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(54) LIQUID CRYSTAL DISPLAY DEVICE

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(57) **ABSTRACT**

A liquid crystal display device includes a liquid crystal panel; a side-lit backlight that emits light towards the liquid crystal panel through a light guide plate, the backlight further having a reflection layer that reflects light that has passed through the liquid crystal panel and the light guide plate in that order; a first λ/4 plate disposed between a first polarizer and the first substrate, the first λ/4 plate having a retarded phase axis that is at a 45° angle with the transmission axis of the first polarizer; a second λ/4 plate disposed between a second polarizer and the second substrate, the second λ/4 plate having a retarded phase axis that is at 45° with the transmission axis of the second polarizer and that is perpendicular to the retarded phase axis of the first λ/4 plate; and a diffusion layer disposed between the first λ/4 plate and the first substrate.

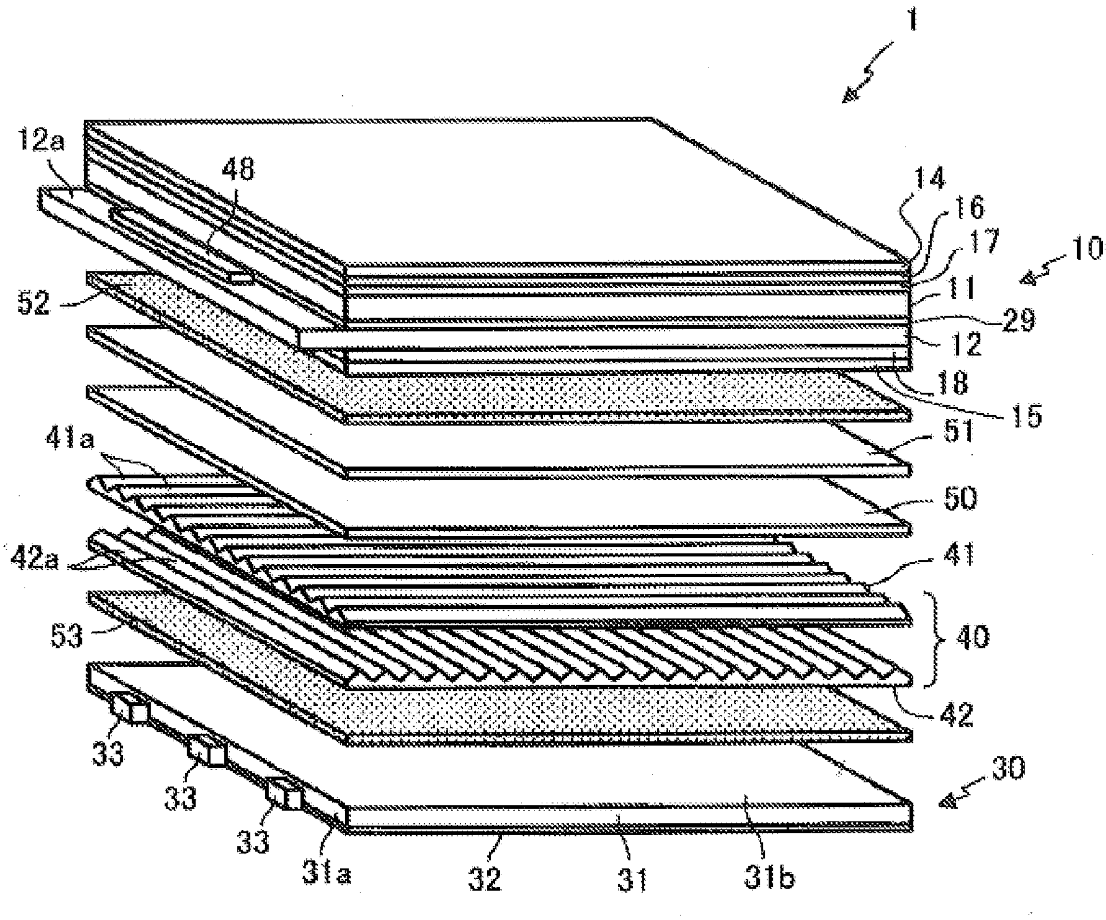
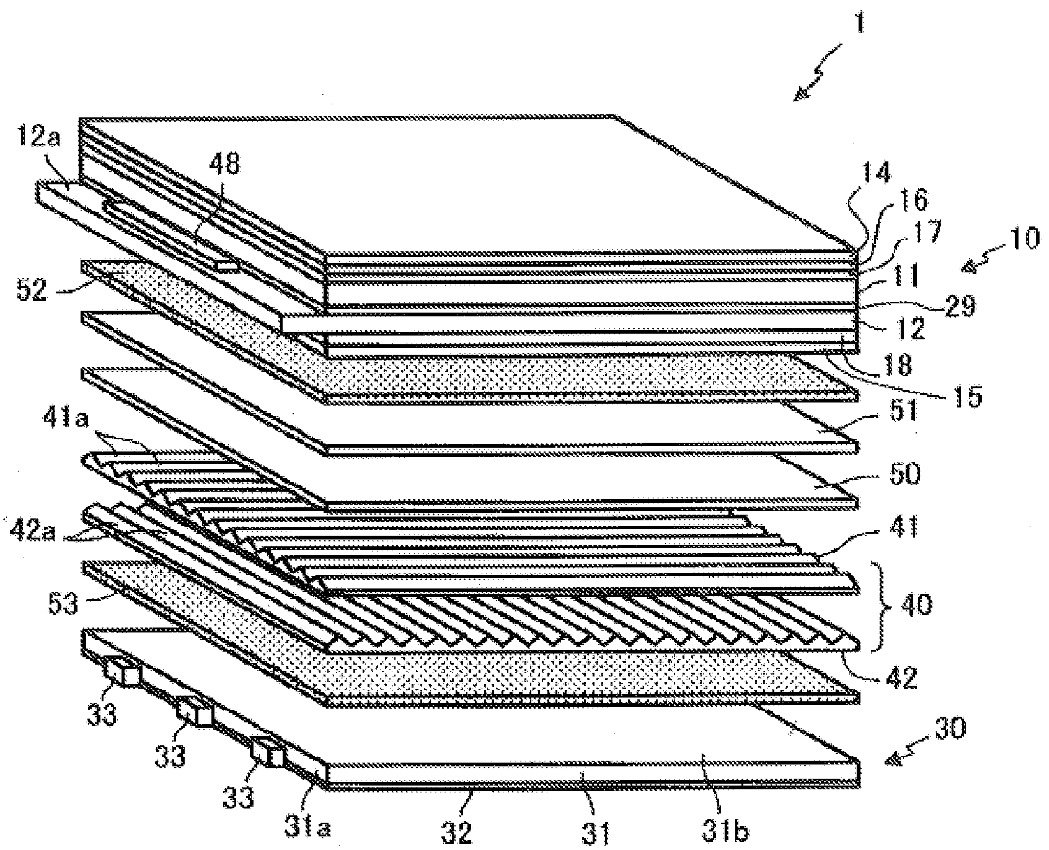


FIG. 1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16
17
10
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52
29
12
18
15
51
41a
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40
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33
33
33
30
31a
32
31
31b

FIG. 2

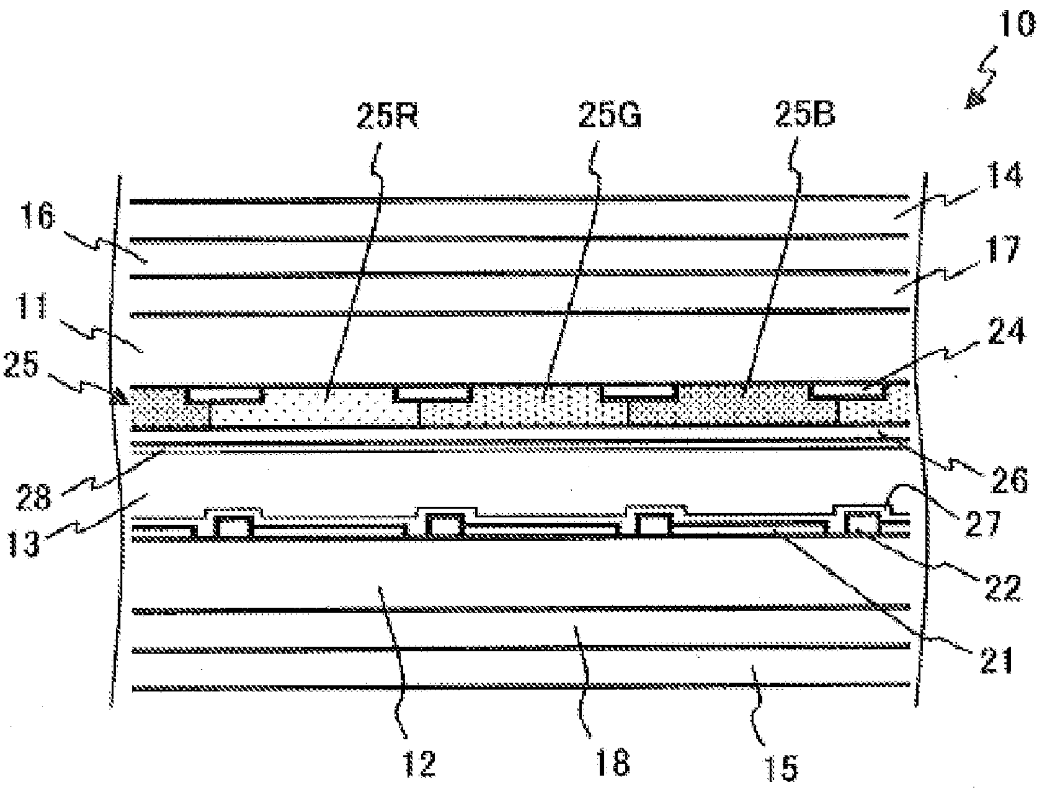
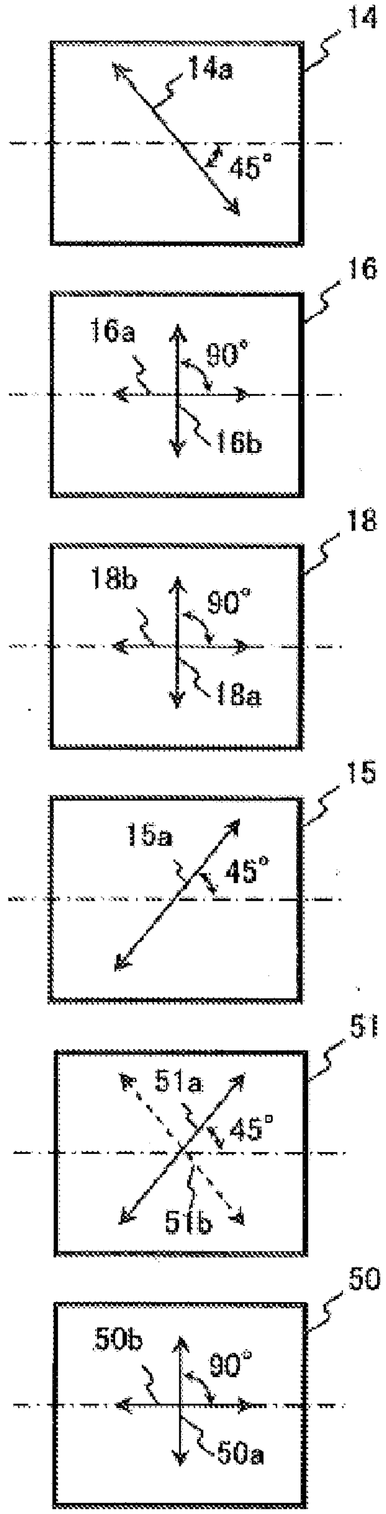


FIG. 3


14
14a
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16
16a
90°
16b
18
18b
90°
18a
15
15a
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51
51a
45°
51b
50
50b
90°
50a

FIG. 4

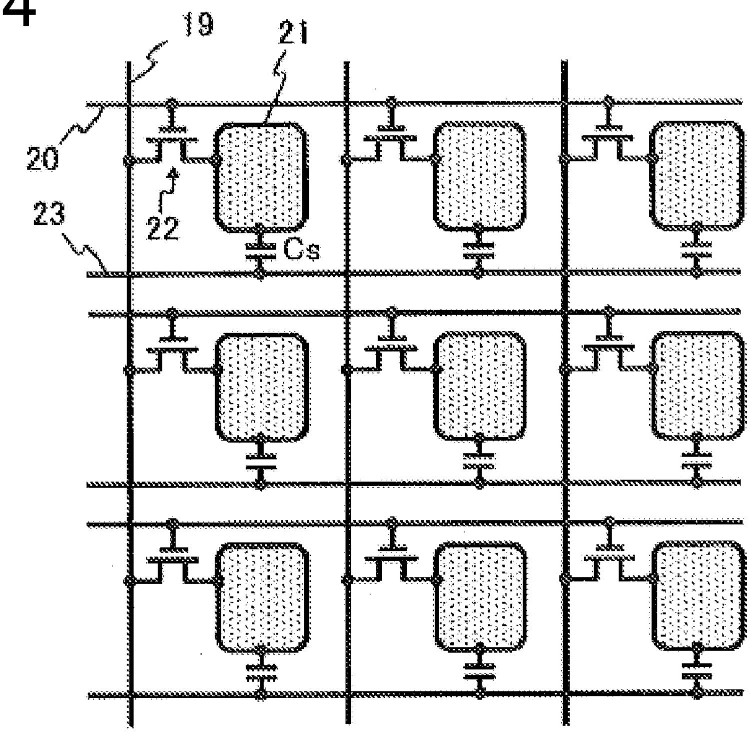


FIG. 5

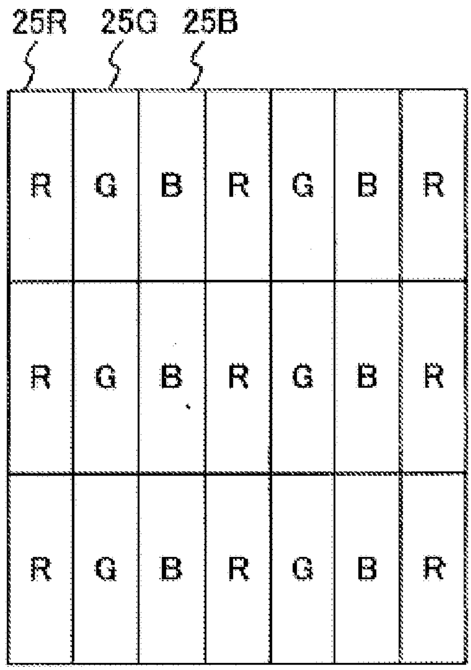


FIG. 6A

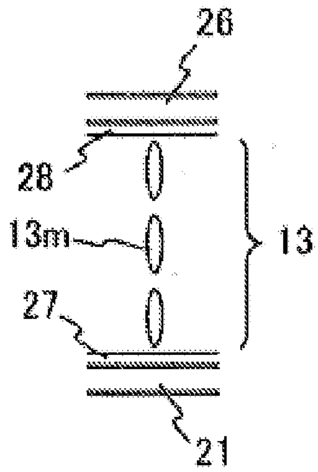


FIG. 6B

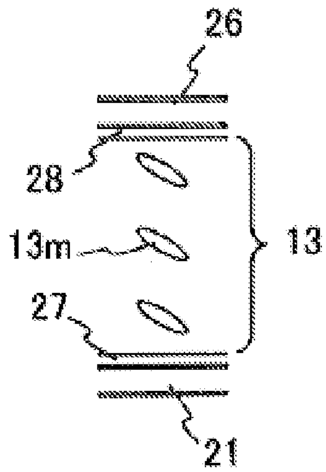


FIG. 7

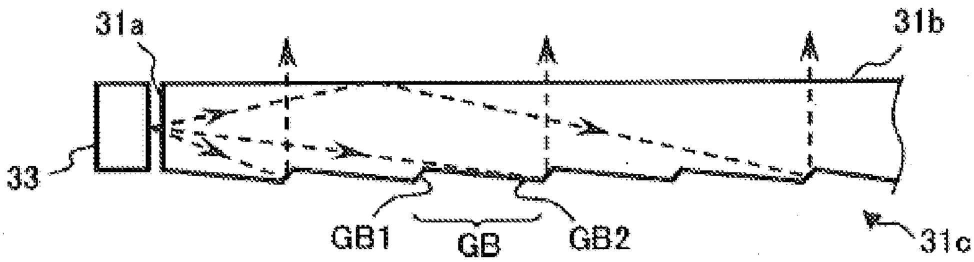


FIG. 8

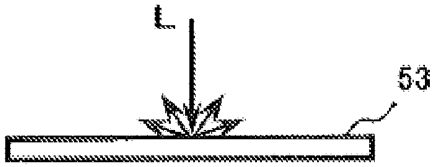


FIG. 9

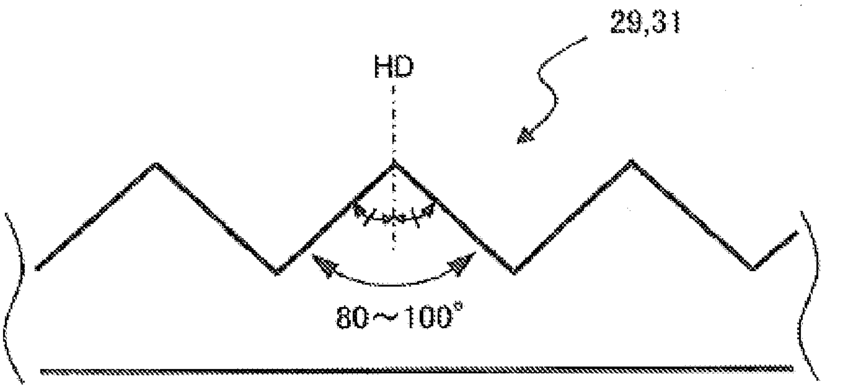


FIG. 10

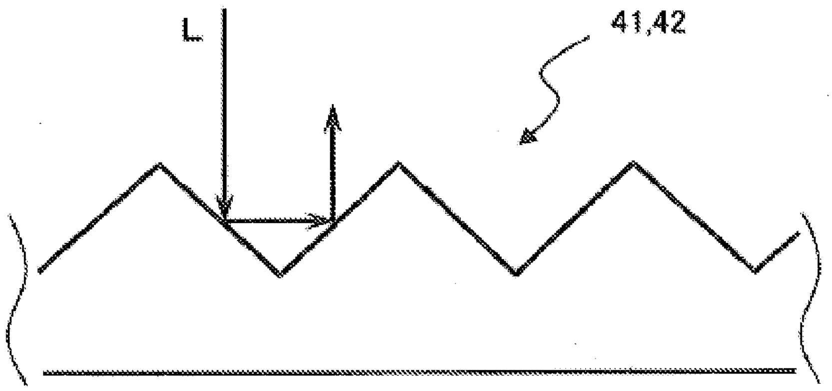


FIG. 11A

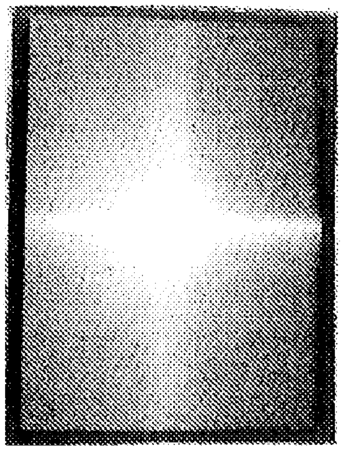


FIG. 11B

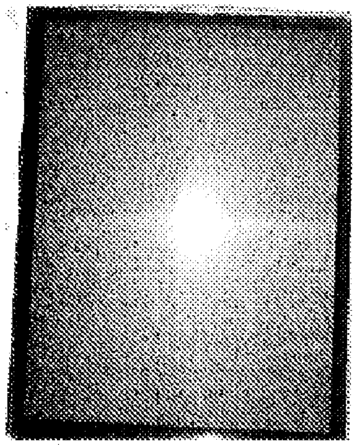
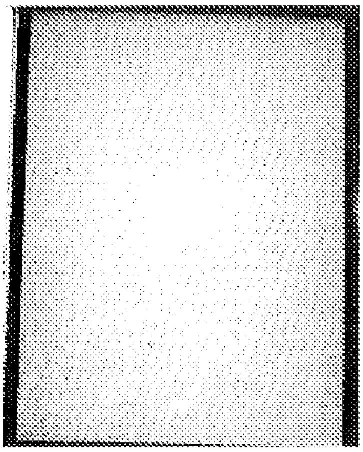


FIG. 11C



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. 2009-255903, filed Nov. 9, 2009, the entire contents of which are hereby incorporated 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 side-lit backlight, capable of displaying using the light emitted from the side-lights, and capable of displaying using external light.

[0004] 2. Description of the Related Art

[0005] In recent years, technologies have been disclosed for liquid crystal display devices that are able to perform both transmissive display, wherein the backlight located behind the liquid crystal panel is used as the light source, and reflective display, wherein external light entering into the front side of the liquid crystal panel passes through the liquid crystal layer of the panel and is reflected back into and through the liquid crystal layer to illuminate the display. For example, Japanese Patent Application Laid-Open Publication No. 2004-93715 discloses a technology that enables each display pixel to perform both transmissive display and reflective display by dividing each display pixel into two regions: in one region, pixel electrodes are formed with transparent materials only, and in the other region, pixel electrodes include reflective materials.

[0006] The disadvantage of this technology is that, since each display pixel is divided into a transmissive area and a reflective area, only half the area of the pixel is dedicated for each display, and the light available for each purpose also decreases by half. This leads to a dimmer and lower visual quality.

SUMMARY OF THE INVENTION

[0007] The purpose of the present invention is to overcome this disadvantage by providing a liquid crystal display device that can utilize both an external light source and a backlight for display illumination, without dividing pixels into transmissive and reflective areas, resulting in a higher visual quality.

[0008] In one aspect, the present invention provides a liquid crystal display device including a liquid crystal panel, including a first substrate having a first electrode thereon, a second substrate having a second electrode thereon, the first electrode on the first substrate facing the second electrode on the second substrate, a liquid crystal layer interposed between the first electrode and the second electrode, the liquid crystal layer including liquid crystal with a negative dielectric constant anisotropy in which liquid crystal molecules are aligned vertically to a substrate surface when 0 V is applied across the first electrode and the second electrode, and are aligned inclinedly in a predetermined direction when a predetermined or higher voltage is applied across the first electrode and the second electrode, and a first polarizer and a second polarizer sandwiching the first substrate and the second substrate therebetween, the first polarizer and the second polarizer having respective transmission axes crossing each other at a right angle; a side-lit backlight that emits light towards the liquid crystal panel through a light guide plate, the backlight further having a reflection layer that reflects light that has passed through the liquid crystal panel and the light guide plate in that order; a first λ/4 plate disposed between the first polarizer and the first substrate, the first λ/4 plate having a retarded phase axis that is at a 45° angle with the transmission axis of the first polarizer; a second λ/4 plate disposed between the second polarizer and the second substrate, the second λ/4 plate having a retarded phase axis that is at 45° with the transmission axis of the second polarizer and that is perpendicular to the retarded phase axis of the first λ/4 plate; and a diffusion layer disposed between the first λ/4 plate and the first substrate.

[0009] In another aspect, the present invention provides a liquid crystal display device including a liquid crystal panel, including a first substrate having a first electrode thereon, a second substrate having a second electrode thereon, the first electrode on the first substrate facing the second electrode on the second substrate, a liquid crystal layer interposed between the first electrode and the second electrode, the liquid crystal layer including liquid crystal with a negative dielectric constant anisotropy in which liquid crystal molecules are aligned vertically to a substrate surface when 0 V is applied across the first electrode and the second electrode, and are aligned inclinedly in a predetermined direction when a predetermined or higher voltage is applied across the first electrode and the second electrode, and a first polarizer and a second polarizer sandwiching the first substrate and the second substrate therebetween, the first polarizer and the second polarizer having respective transmission axes crossing each other at a right angle; a side-lit backlight that emits light towards the liquid crystal panel through a light guide plate, the backlight further having a reflection layer that reflects light that has passed through the liquid crystal panel and the light guide plate in that order; a first phase difference generating member disposed between the first polarizer and the first substrate, the first phase difference generating member circularly polarizing light that has passed through the first polarizer; a second phase difference generating member disposed between the second polarizer and the second substrate, the second phase difference circularly polarizing light that has passed through the second polarizer; and a diffusion layer disposed between the first phase difference generating member and the first substrate.

[0010] 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.

[0011] The 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

[0012] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0013] FIG. **1** is an exploded perspective view of a liquid crystal display device.

[0014] FIG. **2** is an enlarged cross sectional view of a liquid crystal display device.

[0015] FIG. **3** is an explanatory drawing of the relationships among optical axes.

[0016] FIG. **4** is a schematic view of the locations of pixel electrodes.

[0017] FIG. **5** is an example of the color filter arrangement.

[0018] FIG. **6**A is an explanatory drawing of the alignment of liquid crystal molecules when 0 V is applied.

[0019] FIG. **6**B is an explanatory drawing of the alignment of liquid crystal molecules when a predetermined or a higher voltage is applied.

[0020] FIG. **7** is an explanatory drawing of the light path from the light emitting elements, guided by the light guide plate.

[0021] FIG. **8** is an explanatory drawing of backscattering caused by a diffuser.

[0022] FIG. **9** is an enlarged cross sectional view of the prism portion.

[0023] FIG. **10** is an explanatory drawing of the paths of the light reflected by the prism portion.

[0024] FIG. **11**A is an example of the reflection of the sunlight observed with the image of the sun on the display (diffusion layer is not used).

[0025] FIG. **11**B is an example of the reflection of the sunlight observed with the image of the sun on the display (a diffusion layer having a haze value of 45% is used).

[0026] FIG. **11**C is an example of the reflection of the sunlight observed with the image of the sun on the display (a diffusion layer having a haze value of 78% is used).

DETAILED DESCRIPTION OF THE INVENTION

[0027] Embodiments of the present invention are described below. Liquid crystal display device **1** of the present invention can illuminate the display by using the side-lit backlight, as well as by using external light, which is reflected by the side-lit backlight. As shown in FIG. **1**, liquid crystal display device **1** comprises a liquid crystal panel **10**; a light source section **30**, which irradiates illumination light to one side of liquid crystal panel **10**; a light collection section **40**, which is located between light source section **30** and liquid crystal panel **10**; a third retarder **50**, which is located between light collecting section **40** and liquid crystal panel **10**; a reflective polarizer **51**, which is located between the third retarder **50** and liquid crystal panel **10**, a first diffuser **52**, which is located between the reflective polarizer **51** and the liquid crystal panel **10**, and a second diffuser **53**, which is located between light collection section **40** and light source section **30**.

[0028] As shown in FIG. **2**, liquid crystal panel **10** includes a first transparent substrate **11** and the second transparent substrate **12**, which are located opposed to each other and spaced apart from each other by a predetermined distance; a liquid crystal layer **13**, which is sealed in between the first transparent substrate **11** and the second transparent substrate **12**; a first polarizer **14** and a second polarizer **15**, which are located to support the first transparent substrate **11** and the second transparent substrate **12**, wherein the transmission axes of the polarizers cross each other at a right angle; the first retarder **16**, which is located between the first polarizer **14** and the first transparent substrate **11**; a diffusion layer **17**, which is located between the first retarder **16** and the first transparent substrate **11**; and a second retarder **18**, which is located between the second transparent substrate **12** and the second polarizer **15**. As described later, the diffusion layer **17** diffuses certain light. The diffusion layer **17** also serves as an adhesive layer through which the first retarder **16** is bonded to the first transparent substrate **11**.

[0029] As shown in FIG. **3**, the first retarder **16** is disposed so that a retarded phase axis **16***a* and an advanced phase axis **16***b* intersect at a right angle, and the retarded phase axis **16***a* is at a 45° angle with transmission axis **14***a* of the first polarizer **14**. The optical constants for the first retarder **16** are set to provide a phase difference of 1/4 wavelength between the light having a polarization component that is parallel to the retarded phase axis **16***a* and the light having a polarization component that is parallel to the advanced phase axis **16***b*. That is, the first retarder **16** is a so-called λ/4 plate, which, by being disposed relative to the first polarizer **14** as described above, serves as a circular polarizer together with the first polarizer **14**.

[0030] As shown in FIG. **3**, the second retarder **18** has a retarded phase axis **18***a* and an advanced phase axis **18***b*, which intersect each other at a right angle, and the retarded phase axis **18***a* is at a 45° angle with transmission axis **15***a* of the second polarizer **15**, and the retarded phase axis **18***a* is at a 90° angle with retarded phase axis **16***a* of the first retarder **16**. The optical constants for the second retarder **18** are set to provide a phase difference of 1/4 wavelength between the light having a polarization component that is parallel to the retarded phase axis **18***a* and the light having a polarization component that is parallel to the advanced phase axis **18***b*. That is, similar to the first retarder **16**, the second retarder **18** is a so-called λ/4 plate, which, by being disposed relative to the second polarizer **15** as described above, serves as a circular polarizer together with the second polarizer **15**. The arrangement of the second polarizer **15** and the second retarder **18** relative to the first polarizer **14** and the first retarder **16**, which has been described above, allows the second retarder **18** and the second polarizer **15** to block the incoming light, circularly polarized to a predetermined direction after passing through, sequentially, the first polarizer **14** and the first retarder **16**, entering the second retarder **18**. The above-mentioned arrangement of items also allows the first retarder **16** and the first polarizer **14** to block the incoming light, circularly polarized in the predetermined direction after passing through, sequentially, the second polarizer **15** and the second retarder **18**, entering into the first retarder **16**.

[0031] The second transparent substrate **12** has, on the side facing the first transparent substrate **11**, as shown in FIG. **4**, a plurality of signal lines **19**, which are disposed in parallel to one another; a plurality of scanning lines **20**, which are intersecting with the plurality of signal lines **19**; a plurality of pixel electrodes **21**, which are formed of a transparent conductive film such as ITO and are located at the locations corresponding to the intersections of signal lines **19** and scanning lines **20**; and a plurality of thin film transistors **22**, each of which is disposed for each pixel electrode **21**. In other words, a plurality of display pixels are arranged in matrix over the image display area, wherein one pixel electrode **21** and one thin film transistor **22** correspond to each display pixel. Scanning line **20** is formed for each pixel row to send the gate signal to thin film transistor **22**. Signal line **19** is formed in correspondence to each pixel column to apply the display signal voltage to pixel electrode **21** through thin film transistor **22**.

[0032] On the second transparent substrate **12**, auxiliary capacitance line **23** is formed for each pixel row. Auxiliary capacitance Cs is formed for each display pixel by the insulating film located between auxiliary capacitance line **23** and pixel electrode **21**. Auxiliary capacitance line **23** is set to the same potential as the counter electrode **26** described later.

[0033] Thin film transistor **22** has a gate electrode, which is formed on the surface of the second transparent substrate **12**; a gate insulating film, which is made of a transparent insulating material and is formed to cover the gate electrode; an i-type semiconductor film, which is formed over the gate insulating film and faces the gate electrode through the gate insulating film; and a drain electrode and a source electrode, each of which are formed on the respective sides of the i-type semiconductor film through an n-type semiconductor film. For each thin film transistor **22**, the source electrode is connected to the corresponding pixel electrode **21**, the gate electrode is connected to the corresponding scanning line **20**, and the drain electrode is connected to the corresponding signal line **19**.

[0034] As shown in FIG. **2**, the first transparent substrate **11** has, on the side facing the second transparent substrate **12**, a light shield layer **24** having apertures that approximately correspond to pixel electrodes **21**, color filters **25**, and a counter electrode **26**, which are formed in this order from the first transparent substrate **11**. The light shield layer **24** may be formed of a light-shielding metal film or resin film, and the area of the aperture for light transmission is consistent for all display pixels. The area on each pixel electrode **21** that corresponds to the above-mentioned aperture is formed entirely of a transparent conductive film such as ITO. In liquid crystal device **1**, both light for transmissive display and light for reflective display pass through this area. In other words, the entire aperture can be used for both transmissive display and reflective display.

[0035] Color filters **25** have red color filter **25**R for red component, green color filter **25**G for green component and blue color filter **25**B for blue component. As shown in FIG. **5**, for example, a color filter for each color component is provided for each display pixel. The counter electrode **26**, made of a transparent conductive film such as ITO, is formed to provide the same potential for all display pixels. For example, counter electrode **26** is formed as one piece film to cover the entire color filter **25** for all display pixels.

[0036] For each display pixel, alignment films **27** and **28** are applied over pixel electrode **21** and counter electrode **26**, respectively, for controlling the initial alignment of liquid crystal molecules in liquid crystal layer **13**. The alignment films **27** and **28** are, as shown in FIG. **6**A, vertical alignment films that align the liquid crystal molecules **13***m* vertically to the substrate surface when 0 V is applied across the pixel electrode **21** and the counter electrode **26**. Liquid crystal layer **13** comprises liquid crystals with negative dielectric constant anisotropy. As shown in FIG. **6**B, liquid crystal molecules **13***m* are aligned to a predetermined direction when a predetermined or higher voltage is applied across the pixel electrode **21** and the counter electrode **26**. The higher the voltage applied across the pixel electrode **21** and the counter electrode **26**, the further the liquid crystal molecules **13***m* are aligned horizontally to the substrate surface.

[0037] That is, liquid crystal panel **10** is configured in such a way as to prevent the occurrence of an in-plane birefringence in the substrate plane when 0 V is applied across the pixel electrode **21** and the counter electrode **26**; to induce an in-plane birefringence in the substrate plane when a predetermined or higher voltage is applied across the pixel electrode **21** and the counter electrode **26**; and to induce a larger in-plane birefringence as even higher voltage is applied. Preferably, $d \cdot \Delta n$ of liquid crystal layer **13**, wherein d is the thickness of liquid crystal layer **13** and Δn is the birefringence ratio, is set to less than $\lambda/2$. To control the visible light transmission, λ is preferably set to 550 nm, at which the spectral sensitivity of human eyes is believed to be maximized.

[0038] When light that is circularly polarized by the first polarizer **14** and the first retarder **16**, or by the second polarizer **15** and the second retarder **18** enters liquid crystal layer **13**, the light exits liquid crystal layer **13** without being modified when 0 V is applied across the pixel electrode **21** and the counter electrode **26**. The circularly polarized light is, then, linearly polarized again by the retarder located at the exit side of liquid crystal layer **13** to the same polarization direction of the light prior to its entry into the liquid crystal layer **13**. The light, therefore, is blocked by the polarizer on the exit side. In other words, liquid crystal panel **10** can block the light when 0 V is applied across pixel electrode **21** and counter electrode **26**.

[0039] On the other hand, when a predetermined or higher voltage is applied across the pixel electrode **21** and the counter electrode **26**, the light that has entered liquid crystal layer **13** is polarized according to the alignment angle of liquid crystal molecules **13***m*, and then exits the liquid crystal layer **13**. In this case, the light cannot be linearly polarized again by the retarder located at the exit side of liquid crystal layer **13** to the same polarization direction of the light prior to its entry into the liquid crystal layer **13**. The polarizer at the exit side, therefore, lets the light transmit by the amount determined by the alignment angle of liquid crystal molecules. In other words, liquid crystal panel **10** can let the light transmit when a predetermined or higher voltage is applied across the pixel electrode **21** and the counter electrode **26**.

[0040] When a predetermined or higher voltage is applied across the pixel electrode **21** and the counter electrode **26** as described above, liquid crystal molecules **13***m* are, as shown in FIG. **6**B, aligned to a predetermined direction. Since the light entering liquid crystal layer **13** is circularly polarized, if the alignment angles of all liquid crystal molecules **13***m* are the same, the light is presented uniform birefringence regardless of the alignment direction of liquid crystal molecules **13***m*. Therefore, in this embodiment, a high-definition display, free from surface roughness caused by irregular molecule inclination direction, can be obtained.

[0041] The first transparent substrate **11** and the second transparent substrate **12** are bonded by a frame-shaped sealing member **29**, which surrounds the image display area having a plurality of display pixels arranged therein. Liquid crystal is sealed in the space surrounded by the frame-shaped seal member **29** to form the above-mentioned liquid crystal layer **13**.

[0042] As shown in FIG. **1**, liquid crystal panel **10** in the second transparent substrate **12** of the liquid crystal panel **10**, which is facing the first transparent substrate **11** across the liquid crystal layer **13**, the driver circuit **48** is mounted on the projected area **12***a* of the second transparent substrate **12**, which area extends beyond one end of the first transparent substrate **11**. The driver circuit **48** is electrically connected to a plurality of terminals formed on the projected area **12***a*, and sends scanning signals to individual scanning lines **20** via these terminals. It also applies display signal voltages to individual signal lines **19**, and also applies the common voltage to the auxiliary capacitance line **23** and to the counter electrode **26**.

[0043] The driver circuit **48** controls the voltage applied across the liquid crystal layer **13** through the pixel electrode **21** and the counter electrode **26**. As described earlier, the voltage changes the alignment angle of liquid crystal molecules **13***m* to control the amount of light transmitted by each display pixel of the liquid crystal panel **1** is controlled.

[0044] Liquid crystal panel **10** is configured to let the light originated from the light source section **30** enter liquid crystal layer **13** from the side the second transparent substrate **12** is located.

[0045] As shown in FIG. **1**, light source section **30** is a so-called side-lit type backlight, which is located at the side opposite from the liquid crystal panel **10**, and includes a light guide plate **31**, which is larger than the image display area of liquid crystal panel **10** and made of a transparent plate-shaped material; a reflector **32**, which is located against the light guide plate **31**; and a plurality of the light-emitting elements **33**, which emit light towards one of the edge surfaces of light guide plate **31**.

[0046] The plurality of light-emitting elements **33** emit light when the liquid crystal display device of the present invention is in transmission display mode, wherein the light radiated from light source section **30** is utilized for illumination. Each light-emitting element has red, green, and blue LEDs that generate red, green and blue components, respectively. Light-emitting elements **33** preferably have LEDs that can be turned on/off in response to the brightness of the ambient light surrounding the liquid crystal display device.

[0047] Light guide plate **31**, as shown in FIG. **7**, guides each color component of the light emitted from the light emitting element **33** into the edge surface **31***a* of the light guide plate **31**, to the liquid crystal panel **10** through the main surface **31***b* (hereinafter "the first main surface **31***b*"), which is facing the liquid crystal panel **10**. A plurality of grooves GB are formed on another main surface **31***c*, which is facing the first main surface **31***b* (hereinafter "the second main surface **31***c*"). The grooves GB are formed in parallel with edge surface **31***a* to which the light is emitted. The cross section of a groove GB has two sides, GB**1** and GB**2**, which form an apex. GB**1** and GB**2** have respective different inclination angles against the first main surface **31***b* of the light guide plate **31**. More specifically, side GB**1**, which is proximal to the light-emitting elements **33**, has a larger inclination angle than side GB**2**.

[0048] As shown in dashed lines in FIG. **7**, the light generated by the light-emitting element **33** enters the light guide plate **31** through the edge surface **31***a*. The light is then reflected inwards and directed towards the liquid crystal panel **10** through the first main surface **31***b* of the light guide plate **31**. Light guide plate **31** may be made of a transparent material, such as acrylic, that has a larger refractive index than air, e.g., 1.5.

[0049] Reflector **32** reflects the light leaked from the second main surface **31***c* of the light guide panel **31** back into light guide panel **31**, and reflects external light that has entered through liquid crystal panel **10** and light guide plate **31** back to light guide plate **31** and to liquid crystal panel **10**. That is, the reflector **32** improves the light utilization efficiency for transmissive display wherein the liquid crystal display device uses the light generated by the light-emitting elements **33**; and reflects the external light for reflective display wherein the liquid crystal display device uses external light for illumination. The reflector **32** may be a glass substrate or plastic substrate on which a metal such as silver or aluminum is vapor-deposited.

[0050] The second diffuser **53** diffuses the light from the first main surface **31***b* of the light guide plate **31**, to minimize irregular distribution of the light from the light guide plate **31**. The second diffuser **53** includes a transparent sheet with light-scattering particles dispersed throughout having a haze value of about 55% to about 85%. As shown in FIG. **8**, the second diffuser **53** back-scatters a portion of external light L that has entered from outside and passed through liquid crystal panel **10**. The second diffuser **53**, therefore, serves as a supplemental reflector for reflective display in which the liquid crystal display device **1** uses external light for illumination.

[0051] Light collection section **40** is designed to collect the light that was released from light guide plate **31** and then became diffused by the second diffuser **53** on its way to liquid crystal panel **10**, and then to guide the collected light towards the liquid crystal panel **10** for efficient utilization of light. The light collection section **40** includes a first prism array **41** and a second prism array **42**, which are transparent sheet-like members such as acrylic resin. The first prism array **41** has a plurality of straight lines of prism portions **41***a* on one side, and the prism portions **41***a* are arranged in parallel with each other. The first prism array **41** is positioned so that the extending direction of prism portions **41***a* on the first prism array **41** is perpendicular to the extending direction of grooves GB formed on light guide plate **31**, for example. The second prism array **42** has a plurality of straight lines of prism portions **42***a* on one side, and the prism portions **42***a* are arranged in parallel with each other. The second prism array **42** is positioned so that the extending direction of the prism portions **42***a* on the second prism array **42** is parallel to the extending direction of grooves GB formed on the light guide plate **31**, for example. As shown in FIG. **9**, the prism portions **41***a* and **42***a* have a cross section of an isosceles triangle shape which is symmetrical with respect to the normal line HD of liquid crystal panel **10**. Here, the apex angle is within a range of about 80° to about 100°, preferably about 90°.

[0052] Prism arrays **41** and **42** reflect a portion of external light L that has entered from outside and passed through liquid crystal panel **10**, as shown in FIG. **10**, with sloping surfaces constituting prism portions **41***a* and **42***a*. The prism arrays **41** and **42**, therefore, serve as supplemental reflectors for reflective display in which the liquid crystal display device uses external light for illumination.

[0053] Reflective polarizer **51**, as shown in FIG. **3**, has a transmission axis **51***a* and a reflection axis **51***b*, which cross each other at a right angle. The reflective polarizer **51** allows components of incoming light that are parallel to the transmission axis **51***a* transmit, but reflects light components that are parallel to the reflection axis **51***b*. The reflective polarizer **51** is disposed so that its transmission axis **51***a* is parallel to the transmission axis **15***a* of the second polarizer **15**.

[0054] The third retarder **50**, having retarded phase axis **50***a* and advanced phase axis **50***b*, which intersect each other at a right angle, is disposed so that the retarded phase axis **50***a* and the advanced phase axis **50***b* are at a 45° angle with transmission axis **51***a* and reflection axis **51***b* of the reflective polarizer **51**. The third retarder **50** is a so-called λ/4 plate, in which the optical constants of the third retarder **50** are set to provide a phase difference of 1/4 wavelength between the light having a polarization component parallel to the retarded phase axis **50***a* and the light having a polarization component parallel to the advanced phase axis **50***b*.

[0055] The arrangement of the reflective polarizer **51**, the third retarder **50**, and reflector **32** as described above improves the light utilization efficiency. Of the light originating from the light-emitting elements **33** and passing through the light guide plate **31**, the light having a polarization plane that is perpendicular to transmission axis **15***a* of the second polarizer **15** is first reflected by the reflective polarizer **51** on its way to the crystal panel **10** so as to be modified to become parallel to the transmission axis **15***a* of the second polarizer **15**, and then is redirected to liquid crystal panel **10**. The third retarder **50** may be arranged so that the retarded phase axis **50***a* of the third retarder **50** is parallel or perpendicular to retarded phase axis **16***a* of the first retarder **16** or retarded phase axis **18***a* of the second retarder **18**.

[0056] The first diffuser **52**, designed to prevent the occurrence of moire interference between the display pixels on liquid crystal panel **10** and prism arrays **41** and **42** of light collection section **40**, includes a transparent sheet dispersed with light-scattering particles for a haze value of about 60% to about 85%. Similar to the second diffuser **53**, the first diffuser **52** back-scatters a portion of external light that has entered from outside and passed through liquid crystal panel **10**. The first diffuser **52**, therefore, serves as a supplemental reflector for reflective display in which the liquid crystal display device **1** uses external light for illumination. The first diffuser **52** may be an adhesive layer that bonds the reflective polarizer **51** to the liquid crystal panel **10**. That is, the first diffuser **52** may be an adhesive layer that bonds the reflective polarizer **51** and the second polarizer **15**.

[0057] In the liquid crystal display device **1** discussed above, the external light can enter liquid crystal device **1** through the liquid crystal panel **10** and advance to light guide plate **31** regardless of the on/off status of light-emitting elements **33** as long as the voltage that enables light transmission through liquid crystal layer **13** is on. This external light that has reached the light guide plate **31** passes through the first main surface **31***b* of the light guide plate **31** and then the second main surface **31***c* of the light guide plate **31**, bounces off at the reflector **32**, and returns to the liquid crystal panel **10** through the second main surface **31***c* of light guide plate **31** and then the first main surface **3** lb of light guide plate **31**. That is, liquid crystal display device **1** is able to perform both transmissive display in which the light generated by the light-emitting element is used for illumination, and reflective display in which the external light is used for illumination, without dividing each display pixel into two regions: one for transmissive display and another for reflective display.

[0058] In addition to the reflector **32** in the light source section **30** that reflects the external light, liquid crystal display device **1** uses the first diffuser **52**, the second diffuser **53**, and prism arrays **41** and **42** as supplemental external light reflectors. In other words, the liquid crystal display device **1** has multiple reflecting planes between liquid crystal panel **10** and reflector **32**, which causes a blur in the image of liquid crystal panel **10** projected on reflector **32** by external light. This improves the visual quality by preventing the doubling of the image displayed on the liquid crystal panel **10**, which otherwise might take place due to the distance between liquid crystal panel **10** and reflector **32**.

[0059] In above-mentioned exemplary liquid crystal display device **1**, when any portion of the external light L that has passed through the first polarizer **14** and the first retarder **16** is reflected off at the interface such as the surface of the first substrate **11** on the side of the first polarizer **14** prior to the entry into liquid crystal layer **13**, the light reflected as circular polarized is being linearly polarized having polarization components in the direction perpendicular to the transmission axis **14***a* of the first polarizer **14** en route to the first polarizer **14**, and thus is blocked by the first polarizer **14**. That is, in liquid crystal display device **1**, the visibility of the reflective display can be improved because the external light that did not pass through the liquid crystal layer **13** is reflected by the first polarizer **14** and the first retarder **16**.

[0060] Diffusers **52** and **53** or diffusion layer **17** located before or after liquid crystal layer **13** improves visibility in the reflective display by diffusing external light sufficiently even when reflector **32** is minor-finished for efficient reflection of light from light-emitting elements **33**. FIG. **11**A, FIG. **11**B and FIG. **11**C show examples of white displays in the reflective display mode with the image of the sun on the display. FIG. **11**A is the case that diffusion layer **17** is not present; FIG. **11**B is the case that diffusion layer **17** having a haze value of 45% is present; and FIG. **11**C is the case that diffusion layer **17** having a haze value of 78% is present. These examples indicate that diffusion layer **17** having a haze value of at least 45% suppresses the specular reflection of sunlight, which otherwise becomes visible in a shape of a cross for reflective display. The diffusion layer **17** may be disposed between the first polarizer **14** and the first retarder **16**. The diffusion layer **17**, however, is preferably located near the light shield layer **24**, which aperture pattern corresponds to patterns of display pixels in order to maintain high resolution display when utilizing light from the light-emitting element **33**. Therefore, diffusion layer **17** is preferably located between the first retarder **16** and the first substrate **11**. The surface of the first polarizer **14** on the side of external light entry is preferably formed smooth to prevent light diffusion, and, more preferably, is coated with a reflection preventing material.

[0061] Although each light-emitting element **33** is assumed to have red, green and blue LEDs in the embodiment described above, each light-emitting element **33** may have a pseudo-white LED (blue LED+yellow fluorescent material) or high color rendering LED (blue LED+red/green fluorescent material).

What is claimed is:

1. A liquid crystal display device comprising:

a liquid crystal panel, including:

a first substrate having a first electrode thereon,

a second substrate having a second electrode thereon, the first electrode on the first substrate facing the second electrode on the second substrate,

a liquid crystal layer interposed between the first electrode and the second electrode, the liquid crystal layer including liquid crystal with a negative dielectric constant anisotropy in which liquid crystal molecules are aligned vertically to a substrate surface when 0 V is applied across the first electrode and the second electrode, and are aligned inclinedly in a predetermined direction when a predetermined or higher voltage is applied across the first electrode and the second electrode, and

a first polarizer and a second polarizer sandwiching the first substrate and the second substrate therebetween, the first polarizer and the second polarizer having respective transmission axes crossing each other at a right angle;

a side-lit backlight that emits light towards the liquid crystal panel through a light guide plate, the backlight further having a reflection layer that reflects light that has passed through the liquid crystal panel and the light guide plate in that order;

a first λ/4 plate disposed between the first polarizer and the first substrate, the first λ/4 plate having a retarded phase axis that is at a 45° angle with the transmission axis of the first polarizer;

a second λ/4 plate disposed between the second polarizer and the second substrate, the second λ/4 plate having a retarded phase axis that is at 45° with the transmission axis of the second polarizer and that is perpendicular to the retarded phase axis of the first λ/4 plate; and

a diffusion layer disposed between the first λ/4 plate and the first substrate.

2. The liquid crystal display device according to claim **1**, wherein reflective display and transmissive display are performed at a same region of the liquid crystal layer.

3. The liquid crystal display device according to claim **2**, wherein the diffusion layer is an adhesive layer through which the first λ/4 plate and the first substrate are bonded together.

4. The liquid crystal display device according to claim **3**, wherein a surface of the first polarizer on the external light entry side is formed substantially flat to prevent light diffusion and is treated with a reflection prevention coating.

5. The liquid crystal display device according to claim **1**, wherein the diffusion layer has a haze value of about 45% or higher.

6. The liquid crystal display device according to claim **1**, wherein a light shield layer having an aperture corresponding to the second electrode is formed on the first substrate, and at least a portion of the second electrode that overlaps the aperture is formed as a transparent electrode.

7. The liquid crystal display device according to claim **1**, further comprising a third λ/4 plate disposed between the second polarizer and the light guide plate, the third λ/4 plate having a retarded phase axis that is parallel or perpendicular to the retarded phase axis of the first λ/4 plate.

8. The liquid crystal display device according to claim **7**, further comprising a reflective polarizer disposed between the second polarizer and the third λ/4 plate, the reflective polarizer having a reflection axis that is at a 45° angle with the retarded phase axis of the third λ/4 plate.

9. The liquid crystal display device according to claim **8**, further comprising a first diffuser disposed between the second polarizer and the reflective polarizer.

10. The liquid crystal display device according to claim **9**, wherein the first diffuser has a haze value of about 60% to about 85%.

11. The liquid crystal display device according to claim **9**, wherein the first diffuser serves as an adhesive layer that bonds the reflective polarizer and the second polarize.

12. The liquid crystal display device according to claim **8**, further comprising:

a first prism array disposed between the first diffuser and the light guide plate; and

a second prism array disposed between the first prism array and the light guide plate,

wherein prisms of the second prism array are arranged perpendicular to prisms of the first prism array.

13. The liquid crystal display device according to claim **12**, further comprising a second diffuser disposed between the second prism array and the light guide plate.

14. The liquid crystal display device according to claim **13**, wherein the second diffuser has a haze value of about 55% to about 85%.

15. The liquid crystal display device according to claim **1**, wherein the backlight has light-emitting elements that emit light to an edge surface of the light guide plate, and wherein the light guide plate guides light from the light emitting elements towards the liquid crystal panel.

16. A liquid crystal display device comprising:

a liquid crystal panel, including:

a first substrate having a first electrode thereon,

a second substrate having a second electrode thereon, the first electrode on the first substrate facing the second electrode on the second substrate,

a liquid crystal layer interposed between the first electrode and the second electrode, the liquid crystal layer including liquid crystal with a negative dielectric constant anisotropy in which liquid crystal molecules are aligned vertically to a substrate surface when 0 V is applied across the first electrode and the second electrode, and are aligned inclinedly in a predetermined direction when a predetermined or higher voltage is applied across the first electrode and the second electrode, and

a first polarizer and a second polarizer sandwiching the first substrate and the second substrate therebetween, the first polarizer and the second polarizer having respective transmission axes crossing each other at a right angle;

a side-lit backlight that emits light towards the liquid crystal panel through a light guide plate, the backlight further having a reflection layer that reflects light that has passed through the liquid crystal panel and the light guide plate in that order;

a first phase difference generating member disposed between the first polarizer and the first substrate, the first phase difference generating member circularly polarizing light that has passed through the first polarizer;

a second phase difference generating member disposed between the second polarizer and the second substrate, the second phase difference circularly polarizing light that has passed through the second polarizer; and

a diffusion layer disposed between the first phase difference generating member and the first substrate.

* * * * *

专利名称(译)	液晶显示装置

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摘要(译)

一种液晶显示装置，包括：液晶面板;通过导光板向所述液晶面板发射光的侧光式背光源，所述背光源还具有反射层，所述反射层按顺序反射已经通过所述液晶面板和所述导光板的光;设置在第一偏振器和所述第一基板之间的第一λ/ 4板，所述第一λ/ 4板具有与所述第一偏振器的透射轴成45°角的延迟相位轴;设置在第二偏振器和第二基板之间的第二λ/ 4板，所述第二λ/ 4板具有与第二偏振器的透射轴成45°的延迟相位轴，并且垂直于第二偏振器的延迟相位轴所述第一λ/ 4板;以及设置在第一λ/ 4板和第一基板之间的扩散层。