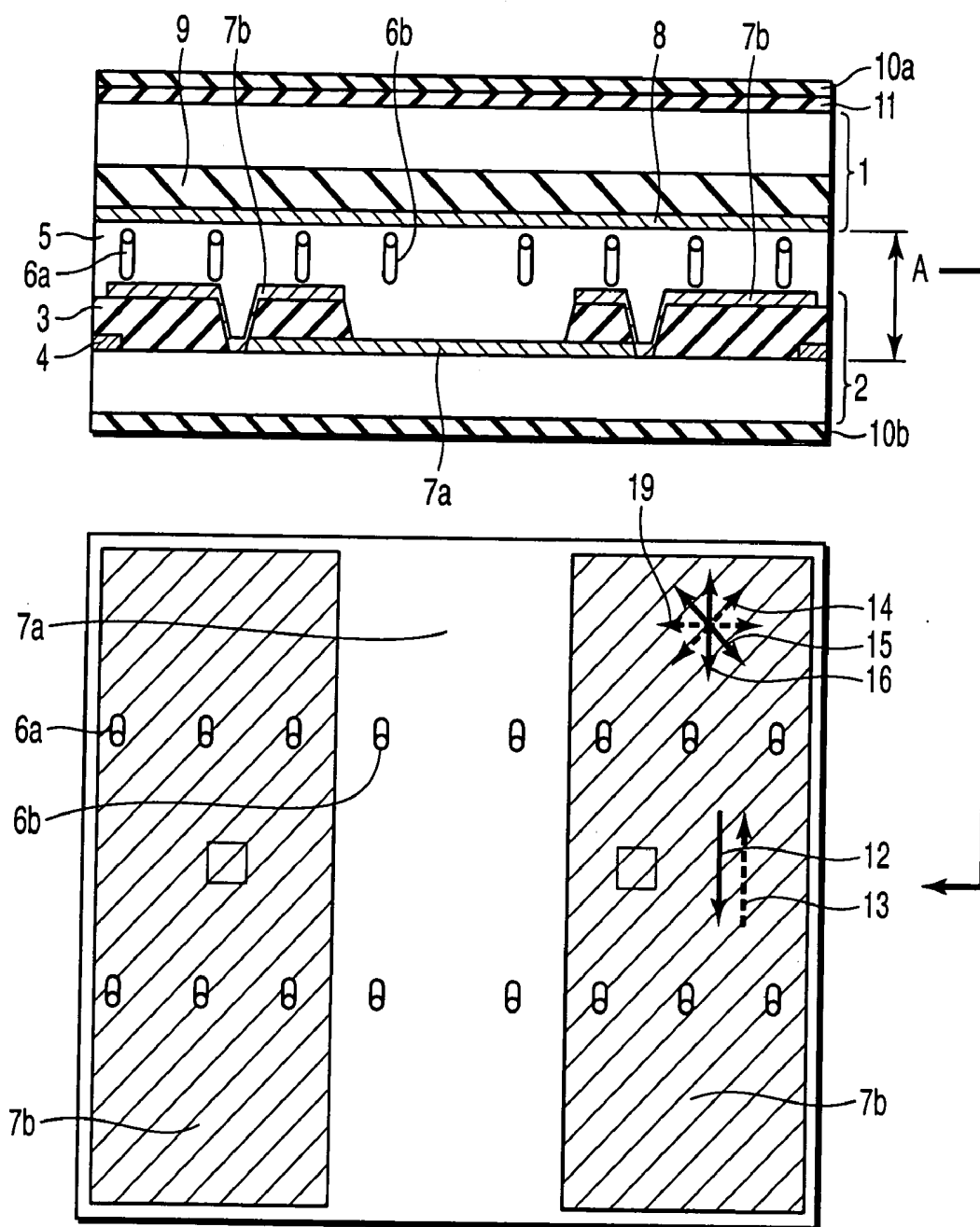


FIG. 10

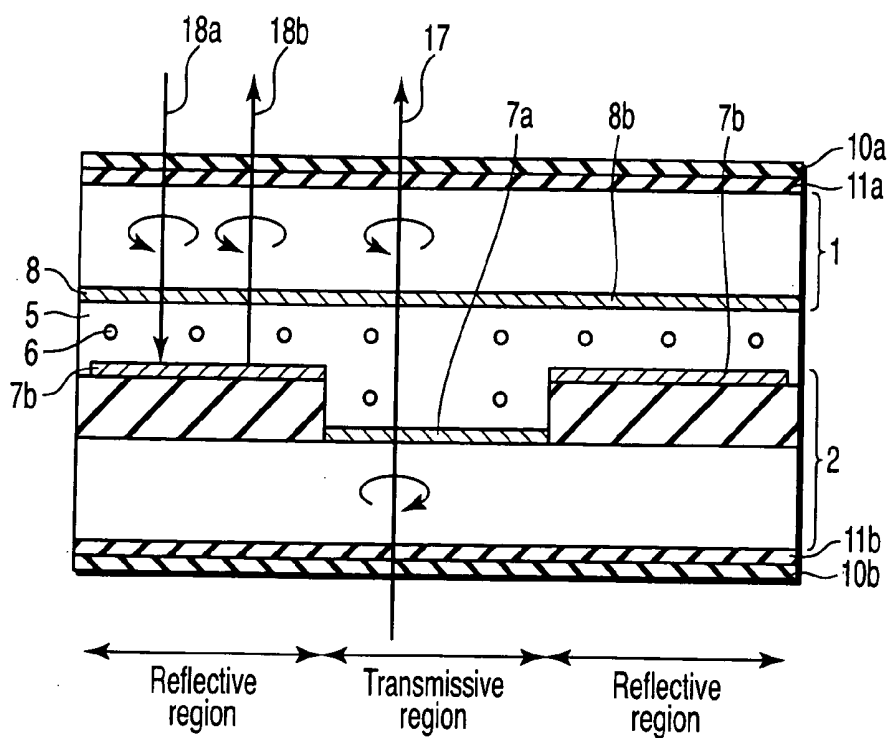


FIG. 11

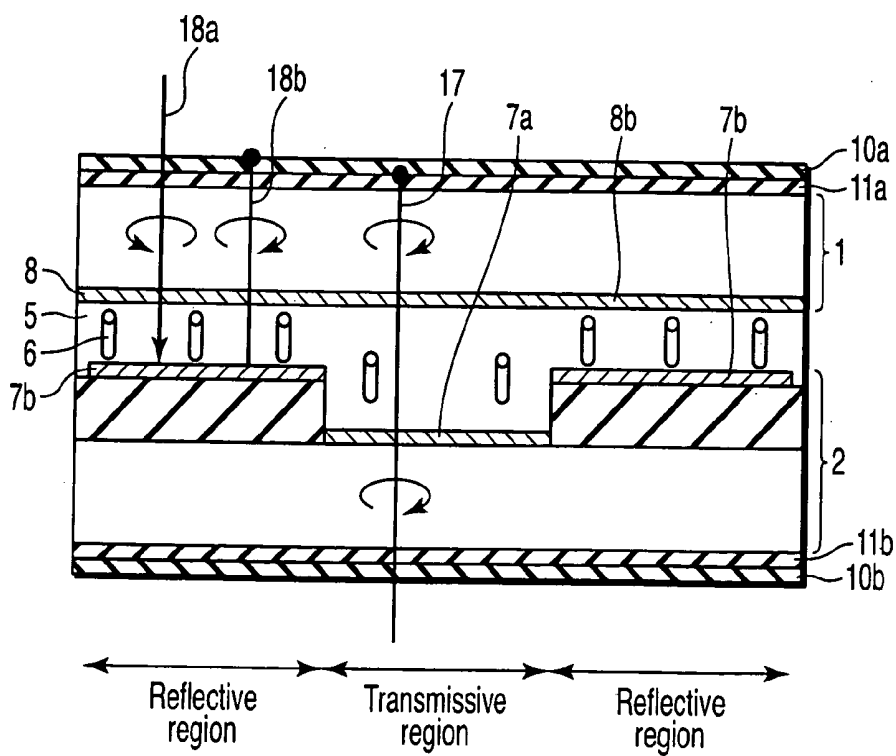


FIG. 12

LIQUID CRYSTAL DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2004-111129, filed Apr. 5, 2004, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a liquid crystal display device having a liquid crystal layer held between a pair of substrates, and in particular, to a liquid crystal display device that uses transmitted light and reflected light to display images.

[0004] 2. Description of the Related Art

[0005] In recent years, liquid crystal display devices have been applied to various fields including notebook personal computers, monitors, car navigation systems, scientific electronic calculators, and medium- and small-sized TVs. For example, reflective type liquid crystal display devices reflect ambient light to display images and are thus suitable for displays for portable apparatuses such as mobile PCs, cellular phones, and car navigation systems which are often used outdoors. However, with these liquid crystal display devices, the brightness of a display screen depends on an ambient illumination environment; images are totally invisible in the dark. Thus, the reflective type liquid crystal display device makes images visible even in the dark by reflecting light from a front-light placed in front of the display screen as an auxiliary light source.

[0006] In general, the reflective type display device is configured to guide front-light light to the display screen via various light guiding members. Thus, it is difficult to obtain a good contrast characteristic owing to reflection at the interface between these light guiding members (Fresnel reflection). This problem does not occur in a transmissive type liquid crystal display device comprising a backlight placed behind the display screen as an auxiliary light source. The transmissive type liquid crystal display device displays an image by reflecting ambient light while transmitting backlight light (see, for example, Jpn. Pat. Appln. KOKAI Publication No. 11-242226). In the dark, the contrast characteristic of the transmissive type liquid crystal display device is superior to that of the reflective type liquid crystal display device. Accordingly, at present, most displays for portable apparatuses use transmissive type liquid crystal display devices.

[0007] Now, with reference to FIGS. 5 to 12, description will be given of the structure and operational principle of conventional transmissive type liquid crystal display devices.

[0008] For example, the conventional transmissive type liquid crystal display device shown in FIGS. 5 to 8 is configured such that a liquid crystal layer 5 is held between a counter substrate 1 and a TFT substrate 2 and has a substantially uniform thickness. In FIGS. 5 and 6, the plan structure of a pixel is shown in association with the range A of the sectional structure of the pixel. In this liquid crystal

display device, a plurality of pixel electrodes are placed on the TFT substrate 2. A common electrode is placed on the counter substrate 1 to face the pixel electrodes. Each of the pixel electrodes is formed of a transparent electrode 7a and a reflective electrode 7b. The common electrode is formed of a transparent electrode 8. Both transparent electrode 7a and reflective electrode 7b are located on an insulating layer 3 covering wiring 4 such as signal lines. The liquid crystal layer 5 includes a nematic liquid crystal having a positive dielectric anisotropy. At the no-voltage-applied time where no voltage is applied between the pixel electrode and the common electrode, liquid crystal molecules 6 are set to a twisted alignment or homogeneous alignment as shown in FIG. 5 to obtain a quarter retardation. At the voltage-applied time where a voltage is applied between the pixel electrode and the common electrode, the liquid crystal molecules 6 are aligned vertically as shown in FIG. 6 by an electric field applied between these electrodes in a normal direction of the liquid crystal layer 5. At this state, the retardation of the liquid crystal layer 5 becomes almost zero. Further, polarizing plates 10a and 10b and quarter wavelength plates 11a and 11b are attached to outer surfaces of the counter substrate 1 and the TFT substrate 2, respectively, so that absorption axes 15 and 14 of the polarizing plates 10a and 10b and slow axes 16 and 19 of the quarter wavelength plates 11a and 11b cross at right angles to function as circular polarizers. Thus, at the no-voltage-applied time in FIG. 7, a quarter retardation is produced in the liquid crystal layer 5. A bright display state is established in both a reflective region corresponding to the reflective electrode 7b and a transmissive region corresponding to the transparent electrode 7a. On the other hand, at the voltage-applied time in FIG. 8, no retardation is produced in the liquid crystal layer 5. Consequently, both reflective region and transmissive region are brought into a dark display state.

[0009] However, with the above transmissive type liquid crystal display device, the retardation of the liquid crystal layer 5 must be a quarter in order to enable display in the reflective region. Accordingly, the retardation of the transmissive region is necessarily a quarter. As shown in FIGS. 7 and 8, the ambient light passes through the liquid crystal layer 5 twice in the reflective region. Consequently, a half retardation is obtained from the reflective region as a whole. However, the backlight light passes through the liquid crystal layer 5 only once in the transmissive region. As a result, only a quarter retardation is obtained from the transmissive region. Since the electric field is applied in the normal direction of the liquid crystal layer 5, the retardation of the liquid crystal layer 5 exceeds zero at the voltage-applied time. Thus, the retardation of the liquid crystal layer 5 is controlled in a range reduced from the quarter. Accordingly, if the transmissive type liquid crystal display device is configured to obtain a dark display state at the voltage-applied time in FIG. 8, linearly polarized light is emitted, as shown in FIG. 7, from the liquid crystal layer 5 in the bright display state established at the no-voltage applied time. Substantially 50% of the emitted light is thus absorbed by the polarizing plate 10a. Thus, disadvantageously, the display of the transmissive region becomes darkish.

[0010] This problem can be solved using, for example, a conventional transmissive type liquid crystal display device shown in FIGS. 9 to 12. The transmissive type liquid crystal display device is configured such that the liquid crystal layer 5 is held between the counter substrate 1 and the TFT

substrate **2** and has different thicknesses in the reflective and transmissive regions of each pixel. In **FIGS. 9 and 10**, the plan structure of a pixel is shown in association with the range **A** of the sectional structure of the pixel. In this transmissive type liquid crystal display device, an insulating layer **3** is formed as a base only for the reflective electrode **7b**. A difference in height between the transparent electrode **7a** and the reflective electrode **7b** is equal to the thickness of the insulating layer **3**. The difference in height is determined to set the thickness of the liquid crystal layer **5** in the transmissive region to be substantially twice as large as that in the reflective region. As a result, the retardation of the liquid crystal layer **5** becomes substantially a half at the no-voltage-applied time. Accordingly, the retardation of the liquid crystal layer **5** becomes a quarter in the reflective region. In this case, the retardation of the liquid crystal layer **5** is controlled by a liquid-crystal-applied voltage in a range of substantial zero to the quarter to specify the brightness of the display. In contrast, in the transmissive region, the retardation of the liquid crystal layer **5** is controlled by the liquid-crystal-applied voltage between substantial zero and the half to specify the brightness of the display. As a result, the total amount of retardation is controlled in the range of zero to the half in either of the transmissive and reflective regions. Therefore, as shown in **FIG. 11**, in the bright display state, circularly polarized light is incident on the quarter wavelength plate **11a** of the counter substrate **1** and can be almost transmitted through the polarizing plate **10a** on the counter substrate **1**.

[0011] However, in manufacturing the transmissive type liquid crystal display device shown in **FIGS. 9 to 12**, it is necessary that both thicknesses of the insulating layer **3** and liquid crystal layer **5** located within the reflective region are controlled to obtain two different thicknesses in the liquid crystal layer **5** for each pixel. This arises a problem of narrowing the process margins. Further, in the transmissive liquid crystal display device shown in **FIGS. 5 to 8** and the transmissive liquid crystal display device shown in **FIGS. 9 to 12**, two electrode patterns for the transparent electrode **7a** and reflective must be provided electrode **7b** on the TFT substrate **2**. This increases the number of processes compared to general transmissive or reflective type liquid crystal display devices. Moreover, in the transmissive liquid crystal display device shown in **FIGS. 5 to 8** and the transmissive liquid crystal display device shown in **FIGS. 9 to 12**, the two quarter wavelength plates **11a** and **11b** must be arranged on the counter substrate **1** and TFT substrate **2**, respectively. This increases the total cost of materials.

BRIEF SUMMARY OF THE INVENTION

[0012] It is an object of the present invention to provide a transmissive type liquid crystal display device that can provide images of sufficient brightness and contrast in various illumination environments without requiring any complicated structures.

[0013] According to the present invention, there is provided a liquid crystal display device comprising: a first and second substrates; a liquid crystal layer held between the first and second substrates and containing a liquid crystal composition; a linear polarizer attached to an outer surface of the first substrate; a circular polarizer attached to an outer surface of the second substrate; a reflective electrode section which is located in an inner surface of the first substrate and

reflects light incident from the second substrate to the liquid crystal layer; a counter electrode section which is located in an inner surface of the second substrate and associated with the reflective electrode section to apply a vertical electric field to the liquid crystal layer in a reflective region corresponding to a range of the reflective electrode section; and a pair of electrodes which are located in the inner surface of the first substrate and associated with each other to apply a lateral electric field to the liquid crystal layer in a transmissive region existing outside the reflective region and allowing transmission of light incident from the first substrate to the liquid crystal layer.

[0014] In this liquid crystal display device, the alignment state of liquid crystal molecules is controlled by the vertical electric field in the reflective region and by the lateral electric field in the transmissive region. In this case, it is unnecessary to provide the reflective electrode together with a transparent electrode on the first substrate or to obtain different thicknesses in the liquid crystal layer. Therefore, the present liquid crystal display device can be manufactured using a process equivalent to that for a liquid crystal display device that uses a selected one of transmitted light and reflected light for display. Moreover, the above structure does not require a quarter wavelength plate which is conventionally provided on the first substrate.

[0015] Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0016] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention, and together with the general description given above and the detailed description of the embodiment given below, serve to explain the principles of the invention.

[0017] **FIG. 1** is a diagram showing the sectional and plan structures of each of pixels provided in a transmissive liquid crystal display device according to an embodiment of the present invention, as well as the alignment state of liquid crystal molecules at a no-voltage-applied time;

[0018] **FIG. 2** is a diagram showing the alignment state of liquid crystal molecules which is obtained at a voltage-applied time in the pixel of the sectional and plan structures shown in **FIG. 1**;

[0019] **FIG. 3** is a sectional view for explaining transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the no-voltage-applied time as shown in **FIG. 1**;

[0020] **FIG. 4** is a sectional view for explaining transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the voltage-applied time as shown in **FIG. 2**;

[0021] FIG. 5 is a diagram showing the sectional and plan structures of each of pixels provided in a conventionally-known transmissive liquid crystal display device, as well as the alignment state of liquid crystal molecules at the no-voltage-applied time;

[0022] FIG. 6 is a diagram showing the alignment state of liquid crystal molecules which is obtained at the voltage-applied time in the pixel of the sectional and plan structures shown in FIG. 5;

[0023] FIG. 7 is a sectional view for explaining transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the no-voltage-applied time as shown in FIG. 5;

[0024] FIG. 8 is a sectional view for explaining transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment at the voltage-applied time as shown in FIG. 6;

[0025] FIG. 9 is a diagram showing the sectional and plan structures of each of pixels provided in another conventionally-known transmissive liquid crystal display device, as well as the alignment state of liquid crystal molecules at the no-voltage-applied time;

[0026] FIG. 10 is a diagram showing the alignment state of liquid crystal molecules which is obtained at the voltage-applied time in the pixel of the sectional and plan structures shown in FIG. 9;

[0027] FIG. 11 is a sectional view for explaining transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the no-voltage-applied time as shown in FIG. 9; and

[0028] FIG. 12 is a sectional view for explaining transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the voltage-applied time as shown in FIG. 10.

DETAILED DESCRIPTION OF THE INVENTION

[0029] With reference to the accompanying drawings, description will be given of a transmissive type liquid crystal display device according to an embodiment of the present invention.

[0030] FIG. 1 shows the sectional and plan structures of each of pixels provided in a transmissive liquid crystal display device according to an embodiment of the present invention, as well as the alignment state of liquid crystal molecules at a no-voltage-applied time. FIG. 2 shows the alignment state of liquid crystal molecules which is obtained at a voltage-applied time in the pixel. FIG. 3 conceptually shows transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the no-voltage-applied time. FIG. 4 conceptually shows transmission, absorption, and polarization of incident light incident on the pixel whose liquid crystal molecules are in the alignment state at the voltage-applied time. In FIGS. 1 and 2, the plan structure of the pixel is shown in association with the range A of the sectional structure of the pixel. Further, in FIGS. 1 to 4,

similar components are denoted by the same reference symbols. Duplicate descriptions will be omitted.

[0031] This transmissive liquid crystal display device is configured such that a liquid crystal layer 5 is held between a counter substrate 1 and a TFT substrate 2 and has a substantially uniform thickness, as shown in FIGS. 1 to 4. The TFT substrate 2 has pairs of first and second reflective electrodes 7 and 8a are arrayed substantially in a matrix, thin film transistors W arranged adjacent to the pairs of first and second reflective electrodes 7 and 8a, and a transparent insulating substrate SA such as glass which supports the pairs of first and second reflective electrodes 7 and 8a and thin film transistors W. The first and second reflective electrodes 7 serve as a reflective electrode section which is located in an inner surface of the TFT substrate 2 and reflects light incident from the counter substrate 1 to the liquid crystal layer 5. The counter substrate 1 has a transparent electrode 8b, a color filter layer 9, and a transparent insulating substrate SB such as glass which supports the transparent electrode 8b and the color filter layer 9. The transparent electrode 8b serves as a counter electrode section which is located in an inner surface of the counter substrate 1 and associated with the reflective electrode section to apply a vertical electric field to the liquid crystal layer 5 in a reflective region corresponding to a range of the reflective electrode section. The vertical electric field is an electric field applied in a normal direction of the liquid crystal layer 5.

[0032] The first and second reflective electrodes 7 and 8a are spaced from each other and serve as a pair of electrodes which are located in the inner surface of the TFT substrate 2 and associated with each other to apply a lateral electric field to the liquid crystal layer 5 in a transmissive region existing outside the reflective region and allowing transmission of light incident from the TFT substrate 2 to the liquid crystal layer 2. The lateral electric field is an electric field applied in a horizontal direction substantially parallel to plane of the TFT substrate 2 which is perpendicular to the normal direction of the liquid crystal layer 5. In this case, the first reflective electrode 7 is a pixel electrode, and the second reflective electrode 8a is a common electrode arranged in lateral with the pixel electrode. The lateral electric field is applied from the pixel electrode (reflective electrode 7) and common electrode (reflective electrode 8a). Further, the transparent electrode 8b is a common electrode facing the reflective electrodes 7, and electrically connected to the common electrode (reflective electrode 8a) of the TFT substrate 2. The vertical electric field is applied from the pixel electrode (reflective electrode 7) and common electrode (transparent electrode 8b). The wiring 4 such as signal lines and the thin film transistors W are located over the transparent insulating substrate SA and covered with the insulating layer 3. The reflective electrode 7 and the reflective electrode 8a are arranged on the same plane which is a surface of the insulating layer 3. In this case, the insulating layer 3 is formed of a transparent resist and a transparent organic film. The reflective electrode 7 and the reflective electrode 8a are formed and separated from each other by patterning a metal layer formed to cover the insulating layer 3. A suitable material for the metal layer is aluminum (Al) or the like, which provides the reflective electrodes 7 and 8a with a high reflectance. The reflective electrode 7 constitutes a drain electrode connected to the thin film transistor W via contact holes formed in the insulating layer 3. The signal line

of the wiring 4 constitutes a source electrode connected to the thin film transistor W. Further, the wiring 4 and the thin film transistor W are arranged outside the transmissive region. Specifically, the wiring 4 is placed between the pixels as a light-shielding film. The thin film transistor W is arranged to overlap the wiring 4 and reflective electrode 7 as a pixel switching device.

[0033] The color filter layer 9 includes colored layers of red R, green G, and blue B arranged in stripes on the transparent insulating substrate SB. The transparent electrode 8b is, for example, of an ITO (Indium Tin Oxide) layer formed on the color filter layer 9. The colored layers of R, G, and B face the columns of the pairs of reflective electrodes 7 and 8a, arranged substantially in a matrix on the side of the TFT substrate 2. Thus, three pairs of reflective electrodes 7 and 8a arranged in a row direction and facing the colored layers of R, G, and B are defined as three subpixels constituting one color pixel.

[0034] In each pixel (each subpixel of the color pixel), the alignment state of liquid crystal molecules is controlled based on the vertical electric field in the reflective region corresponding to a range of the reflective electrode 7, and based on the lateral electric field in the transmissive region outside the reflective electrode 7. In this case, the retardation of the liquid crystal layer 5 must be a quarter in the reflective region. However, a sufficient light utilization efficiency is obtained even when the retardation of the liquid crystal layer 5 is a quarter in the transmissive region. Thus, the thickness of the liquid crystal layer 5 is equal in the transmissive region and in the reflective region. Images are displayed utilizing both reflected light obtained from the reflective region of each pixel and transmitted light obtained from the transmissive region of the pixel.

[0035] The liquid crystal layer 5 contains a nematic liquid crystal having a positive dielectric anisotropy as a liquid crystal component. The nematic crystal may be, for example, ZLI-4792, manufactured by Melc Co., Ltd. At the no-voltage-applied time where no voltage is applied between the pixel electrode and the common electrode, liquid crystal molecules are in a homogeneous alignment to obtain a quarter retardation.

[0036] In order to vary the slow axis of the liquid crystal layer 5 through substantially 90° in the transmissive region, since liquid crystal molecules are set in the homogeneous alignment in the liquid crystal layer 5 at the no-voltage-applied time, it is necessary that the alignment direction of the liquid crystal molecules is almost orthogonal to the direction of the lateral electric field. Thus, horizontal alignment films (not shown) are formed in contact with the liquid crystal layer 5 to cover the reflective electrodes 7 and 8a of the TFT substrate 2 and the transparent electrode 8b of the counter substrate 1. The horizontal alignment films are obtained as a result of a rubbing process effected on an alignment film material that is SE7492, manufactured by NISSAN CHEMICAL INDUSTRIES LTD. and applied to each of the substrates. As shown in FIGS. 1 and 2, the rubbing process is effected in the rubbing direction 12 for the alignment film material on the counter substrate 1 and in the rubbing direction 13 for the alignment film material on the TFT substrate 2. For implementation of the liquid crystal molecules aligned as shown in FIGS. 1 and 2, the actual rubbing directions are offset, by about 1°, from the longi-

tudinal direction of the common electrode (reflective electrode 8a) on the TFT electrode 2, thus allowing the alignment direction of the liquid crystal molecules to be changed more uniformly by the lateral electric field.

[0037] Further, a set of polarizing plate 10a and quarter wavelength plate 11 is attached to an outer surface of the counter substrate 1. A polarizing plate 10b is attached to an outer surface of the TFT substrate 2. The absorption axis 14 of the polarizing plate 10b is set at an angle of 45° to the alignment direction of the liquid crystal molecules at the no-voltage-applied time. Linearly polarized light transmitted through the polarizing plate 10b is converted by the liquid crystal layer 5 into right circularly polarized light and left circularly polarized light. The absorption axis 15 of the polarizing plate 10a is set in a direction 15 shown in FIGS. 1 and 2. The slow axis 16 of the quarter wavelength plate 11 is set in a direction shown in FIGS. 1 and 2. The set of quarter wavelength plate 11 and polarizing plate 10a serves as a circular polarizer. The quarter wavelength plate 11 is obtained by uniaxially orientating polycarbonate or an arton resin, or an inverse wavelength dispersion resin manufactured by TEIJIN LIMITED, or biaxially orienting one of these materials to provide it with a function for compensating for the viewing angle characteristics of the polarizing plates 10a and 10b. Alternatively, a half wavelength plate and a quarter wavelength plate may be combined together so as to eliminate the wavelength dispersion characteristic of the retardation. In this case, the slow axis obtained as a whole may be set in the above direction.

[0038] In the transmissive region, the alignment direction of the liquid crystal molecules is controlled by the lateral electric field so as to maintain the retardation of the liquid crystal layer 5 and change the direction of the slow axis for the retardation. That is, the liquid crystal molecules in the transmissive region operate in the in-plane switching mode (IPS mode) conventionally used for the transmissive type. In this case, the retardation of the liquid crystal layer 5 is set to a quarter at a wavelength of 550 nm, which is a visible light wavelength having a high luminosity factor. Here, the product $\Delta n d$ of the refractive anisotropy Δn of the liquid crystal composition in the liquid crystal layer 5 and the thickness d of the liquid crystal layer 5 is assumed to be 132 nm. It is also assumed that light incident from the TFT substrate 2 to the liquid crystal layer 5 is linearly polarized similarly to light emitted by a backlight BL and then transmitted through the polarizing plate 10b. Then, the polarization state of light transmitted through the liquid crystal layer 5 can be controlled between right circularly polarized light and left circularly polarized light. (In FIGS. 3 and 4, reference numeral 17 conceptually denotes the direction in which light travels, the amount of light transmitted, and the polarization state in connection with the transmissive region. Reference numeral 18a conceptually denotes the direction in which light incident on the reflective electrodes 7 travels, the amount of light transmitted, and the polarization state in connection with the reflective region. Reference numeral 18b conceptually denotes the direction in which light reflected by the reflective electrode 7 travels, the amount of light transmitted, and the polarization state in connection with the reflective region. These are shown by the same reference numerals in the figures of the conventional example.)

[0039] Light transmitted through the liquid crystal layer 5 is converted by the quarter wavelength plate 11 into linearly polarized light whose direction is set orthogonal between the voltage-applied time and the no-voltage-applied time, as shown in FIGS. 3 and 4. This light can be controlled between a state in which almost 100% of it is transmitted through the polarizing plate 10a and a state in which almost 100% of it is absorbed by the polarizing plate 10a. In contrast, in the reflective region, the liquid crystal molecules operate similarly to the reflective region of the conventional transreflective liquid crystal display device shown in FIG. 5, by means of the vertical electric field between the reflective electrode 7 and the transparent electrode 8b.

[0040] At the no-voltage-applied time in FIG. 3, the liquid crystal layer 5 provides a quarter retardation. Consequently, both reflective region and transmissive region are brought into the bright display state. On the other hand, at the voltage-applied time in FIG. 4, no retardation is produced in the liquid crystal layer 5. Consequently, both reflective region and transmissive region are brought into the dark display state.

[0041] In the transreflective liquid crystal display device according to the present embodiment, the second reflective electrode 8a is spaced from the first reflective electrode 7 to transmit light incident from the TFT substrate 2 to the liquid crystal layer 5 while applying a lateral electric field to the liquid crystal layer 5. Thus, the alignment state of the liquid crystal molecules 6a in the reflective region is controlled by the vertical electric field, and the alignment state of the liquid crystal molecules 6b in the transmissive region are controlled by the lateral electric field. In this case, it is unnecessary to provide the reflective electrode together with a transparent electrode on the TFT substrate 2 or to obtain different thicknesses in the liquid crystal layer 5. Therefore, the present liquid crystal display device can be manufactured using a process equivalent to that for a liquid crystal display device that uses a selected one of transmitted light and reflected light for display. Moreover, by providing the quarter wavelength plate 11 on the counter substrate 1 as described above, it is unnecessary to provide any other quarter wavelength plate on the TFT substrate 2.

[0042] The common electrode (transparent electrode 8b) of the counter substrate 1 is not provided for the transmissive region. However, even if the common electrode (transparent electrode 8b) of the counter substrate 1 is provided for the reflective and transmissive regions, a sufficient lateral electric field is ensured, thus enabling the above control. In this case, the luminance of the transmissive region decreases slightly by an amount corresponding to the transmittance of ITO, which is the material of the transparent electrode 8b. However, it is possible to obviate the need for patterning of the ITO layer which is carried out to provide a common electrode (transparent electrode 8b) on the counter substrate 1.

[0043] Further, light must pass through the color filter layer 9 twice in the reflective region. Accordingly, the amount of light transmitted through the reflective region is slightly larger than that transmitted through the transmissive region if the colors of the color filter layer 9 have a uniform density. Thus, by setting the density of the colors in the color filter layer 9 so that the density in the reflective region is lower than that in the transmissive region, it is possible to

provide the reflective region with a sufficient luminance while providing the transmissive region with a sufficient color density and a sufficient color reproduction range. Alternatively, the color reproduction range of the reflective region can be made almost comparable to that of the transmissive region by reducing the thickness of the color filter layer 9 in the reflective region compared to the transmissive region, forming a hole in a part of the color filter layer in the reflective region, or reducing the concentration of pigments or dyes used in the reflective region of the color filter layer 9 compared to the transmissive region of the color filter layer 9. For only monochromatic display, the color filter layer 9 can be omitted. Further, the subpixels previously described are monochromatic pixels.

MANUFACTURE EXAMPLE 1

[0044] The transreflective liquid crystal display device shown in FIGS. 1 and 2 was produced. The contrast characteristic of the display device was measured by selectively applying a driving voltage of 4V between the pixel and common electrodes of the transreflective liquid crystal display device via the thin film transistors W. The contrast exhibited a large value of 500:1 at an illuminance of 0 lux when the backlight BL was turned on and also a large value of 30:1 even at a=100,000 lux. Further, the integrated reflectance of the display device was measured at the no-voltage-applied time; the integrating-sphere reflectance exhibited a large value of 5%. Moreover, the transmittance of the display device was measured at the no-voltage-applied time; the transmittance exhibited a large value of 10%.

COMPARATIVE EXAMPLE 1

[0045] The transreflective type liquid crystal display device shown in FIGS. 5 and 6 was produced. In this case, the aperture ratio of the pixels, the transmittance of the color filter, and the aperture ratio of the transmissive region to the reflective region were similar to those in Manufacture Example 1. The contrast characteristic of the transreflective liquid crystal display device according to Comparative Example 1 was measured in the same manner as in Manufacture Example 1. The contrast exhibited a large value of 500:1 at an illuminance of 0 lux when the backlight BL was turned on and also a large value of 30:1 even at a=100,000 lux. Further, the integrated reflectance of the display device was measured at the no-voltage-applied time; the integrating-sphere reflectance exhibited a large value of 5%. However, when the transmittance of the display device was measured at the no-voltage-applied time, it exhibited a value of 5%, which is only half that in Manufacture Example 1.

COMPARATIVE EXAMPLE 2

[0046] The transreflective type liquid crystal display device shown in FIGS. 9 and 10 was produced. In this case, the aperture ratio of the pixels, the transmittance of the color filter, and the aperture ratio of the transmissive region to the reflective region were similar to those in Manufacture Example 1. The contrast characteristic of the transreflective liquid crystal display device according to Comparative Example 2 was measured in the same manner as in Manufacture Example 1. The contrast exhibited a large value of 500:1 at an illuminance of 0 lux when the backlight BL was turned on and also a large value of 30:1 even at a=100,000

lux. Further, the integrated reflectance of the display device was measured at the no-voltage-applied time; the integrating-sphere reflectance exhibited a large value of 5%. Moreover, the transmittance of the display device was measured at the no-voltage-applied time; the transmittance exhibited a large value of 10%. However, it was difficult to appropriately perform control that varies the thickness of the liquid crystal layer between the transmissive region and the reflective region. Specifically, the thickness of the insulating film, which determines the difference in height between the reflective electrodes and the transparent electrode, was not uniform. As a result, images were not uniformly displayed.

[0047] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A liquid crystal display device comprising:

- a first and second substrates;
- a liquid crystal layer held between said first and second substrates and containing a liquid crystal composition;
- a linear polarizer attached to an outer surface of said first substrate;
- a circular polarizer attached to an outer surface of said second substrate;
- a reflective electrode section which is located in an inner surface of said first substrate and reflects light incident from said second substrate to the liquid crystal layer;
- a counter electrode section which is located in an inner surface of said second substrate and associated with

said reflective electrode section to apply a vertical electric field to said liquid crystal layer in a reflective region corresponding to a range of said reflective electrode section; and

a pair of electrodes which are located in the inner surface of said first substrate and associated with each other to apply a lateral electric field to said liquid crystal layer in a transmissive region existing outside said reflective region and allowing transmission of light incident from said first substrate to said liquid crystal layer.

2. The liquid crystal display device according to claim 1, wherein said reflective electrode section includes a reflective electrode which serves as at least one of said pair of electrodes.

3. The liquid crystal display device according to claim 1, wherein the first substrate has a wiring and switching device located outside said transmissive region and blow said reflective electrode section.

4. The liquid crystal display device according to claim 1, wherein said circular polarizer includes a combination of a linear polarizing plate and a quarter wavelength plate, and said liquid crystal layer is set to have a substantially quarter retardation with respect to incident light of wavelength $\lambda=550$ nm.

5. The liquid crystal display device according to claim 1, wherein said liquid crystal layer contains crystal molecules which are set to a homogeneous alignment at a no-voltage-applied time in a direction orthogonal to a direction of the lateral electric field.

6. The liquid crystal display device according to claim 1, wherein a color filter layer is formed as an underlayer for said counter electrode section.

7. The liquid crystal display device according to claim 6, wherein said color filter layer has a higher transmittance in said reflective region than in said transmissive region.

* * * * *

专利名称(译)	液晶显示装置		
公开(公告)号	US20050219446A1	公开(公告)日	2005-10-06
申请号	US11/097347	申请日	2005-04-04
[标]申请(专利权)人(译)	HISATAKE YUZO		
申请(专利权)人(译)	HISATAKE YUZO		
当前申请(专利权)人(译)	东芝松下显示技术有限公司.		
[标]发明人	HISATAKE YUZO		
发明人	HISATAKE, YUZO		
IPC分类号	G02F1/1335 G02F1/1343		
CPC分类号	G02F1/133555 G02F1/134363 G02F2203/09 G02F2001/134381 G02F2001/134318		
优先权	2004111129 2004-04-05 JP		
外部链接	Espacenet USPTO		

摘要(译)

一种液晶显示装置，包括：TFT基板，对置基板，保持在TFT基板和对基板之间并含有液晶组合物的液晶层，附着在TFT基板外表面上的线性偏振器，圆偏振器附着在对向基板的外表面上的反射电极部分，位于TFT基板的内表面中的反射电极部分，对电极部分位于对向基板的内表面中。反射电极部分包括一对电极，以向液晶层施加横向电场。

