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(54) **REVERSE REFLECTANCE MODE
DIRECT-VIEW LIQUID CRYSTAL DISPLAY
EMPLOYING A LIQUID CRYSTAL HAVING
A CHARACTERISTIC WAVELENGTH IN
THE NON-VISIBLE SPECTRUM**

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(76) **Inventors: Bao-Gang Wu, Murphy, TX (US);
Jianan Hou, Germantown, MD (US);
Jianmi Gao, Richardson, TX (US);
Yong-Jing Wang, Ossining, NY (US);
Shushan Li, Plano, TX (US); Ruihai
Sun, Wylie, TX (US); Gang Chen,
Plano, TX (US)**

(57) **ABSTRACT**

Disclosed are various reverse-mode direct-view liquid crystal displays (LCD) employing a liquid crystal having a characteristic wavelength in the non-visible spectrum, including reflective and transmissive mode displays, and methods of fabrication. In accordance with the principles disclosed, a reflectance mode direct-view LCD includes a polarizer, a reflector, and a cholesteric liquid crystal (CLC) packed between the polarizer and reflector and having a characteristic wavelength to reflect non-visible spectrum. Portions of the CLC can selectively exhibit a planar state or a focal-conic state, the portions of the CLC in the planar state appearing black, and the portions of the CLC in the focal-conic state appearing white to an observer of the LCD. A transmissive mode LCD is derived by further combination of polarizers, transmissive mirrors and internal light sources.

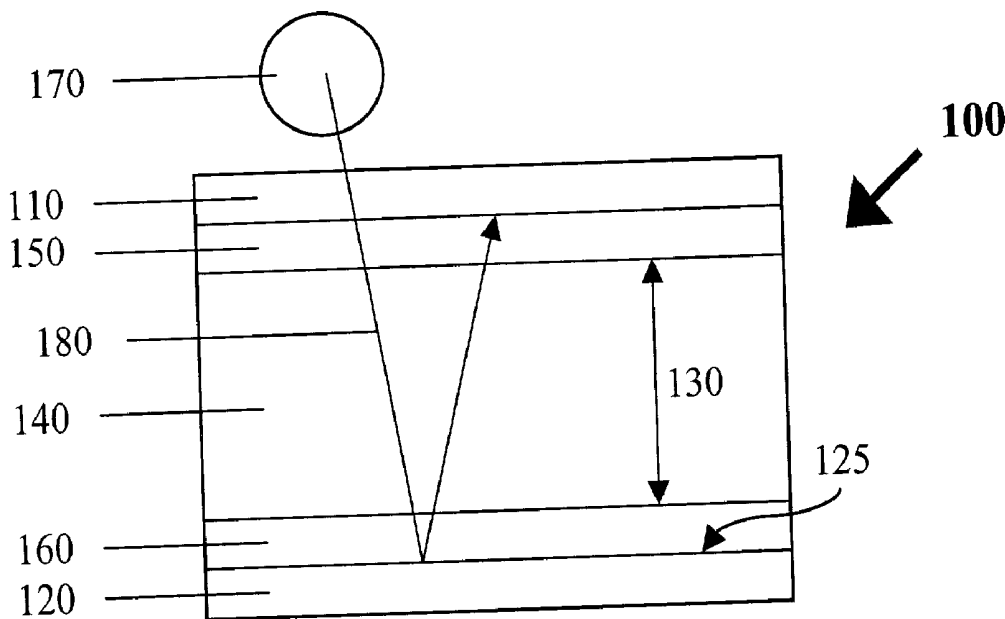
Correspondence Address:
HITT GAINES & BOISBRUN P.C.
P.O. BOX 832570
RICHARDSON, TX 75083 (US)

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Related U.S. Application Data

(63) **Continuation-in-part of application No. 09/874,519,
filed on Jun. 4, 2001, now Pat. No. 6,462,805.**



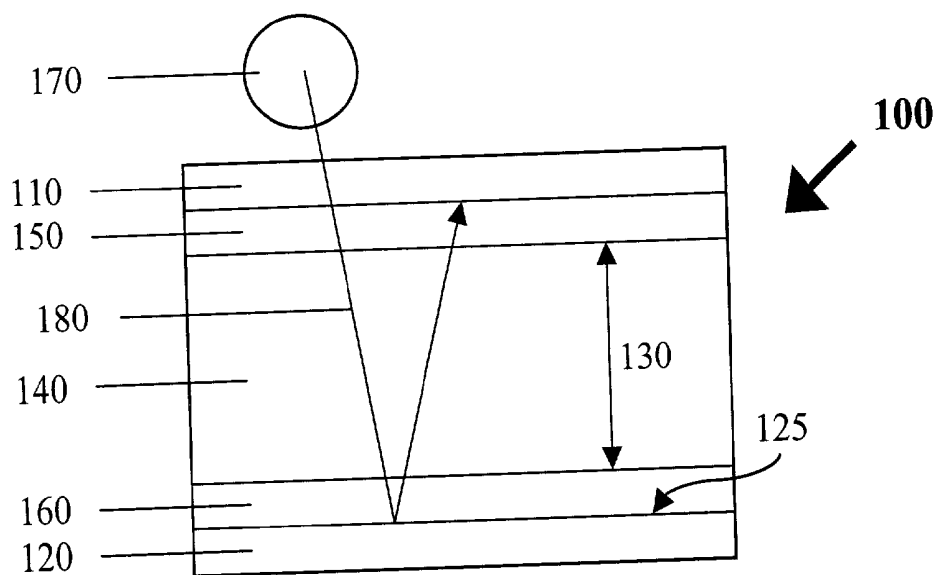


FIGURE 1A

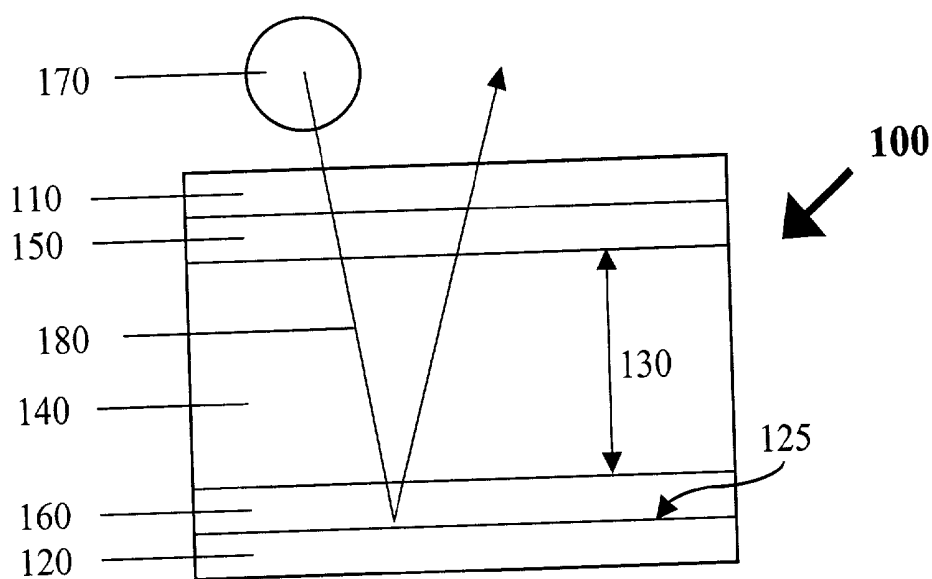


FIGURE 1B

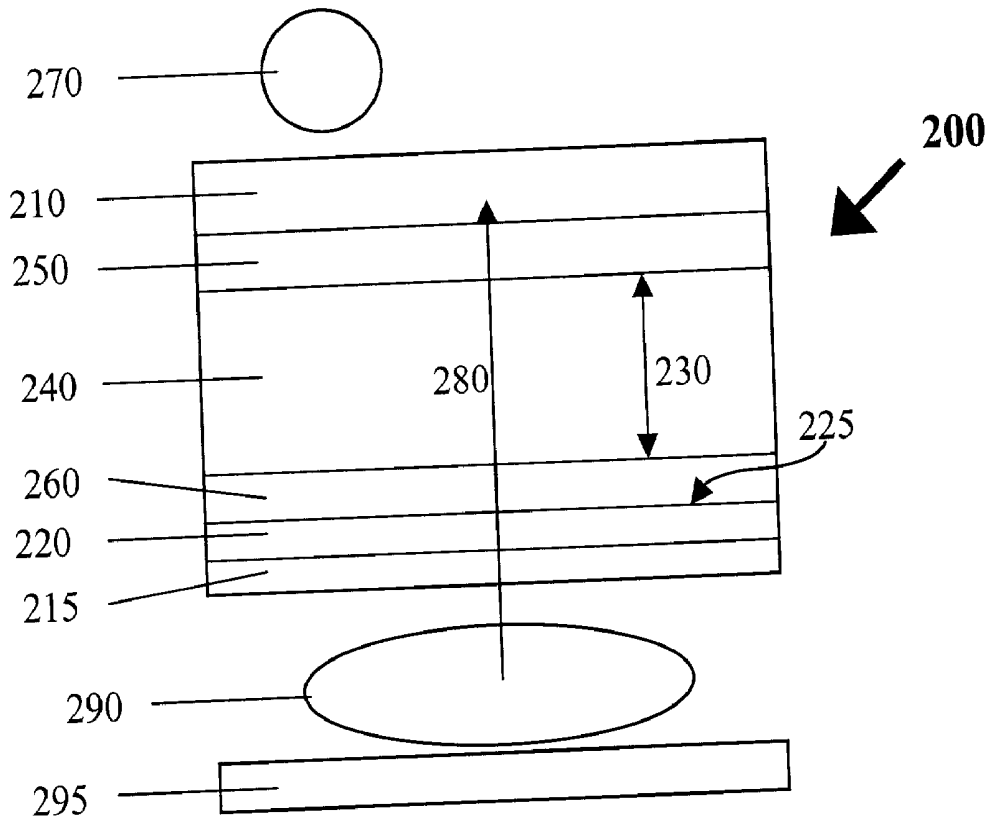


FIGURE 2A

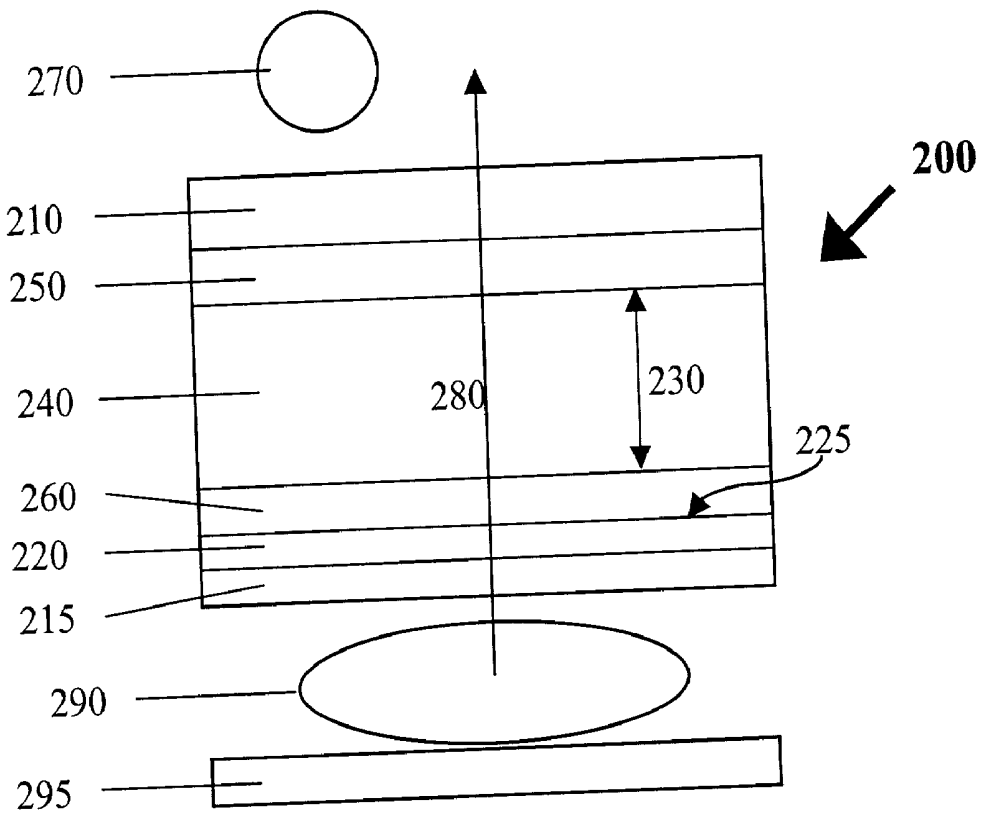


FIGURE 2B

300

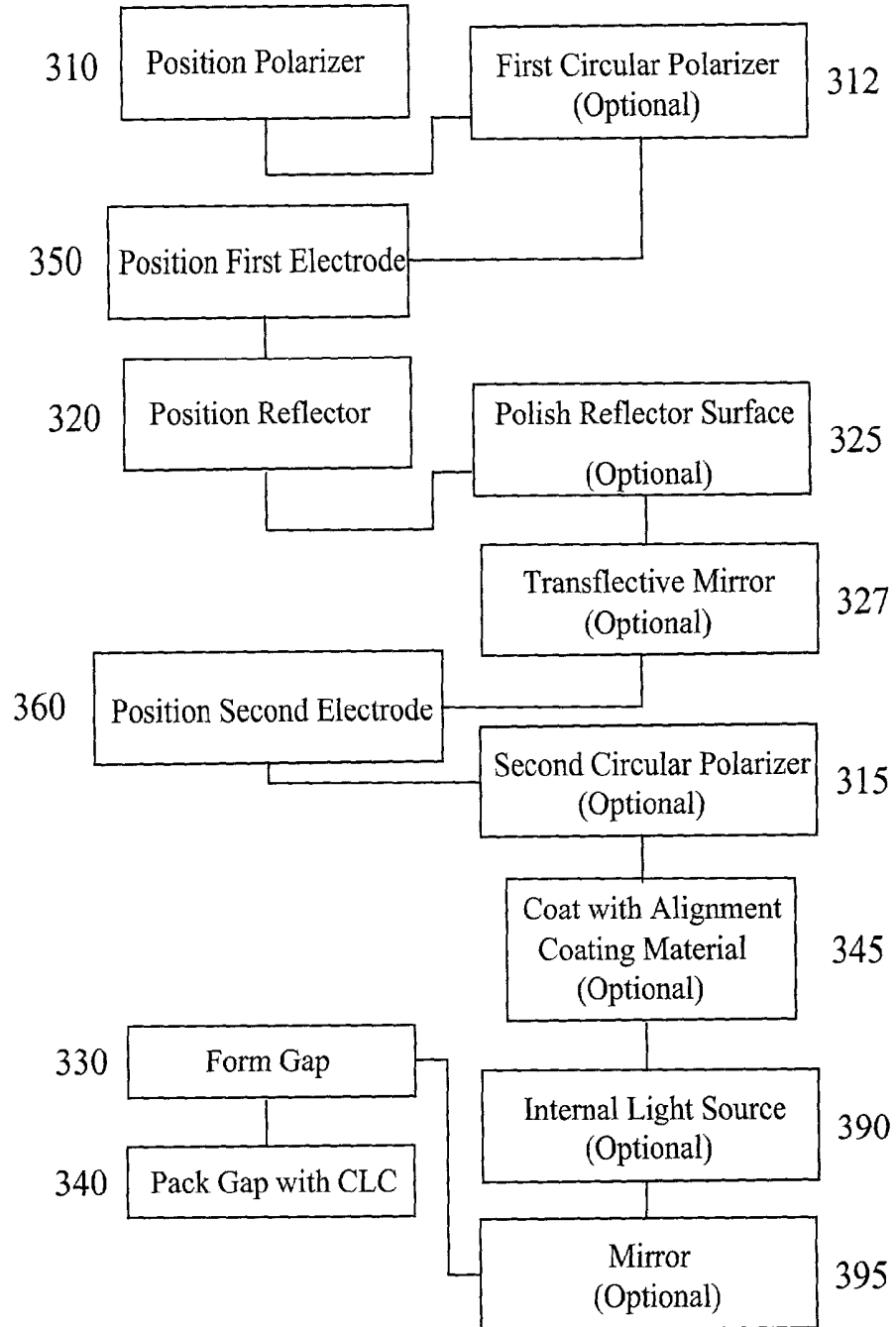


FIGURE 3

REVERSE REFLECTANCE MODE DIRECT-VIEW LIQUID CRYSTAL DISPLAY EMPLOYING A LIQUID CRYSTAL HAVING A CHARACTERISTIC WAVELENGTH IN THE NON-VISIBLE SPECTRUM

CROSS-REFERENCE TO APPLICATION

[0001] This continuation-in-part application claims the benefit of U.S. application Ser. No. 09/874,519, entitled, "Reverse-mode Direct-view Liquid Crystal Display Employing a Liquid Crystal Having a Characteristic Wavelength in the Non-visible Spectrum," to Bao-Gang Wu, Jianan Hou, Jianmi Gao, Yong-Jing Wang, Shushan Li, Rui Hai Sun and Gang Chen, filed on Jun. 4, 2001, commonly assigned with the present invention and incorporated herein by reference as if reproduced herein in its entirety.

TECHNICAL FIELD OF THE INVENTION

[0002] The present invention is directed, in general, to liquid crystal displays and, more specifically, to reflective and transreflective black-and-white and color cholesteric liquid crystal displays.

BACKGROUND OF THE INVENTION

[0003] The development of improved low-power-consumption flat-panel liquid crystal displays (LCDs) is an area of very active research, driven by the proliferation and demand for portable electronic appliances, including computers and wireless telecommunications devices. Moreover, as the quality of LCDs improve, and the cost of manufacturing declines, LCDs may eventually replace conventional display technologies, such as cathode-ray-tubes.

[0004] Cholesteric liquid crystal ("CLC") technology is a particularly attractive candidate for many display applications. CLC displays can be used to provide bi-stable and multi-stable displays that, owing to their stability, do not require a continuous driving circuit to maintain a display image, thereby significantly reducing power consumption. Moreover, some CLC displays can be easily viewed in ambient light without the need for back-lighting; such displays are referred to as "reflective" mode displays, while those requiring a back-light are referred to as "transmissive" mode displays. The elimination of the need for back-lighting is particularly significant in that lighting requirements typically represent approximately 90 percent of the total power consumption of conventional LC displays. While a reflective mode display is suitable for some applications, and a transmissive mode display is suitable for others, there are certain applications in which it is desirable to have a display operable in both reflective and transmissive modes, that is, a transreflective mode. Moreover, the visibility of a LC display is governed in part by the contrast between the quality of bright and dark states of LC cells in the display. For example, traditional normal mode CLC displays, using CLCs having a characteristic wavelength for the reflection of light in the visible spectrum, may have poor contrast because of an unfavorably low brightness to darkness ratio.

[0005] Accordingly, to meet the growing demand for LCDs, there is a need in the art for high contrast LCDs operable in reflective and transreflective modes.

SUMMARY OF THE INVENTION

[0006] To address the above-described deficiencies of the prior art, the present invention provides a reverse mode

direct-view liquid crystal displays employing a liquid crystal having a characteristic wavelength to reflect light in the non-visible spectrum, including reflective and transreflective mode displays, and methods of fabricating such displays. In accordance with the principles disclosed, the basic structure of the direct-view liquid crystal display (LCD) includes a polarizer, a reflector and a cholesteric liquid crystal (CLC) located in a gap between the polarizer and reflector such that the CLC receives light reflected from the reflector. The CLC has a characteristic wavelength in the non-visible spectrum and is capable of exhibiting planar or focal-conic states. Thus, portions of the LCD can be controlled to selectively exhibit a planar state or a focal-conic state, thereby achieving high contrast.

[0007] In one embodiment, the polarizer comprises a first circular polarizer, the reflector comprises a transreflective mirror and the direct-view LCD further comprises a second circular polarizer located posterior to the transreflective mirror with a light source located posterior to the second circular polarizer.

[0008] The foregoing has outlined, preferred and alternative features of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiment as a basis for designing or modifying other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0010] **FIGS. 1A and 1B** illustrates a cross-sectional view of an exemplary reverse mode reflective LCD structure, in accordance with the principles of the present invention, and its operation when its liquid crystal is in planar and focal-conic states, respectively;

[0011] **FIGS. 2A and 2B** illustrates a cross-sectional view of an exemplary reverse mode transreflective LCD structure, in accordance with the principles of the present invention, and its operation in a transmissive manner when its liquid crystal is in planar and focal-conic states, respectively; and

[0012] **FIG. 3** illustrates exemplary embodiments of a method of fabricating a direct-view LCD, in accordance with the principles of the present invention.

DETAILED DESCRIPTION

[0013] As described with reference to the exemplary embodiments illustrated in **FIGS. 1-2** and method of fabrication in **FIG. 3**, the present invention discloses the heretofore unrecognized capability to construct a direct-view LCD by combining a CLC having a characteristic intrinsic reflective wavelength, λ_0 , reflecting light maximally in the non-visible spectrum, with one or more linear, circular, or substantially circular, polarizers, and a reflective or a trans-

fective mirror. For purposes of the present invention, visible light is defined as the range of the light spectrum that the human visual system is relatively most sensitive to, i.e., a relative sensitivity of about greater than 5%, compared to the most sensitive wavelength, between about 450 nm to about 700 nm, with the non-visible spectrum laying above and below this range.

[0014] In particular embodiments, the CLC comprises a mixture of a nematic liquid crystal, and a chiral dopant. The mixture may comprise about 60 percent to about 90 percent by weight of the nematic liquid crystal, with a balance of the mixture comprising the chiral dopant. In certain embodiments, the mixture contains sufficient amounts of the appropriate dopant or combination of dopants to produce a helical CLC structure having a characteristic pitch that establishes a maximum reflective wavelength within either an infrared or an ultraviolet region of the light spectrum. In an exemplary embodiment, the infrared range may be greater than 700 nm and the ultraviolet range may be less than 450 nm.

[0015] In other embodiments, however, the infrared range may be greater than 780 nm and the ultraviolet range may be 400 nm or less. Portions of the CLC may be selectively controlled to exhibit a planar state or a focal-conic state. Portions of the CLC in the planar state within the direct-view LCD appear black to an observer, and portions of the CLC in the focal-conic state within the direct-view LCD appear white to an observer of the LCD.

[0016] Referring to FIGS. 1A and 1B, illustrated is a cross-sectional view of a reverse reflectance mode LCD 100, and its operation when CLC 140 is in planar and focal-conic states, respectively. LCD 100 comprises a polarizer 110, a reflector 120, thereby forming a gap 130 between the polarizer 110 and reflector 120, and a CLC 140 of the above described embodiments located in the gap 130 such that said CLC 140 receives light reflected from said reflector 120. The gap 130 generally ranges from about 1 micron to about 6 microns, and in certain preferred embodiments is about 2 to about 3 microns. The polarizer 110 and reflector 120 may be comprised of conventional materials well-known to those of ordinary skill in the art. The reflector 120 for example may be comprised of Aluminum.

[0017] With continuing reference to FIGS. 1A and 1B, LCD 100 may also include first electrode 150 adjacent an inner surface of the polarizer 110 and second electrode 160 adjacent an inner surface of the reflector 120. Electrodes 150, 160 are preferably made from conventional substantially transparent materials, such as indium tin oxide (ITO), and optionally laminated onto a glass substrate. The electrodes 150, 160 may further be optionally coated with an alignment coating material, for example, comprising a polyimide. Preferably, overlying polyimide layers on the two electrodes 150, 160 are buffed antiparallel to each other. The first and second electrodes, 150, 160 are further coupled to a conventional driving circuit (not shown) operative to cause the CLC 140 to selectively transform to a planar or focal-conic state. When in the planar state, the CLC 140 will reflect incident light having the same polarity as polarizer 110 from external light source 170 maximally at λ_0 , plus an associated bandwidth, but allow nonreflected light 180 at substantially all wavelengths of light outside of the reflected bandwidth to pass through without effecting its polarity. When in the focal-conic state, however, the CLC 140 is

operative to optically retard and scatter at all wavelengths, thereby changing the polarity of the nonreflected light 180.

[0018] With continuing reference to FIGS. 1A and 1B, in one exemplary embodiment, the polarizer 110 is a conventionally made first circular polarizer, comprising for example, a linear polarizer and a quarter wavelength retarder. The polarizer 110 may preferably be positioned on the outer surface of the first electrode 150; those skilled in the art, however, will recognize that the polarizer 110 alternatively could be positioned on the inner surface of the first electrode 150, or the polarizer 110 could have a first electrode integrally formed therewith.

[0019] With continuing reference to FIGS. 1A and 1B, in another exemplary embodiment, the reflector 120 is positioned on the outer surface of the second electrode 160; those skilled in the art, however, will recognize that the reflector 120 alternatively could be positioned on the inner surface of the second electrode 160, or the reflector 120 could have a second electrode integrally formed therewith, and thereby minimize parallax effects. Furthermore, the reflector 120 can have a colored surface, such that the reflected light appears to an observer to have substantially the same color as the reflector 120. Thus, different portions (i.e., pixels) of the display may have different colored reflectors, providing a multi-color display. Alternatively, a color filter (not shown) may be used to provide a single or multi-color display.

[0020] With continuing reference to FIG. 1A, shown is the operation of a preferred embodiment of LCD 100 when CLC 140 is in the planar state. Nonreflected light 180, including visible light, is circularly polarized as it passes through the polarizer 110. The polarity of the light 180 is either right or left circularly polarized, depending on the handedness of polarizer 110 when configured to be a circular polarizer. According to the principles of the present invention, the polarity of the light 180 is substantially unaffected as it passes through the CLC 140. Moreover, because λ_0 is in the nonvisible region of the spectrum, substantially all light 180 in the visible region of the spectrum reaching the CLC 140 will not be reflected by the CLC 140. The light 180 passing through the CLC 140 retains its polarity, until it is reflected by reflector 120, which will cause the handedness of the circular polarity to be reversed. For example, if the polarizer 110 has right-hand circular polarity, the light 180 reflected by reflector 120 and received by CLC 140 will have left-hand circular polarity. Because the polarity of the light 180 passing through CLC 140 is reversed upon reflection from reflector 120, polarizer 110 will block the exit of light 180. In one preferred embodiment, where λ_0 is in the ultraviolet spectrum, polishing a surface 125 of reflector 120 at a boundary between CLC 140 and reflector 120 is thought to minimize changes to the polarity of light 180, thereby maximizing the blockage of light 180 reaching polarizer 110. Thus, an observer of LCD 100 when CLC 140 is in the planar state will observe the LCD to be black.

[0021] Turning now to FIG. 1B, shown is the operation of a preferred embodiment of LCD 100 when CLC 140 is in the focal-conic state. Due to the light retarding and scattering properties of CLC 140 when in the focal-conic state, the polarity of nonreflected light 180 passing through polarizer 110 is altered both prior and subsequent to reflection by reflector 120 and received by the CLC 140. As noted above,

because λ_0 is in the nonvisible region of the spectrum, substantially all light **180** in the visible region of the spectrum reaching the CLC **140** will not be reflected by the CLC **140**. Consequently, at least a portion of the light **180** will have a circular polarity of the same handedness as circular polarizer **120**, and therefore exit LCD **100**. And because λ_0 is in the nonvisible region of the spectrum, substantially all light in the visible region of the spectrum will pass through the CLC and appear to an observer of the LCD **100** as a white display. In a preferred embodiment, where λ_0 is in the infrared spectrum, the LCD **100** further includes an alignment coating material and the gap **130** thickness is about 2 microns. Preferably the alignment coating material, for example a polyimide, is coated over electrodes **150**, **160** and the two coatings are rubbed anti-parallel to each other. The alignment coating material, gap **130** and CLC **140** when in the focal conic state cooperate to act as a quarter wavelength retarder. The polarity of the light **180** is thereby favorably altered to match that of polarizer **110**, allowing increased amounts of light **180** to exit LCD **100**. Thus, an observer of the reflective LCD **100** when CLC **140** is in the focal-conic state will observe the LCD to be white. In summary, the LCD **100** is capable of a substantially black and white display, corresponding to the CLC **140** in the planar and focal-conic state, respectively.

[0022] Turning now to FIGS. 2A and 2B, illustrated is a cross-sectional view of an exemplary embodiment of a reverse transreflectance mode LCD **200**, showing its operation in a transmissive manner when its liquid crystal **240** in gap **230** is in planar and focal-conic states, respectively. The polarizer is preferably a first circular polarizer **210** and the reflector is a transfective mirror **220**. Transfective mirror **220** is operative to reflect external incident light from the front of LCD **200** or transmit incident light from the rear. The transfective mirror **220** may be made of conventional materials well known to those of ordinary skill in the art, for example Aluminum. LCD **200** may include conventional first **250** and second **260** electrodes and driver (not shown), analogous to that described for LCD **100**, including the alternative embodiments detailed above.

[0023] With continuing reference to FIGS. 2A and 2B, LCD **200** further includes a second circular polarizer **215** positioned posterior to the transfective mirror **220**, and internal light source **290** positioned posterior to the second circular polarizer **215**. For example, the light source **290** may be a conventional LCD backlight, such as an electroluminescent panel. The second circular polarizer **215** has a polarity different than the first circular polarizer **210**, and preferably of the opposite handedness. In one preferred embodiment, a surface of the transfective mirror **220** may be polished at a boundary between the CLC **240**, analogous to that described for LCD **100**. Optionally, LCD **200** fabrication may further include positioning a mirror **295** posterior to the light source **290**. Mirror **295** reverses the polarity of the light blocked by the second circular polarizer **215**, thus increasing the amount of light passing through polarizer **215**.

[0024] With continuing reference to FIGS. 2A and 2B, in the exemplary embodiment, the first circular polarizer **210** is positioned on the outer surface of first electrode **250**. Those skilled in the art, however, will recognize that the first circular polarizer **210** could alternatively be positioned on the inner surface of the first electrode **250**, or the first

circular polarizer **210** could have the first electrode **250** integrally formed therewith. Similarly, although the transfective mirror **220** is positioned on the outer surface of the second electrode **260**, the transfective mirror **220** could be positioned on the inner surface of the second electrode **260**, or the transfective mirror **220** could have the second electrode **260** integrally formed therewith. Furthermore, the transfective mirror **220** can have a colored surface, such that reflected light appears to an observer to have substantially the same color as the transfective mirror **220**. Moreover, different portions (i.e., pixels) of the display could have different colored transfective mirrors, whereby a multi-color display can be provided. Alternatively, a color filter can be used to provide a single or multi-color display.

[0025] With continuing reference to FIG. 2A, the operation of LCD **200** in the transmissive mode is depicted when CLC **240** is in a planar state. Light emitted from light source **290** is circularly polarized on passing through the second circular polarizer **215** and transfective mirror **220**. Non-visible light having the same polarity as polarizer **215** at λ_0 and its associated bandwidth will be reflected by the CLC **240**, while other wavelengths of non-reflected light **280**, including visible light, will pass through the CLC **240**. According to the principles of the present invention, the polarity of the non-reflected light **280** is substantially unaffected on passing through CLC **240** when the CLC **240** is in a planar state. Consequently, the non-reflected light **280** on reaching the first circular polarizer **210**, will be blocked because the polarity of the first and second circular polarizers **210** and **220** are of different, preferably opposite handedness. Similar to that described for LCD **100**, in a preferred embodiment, polishing a surface of the transfective mirror **220** at a boundary between the CLC **240** and the transfective mirror **220** reduces disturbance of the polarity of the non-reflected light **280**. Therefore, an observer of the LCD **200** operating in the transmissive mode will observe a black state corresponding to portions of the CLC **240** in the planar state.

[0026] Turn now the FIG. 2B, the operation of LCD **200** in the transmissive mode is depicted when CLC **240** is in a focal-conic state. Because of the light scattering and retarding effects of the focal-conic structure, the polarity of non-reflected light **280** is altered as it passes through portions of the CLC **240** in the focal-conic state. Consequently, a portion of the light **280** will have a circular polarity handedness corresponding to the handedness of first circular polarizer **210**, and will thus exit LCD **200**. Similar to that described for LCD **100**, in a preferred embodiment, LCD **200** further includes an alignment coating material on electrodes **250**, **260** and having an adjusted gap **230** thickness of about two microns to create a quarter wavelength retarder effect when the CLC **240** is in the focal conic state, thereby increasing the amount of light **280** exiting LCD **200**. Therefore, an observer of LCD **200** operating in the transmissive mode will observe a white state corresponding to portions of the CLC **240** in the focal-conic state. Thus the LCD **200** is capable of a substantially black and white display, corresponding to the CLC **240** in the planar and focal-conic state, respectively.

[0027] The operation of LCD **200** in a reflective mode using external incident light source **270**, when its liquid

crystal is in planar and focal-conic states, is substantially the same as described above for LCD 100 and illustrated in FIGS. 1A and 1B.

[0028] Turning now to FIG. 3, illustrated is an exemplary embodiment of a method of fabricating a reverse mode direct-view LCD 300, in accordance with the principles of the present invention. The LCD is fabricated by positioning a polarizer 310, positioning a reflector 320, thereby forming a gap 330 between the polarizer and reflector, and packing the gap 340 with a CLC having a λ_0 in the non-visible spectrum and capable of exhibiting a planar state or a focal-conic state. Conventional packing techniques, such as capillary or vacuum filling, well known to those skilled in the art, may be used. Packing with the CLC includes packing a mixture of a nematic liquid crystal and a chiral dopant. In certain embodiments, the mixture comprises about 60 percent to about 90 percent by weight of the nematic liquid crystal and a balance of the mixture comprises the chiral dopant. One of ordinary skill in the art will understand that the chiral dopant may, in some embodiments, contain a combination of chiral dopants to produce the desired λ_0 in an ultraviolet or infrared region of the spectrum. In certain embodiments, forming the gap 330 results in gaps ranging from about 1 micron to about 6 microns and in certain preferred embodiments, about 2 micron to about 3 microns. When λ_0 is in the infrared spectrum, the gap is preferably about 2 microns. In yet other preferred embodiments, when λ_0 falls within the ultraviolet spectrum, the reflector is polished 325. Fabricating the LCD 300 further includes positioning conventional first and second electrodes 350, 360; as discussed above the electrodes could alternately be formed and positioned integrally with the polarizer 310 or reflector 320. In certain preferred embodiments, alignment coating materials rubbed antiparallel to each other may be coated 345 onto the electrodes.

[0029] With continuing reference to FIG. 3, alternative embodiments of fabricating the LCD 300, including fabricating an LCD for operation in the transmissive mode, are also illustrated. Fabrication may further include positioning the reflector comprising a transmissive mirror 327, and positioning the polarizer comprising a first circular polarizer 312. Fabrication further includes positioning a second circular polarizer 315 posterior to the transmissive mirror, the second circular polarizer having a polarity different from the first polarizer, preferably of opposite handedness, and positioning an internal light source 390 posterior to the second circular polarizer. In certain preferred embodiments, fabricating further includes positioning a mirror 395 posterior to the light source.

EXAMPLES

[0030] Five different types of direct-view LCDs were prepared according to the present invention: reflective reverse-mode and transmissive reverse-mode, each having a λ_0 in either an infrared or ultraviolet region of the light spectrum. For all five preparations, unless otherwise indicated, two pieces of four inch square glass substrates, were laminated with electrode material comprising ITO having a resistance of 60 Ω per square inch. The ITO layers were then coated with an alignment coating material of polyimide (PI-150; Nissan Chemical Industries, Ltd., Houston, Tex.). The polyimide coatings were buffed anti-parallel to each other. The electrodes were then laminated to a polarizer and a reflector, described below, to form test cells.

[0031] The desired electronic waveforms were applied on the cell as described in U.S. Pat. No. 5,625,477, entitled, "Zero Field Multistable Cholesteric Liquid Crystal Display;" U.S. Pat. No. 5,889,566, entitled, "Multistable Cholesteric Liquid Crystal Devices Driven By Width-Dependent Voltage Pulses;" and U.S. Pat. No. 5,933,203, entitled, "Apparatus for and Method Of Driving A Cholesteric Liquid Crystal Flat Panel Display," all to Bao-Gang Wu, et. al., which are commonly assigned with the present invention, and incorporated herein by reference as if reproduced herein in its entirety. Using the apparatus described in the above cited references, every pixel of the cell can be switched between planar state and focal conic states. All nematic liquid crystals and chiral dopants were obtained from EM industries (Hawthorne, N.Y.).

[0032] A reflective reverse-mode type LCD (designated LCD-1) having a λ_0 in the infrared range was prepared in the following way. A circular polarizing plate, comprising a quarter wave length retarder ($\frac{1}{4}\lambda$) having a maximum transmittance at 550 nm and linear polarizer, was laminated onto the first substrate. A reflector, comprising a thin reflective aluminum layer, was coated onto the second substrate. Unless otherwise indicated, spacers were used to form a gap of about 3 microns between the polarizer and reflector. A liquid crystal mixture containing by weight about 90.1% ZLI-5400-100™ (nematic liquid crystal), and chiral dopant, comprising about 3.8% ZLI-4571™, and 6.1% ZLI-811™, was packed into the gap. A second reflective reverse-mode type LCD (designated LCD-2) having a λ_0 in the ultraviolet range was prepared by filling a similarly fabricated cell with a liquid crystal mixture containing about 63.1% by weight ZLI-5400-100™, and chiral dopant comprising by weight: about 22.4% CB-15™, 6.5% ZLI-4572™, and 8.0% ZLI-3786™, and using the same front surface and backside configuration as described above.

[0033] The resulting reflective reverse-mode type LCDs have a λ_0 centered at about 780 nm and about 400 nm, for LCD-1 and LCD-2, respectively. For both LCDs, planar state and focal conic states are stable for at least one month in the absence of an electrical field. And for both LCDs, the planar state appears as black and the focal conics state appears as white.

[0034] A third reflective reverse-mode type LCD (designated LCD-3) having a λ_0 in the infrared range was prepared as described above, but with the following modifications. The polyimide alignment coating comprised a mixture of by weight 25% SE1211™ and 75% SE5291™, both from Nissan Chemical Industries. A liquid crystal mixture containing by weight about 91.2% MLI-6625™ (nematic liquid crystal), and chiral dopant, comprising about 6% CB-15™ and 3% ZLI-4578™, was packed into the gap. In this configuration, when in the focal conic state, LCD-3 produces a $\frac{1}{4}\lambda$ effect centered at 550 nm. This in turn increases the amount of light exiting LCD-3, thereby making the cell appear a brighter white to an observer.

[0035] A transmissive reverse-mode type LCD (designated LCD-4) having a characteristic wavelength in the infrared range was prepared by filling the cell with a liquid crystal mixture containing the same relative amounts of ZLI-5400-100™, ZLI-4572™ and ZLI-3786™ as described above for LCD-1. A first circular polarizing plate, similar to that described above, was laminated onto the front surface of the

display. A conventional transfective mirror was positioned on the backside of the cell, and a second circular polarizing plate was laminated onto the backside of the transfective mirror. Finally, back-lighting was placed behind the backside of the second circular polarizing plate. A second transfective reverse-mode type LCD (designated LCD-5) having a characteristic wavelength in the ultraviolet range was prepared by filling the cell with a liquid crystal mixture containing the same relative amounts by weight of ZLI-5400-100™, CB-15™, ZLI-4572™, and ZLI-3786™ as described above for LCD-2, and using the same front surface and backside configuration as described above for LCD-4.

[0036] The resulting transfective reverse-mode type LCDs have a λ_0 centered at about 780 nm and about 400 nm, for LCD-4 and LCD-5, respectively. For both LCDs, planar state and focal conic states are stable at least one month in the absence of an electrical field. In the transmissive mode, when the back-light was on, the planar state appears as black and the focal conics state appears as white. Similarly, in the reflective mode, when the back-light was off, the planar state appears as black and the focal conics state appears as white.

[0037] From the foregoing detailed description, it is apparent that the present application discloses novel reverse-mode direct-view liquid crystal displays employing liquid crystal having a characteristic wavelength to reflect light in the non-visible spectrum, including reflective and transfective displays.

[0038] Although the present invention and its advantages have been described in detail, those skilled in the art should understand that they can make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention.

What is claimed is:

1. A direct-view liquid crystal display (LCD), comprising:
 - a polarizer;
 - a reflector; and
 - a cholesteric liquid crystal (CLC) located in a gap between said polarizer and reflector such that said CLC receives light reflected from said reflector, said CLC having a characteristic wavelength in the non-visible spectrum and capable of exhibiting a planar state or a focal-conic state.
2. The direct-view LCD recited in claim 1 wherein said CLC comprises a mixture of a nematic liquid crystal and a chiral dopant.
3. The direct-view LCD recited in claim 2 wherein said mixture comprises about 60 percent to about 90 percent by weight of said nematic liquid crystal and a balance of said mixture comprising said chiral dopant.
4. The direct-view LCD recited in claim 1 wherein said gap ranges from about 1 micron to about 6 microns.
5. The direct-view LCD recited in claim 1 wherein said gap ranges from about 2 microns to about 3 microns.
6. The direct-view LCD recited in claim 1 wherein said LCD further includes an alignment coating material.
7. The direct-view LCD recited in claim 6 wherein said alignment coating material comprises a polyimide.
8. The direct-view LCD recited in claim 1 wherein said characteristic wavelength of said CLC is in the infrared spectrum.

9. The direct-view LCD recited in claim 8 wherein said characteristic wavelength of said CLC is greater than about 780 nm.

10. The direct-view LCD recited in claim 8 wherein said characteristic wavelength of said CLC is greater than about 700 nm.

11. The direct-view LCD recited in claim 8 wherein where said LCD includes two alignment coating materials, and said coating materials, said gap and said CLC, when in the focal conic state, cooperate to act as a quarter wavelength retarder.

12. The direct-view LCD recited in claim 6 wherein said CLC further includes said alignment coating material comprising a polyimide and said gap is about 2 microns.

13. The direct-view LCD recited in claim 1 wherein said characteristic wavelength of said CLC is in the ultraviolet spectrum.

14. The direct-view LCD recited in claim 13 wherein said characteristic wavelength of said CLC is less than about 380 nm.

15. The direct-view LCD recited in claim 13 wherein said characteristic wavelength of said CLC is less than about 450 nm.

16. The direct-view LCD recited in claim 13 wherein a surface of said reflector at a boundary between said CLC and said reflector is polished.

17. The direct-view LCD recited in claim 1 further comprising a first electrode adjacent an inner surface of said polarizer and a second electrode adjacent an inner surface of said reflector.

18. The direct-view LCD recited in claim 1 wherein said polarizer comprises a first circular polarizer.

19. The direct-view LCD recited in claim 18 wherein said reflector comprises a transfective mirror and said direct view LCD further comprises a second circular polarizer located posterior to said transfective mirror said second circular polarizer having a polarity different from said first polarizer, and a light source located posterior to said second circular polarizer.

20. The direct-view LCD recited in claim 18 further comprises a mirror located posterior to said light source.

21. The direct-view LCD recited in claim 1 wherein said reflector has a colored surface.

22. A method of fabricating a direct-view LCD comprising the steps of:

positioning a polarizer;

positioning a reflector thereby forming a gap between said polarizer and reflector; and

packing said gap with a cholesteric liquid crystal (CLC) such that said CLC receives light reflected from said reflector, said CLC having a characteristic wavelength in the non-visible spectrum and capable of exhibiting a planar state or a focal-conic state.

23. The method as recited in claim 22 wherein fabricating said direct-view LCD includes packing with said CLC comprising a mixture of a nematic liquid crystal and a chiral dopant.

24. The method as recited in claim 22 wherein fabricating said direct-view LCD includes packing with said mixture comprising about 60 percent to about 90 percent by weight of said nematic liquid crystal and a balance of said mixture comprising said chiral dopant.

25. The method as recited in claim 22 wherein fabricating said direct-view LCD includes said forming said gap ranging from about 1 micron to about 6 microns.

26. The method as recited in claim 22 wherein fabricating said direct-view LCD includes said forming said gap ranging from about 2 microns to about 3 microns.

27. The method as recited in claim 22 wherein fabricating said direct-view LCD further includes coating said polarizer and said reflector with an alignment coating material.

28. The method as recited in claim 27 wherein fabricating said direct-view LCD further includes coating with said alignment coating material comprising a polyimide.

29. The method as recited in claim 22 wherein fabricating said direct-view LCD includes said packing said CLC having said characteristic wavelength in the infrared spectrum.

30. The method as recited in claim 22 wherein said characteristic wavelength of said CLC is greater than about 780 nm.

31. The method as recited in claim 22 wherein said characteristic wavelength of said CLC is greater than about 700 nm.

32. The method as recited in claim 29 wherein fabricating said direct-view LCD further includes coating said polarizer and said reflector with an alignment coating material, and said coating materials, said gap and said CLC, when in the focal conic state, cooperate to act as a quarter wavelength retarder.

33. The method as recited in claim 27 wherein fabricating said direct-view LCD further includes said alignment coating material comprising a polyimide and said gap is about 2 microns.

34. The method as recited in claim 22 wherein fabricating said direct-view LCD includes said packing said CLC having said characteristic wavelength in the ultraviolet spectrum.

35. The method as recited in claim 34 wherein said characteristic wavelength of said CLC is less than about 380 nm.

36. The method as recited in claim 34 wherein said characteristic wavelength of said CLC is less than about 450 nm.

37. The method as recited in claim 34 wherein fabricating said direct-view LCD further includes polishing a surface of said reflector, said surface at a boundary between said CLC and said reflector.

38. The method as recited in claim 22 wherein fabricating said direct-view LCD further includes positioning a first electrode adjacent an inner surface of said polarizer and positioning a second electrode adjacent an inner surface of said reflector.

39. The method as recited in claim 22 wherein fabricating said direct-view LCD includes positioning said polarizer comprising a first circular polarizer.

40. The method as recited in claim 39 wherein fabricating said direct-view LCD includes positioning said reflector comprising a transfective mirror, and said fabricating further comprises positioning a second circular polarizer posterior to said transfective mirror said second circular polarizer having a polarity different from said first polarizer, and positioning a light source posterior to said second circular polarizer.

41. The method as recited in claim 40 wherein fabricating said direct-view LCD includes positioning a mirror posterior to said light source.

42. The method as recited in claim 22 wherein fabricating said direct-view LCD includes positioning a reflector with a colored surface.

* * * * *

专利名称(译)	反射率模式直视液晶显示器采用具有非可见光谱中的特征波长的液晶		
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[标]申请(专利权)人(译)	吴宝岗 侯佳男 高尖米 王勇JING 李蜀山 SUN瑞海 陈刚		
申请(专利权)人(译)	吴宝岗 侯浙江迦南 高尖米 王永JING 李蜀山 SUN瑞海 陈刚		
当前申请(专利权)人(译)	DISPLAY研究INCORPORATED		
[标]发明人	WU BAO GANG HOU JIANAN GAO JIANMI WANG YONG JING LI SHUSHAN SUN RUIHAI CHEN GANG		
发明人	WU, BAO-GANG HOU, JIANAN GAO, JIANMI WANG, YONG-JING LI, SHUSHAN SUN, RUIHAI CHEN, GANG		
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摘要(译)

公开了采用具有非可见光谱中的特征波长的液晶的各种反向模式直视液晶显示器 (LCD) , 包括反射和透反模式显示器 , 以及制造方法。根据所公开的原理, 反射模式直视LCD包括偏振器, 反射器和填充在偏振器和反射器之间并具有反射不可见光谱的特征波长的胆甾型液晶 (CLC) 。 CLC的一部分可以选择性地呈现平面状态或焦点圆锥状态, 处于平面状态的CLC部分呈现黑色, 并且处于焦点圆锥状态的CLC部分对于LCD的观察者呈现白色。透射反射模式LCD通过偏振器, 透反射镜和内部光源的进一步组合得到。

