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(54) **DISPLAY DEVICE, ELECTRONIC DEVICE AND LIGHT GUIDE**

ANZEIGEGERÄT, ELEKTRONISCHE VORRICHTUNG UND LICHTLEITER

DISPOSITIF D'AFFICHAGE, DISPOSITIF ELECTRONIQUE ET GUIDE LUMINEUX

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- **PATENT ABSTRACTS OF JAPAN vol. 013, no. 333 (E-794), 26 July 1989 (1989-07-26) -& JP 01 096922 A (MITSUBISHI RAYON CO LTD), 14 April 1989 (1989-04-14)**
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Description

Technical Field

[0001] The present invention relates to a technical field of a display device such as a liquid crystal device, and more particularly to a technical field of a transflective monochrome or color display device capable of displaying while switching between a reflective display and a transmissive display, and an electronic apparatus using such a display device.

Background Art

[0002] So far, reflective liquid crystal devices, because of its small power consumption, have come into widespread use as additional sections of portable units, apparatus and others, while there is a problem which arises with the reflective liquid crystal devices, however, in that, because a display is made visible through the use of the external light, the display is unreadable in the dark. For this reason, a transflective liquid crystal device, in which a display is made visible through the use of the external light in the light as in common reflective liquid crystal devices but through the use of an internal light source in the dark, has been proposed as exemplified by Japanese Unexamined Utility Model Publication No. 57-049271. Particularly, in connection with a transflective liquid crystal device utilizing a polarization axis variable means for rotating a polarization axis of a TN (Twisted Nematic) liquid crystal, a STN (Super-Twisted Nematic) liquid crystal or the like, this applicant has proposed a transflective display device using, as a means to better the brightness in the reflective display, a polarized light splitter which causes the reflection of a linearly polarized light component running in a predetermined direction while allowing the transmission of a linearly polarized light component advancing in a direction perpendicular thereto (Japanese Patent Application No. 8-245346). Referring to Fig. 22, a description will be made hereinbelow of a transflective display device using this polarized light splitter.

[0003] In Fig. 22, a TN liquid crystal panel is composed of an upper polarizer 5130, an upper glass substrate 5302, a lower glass substrate 5304, a polarized light splitter 5160, a semipermeable light absorbing layer 5307 and a light source 5210. In the illustration, a TN liquid crystal, placed between the upper glass substrate 5302 and the lower glass substrate 5304, is divided into a voltage non-applied area 5120 and a voltage applied area 5110.

[0004] First, a description will be given hereinbelow of achromatic display of a reflective display. Incident light from the exterior of the display device, indicated as an optical path 5601, turns through the upper polarizer 5130 to linearly polarized light in a direction parallel with the paper surface, and then form a linearly polarized light component in a direction perpendicular to the paper surface with its polarizing direction being twisted by 90° in the voltage non-applied section 5120 of the TN liquid crystal panel , and further is reflected on the polarized light splitter 5160 in a state of the same linearly polarized light in the direction perpendicular to the paper surface, and again undergoes a twist of 90° in its polarizing direction in the voltage non-applied section 5120 of the TN liquid crystal panel to develop into a linearly polarized light component in a direction parallel with the paper surface, finally going out of the upper polarizer 5130. Accordingly, no application of a voltage to the TN liquid crystal panel makes a white display. Thus, the white display light is light reflected on the polarized light splitter 5160, which produces a brighter display than a conventional transflective display device. The light indicated by an optical path 5603 forms linearly polarized light in a direction parallel with the paper surface due to the upper polarizer 5130, and advances with its polarizing direction remaining intact even in the voltage applied section 5110 of the TN liquid crystal panel and with it remaining the same linearly polarized light in the direction parallel with the paper surface, and further transmits with its polarizing direction being also kept intact even in the polarized light splitter 5160, thereafter being absorbed by the semipermeable light absorbing layer 5307 to produce a black display.

[0005] Secondly, a description will be given hereinbelow of achromatic display of a transmissive display. Light indicated by an optical path 5602 passes through an opening section made in the semipermeable light absorbing layer 5307 and turns to linearly polarized light in a direction parallel with the paper surface in the polarized light splitter 5160, and then undergoes a twist of 90° in its polarizing direction in the voltage non-applied section 5120 of the TN liquid crystal panel to form linear polarized light perpendicular to the paper surface, thereafter absorbed in the upper polarizer 5130 to produce a black display. Light indicated by an optical path 5604 comes in through an opening section made in the semipermeable light absorbing layer 5307 and turns through the polarized light splitter 5160 to a linearly polarized light in a direction parallel with the paper surface and passes through the upper polarizer 5130 with its polarizing direction being kept intact even in the voltage applied section 5110 of the TN liquid crystal panel and with it remaining the same linearly polarized light parallel with the paper surface, thus providing a white display.

[0006] As described above, the transflective display device (Japanese Patent Application No. 8-245346) this applicant has proposed can accomplish more proper switching between a reflective display and a transmissive display in accordance with ON/OFF of a light source, which provides a relatively bright reflective display.

[0007] On the other hand, with the recent progress of portable equipment (portable telephones, PDAs, watches) or OA equipment, a request has existed for coloring in liquid crystal displays, and even a requirement for coloring has occurred in equipment using such a transflective liquid crystal device. In general, a color filter is put to use for coloring of displays on a liquid crystal device. However, the color filter absorbs light so that the display tends to be dark. Therefore, in order to enhance the utilization efficiency of light, there has sometimes been employed a mode (which will be referred to hereinafter as an "SPD") in which a polarizer is provided only on the visible side of the liquid crystal device and a reflecting layer is provided on an inner surface of a liquid crystal substrate. In the case of this SPD mode, only one polarizer can improve the utilization efficiency of light. Additionally, for realizing a transflective liquid crystal device with the SPD mode, a hole(s) is made in a portion of the reflecting layer or the reflecting layer is made relatively thin; whereupon, the reflecting layer has a permeable function to enable a transmissive display.

[0008] Japanese patent application number 07036025A, published on 7th February 1995, discloses a back-light source which does not change its brightness depending on an observing angle. To achieve this the wavelength of the bright-line spectra of the fluorescent tube constituting the light source is made to extend between the center of the selective reflection wavelength region of a liquid crystal layer at the time of perpendicular incidence on the liquid crystal layer and its short-wavelength end. Since the luminous body is formed of the fluorescent tube having the bright-line spectra, the wavelength of the spectra is made to be coincident with the selective reflection wavelength region of the CH liquid crystal layer. The liquid crystal of the spectra is set between the center of the selective reflection wavelength region of the liquid crystal layer at the time of perpendicular incidence on the liquid crystal layer and its short-wavelength end and, therefore, even if the wavelength is shifted to the short-wavelength end of the selective reflection wavelength region by the angle, the bright-line spectra of the tube do not deviate from the selective reflection wavelength region of the CH liquid crystal layer in the range of the wide angle, and a back-light source having a high brightness in the wide angle range is obtained.

Disclosure of the Invention

[0009] However, the use of the polarized light splitter shown in Fig. 22 causes a positive-negative reversal phenomenon due to a difference between incidence on the polarized light splitter from the upper side and incidence from the lower side. Thus, the mode of the positive-negative reversal between a transmissive display and a reflective display creates a problem in that it is unsuitable for the display device depending on the applications of the display device, or is impracticable. Additionally, because of the use of the semipermeable light absorbing layer, the utilization efficiency of light drops, particularly at the transmissive display, it becomes dark.

[0010] On the other hand, with the transflective liquid crystal disclosed in Japanese Unexamined Utility Model Publication No. 57-049271, since a thick transparent substrate of a liquid crystal panel is interposed between a liquid crystal layer and a transflective layer, double image or display bleeding occurs due to parallax, particularly for coloring, the color filter cannot exhibit sufficient color development.

[0011] Furthermore, the SPD mode requires lowering reflectance of a reflecting layer, which leads to a dark reflective display. Conversely, if the reflectance of the reflecting layer is increased in order to brighten the reflective display, then a dark transmission display occurs, which requires the enhancement of back light luminance. As described above, with the conventional transflective color display device, extreme difficulty is encountered in accomplishing a bright good-looking color display not only at the reflective display and but also at the transmissive display.

[0012] Accordingly the present invention has been developed in consideration of the above-mentioned problems, and in a first aspect thereof provides a display device having the features recited in claim 1. An electronic apparatus incorporating the display device forms a second aspect in accordance with claim 9.

[0013] Embodiments of the invention are set forth in the dependent claims.

[0014] The operations and other advantages of this invention will become apparent from the following description of embodiments.

Brief Description of the Drawings

[0015]

Fig. 1 is a perspective view schematically showing a polarized light splitter for use in a display device according to each of the embodiments of the present invention.

Fig. 2 is an illustration for explaining the principle of a reflective display in monochrome display devices according to first to sixth embodiments of this invention.

Fig. 3 is an illustration for explaining the principle of a transmissive display in monochrome display devices according to first and second examples, which do not form part of the claimed invention, and first to fourth embodiments of this invention.

Fig. 4 is an exploded cross-sectional view for explaining a display device according to the first example.

Fig. 5 is an exploded cross-sectional view for explaining a display device according to a second example.

Fig. 6 is an illustration of displays in the first and second examples.

Fig. 7 is an exploded cross-sectional view for explaining a display device according a first embodiment of this invention.

Fig. 8 is a schematic cross-sectional view for explaining a display device according to a third embodiment of this invention.

Fig. 9 is an illustration for explaining the principle of a reflective display of color display devices according to third to fifth examples and fifth to tenth embodiments of this invention.

Fig. 10 is an illustration for explaining the principle of a transmissive display of the color display devices according to the third to fifth examples and fifth to tenth embodiments of this invention.

Fig. 11 is an exploded cross-sectional view for explaining a display device according to the third example.

Fig. 12 is an exploded cross-sectional view for explaining the display device according to the fourth example.

Fig. 13 is a characteristic illustration of a characteristic of a color filter for use in the display device according to the fifth example.

Fig. 14 is a table showing transmittance ratios and chromaticities of red, green and blue colors of the color filter for use in the display device according to fifth example.

Fig. 15 is an exploded cross-sectional view for explaining the display device according to a fifth embodiment of this invention.

Fig. 16 is an exploded cross-sectional view for explaining the display device according to a seventh embodiment of this invention.

Fig. 17 is an exploded cross-sectional view for explaining the display device according to a ninth embodiment of this invention.

Fig. 18 is an illustration for explaining the display device according to the ninth embodiment of this invention.

Fig. 19 is schematic cross-sectional view for explaining the display device according to a tenth embodiment of this invention.

Fig. 20 is an illustration of a surface configuration of a display device according to an eleventh embodiment of this invention.

Fig. 21 is a schematic perspective view showing various types of electronic apparatus according to a twelfth embodiment of this invention.

Fig. 22 is a schematic cross-sectional view for explaining a conventional display device.

Best Mode for Carrying out the Invention

[0016] Referring to the drawings, in each of the embodiments, a description will be given hereinbelow of the best modes of the present invention.

(Operational Principle of Monochrome Display Device)

[0017] First of all, referring to Figs. 1, 2 and 3, the description will begin at the operational principle of monochrome display devices according to first and second examples and first to fourth embodiments of this invention to be explained later. Fig. 1 is a perspective view schematically showing a polarized light splitter for use in each example and embodiment of this invention, Fig. 2 is an illustration for describing a case in which the external light is incident on a monochrome display device using this polarized light splitter, and Fig. 3 is an illustration for describing a case in which a light source is turned on in this monochrome display device.

[0018] In Fig. 1, a polarized light splitter 160 has a construction in which two different layers, an A layer 1 and a B layer 2, are piled up alternately on each other to produce a piled-up structure of a plurality of layers. The refractive index (nAX) of the A layer 1 in the X direction and the refractive index (nAY) thereof in the Y direction differ from each other. The refractive index (nBX) of the B layer 2 in the X direction and the refractive index (nBY) thereof in the Y direction are equal to each other. Furthermore, the refractive index (nAY) of the A layer 1 in the Y direction and the refractive index (nBY) of the B layer in the Y direction are equal to each other.

[0019] Thus, of the light incident on the polarized light splitter 160 from a direction perpendicular to the upper surface 5 of the polarized light splitter 160, the linearly polarized light in the Y direction penetrates the polarized light splitter 160 and is outputted from the lower surface 6 as the linearly polarized light in the Y direction. On the other hand, of the light incident on the polarized light splitter 160 from a direction perpendicular to the lower surface 6 of the polarized light splitter 160, the linearly polarized light in the Y direction penetrates the polarized light splitter 160 and emerges from the upper surface 5 as the linearly polarized light in the Y direction. The Y direction forming the penetrating direction will be referred to herein as a polarization axis.

[0020] When the thickness of the A layer 1 in the Z direction is taken as tA, the thickness of the B layer 2 in the Z direction is taken as tB and the wavelength of the incident light is taken as λ, if

$$tA \cdot nAX + tB \cdot nBX = \lambda/2, \qquad \text{......} \quad (2)$$

then, of the light incident on the polarized light splitter 160 in the direction perpendicular to the upper surface 5 of the polarized light splitter 160, the linearly polarized light in the X direction is reflected by this polarized light splitter 160 as the linearly polarized light in the X direction. Additionally, the linearly polarized light having the wavelength λ and incident on the lower surface 6 of the polarized light splitter 160 is reflected by this polarized light splitter 160 as the linearly polarized light in the X direction. The X direction forming the reflection direction will be referred to herein as a reflection axis.

[0021] Furthermore, when the thickness tA of the A layer 1 in the Z direction and the thickness tB of the B layer 2 in the Z direction are changed variously to satisfy the foregoing equation (2) throughout the overall wavelength range of the visible light, a polarized light splitter is obtainable which, in addition to the monochrome, throughout all the white light, reflects the linearly polarized light in the X direction as the linearly polarized light in the X direction and transmits the linearly polarized light in the Y direction as the linearly polarized light in the Y direction.

[0022] Such a polarized light splitter has been disclosed as a reflecting polarizer in the International Publication (WO95/17692).

[0023] Fig. 2 is an illustration for explaining a case in which the external light is incident on a display device using the polarized light splitter 160 (that is, a reflective display).

[0024] In Fig. 2, this display device employs a TN liquid crystal 140 as polarization axis variable means. Above the TN liquid crystal 140, a polarizer 130 is provided as one example of first polarized light splitting means. Under the TN element 140, in order, a polarizer 135 is located as one example of second polarized light splitting means, a light scattering layer 150 is located as one example of a light diffusion means, and a polarized light splitter 160 is located as one example of third polarized light splitting means. Additionally, under the polarized light splitter 160, a light guide 190 is placed as one example of a light guider for guiding light source light emitted from a light source 191 such as an LED so that it is incident on the polarized light splitter 160 from the underside, and a reflecting plate 200 is situated under the light guide 190.

[0025] First, referring to Fig. 2, a description will be made as the left side of this display device under the external light is a voltage applied section 110 while the right side thereof is a voltage non-applied section 120.

[0026] In the voltage non-applied section 120 on the right side, the natural light 121 turns through the polarizer 130 to linearly polarized light parallel with the paper surface, and then forms linearly polarized light in a direction perpendicular to the paper surface with its polarizing direction being twisted 90° by the TN liquid crystal 140, thereafter passing through the polarizer 135 as linearly polarized light in a direction perpendicular to the paper surface. This linearly polarized light is developed into white scattering light by means of the light scattering layer 150, and subsequently is evolved into linearly polarized light perpendicular to the paper surface by means of the polarized light splitter 160, thereafter penetrating the same polarized light splitter 160. Subsequently, the linearly polarized light passes through the transparent light guide 190 and, after being reflected on the reflecting plate 200, again passes through the light guide 190 and the polarized light splitter 160 as linearly polarized light in a direction perpendicular to the paper surface. This linearly polarized light is again evolved into white scattering light by the light scattering layer 150 and developed into linearly polarized light in a direction perpendicular to the paper surface by the polarizer 135, before passing through this polarizer 135. Furthermore, it undergoes a twist of its polarizing direction by 90° in the TN liquid crystal 140 to produce linearly polarized light in a direction parallel with the paper surface, then emerging from the polarizer 130 as linearly polarized light 122 in a direction parallel with the paper surface.

[0027] Particularly, in this invention, since the light scattering layer 150 is provided between the polarizer 135 and the polarized light splitter 160, when the light 122 is viewed from the polarizer 130 side, it looks as if the scattering plane of the light diffusion layer 150 in which the reflected light is scattered forwardly is at the reflecting position. That is, because of the forward scattering in the light diffusion layer 150, little or no image nor shadow appears at the more rear side than the light diffusion layer 150. Accordingly, in the device structure, even if the distance from the TN liquid crystal 140 to the reflecting plate 200 is prolonged, no double image nor bleeding in display occurs due to the parallax resulting therefrom.

[0028] Incidentally, such a light scattering layer 150 is also producible, for example, by mixing, into a polymeric resin, particulate of a resin different in refractive index from the polymeric resin. Additionally, this light scattering layer 150 can be formed to have a forward scattering characteristic, for example, at a haze value of approximately 15 to 95%, while the degree of the forward scattering characteristic depends experientially, experimentally and theoretically upon the device specification or the required image quality.

[0029] The light reflected on the reflecting plate 200 includes, in addition to linearly polarized light in a direction perpendicular to the paper surface, linearly polarized light in a direction parallel with the paper surface. This linearly polarized light parallel with the paper surface is reflected on the polarized light splitter 160 and is again reflected by the reflecting plate 200 so that its polarizing direction varies, at least partially form linearly polarized light in a direction perpendicular to the paper surface. This linearly polarized light passes through the polarized light splitter 160. The repetition of this operation enables effective utilization of light for brightness. In this way, in the voltage non-application section, the light incident thereon can effectively be used owing to the polarized light splitter 160 to produce a bright display.

[0030] In the voltage applied section 110 on the left side, the natural light 111 turns to linearly polarized light in a direction parallel with the paper surface by means of the polarizer 130, and subsequently passes through the TN liquid crystal 140 without changing its polarizing direction and is absorbed by the polarizer 135, thereby producing a dark state.

[0031] As described above, in the case of the reflective display, in the voltage non-applied section 120, the light reflected on the reflecting plate 200 is scattered forwardly by the light scattering layer 150 to be once developed into white scattering light, so it is possible to reduce the double image and bleeding in display and further to effectively utilize the light by the polarized light splitter 160, thereby offering a bright display. On the other hand, in the voltage applied section 110, the light is absorbed by the polarizer 135 to produce a dark display so that high contrast is attainable.

[0032] Furthermore, referring to Fig. 3, a description will be given of a case in which the light source 191 is turned on (that is, the transmissive display). The device shown in Fig. 3 is identical to that shown in Fig. 2.

[0033] In the voltage non-applied section 120 on the right side, of the light source light 125, the linearly polarized light in a direction perpendicular to the paper surface passes through the polarized light splitter 160. Additionally, of the light source light 125, the linearly polarized light in a direction parallel with the paper surface is reflected on the polarized light splitter 160 and again reflected on the reflecting plate 200 so that its polarizing direction varies, so that a portion thereof forms linearly polarized light in a direction perpendicular to the paper surface and passes through the polarized light splitter 160. When this operation is repeated, almost all the light passes through the polarized light splitter 160. The linearly polarized light passing through the polarized light splitter 160 and running in the direction perpendicular to the paper surface is evolved into white scattering light by the light scattering layer 150 and then developed by the polarizer 135 into linearly polarized light in a direction perpendicular to the paper surface to pass through the polarizer 135. This light undergoes a twist of its polarizing direction by 90° in the TN liquid crystal 140 to form linearly polarized light in a direction parallel with the paper surface, then passing through the polarizer 130. That is, it is possible to effectively use almost all the light, thus offering extreme brightness.

[0034] In the voltage applied section 110 on the left side, as well as the voltage applied section 120, the light source light 115 reaches the TN liquid crystal 140 and then turns to linearly polarized light in a direction perpendicular to the paper surface without a change of its polarizing direction by the TN liquid crystal 140, and subsequently is absorbed by the polarizer 130, thereby producing darkness.

[0035] As described above, in the case of the transmissive display, in the voltage non-applied section 120, it is possible to effectively use almost all the light owing to the polarized light splitter 160, thus offering extreme brightness. In the voltage applied section 110, the polarizer 130 performs the absorption to produce darkness. Accordingly, in the state where the light source 190 comes on, a black display is attainable on the background of the light source color. That is, it is possible to gain a monochrome display without causing the positive-negative reversal between the transmissive display relying on the light source light and the reflective display (see Fig. 2) relying on the external light.

[0036] Incidentally, although the above description relates to the normally white mode, the normally black mode is also acceptable. However, in the normally white mode, the brightness effect not only in the reflective display but also in the transmissive display is still exhibitable.

[0037] In addition, in the above description, although the TN liquid crystal 140 has been used as an example, even if in place of the TN liquid crystal 140 there is employed another device such as a STN liquid crystal or an ECB (Electrically Controlled Birefringence) liquid crystal in which the polarization axis is changeable by voltages or the like, the basic operational principle is the same.

[0038] A description will be given hereinbelow of first and second examples, which do not form part of the invention as claimed, and first to fourth embodiments, which do form part of the invention as claimed based on the operational principle described above with reference to Figs. 1 to 3.

(First Example)

[0039] Fig. 4 is an exploded cross-sectional view for explaining a display device according to a first example.

[0040] In the display device 10 according to this example, as one example of the polarization axis variable means, an STN cell 20 is put to use. Above the STN cell 20, a retardation film 14 and a polarizer 12 are provided in this order. Under the STN cell 20, a polarizer 15 and a polarized light splitter 40 are provided in this order. Additionally, there is placed a light source 70 whereby light can be incident on the polarized light splitter 40 from the underside. An LED (Light Emitting Diode) 71 is employed as the light source 70, and light therefrom is emitted upwardly through a light guide 72. Under the light guide 72, a diffusion plate 30 is provided as one example of light diffusion means and a reflecting plate 80 is set as one example of light reflecting means. In Fig. 4, for convenience in the description, the respective members are shown in a state spaced from each other, but in fact these members are disposed in a state adhered closely to each other.

[0041] As preferable transparent materials for formation of the light guide 72, there are transparent resins such as an acrylic resin, a polycarbonate resin and an amorphous polyolefine resin, inorganic transparent materials such as a glass, and complexes thereof. The thickness is 0.3 to 2 mm. Small projections exist on its surface, and the size of the projections is required to be above approximately 5 μm for the prevention of the influence of diffraction, because the wavelength of the visible light is approximately from 380 nm to 700 nm. Additionally, in order to prevent us from caring about the projections when seeing with the naked eye, preferably the size thereof is below approximately 300 μm. Still additionally, taking the convenience in production into consideration, preferably the size of the projections is approximately above 10 μm but below 100 μm. Moreover, the ratio between the height of the projections and the width thereof (if it has a general cylindrical configuration, its diameter) can be less than 1 : 1. In this embodiment, the configuration of the projections is a cylinder having a diameter of 20 μm and a height of 15 μm, and the pitch is 20 μm.

[0042] The reflecting plate 80 is made in a manner that aluminum is deposited on a PET film or silver is deposited thereon, alternatively it can be aluminum foil or the like. As the configuration of the surface of the reflecting plate 80, a mirror surface or a scattering surface is acceptable.

[0043] In the STN cell 20, an STN liquid crystal 26 is enclosed in a cell comprising two glass substrates 21 and 22 and a seal member 23. A transparent electrode 24 is put on a lower surface of the glass substrate 21 while a transparent electrode 25 is placed on an upper surface of the glass substrate 22. As the transparent electrodes 24 and 25, it is possible to use an ITO (Indium Tin Oxide), a tin oxide or the like. The retardation film 14 is used as a color compensation optical anisotropy, and is used for correcting the coloring made in the STN cell 20. As the polarized light splitter 40 in this example, the polarized light splitter described with reference to Fig. 1 is put to use.

[0044] Secondly, a description will be given of an operation of the display device 10 according to this example.

[0045] First, the description will begin at a reflective display utilizing the external light.

[0046] In the voltage non-applied area, the external light becomes linearly polarized light in a predetermined direction due to the polarizer 12, and then its polarizing direction is twisted a predetermined angle by means of the STN cell 20. This linearly polarized light passes through the polarizer 15 and the polarized light splitter 40 and further passes through the light guide 72, thereafter being reflected on the reflecting plate 80. The reflected light again passes through the light guide 72, the polarized light splitter 40 and the polarizer 15 and reaches the STN cell 20 where its polarizing direction is twisted by a predetermined angle, finally emerging as linearly polarized light from the polarizer 12. Also, the light whose polarizing direction is changed in the reflecting plate 80 is repeatedly reflected between the polarized light splitter 40 and the reflecting plate 80 and advances from the polarized light splitter 40 to the STN cell 20 in due course, thus producing a bright display. Since the diffusion plate 30 is provided between reflecting plate 80 and the polarized light splitter 40, the reflected light from the polarized light splitter 40 becomes white.

[0047] On the other hand, in the voltage applied area, the natural light becomes linearly polarized light in a predetermined direction by means of the polarizer 12, and then passes through the STN cell 20 as linearly polarized light and is absorbed by the polarizer 15, thus producing darkness.

[0048] Furthermore, a description will be given of a transmissive display using the light source light.

[0049] When the light source comes on, in the voltage non-applied area, light emitted from the light source 70 forms linearly polarized light through the polarized light splitter 40 and penetrates it. This linearly polarized light is evolved into linearly polarized light in a predetermined direction by the STN cell 20 and then outputted without being absorbed by the polarizer 12.

[0050] On the other hand, in the voltage applied area, light emitted from the light source 70 becomes linearly polarized light through the polarized light splitter 40 and penetrates it. This linearly polarized light is developed into linearly polarized light in a predetermined direction by the STN cell 20 and is absorbed by the polarizer 12. That is, darkness occurs.

[0051] In consequence, not only under the external light but also under the light source lighting, it is possible to provide a bright positive display in which black appears on the background of white, with no positive-negative reversal. Additionally, since the diffusion plate 30 is provided between the STN cell 20 and the reflecting plate 80, even if the distance therebetween is long, it is possible to reduce the double image and bleeding in the reflective display. Still additionally, since the polarized light splitter 40 enables the effective utilization of light, it is possible to offer both bright reflective and transmissive displays.

(Second Example)

[0052] Fig. 5 is a schematic illustration for explaining a liquid crystal display device according to a second example, which does not form part of this invention. The second example differs from the above-described first example in that the diffusion 30 is positioned above the light guide 72. Other constructions are the same as those in the first example. In Fig. 5, the components similar to those in Fig. 4 are marked with the same reference numerals, and the description thereof will be omitted.

[0053] Fig. 6 shows a display according to the first example and a display according to the second example, designated at (A) and (B), respectively, with both displaying "EPSON". Combined with an image appearing on the liquid crystal layer, a shadow appears dimly on the diffusion plate 30 due to the reflection on the reflecting plate 80. In this first example, the shadow is seen dimly at a rear side corresponding to the thickness of the light guide 72, while in the second example, the shadow does not lie deep, so the image is easier to see. In Fig. 6, for comparison in operation between the second example and the first example, the double image is shown remarkably. But in fact, since the diffusion plate 30 is provided between the STN cell 20 and the reflecting plate 80 as mentioned above in the first example, although inferior to the second example, also in the first example the double image or bleeding is reducible in the reflective display.

(First Embodiment)

[0054] Fig. 7 is a schematic illustration for explaining a liquid crystal display device according to a first embodiment of this invention. The first embodiment differs from the above-described example in that the diffusion plate 30 is positioned above the polarized light splitter 40. Other constructions are the same as those in the first example. In Fig. 7, components corresponding to those in Fig. 4 are marked with the same reference numerals, and the description thereof will be omitted.
[0055] With the first embodiment, the distance between the diffusion plate 30 and the STN cell 20 is shortened, and double image, see Fig. 6, or bleeding in display is reducible accordingly.

(Second Embodiment)

[0056] A second example differs from the above-described first embodiment in that a pressure sensitive adhesive containing a diffusing agent is used as the diffusion plate 30. Other constructions are the same as those in the first example.
[0057] According to the second embodiment, as well as the first embodiment, double image, see Fig. 6, or bleeding in display is reducible. In addition, as seen in Fig. 7, the polarizer 15 and the polarized light splitter 40, integrated with each other, can be adhered to the STN cell 20, which is advantageous on manufacturing.

(Third Embodiment)

[0058] Fig. 8 is a schematic illustration for explaining a liquid crystal display device according to a third embodiment of this invention. The difference of the third embodiment from the above-described first example is that the diffusion plate 30 is positioned above the polarizer 15. Other constructions are the same as those in the first example. In Fig. 8, components corresponding to those in Fig. 4 arc marked with the same reference numerals, and the description thereof will be omitted.
[0059] According to the third embodiment, the distance between the diffusion plate 30 and the STN cell 20 is shortened, and the double image, see Fig. 6, or the bleeding is reducible accordingly.

(Fourth Embodiment)

[0060] The difference of a fourth embodiment from the above-described third embodiment is that, in place of the polarized light splitter described with reference to Fig. 1, a combination of a circularly polarizer, constructed with a cholesteric liquid crystal or the like, and a $\lambda/4$ plate is used as the polarized light splitter 40. Other constructions are the same as those in the first example.
[0061] According to the fourth embodiment, as in the case of the third embodiment, the double image, see Fig. 6, or the bleeding is reducible.

(Operational Principle of Color Display Device)

[0062] Furthermore, referring to Figs. 9 and 10, a description will be given of an operational principle of a color display device related to third to fifth examples and fifth to tenth embodiments of this invention which will be described later. Fig. 9 is an illustration for explaining a case in which the external light is incident on a color display device using the polarized light splitter shown in Fig. 1 (that is, a reflective display), while Fig. 10 is an illustration for describing a case in which a light source is turned on in this color display device (that is, a transmissive display). In Figs. 9 and 10, components corresponding to those in Figs. 2 and 3 are marked with the same reference numerals, and they will be omitted from the description.
[0063] In Figs. 9 and 10, this display device is equipped with a color filter 145 forming one example of coloring means and adjacent to the lower side of the TN liquid crystal 140.
[0064] First, referring to Fig. 9, a description will be given of the case of the external light incidence (that is, the reflective display), assuming that the left side of this display device under the external light is used as a voltage applied section 110 and the right side thereof is used as a voltage non-applied section 120.
[0065] In the voltage non-applied section 120 on the right side, the natural light 121 turns to linearly polarized light in a direction parallel with the paper surface through the polarizer 130 and then forms linearly polarized light in a direction perpendicular to the paper surface with its polarizing direction being twisted 90° by the TN liquid crystal 140, and further

passes through the color filter 145 and penetrates the polarizer 135 as linearly polarized light in a direction perpendicular to the paper surface. This linearly polarized light is evolved into white scattering light by the light scattering layer 150, and is developed into linearly polarized light in a direction perpendicular to the paper surface by the polarized light splitter 160, before passing through this polarized light splitter 160. Additionally, this light passes through the transparent light guide 190 and is reflected on the reflecting plate 200 to again pass through the light guide 190 and the polarized light splitter 160 as linearly polarized light in a direction perpendicular to the paper surface. This linearly polarized light is again evolved into white scattering light by the light scattering layer 150 and then is developed into linearly polarized light in a direction perpendicular to the paper surface by the polarizer 135, before passing through this polarizer 135. Still additionally, after passing through the color filter 145, the linearly polarized light becomes a linearly polarized light in a direction parallel with the paper surface with its polarizing direction being twisted 90° by the TN liquid crystal, and outputted from the polarizer 130 as linearly polarized light 122 in a direction parallel with the paper surface.

[0066] Particularly in this invention, since the light scattering layer 150 is provided between the polarizer 135 and the polarized light splitter 160, when the light 122 is viewed from the polarizer 130 side, it seems that the scattering plane of the light diffusion layer 150 whereby the reflected light is scattered forwardly is at the reflecting position. That is, owing to the forward scattering in the light diffusion layer 150, images or shadows are hardly seen on the rear side of the light diffusion layer 150. Accordingly, even if, in the construction of the device, the distance from the TN liquid crystal 140 to the reflecting plate 200 is prolonged, double image or bleeding in display, caused by the parallax resulting therefrom, particularly bleeding of the colors produced by the color filter 145, does not occur.

[0067] Moreover, the light reflected on the reflecting plate 200 includes, in addition to the linearly polarized light in the direction perpendicular to the paper surface, linearly polarized light in a direction parallel with the paper surface. The linearly polarized light in the direction parallel with the paper surface is reflected on the polarized light splitter 160 and again reflected on the reflecting plate 200 so that its polarizing direction varies; whereupon, a portion of the linearly polarized light forms linearly polarized light in a direction perpendicular to the paper surface which in turn, passes through the polarized light splitter 160. The repetition of this operation enables effective utilization of light for brightness. In this way, in the voltage non-application section, the incident light can effectively be utilized owing to the polarized light splitter 160, thereby offering a bright display.

[0068] In the voltage applied section 110 on the left side, the natural light 111 turns through the polarizer 130 to linearly polarized light in a direction parallel with the paper surface, and then passes through the TN liquid crystal 140 without a change of its polarizing direction, and is absorbed by the polarizer 135, thereby producing darkness.

[0069] As described above, in the case of the reflective display, in the voltage non-applied section 120, the light reflected on the reflecting plate 200 is scattered forwardly by the light scattering layer 150 to be evolved into white scattering light, so double image or bleeding in display, particularly bleeding of colors produced by the color filter 145, is reducible, and further the polarized light splitter 160 accomplishes effective utilization of light to produce a bright display. On the other hand, in the voltage applied section 110, light is absorbed by the polarizer 135 to produce darkness, so high contrast is obtainable.

[0070] Furthermore, referring to Fig. 10, a description will be given of a case in which the light source 191 comes on (that is, the transmissive display). The display device shown in Fig. 10 is identical to that shown in Fig. 9.

[0071] In the voltage non-applied section 120 on the right side, of the light source light 125, linearly polarized light in a direction perpendicular to the paper surface passes through the polarized light splitter 160. On the other hand, of the light source light 125, linearly polarized light in a direction parallel with the paper surface is reflected on the polarized light splitter 160 and again reflected on the reflecting plate 200 so that its polarizing direction varies; whereupon, a portion thereof forms linearly polarized light in a direction perpendicular to the paper surface and passes through the polarized light splitter 160. The repetition of this operation enables the passing of almost all the light through the polarized light splitter 160. The linearly polarized light in the direction perpendicular to the paper surface, passing through the polarized light splitter 160, is formed through the light scattering layer 150 into white scattering light and then developed into linearly polarized light in a direction perpendicular to the paper surface by means of the polarizer 135, before passing through this polarizer 135. Subsequently, after passing through the color filter 145, the linearly polarized light becomes linearly polarized light in a direction parallel with the paper surface with its polarizing direction being twisted 90° by the TN liquid crystal 140, then passing through the polarizer 130. That is, an extremely bright display is attainable though the effective utilization of almost all the light.

[0072] In the voltage applied section 110 on the left side, as in the voltage applied section 120, light source light 115 reaches the TN liquid crystal 140 to form linearly polarized light in a direction perpendicular to the paper surface without a change of its polarizing direction, and is absorbed by the polarizer 130 into darkness.

[0073] As described above, in the case of the transmissive display, in the voltage non-applied section 120, the polarized light splitter 160 permits effective utilization of light for extreme brightness, while in the voltage applied section 110, the light is absorbed by the polarizer 130 into darkness. Accordingly, at the lighting of the light source 190, a color display is obtainable on the background of the light source color. That is, a color display is feasible without positive-negative reversal in the transmissive display (see Fig. 3) relying on the light source light and in the reflective display (see Fig. 2) relying on the external light.

[0074] Particularly, in this case, since the color pitch of the color filter 145 is, for example, as fine as approximately 80 μm, in the reflective display, the incident light and the outgoing light (that is, reflected light) related to the same external light portion passing through a going and returning optical path between at least the color filter 145 and the reflecting plate 200 (an optical path includes, in addition to this optical path, one or a plurality of going and returning optical paths between the reflecting plate 200 and the polarized light splitter 160) considerably longer than this pitch substantially pass through different color portions of the color filter 145. However, since the light scattering layer 150 is interposed between the polarizer 135 and the polarized light splitter 160, even if the incident light passes through the color portions of the color filter 145 to be colored before being reflected, when passing through the light scattering layer 150, the light passing through the color portions of the color filter 145 is diffused forwardly, and further diffused forwardly in again passing through the light scattering layer 150 as the outgoing light reflected on the reflecting plate 200. In consequence, the red, green and blue lights resulting from the passing of the incident light through the color filter 145 are mixed with each other to produce an optical condition almost identical to an optical condition in which, when viewed from the polarizer 130 side, white scattering light is emitted from the scattering plane of the light scattering layer 150 and is incident on the color filter 145 in this state. Thus, irrespective of what color of the color filter 145 the incident light passes through, the color of the outgoing light becomes the color of the color filter 145 through which the outgoing light passes. Accordingly, even if the distance from the TN liquid crystal 140 to the reflecting plate 200 is prolonged in the device construction, the bleeding of the color produced through the color filter 145 does not occur, which is very advantageous.

[0075] Incidentally, if the color filter 145 shows a dot matrix display of red, green and blue, on this principle, multi-color and full-color display is feasible.

[0076] Although the above description relates to the normally white mode, the normally black is also acceptable. However, in the normally white mode, the brightness effect not only in the reflective display but also in the transmissive display is still exhibitable.

[0077] In addition, in the above description, although the TN liquid crystal 140 has been used as an example, even if in place of the TN liquid crystal 140 there is employed another device such as a STN liquid crystal or an ECB (Electrically Controlled Birefringence) liquid crystal in which the polarization axis is changeable by voltages or the like, the basic operational principle is the same.

[0078] A description will be given hereinbelow of third to fifth examples and fifth to tenth embodiments based on the operational principle described above with reference to Figs. 9 and 10.

(Third Example)

[0079] Fig. 11 is a schematic illustration for explaining a liquid crystal display device according to a third example. The third example differs from the above-described first example in that color filters 27 are provided in the interior of the STN cell 20. Other constructions are the same as those in the first example. In Fig. 11, components corresponding to those in Fig. 4 are marked with the same reference numerals, and the description thereof will be omitted.

[0080] More concretely, in Fig. 11, the transparent electrode 24 is placed on a lower surface of the glass substrate 21 and transparent electrodes 25 are put on an upper surface of the glass substrate 22 to form a dot matrix, with red, green and blue color filters 27 being formed on a lower surface of the transparent electrode 24 to coincide with the electrode pattern of the transparent electrodes 25. The retardation film 14 is made to correct the coloring by the STN cell 20 for achromatic display. The direction of the polarization axis of the polarized light splitter 40 coincides with the direction of the polarization axis of the polarizer 15.

[0081] Secondly, a description will be given of an operation of the display device 10 according to this example.

[0082] The description begins at a reflective display using the external light.

[0083] Under the external light, in a voltage non-applied area, the natural light becomes linearly polarized light in a predetermined direction by means of the polarizer 12, and turns to linearly polarized light with its polarizing direction being twisted a predetermined angle by the STN cell 20, and further passes through the polarizer 15 and the polarized light splitter 40, and even passes through the light guide 72 to be reflected on the reflecting plate 80. The reflected light again passes through the light guide 72 and the polarized light splitter 40 and the polarizer 15 and is outputted as linearly polarized light from the polarizer 12 after it polarizing direction is twisted a predetermined angle. Furthermore, also the light whose polarizing direction is changed by the reflecting plate 80 is repeatedly reflected between the polarized light splitter 40 and the reflecting plate 80, and eventually comes out of the polarized light splitter 40 and advances to the STN cell 20, thereby obtaining a bright display. At this time, if the light passes through the color filter 27, one of the red, green and blue colors develops. Since the diffusion plate 30 is provided between the reflecting plate 80 and the polarized light splitter 40, the reflected light from the polarized light splitter 40 is scattered, thus providing a wide-visible-angle and good-looking display while suppressing the color bleeding.

[0084] On the other hand, in the voltage applied area, the natural light becomes linearly polarized light in a predetermined direction by means of the polarizer 12, and then passes through the STN cell 20 as the linearly polarized light, and further is absorbed by the polarizer 15, thereby producing darkness.

[0085] Secondly, a description will be made of a transmissive display using light source light.

[0086] Under the lighting of the light source 70, the light emitted from the light source 70 becomes linearly polarized light through the polarized light splitter 40, before passing through it. This linearly polarized light becomes linearly polarized light in a predetermined direction by means of the STN cell 20, and is outputted without being absorbed by the polarizer 12. At this time, when the light passes through the color filter 27, one of the red, green and blue colors appears.

[0087] On the other hand, in the voltage applied area, the light emitted from the light source 70 becomes linearly polarized light by the polarized light splitter 40 and passes therethrough. This linearly polarized light turns to linearly polarized light in a predetermined direction through the STN cell 20, and is absorbed by the polarizer 12, thereby producing darkness.

[0088] As a result, a color display is obtainable not only under the external light but also under the lighting of the light source without positive-negative reversal by the color filter 27. Additionally, since the diffusion plate 30 is placed between the STN cell 20 and the reflecting plate 80, even if the distance therebetween is long, double image or bleeding (particularly, color bleeding) is reducible in the reflective display. Still additionally, since the polarized light splitter 40 enables the effective utilization of light, brightness is producible in both reflective and transmissive displays.

[0089] Examining the optical anisotropy in a plane of the light guide 72, chrominance non-uniformity occurs at a place having an anisotropy above 400 nm, whereas no chrominance non-uniformity occurs at a place having an anisotropy below 150 nm. Accordingly, it is preferable that the optical anisotropy in a plane of the light guide 72 is set to be below 400 nm, most preferably below 150 nm.

(Fourth Example)

[0090] Fig. 12 is a schematic illustration for explaining a liquid crystal display device according to a fourth example. The difference of the fourth example from the above-described third example is that the diffusion plate 30 is positioned above the light guide 72. Other constructions are the same as those in the third example. In Fig. 12, components corresponding to those in Fig. 11 are marked with the same reference numerals, and the description thereof will be omitted.

[0091] A display according to the third example and a display according to the fourth example are shown at (A) and (B) in Fig. 6, respectively, as in the case of the display according to the first example and the display according to the second example. That is, in the third example, a shadow clearly appears on the rear side corresponding to the thickness of the light guide 72, whereas in the fourth example, the shadow becomes dim so that the display is easy to see.

(Fifth Example)

[0092] In the fifth example, in addition to the above-described construction according to the fourth example, provided is a color filter 24 of red, green and blue, different in transmittance ratio.

[0093] When the average transmittance ratio of the color filter 24 is changed variously, if the average transmittance ratio exceeds 80%, the color purity drops so that the color recognition decreases. On the other hand, if the average transmittance ratio becomes below 30%, the brightness in the reflective display decreases so that the display is hard to read. Accordingly, preferably the average transmittance ratio of the color filter 24 is in a range of 30 to 80%, more preferably in a range of 45 to 70%.

[0094] The spectral characteristics of two kinds of color filters A and B different in average transmittance ratio from each other in the fifth example are shown in Figs. 13(a) and (b), respectively. The average transmittance ratio of the color filter A is 58.1% while the average transmittance ratio of the color filter B is 67.7%. Furthermore, Fig. 14, in the form of a table, shows transmittance ratios and chromaticities of red, green and blue in the color filters A and B.

[0095] As seen from the table of Fig. 14, as compared with the use of the color filter B, in the case of the employment of the color filter A, although the reflective display is relatively dark, a display having an excellent color purity is attainable, so this is preferable.

(Fifth Embodiment)

[0096] Fig. 15 is a schematic illustration for explaining a liquid crystal display device according to a fifth embodiment of this invention. The difference of the fifth embodiment from the above-described third example is that the diffusion plate 30 is positioned above the polarized light splitter 40. Other constructions are the same as those in the third example. In Fig. 15, components corresponding to those in Fig. 11 are marked with the same reference numerals, and the description thereof will be omitted.

[0097] According to the fifth embodiment, the distance between the diffusion plate 30 and the STN cell 20 is shortened; so the double image, shown in Fig. 6, and bleeding in display is reducible accordingly.

(Sixth Embodiment)

[0098] A difference of a sixth embodiment from the above-described fifth embodiment is that a pressure sensitive adhesive containing a diffusing agent is used as the diffusion plate 30. Other constructions are the same as those in the fifth embodiment.
[0099] According to the sixth embodiment, as well as the fifth embodiment, the double image, shown in Fig. 6, and bleeding in display is reducible. In addition, the polarizer 15 and the polarized light splitter 40 in Fig. 15 are integrally adhered onto the STN cell 20, which is advantageous in manufacturing.

(Seventh Embodiment)

[0100] Fig. 16 is a schematic illustration for explaining a liquid crystal display device according to a seventh embodiment of this invention. The seventh embodiment differs from the above-described third example in that the diffusion plate 30 is positioned above the polarizer 15. Other constructions arc the same as those in the third example. In Fig. 16, parts corresponding to those in Fig. 11 are marked with the same reference numerals, and the description thereof will be omitted.
[0101] According to the seventh embodiment, the distance between the diffusion plate 30 and the STN cell 20 is shortened, so the double image, shown in Fig. 6, or bleeding in display is reducible accordingly.

(Eighth Embodiment)

[0102] The difference of an eighth embodiment from the above-described fifth embodiment is that, in place of the polarized light splitter described with reference to Fig. 1, a combination of a circularly polarizer, constructed with a cholesteric liquid crystal or the like, and a $\lambda/4$ plate is used as the polarized light splitter 40. Other constructions are the same as those in the fifth embodiment.
[0103] According to the eighth embodiment, as in the case of the fifth embodiment, the double image, see Fig. 6, or the bleeding is reducible.

(Ninth Embodiment)

[0104] Fig. 17 is a schematic illustration for explaining a liquid crystal display device according to a ninth embodiment of this invention. The ninth embodiment differs from the above-described seventh embodiment in that a Lumisty85 produced by Sumitomo Chemical Co., Ltd. is placed on an upper surface of the reflecting plate 80. Other constructions are the same as those in the seventh embodiment. In Fig. 17, parts corresponding to those in Fig. 16 are marked with the same reference numerals, and the description thereof will be omitted.
[0105] The "Sumitomo Chemical Produced Lumisty85" exhibits an effect to make the output angle $\theta 2$ of light differ from the incidence angle $\theta 1$ as shown in Fig. 18 when combined with the reflecting plate 80. That is, when incident light 801 is incident on the Lumisty85 at the incidence angle $\theta 1$, the light 801 is outputted as diffused light. At this time, the output angle in the direction 802 having the highest intensity is taken as $\theta 2$. Thus, the incidence angle $\theta 1$ and the output angle $\theta 2$ differ from each other. This is because the Lumisty has the following structure and characteristic. In the Lumisty, layers different in refractive index from each other are arranged at an interval of approximately 3 μm in a film, and this construction causes a diffraction phenomenon to produce diffusion of light. The directional control of the diffused light is possible through the adjustment of the layer construction. When the incidence angle is 70°, the output angle is 90°. In this way, when a screen is viewed from the vertical direction, the screen is bright and easy to see without being dark due to the shadow of the observer. Additionally, the contrast also upgrades.
[0106] In addition, even if a prism sheet or a hologram is used in place of the Lumisty, similar effects are obtainable.

(Tenth Embodiment)

[0107] As shown in Fig. 19, in a liquid crystal display device 1001 according to this embodiment, a liquid crystal cell 1010 having an STN liquid crystal is used as one example of polarization axis variable means. Above the liquid crystal cell 1010, a retardation film 1030 and an upper polarizer 1020 forming one example of a first polarized light splitter are located in this order. Under the liquid crystal cell 1010, a lower polarizer 1040 forming one example of a second polarized light splitter, a pressure sensitive adhesive 1050 containing a light diffusing agent, forming one example of light diffusing means, a polarized light splitter 1060 forming a third polarized light splitting means, a light guide plate 1070 constituting a portion of the light guider and a reflecting plate 1080 forming one example of light reflecting means are provided in this order. The pressure sensitive adhesive 1040 containing light diffusing agent has both functions: a light diffusion effect and an adhesion effect, and the lower polarizer 1040 and the polarized light splitter 1060 are adhered. Additionally, a pressure sensitive adhesive also lies on an upper surface of the lower polarizer 1040, and it can be adhered to the liquid crystal cell 10.

[0108] In the liquid crystal cell 1010, an STN liquid crystal 1014 is enclosed in a cell comprising two glass substrates 1011 and 1012 and a seal member 1013. The product An × Δ d of the optical anisotropy Δn of the STN liquid crystal 1014 in the liquid crystal cell 1010 and the thickness d of the liquid crystal layer is set at, for example, 860 nm. Transparent electrode lines 1015 and 1016 are formed inside the two glass substrates 1011 and 1012, respectively. Additionally, to the transparent electrode lines 1016 of the lower glass substrate 1012, red, green and blue color filters 1017 are located on the transparent electrode line 1015 of the upper glass substrate 1011. The use of the retardation film 1030 is for accomplishing the color compensation.

[0109] An LED 1120 forming one example of a light source is located on a PCB substrate 1090 so that light is emitted upwardly from the LED 1120. In addition, for the introduction of light from the LED 1120, together with the light guide plate 1070, a light guide 1110 forming one example of the light guider is provided on the PCB substrate 1090. Still additionally, the left and right positions of the liquid crystal cell 1010 and others are determined by the light guide 1110, and a structure comprising the liquid crystal cell 1010 and others is fixed thereby. The light guide 1110 extends upwardly, and the light guide plate 1070 is put in an intermediate portion thereof so that the light introduced from the LED 1120 into the light guide 1110 is further introduced into the light guide plate 1070. Moreover, an upper end portion of the light guide 1110 is bent toward the inside of the upper polarizer 1020. The lower side of the upper end portion of the light guide 1110 and the upper polarizer 1020 are fixed to each other through a double-faced adhesive tape 1112. The light guide 1110 can also be a cavity surrounded by a transparent plastic plate or the like, alternatively by an opaque plastic plate having a reflecting function.

[0110] Light from the LED 1120 is guided through the light guide 1110 to be introduced into the interior of the liquid guide plate 1070 and then outputted toward the polarized light splitter 1060 side. On the other hand, the light guide plate 1070 transmits the light from the liquid crystal cell 1010 side to the reflecting plate 1080.

[0111] The polarized light splitter 1060 has a structure similar to that shown in Fig. 1.

[0112] Particularly, in this embodiment, a pressure sensitive adhesive is placed on an upper surface of the reflecting plate 1080 which in turn, is adhered to the light guide plate 1070. In this adhering process, for easy manufacturing, the light guide plate 1070 is made so as not to have a large projection in its thickness direction. Accordingly, the light guide plate 1070 is made from a transparent plastic flat-plate having a thickness of approximately 0.7 mm.

[0113] When the liquid crystal cell 1010 is frame-rate-controlled, a bright full-color display is attainable not only when the external light is used and but also when the LED is in the on condition.

[0114] Furthermore, if, in place of the lower glass substrate 1012, a plastic film as thin in thickness as below 0.12 mm is used, a bright full-color display with a high color purity is obtainable.

[0115] According to the tenth embodiment thus constructed, the color filters 1017 can provide a color display without positive-negative reversal not only under the external light but also under the lighting of the light source. Additionally, since the pressure sensitive adhesive 1050 containing light diffusing agent is interposed between the liquid crystal cell 1010 and the reflecting plate 1090, if the distance therebetween is prolonged, the double image or the bleeding (particularly, color bleeding) is reducible in the reflective display. Still additionally, since the effective utilization of light is feasible through the use of the polarized light splitter 1060, both the reflective and transmissive displays becomes bright.

(Eleventh Embodiment)

[0116] An eleventh embodiment according to this invention relates to a light guide 72 suitable for use in the above-described display devices according to the first to fifth examples and first to ninth embodiments.

[0117] That is, the light guide 72 used in the display devices according to the first to fifth examples and first to ninth embodiments of this invention is made from a transparent plastic plate, such as polycarbonate or acrylic, and has a thickness of 0.3 to 2 mm, and further has irregularities on its surface. Preferably, the size thereof is in a range of approximately 10 to 200 μm and the pitch thereof is in a range of approximately 20 to 400 μm. Furthermore, preferably, the configuration thereof is, for example, a generally hemispherical projection as shown in Fig. 20(a), a conical recess as shown in Fig. 20(b), a generally hemispherical recess as shown in Fig. 20(c), a cylindrical projection as shown in Fig. 20(d), a conical projection as shown in Fig. 20(e), and other configurations are also acceptable. Additionally, it is also appropriate that the density distribution of the irregularities is changed in a plane so that the surface luminance of the light guider becomes uniform. Because of having irregularities on its surface, the light guide 72 also serves as a diffusion plate.

[0118] In addition, the light guide 72 is produced with the injection molding, and in order to lessen the optical anisotropy, undergoes heating or pressuring treatment.

(Twelfth Embodiment)

[0119] A twelfth embodiment relates to an electronic apparatus incorporating the monochrome or color liquid crystal display device according to each of the above-described examples and embodiments.

[0120] That is, when the liquid crystal display device is used, for example, for a display section 172 of a portable telephone 171 shown in Fig. 21(a), it is possible to realize an energy-saving portable telephone providing a bright high-contrast reflective or transmissive display even in the daylight, in the shade or in room.

[0121] Furthermore, if it is used for a display section 174 of a wristwatch 173 shown in Fig. 21 (b), it is possible to realize an energy-saving wristwatch providing a bright high-contrast reflective or transmissive display even in the daylight, in the shade or in a room.

[0122] Still furthermore, if it is employed for a display screen 176 attached to a mainframe 177 of a personal computer (or an information terminal) 175 shown in Fig. 21(c), it is possible to realize an energy-saving personal computer providing a bright high-contrast reflective or transmissive display even in the daylight, in the shade or in room.

[0123] In addition to the electronic apparatus shown in Fig. 21, the liquid crystal display devices according to the examples and embodiments are also applicable to electronic apparatuses, such as a liquid crystal television, a viewfinder or monitor direct-viewing video tape recorder, a car navigation apparatus, an electronic pocketbook, a desk computer, a word processor, an engineering work station (EWS), a television telephone, a POS terminal and an apparatus equipped with a touch panel.

Industrial Applicability

[0124] The display devices according to this invention are available as various types of display devices capable of providing a bright good-looking monochrome or color display, and further they are available as display devices constituting display sections of various types of electronic apparatus. Furthermore, the electronic apparatus according to this invention is applicable to a liquid crystal television, a viewfinder or monitor direct-viewing video tape recorder, a car navigation apparatus, an electronic pocketbook, an electronic calculator , a word processor, a work station, a portable telephone, a television telephone, a POS terminal, a touch panel and others, using such a display device.

Claims

1. A display device comprising:

a first polarized light splitting plate (130) functioning as a polarized light splitting plate which transmits, absorbs or reflects incident light in accordance with a polarized light - component;
a second polarized light splitting plate (135) functioning as a polarized light splitting plate which transmits, absorbs or reflects incident light in accordance with a polarized light component;
a liquid crystal panel (140) positioned between the first and second polarized light splitting plates (130, 135), said liquid crystal panel having a variable transmissive polarization axis;
a reflecting layer (200) located on the opposite side of said second polarized light splitting plate (135) with respect to said liquid crystal panel (140);
a light source (191);
a light guider (190) positioned between said second polarized light splitting plate (135) and said reflecting layer (200);
a third polarized light splitting plate (160) positioned between said second polarized light splitting plate (135) and said light guider (190), said third polarized light splitting plate (160) transmitting or reflecting light in accordance with a polarization component of the light, and
a forward scattering plate (150) positioned on the reflecting layer side of the liquid crystal panel (140);
characterized in that:

the forward scattering plate (150) is positioned between said liquid crystal panel (140) and said third polarized light splitting plate (160), said forward scattering plate (150) scattering forwardly each of light from said reflecting layer (200) side toward said liquid crystal panel (140) side and light from said liquid crystal panel (140) side toward said reflecting layer (200) side.

2. A display device according to claim 1, wherein said light guider (190) has a low refractive index anisotropy.

3. A display device according to claim 2, wherein said light guider (160) further has an optical axis direction which lies in a plane of said light guider (160).

4. A display device according to claim 1, wherein a direction of a polarization axis of said second polarized light splitting plate (135) coincides approximately with a direction of a polarization axis of said third polarized light splitting plate (160).

5. A display device according to claim 2, wherein the refractive index anisotropy of said light guider (190) and a thickness of said light guider (190) define an optical anisotropy of said light guider (190), said optical anisotropy having a value set to be below 400 nm.

6. A display device according to claim 5, wherein said optical anisotropy has a value set to be below 150 nm.

7. A display device according to claim 1, wherein said third polarized light splitting plate (160) is a polarized light splitting plate which reflects, of said incident light, a linearly polarized light component in a direction substantially perpendicular to the direction of said polarization axis of said third polarized light splitting plate (160).

8. A display device according to claim 1, further comprising coloring means interposed between said first polarized light splitting plate (130) and said light guider (190).

9. An electronic apparatus incorporating said display device according to claim 1.

Patentansprüche

1. Anzeigegerät, umfassend:

eine erste Teilerplatte für polarisiertes Licht (130), die als Teilerplatte für polarisiertes Licht dient, die einfallendes Licht entsprechend einer polarisierten Lichtkomponente durchlässt, absorbiert oder reflektiert;
eine zweite Teilerplatte für polarisiertes Licht (135), die als Teilerplatte für polarisiertes Licht dient, die einfallendes Licht entsprechend einer polarisierten Lichtkomponente durchlässt, absorbiert oder reflektiert;
eine Flüssigkristallplatte (140), die zwischen der ersten und zweiten Teilerplatte für polarisiertes Licht (130, 135) angeordnet ist, wobei die Flüssigkristallplatte eine variable transmissive Polarisationsachse aufweist;
eine reflektierende Schicht (200), die sich an der gegenüber liegenden Seite der zweiten Teilerplatte für polarisiertes Licht (135) in Bezug auf die Flüssigkristallplatte (140) befindet;
eine Lichtquelle (191);
einen Lichtleiter (190), der zwischen der zweiten Teilerplatte für polarisiertes Licht (135) und der reflektierenden Schicht (200) angeordnet ist;
eine dritte Teilerplatte für polarisiertes Licht (160), die zwischen der zweiten Teilerplatte für polarisiertes Licht (135) und dem Lichtleiter (190) angeordnet ist, wobei die dritte Teilerplatte für polarisiertes Licht (160) Licht entsprechend einer Polarisationskomponente des Lichts durchlässt oder reflektiert; und
eine Vorwärts-Streuungsscheibe (150), die an der Seite der reflektierenden Schicht der Flüssigkristallplatte (140) angeordnet ist;
dadurch gekennzeichnet, dass:

die Vorwärts-Streuungsscheibe (150) zwischen der Flüssigkristallplatte (140) und der dritten Teilerplatte für polarisiertes Licht (160) angeordnet ist, wobei die Vorwärts-Streuungsscheibe (150) sowohl Licht von der Seite der reflektierenden Schicht (200) zu der Seite der Flüssigkristallplatte (140) wie auch Licht von der Seite der Flüssigkristallplatte (140) zu der Seite der reflektierenden Schicht (200) vorwärts streut.

2. Anzeigegerät nach Anspruch 1, wobei der Lichtleiter (190) eine geringe Brechungsindex-Anisotropie aufweist.

3. Anzeigegerät nach Anspruch 2, wobei der Lichtleiter (190) des Weiteren eine Richtung der optischen Achse aufweist, die in einer Ebene des Lichtleiters (190) liegt.

4. Anzeigegerät nach Anspruch 1, wobei eine Richtung einer Polarisierungsachse der zweiten Teilerplatte für polarisiertes Licht (135) annähernd mit einer Richtung einer Polarisierungsachse der dritten Teilerplatte für polarisiertes Licht (160) übereinstimmt.

5. Anzeigegerät nach Anspruch 2, wobei die Brechungsindex-Anisotropie des Lichtleiters (190) und eine Dicke des Lichtleiters (190) eine optische Anisotropie des Lichtleiters (190) definieren, wobei die optische Anisotropie einen Wert aufweist, der unter 400 nm eingestellt ist.

6. Anzeigegerät nach Anspruch 5, wobei die optische Anisotropie einen Wert aufweist, der unter 150 nm eingestellt ist.

7. Anzeigegerät nach Anspruch 1, wobei die dritte Teilerplatte für polarisiertes Licht (160) eine Teilerplatte für polarisiertes Licht ist, die von dem einfallenden Licht eine linear polarisierte Lichtkomponente in eine Richtung reflektiert, die im Wesentlichen senkrecht zu der Richtung der Polarisierungsachse der dritten Teilerplatte für polarisiertes Licht (160) liegt.

8. Anzeigegerät nach Anspruch 1, des Weiteren umfassend ein Färbungsmittel, das zwischen der ersten Teilerplatte für polarisiertes Licht (130) und dem Lichtleiter (190) eingesetzt ist.

9. Elektronische Vorrichtung, die das Anzeigegerät nach Anspruch 1 enthält.

Revendications

1. Dispositif d'affichage comprenant :

   une première lamelle de décomposition de lumière polarisée (130) fonctionnant en tant que lamelle de décomposition de la lumière polarisée laquelle transmet, absorbe ou réfléchit de la lumière incidente en fonction d'une composante de lumière polarisée ;
   une deuxième lamelle de décomposition de lumière polarisée (135) fonctionnant en tant que lamelle de décomposition de la lumière polarisée laquelle transmet, absorbe ou réfléchit de la lumière incidente en fonction d'une composante de lumière polarisée ;
   un panneau à cristaux liquides (140) disposé entre les première et la deuxième lamelles de décomposition de lumière polarisée (130, 135), ledit panneau à cristaux liquides ayant un axe de polarisation transmissif variable ;
   une couche réfléchissante (200) située du côté opposé à ladite deuxième lamelle de décomposition de lumière polarisée (135) compte tenu dudit panneau à cristaux liquides (140) ;
   une source lumineuse (191) ;
   un guide lumineux (190) disposé entre ladite deuxième lamelle de décomposition de lumière polarisée (135) et ladite couche réfléchissante (200) ;
   une troisième lamelle de décomposition de lumière polarisée (160) disposée entre ladite deuxième lamelle de décomposition de lumière polarisée (135) et ledit guide lumineux (190), ladite troisième lamelle de décomposition de lumière polarisée (160) transmettant ou réfléchissant la lumière en fonction d'une composante de polarisation de la lumière, et
   une lamelle de diffusion vers l'avant (150) disposée du côté de la couche réfléchissante du panneau à cristaux liquides (140) ;
   caractérisé en ce que :

      la lamelle de diffusion vers l'avant (150) est disposée entre ledit panneau à cristaux liquides (140) et ladite troisième lamelle de décomposition de lumière polarisée (160), ladite lamelle de diffusion vers l'avant (150) diffusant vers l'avant toute la lumière provenant du côté de ladite couche réfléchissante (200) vers le côté dudit panneau à cristaux liquides (140) et toute la lumière provenant du côté dudit panneau à cristaux liquides (140) vers le côté de ladite couche réfléchissante (200).

2. Dispositif d'affichage selon la revendication 1, ledit guide lumineux (190) présentant un faible indice de réfraction anisotropique.

3. Dispositif d'affichage selon la revendication 2, ledit guide lumineux (160) possédant par ailleurs une direction d'axe optique se situant dans un plan dudit guide lumineux (160).

4. Dispositif d'affichage selon la revendication 1, une direction d'un axe de polarisation de ladite deuxième lamelle de décomposition de lumière polarisée (135) coïncidant approximativement avec une direction d'un axe de polarisation de ladite troisième lamelle de décomposition de lumière polarisée (160).

5. Dispositif d'affichage selon la revendication 2, l'indice de réfraction anisotropique dudit guide lumineux (190) et une épaisseur dudit guide lumineux (190) définissant une anisotropie optique dudit guide lumineux (190), ladite anisotropie optique étant d'une valeur fixée de manière à être inférieure à 400 nm.

6. Dispositif d'affichage selon la revendication 5, ladite anisotropie optique étant d'une valeur fixée de manière à être inférieure à 150 nm.

7. Dispositif d'affichage selon la revendication 1, ladite troisième lamelle de décomposition de lumière polarisée (160) étant une lamelle de décomposition de la lumière polarisée laquelle réfléchit, parmi ladite lumière incidente, une composante de lumière polarisée linéairement dans une direction essentiellement perpendiculaire à la direction dudit axe de polarisation de ladite troisième lamelle de décomposition de lumière polarisée (160).

8. Dispositif d'affichage selon la revendication 1, comprenant par ailleurs un moyen de coloration intercalé entre ladite première lamelle de décomposition de lumière polarisée (130) et ledit guide lumineux (190).

9. Appareil électronique incorporant ledit dispositif d'affichage selon la revendication 1.

FIG. 1

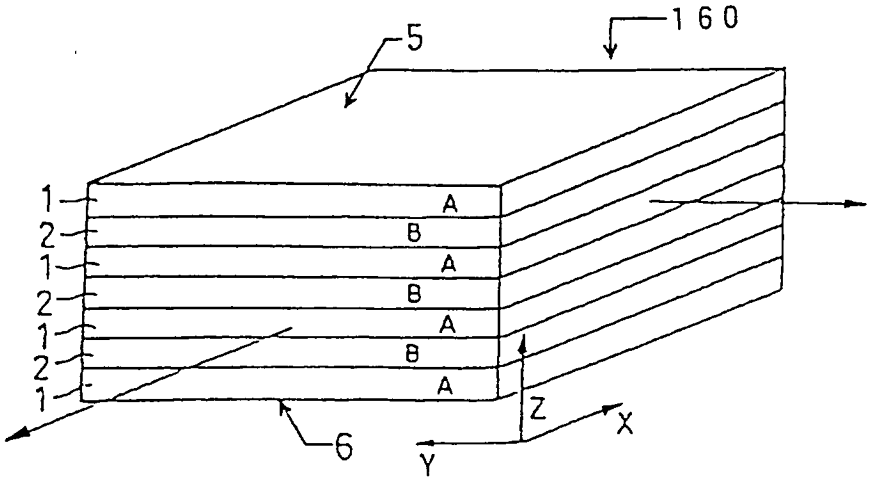

FIG. 2

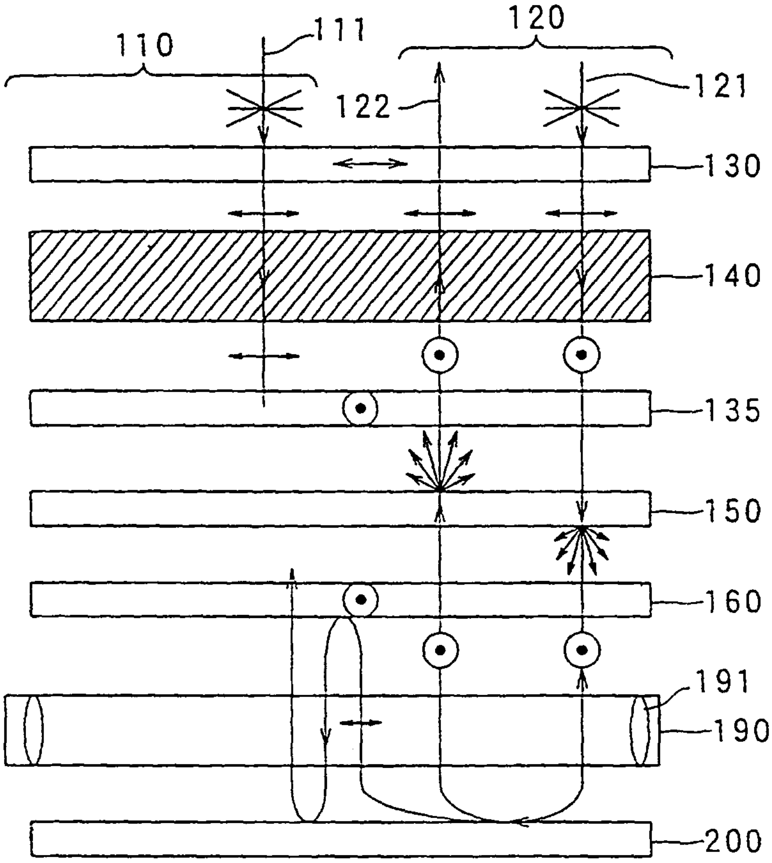

FIG. 3

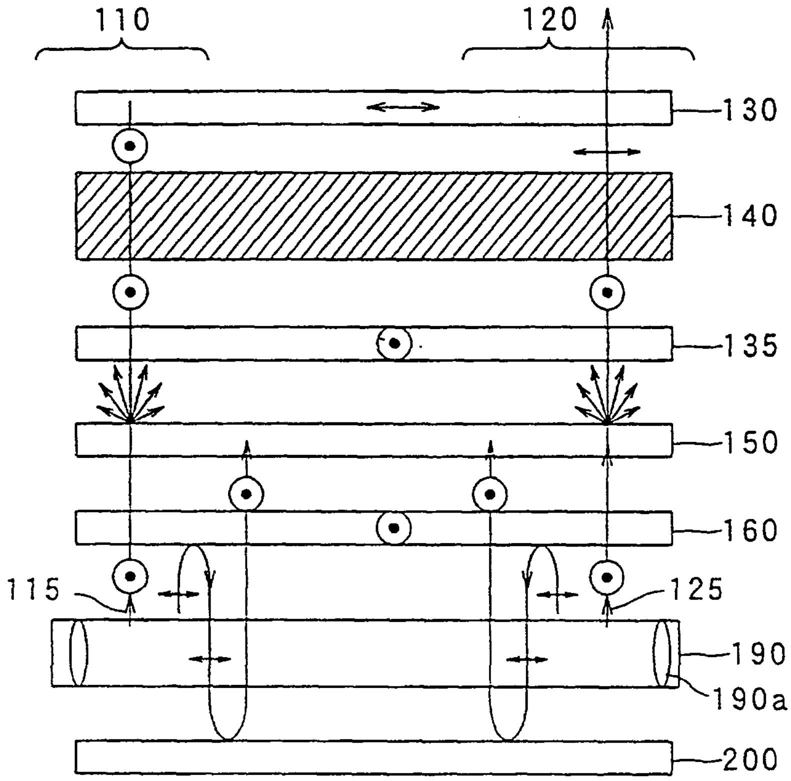
110
120
130
140
135
150
160
115
125
190
190a
200

FIG. 4

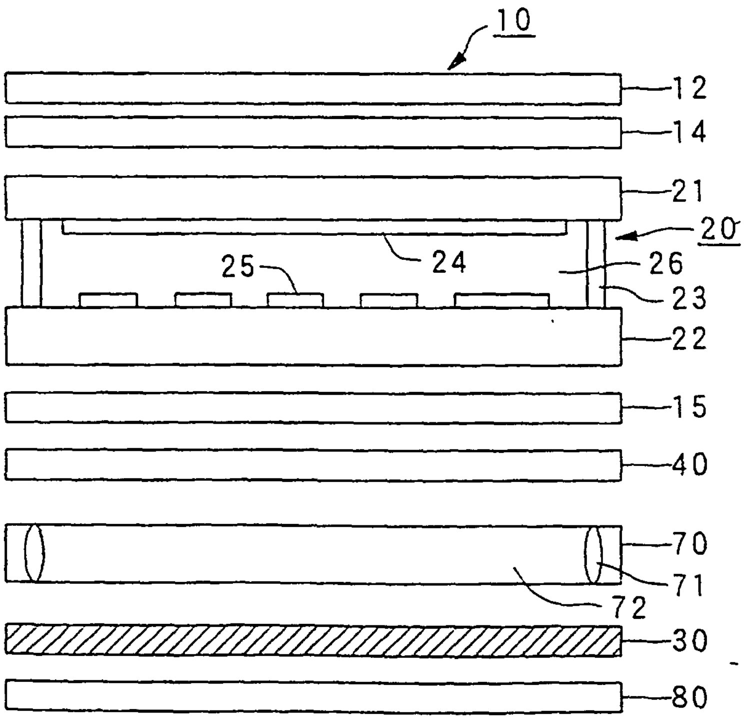
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FIG. 5

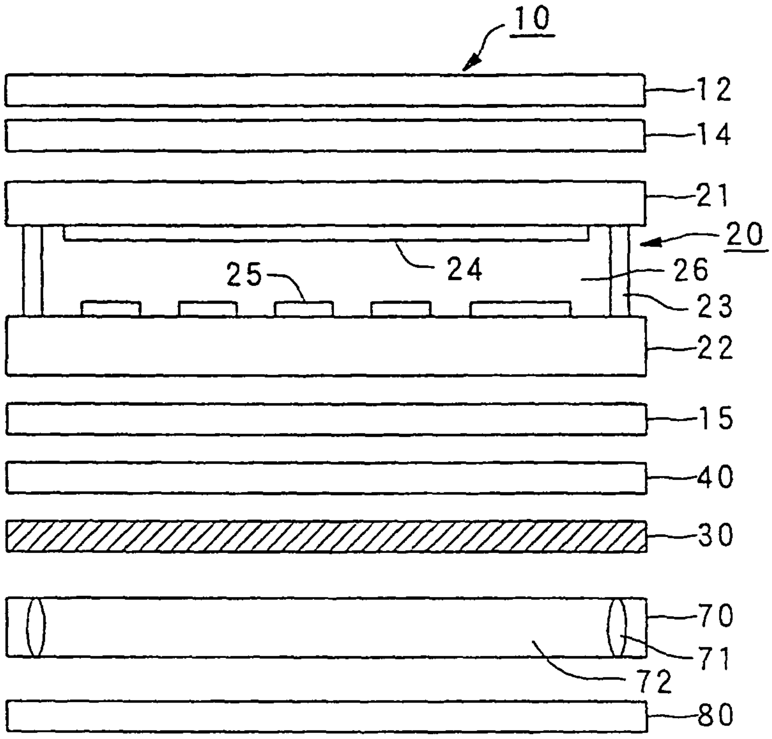


FIG. 6

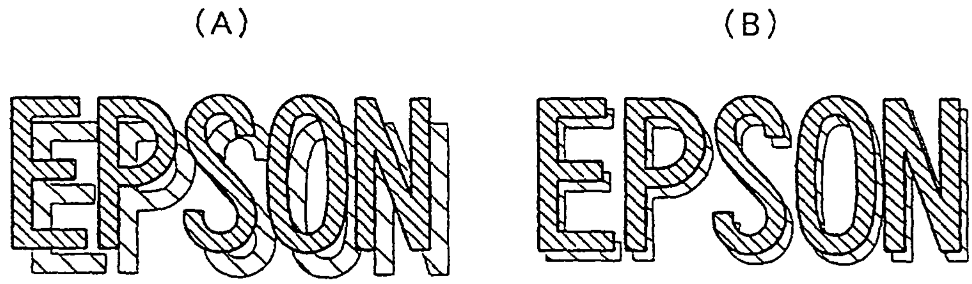
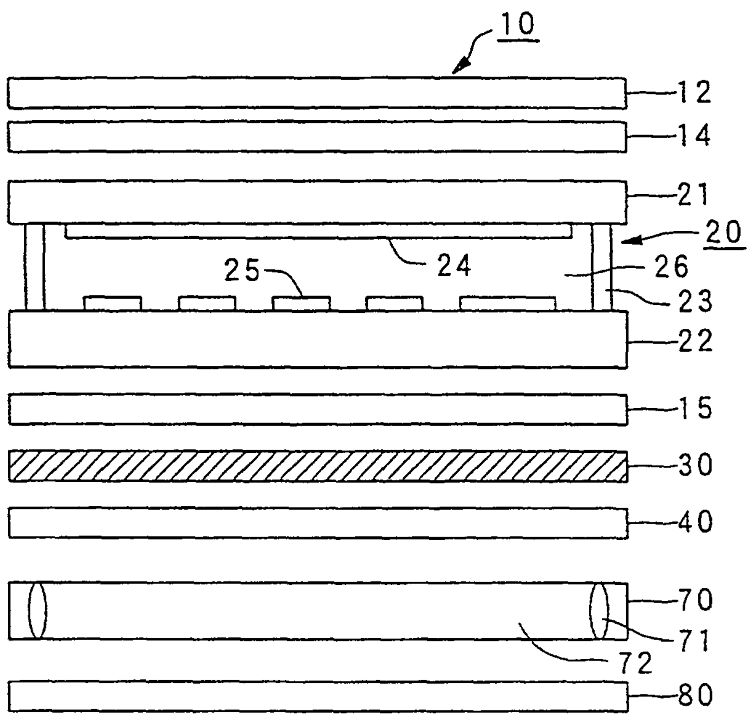


FIG. 7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72
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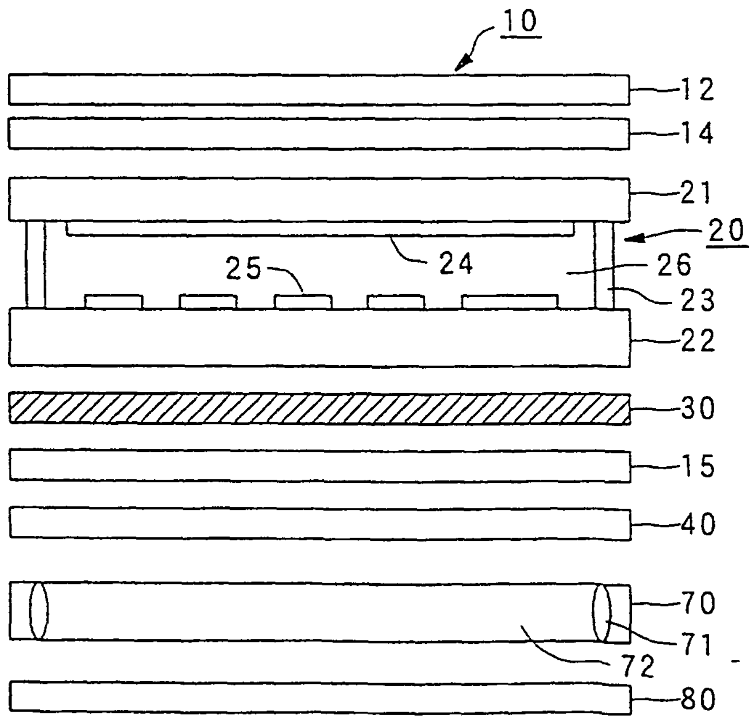
FIG. 8


10
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22
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70
71
72
80

FIG.9

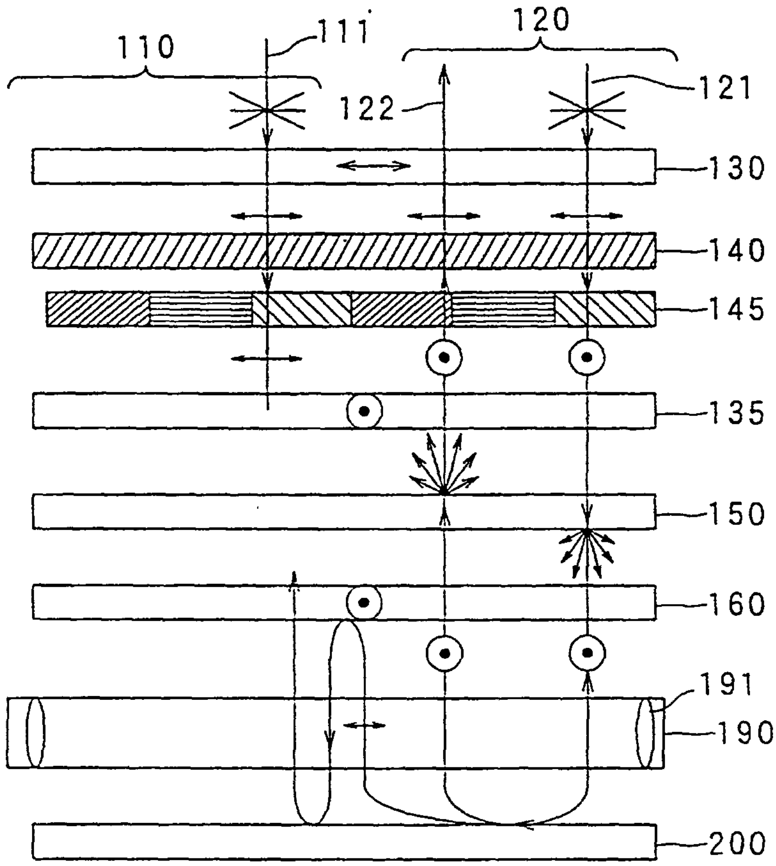

FIG. 10

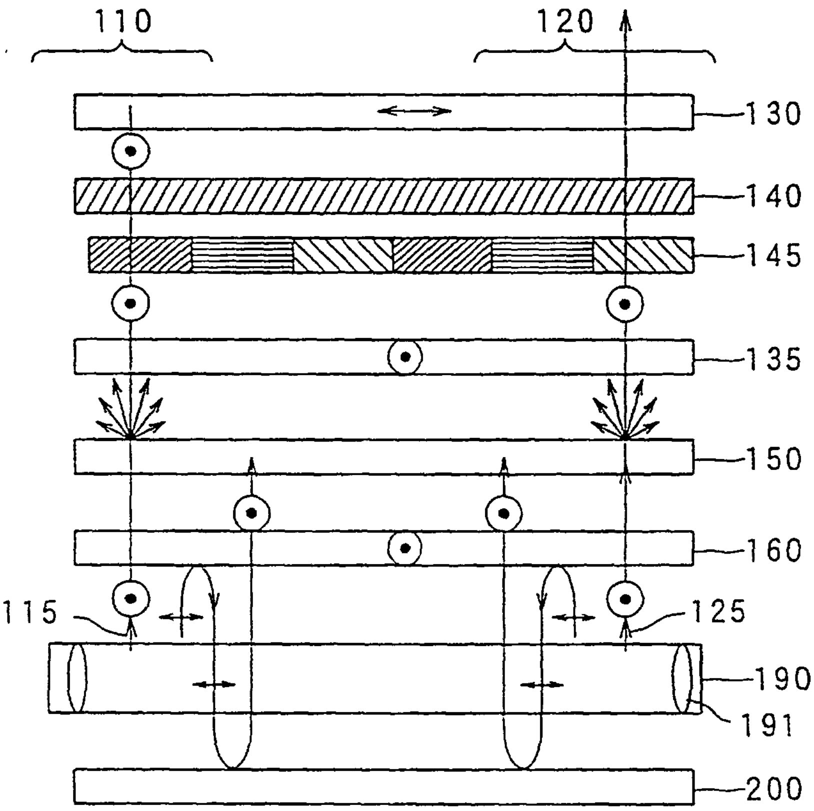

FIG. 11

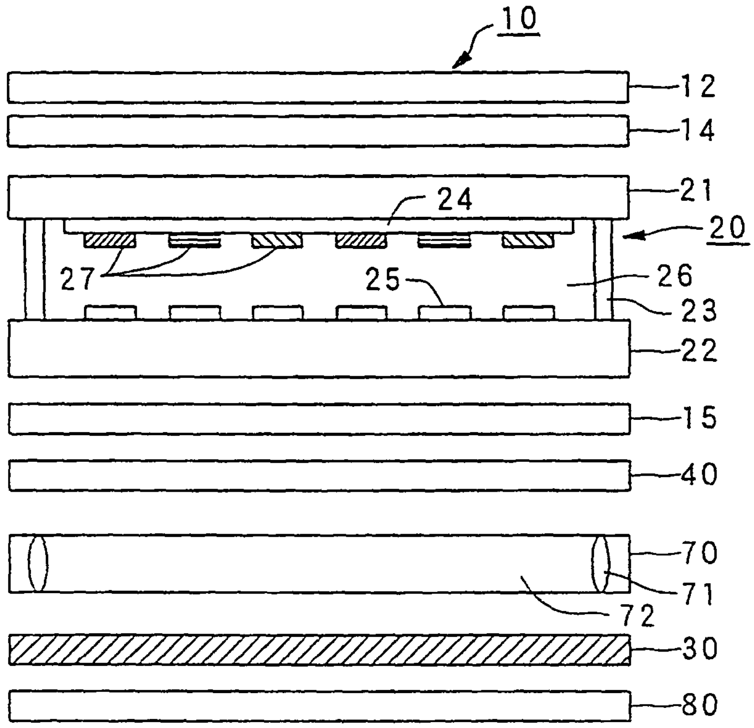
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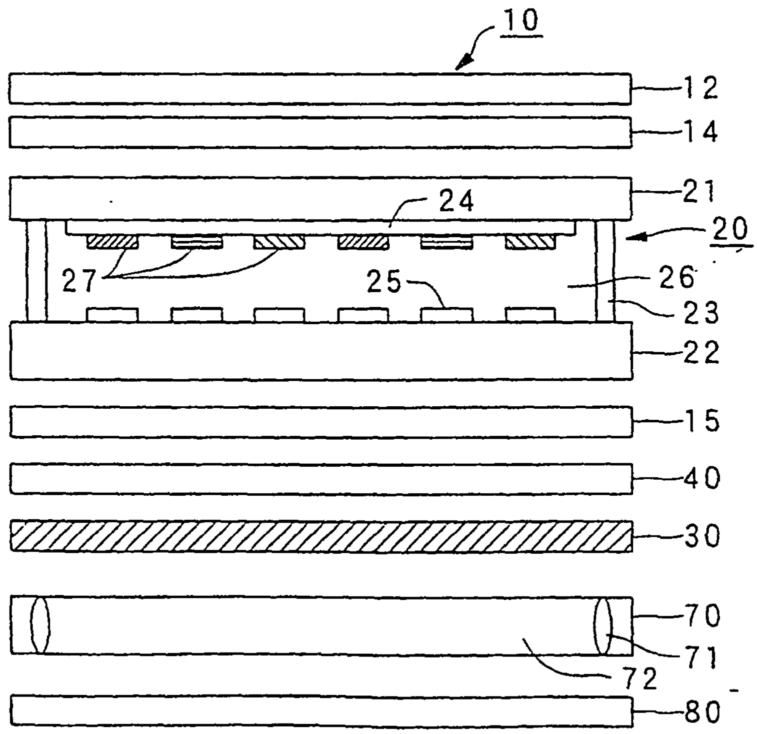
FIG. 12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72
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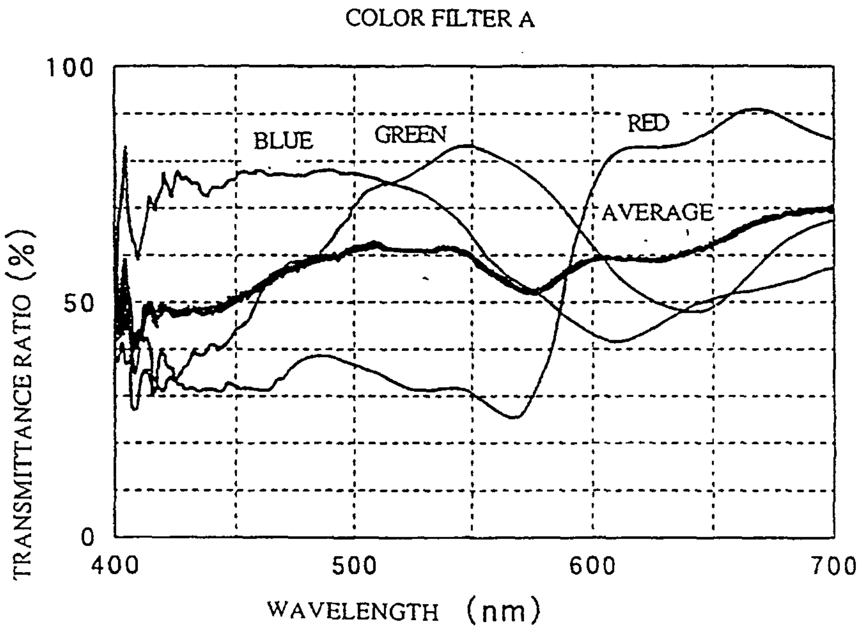
FIG. 13

(A)


COLOR FILTER A
100
50
0
TRANSMITTANCE RATIO (%)
400
500
600
700
WAVELENGTH (nm)
BLUE
GREEN
RED
AVERAGE

(B)

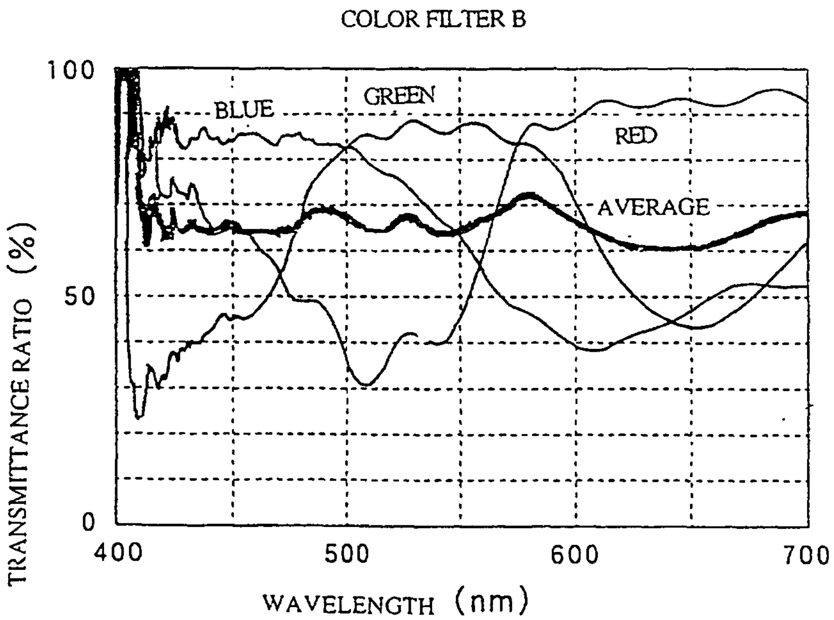

COLOR FILTER B
100
50
0
TRANSMITTANCE RATIO (%)
400
500
600
700
WAVELENGTH (nm)
BLUE
GREEN
RED
AVERAGE

FIG. 14

	COLOR FILTER A			COLOR FILTER B		
	TRANSMITTANCE RATIO	CHROMATICITY		TRANSMITTANCE RATIO	CHROMATICITY	
	Y	x	y	Y	x	y
AVERAGE	58.1	0.315	0.329	67.7	0.309	0.319
RED	42.3	0.399	0.314	62.0	0.363	0.281
GREEN	71.9	0.317	0.380	80.2	0.313	0.395
BLUE	60.1	0.266	0.294	60.9	0.249	0.276

FIG. 15

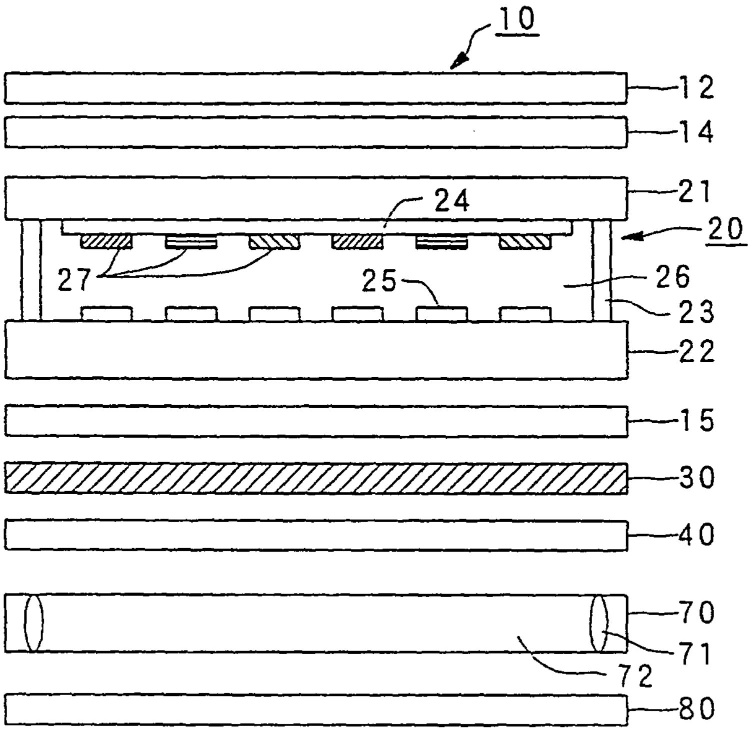
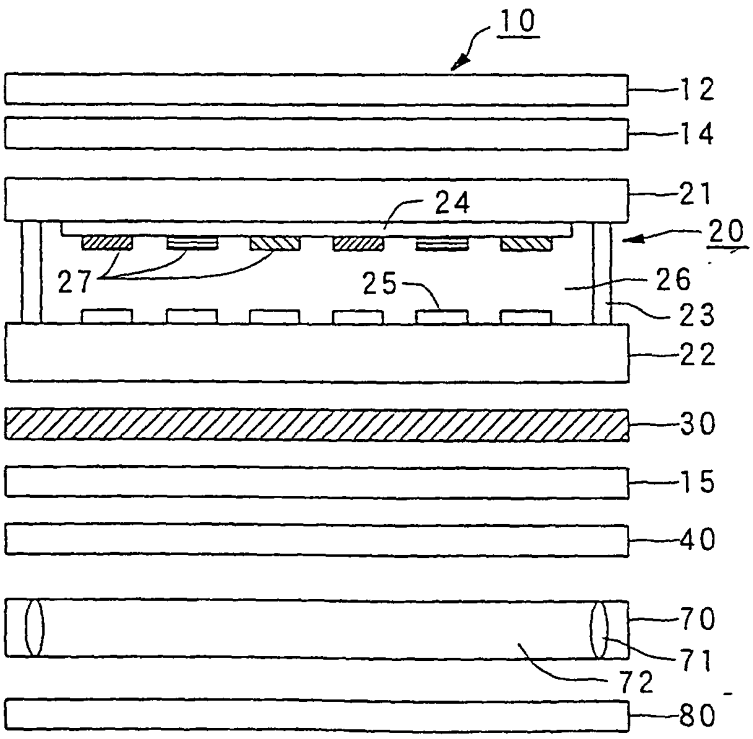

10
12
14
21
24
20
27
25
26
23
22
15
30
40
70
71
72
80

FIG. 16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70
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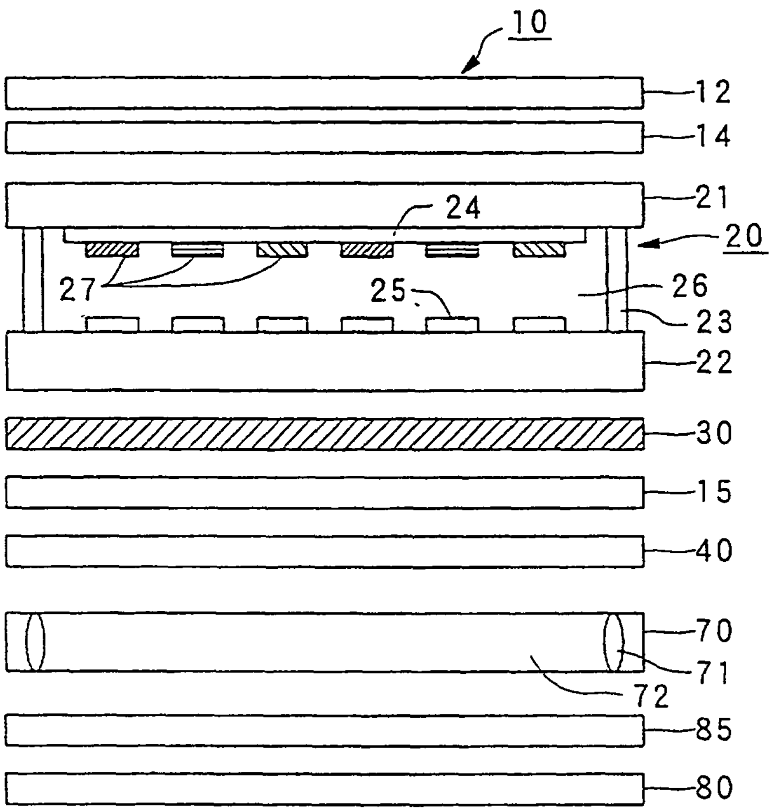
72
80

FIG. 17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27
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26
23
22
30
15
40
70
71
72
85
80

FIG. 18

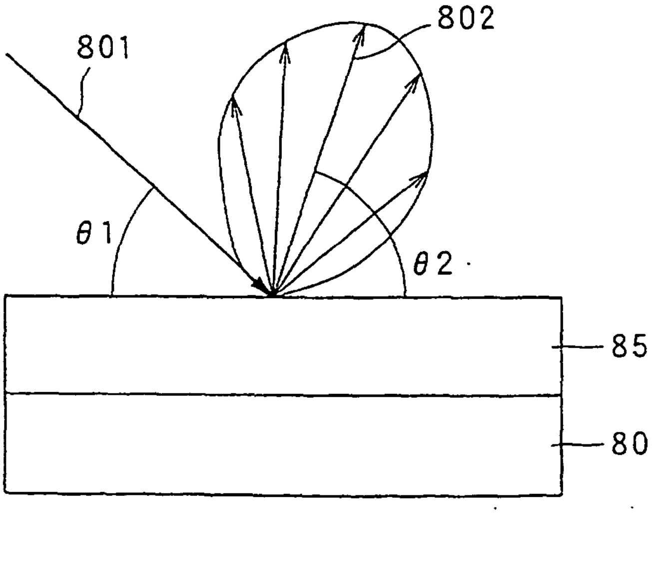

801
802
θ1
θ2
85
80

FIG. 19

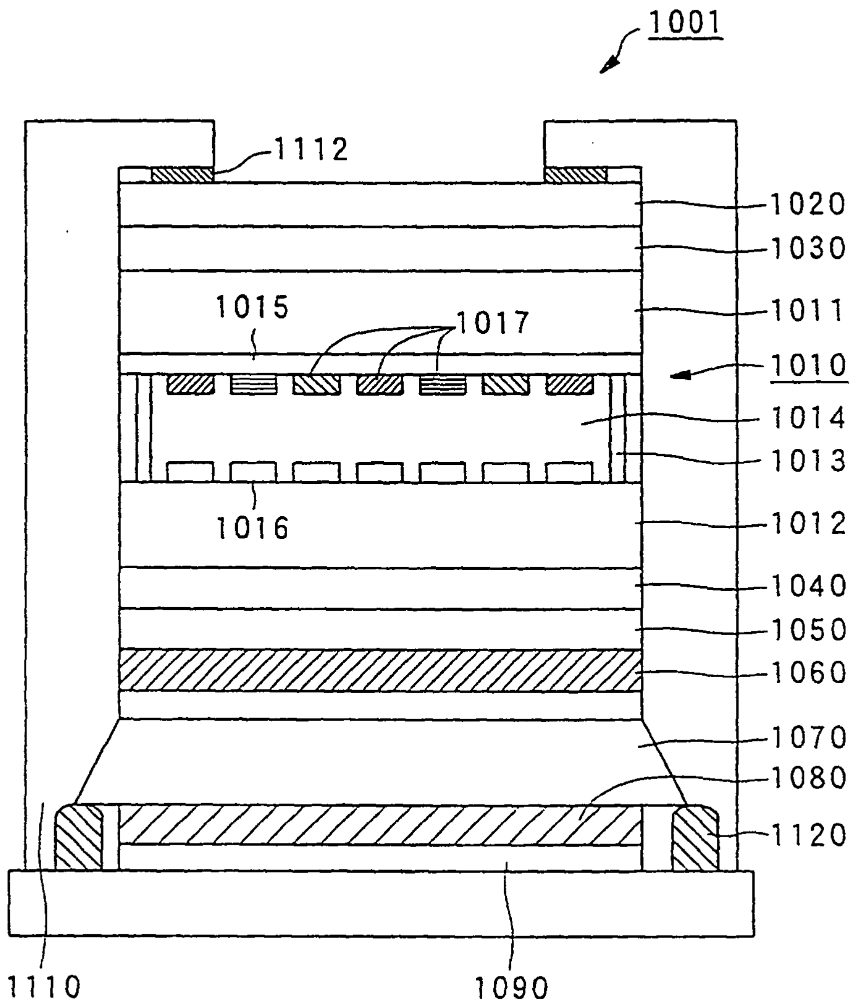

1001
1112
1020
1030
1015
1017
1011
1010
1014
1013
1016
1012
1040
1050
1060
1070
1080
1120
1110
1090

FIG. 20

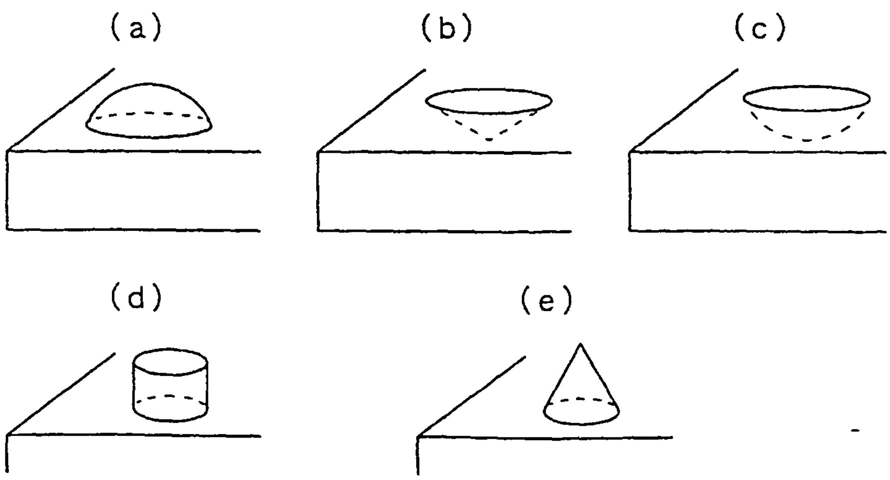

(a)
(b)
(c)
(d)
(e)

FIG. 21

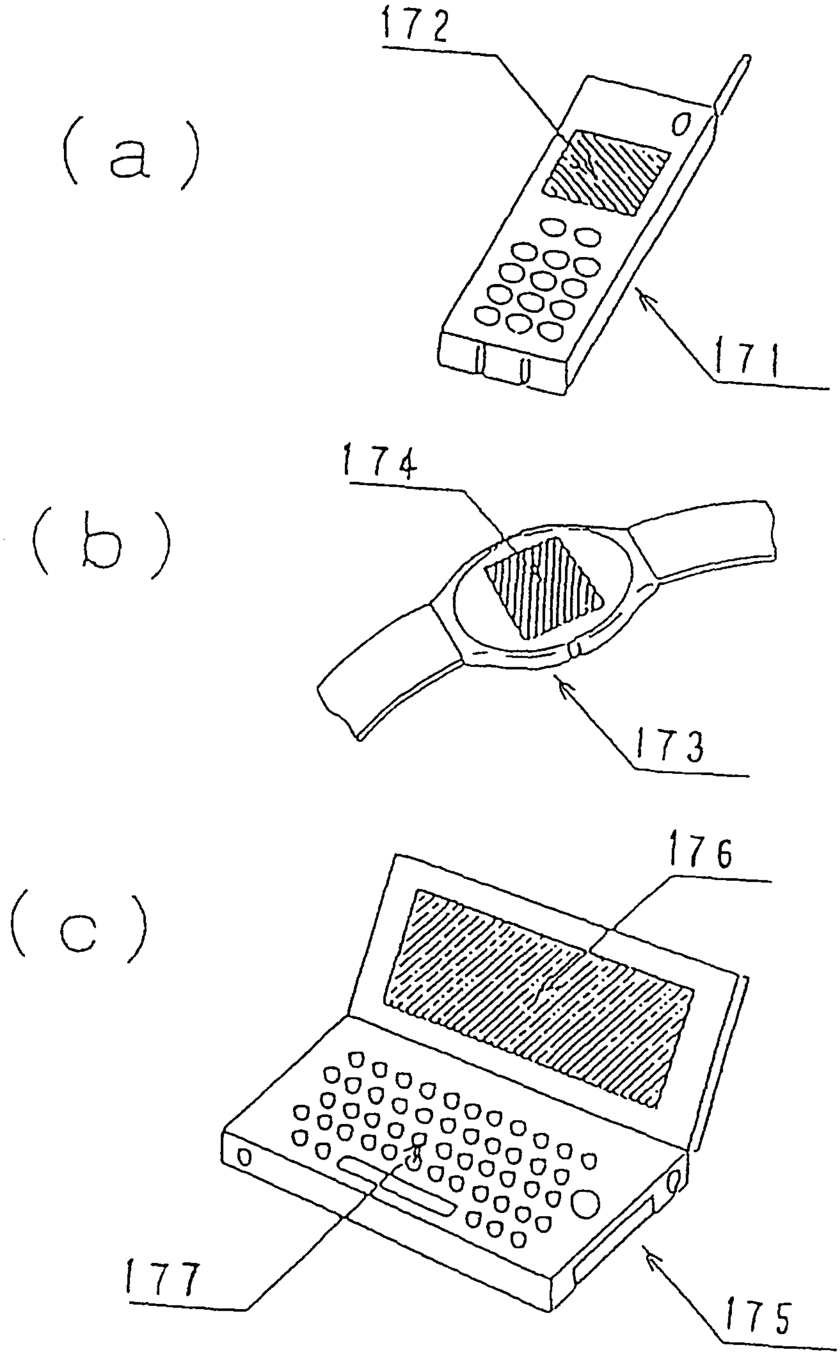
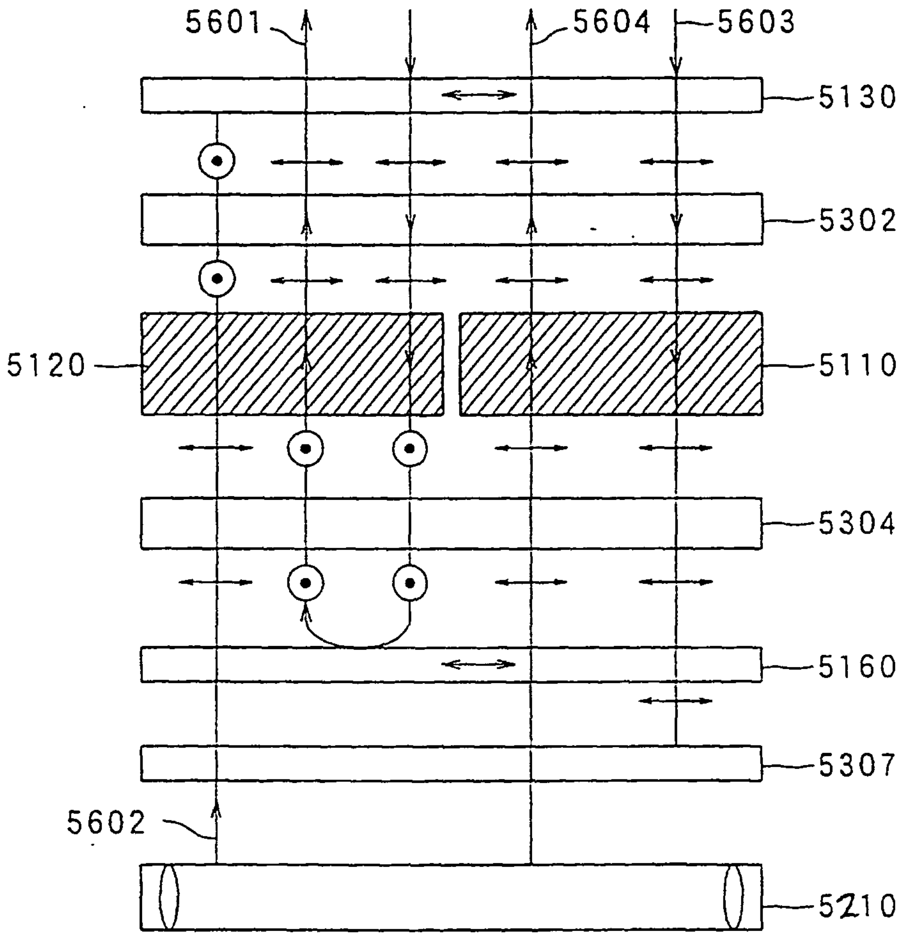


FIG. 22



REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 57049271 A **[0002] [0010]**
- JP 8245346 A **[0002] [0006]**
- JP 07036025 A **[0008]**
- WO 9517692 A **[0022]**

patsnap

专利名称(译)	显示设备，电子设备和光导		
公开(公告)号	EP1067424B1	公开(公告)日	2009-01-07
申请号	EP2000900929	申请日	2000-01-25
[标]申请(专利权)人(译)	精工爱普生株式会社		
申请(专利权)人(译)	SEIKO EPSON CORPORATION		
当前申请(专利权)人(译)	SEIKO EPSON CORPORATION		
[标]发明人	TSUCHIHASHI TOSHIHIKO SEIKO EPSON CORPORATION IIJIMA CHIYOAKI SEIKO EPSON CORPORATION		
发明人	TSUCHIHASHI, TOSHIHIKO, SEIKO EPSON CORPORATION IIJIMA, CHIYOAKI, SEIKO EPSON CORPORATION		
IPC分类号	G02F1/1335		
CPC分类号	G02F1/133536		
代理机构(译)	斯特，CLIFFORD MARK		
优先权	1999023719 1999-02-01 JP 1999159899 1999-06-07 JP		
其他公开文献	EP1067424A1 EP1067424A4		
外部链接	Espacenet		

摘要(译)

TN液晶140用作液晶面板，偏振器130设置在TN液晶140上方，而偏振器135，光散射层150和偏振分光器160依次设置在TN液体下此外，在偏振光分光器160下方，设置有用于从偏振光分光器160下方引入光源191的光和反射板200的光导190.偏振光分光器160是反射偏振器。可以实现光的有效利用，从而可以获得极其明亮的反射和透射显示。另外，由于设置了光漫射层150，即使从TN液晶140到反射板200的距离延长，在反射显示器中也不会出现双重图像或显示出血。

$$tA \cdot nAX + tB \cdot nBX = \lambda/2, \quad \ldots\ldots (2)$$