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

(11) EP 1 599 758 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
07.05.2008 Bulletin 2008/19

(21) Application number: **04715065.1**

(22) Date of filing: **26.02.2004**

(51) Int Cl.:
G02F 1/139 *(2006.01)*

(86) International application number:
PCT/US2004/005797

(87) International publication number:
WO 2004/077392 (10.09.2004 Gazette 2004/37)

(54) **VERTICALLY ALIGNED NEMATIC MODE LIQUID CRYSTAL DISPLAY HAVING LARGE TILT ANGLES AND HIGH CONTRAST**

VERTIKAL AUSGERICHTETE FLÜSSIGKRISTALLANZEIGE IM NEMATISCHEN MODUS MIT GROSSEN NEIGUNGSWINKELN UND HOHEM KONTRAST

AFFICHEUR A CRISTAUX LIQUIDES EN MODE NEMATIQUE, ALIGNES VERTICALEMENT A GRAND ANGLE DE BASCULEMENT ET FORT CONTRASTE

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

(30) Priority: **26.02.2003 US 450370 P**
15.05.2003 US 438511

(43) Date of publication of application:
30.11.2005 Bulletin 2005/48

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- **PATENT ABSTRACTS OF JAPAN vol. 1996, no. 06, 28 June 1996 (1996-06-28) -& JP 08 043825 A (FUJITSU LTD), 16 February 1996 (1996-02-16)**
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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to liquid crystal displays (LCDs), and more particularly to reflective liquid crystal on silicon (LCOS) displays.

BACKGROUND OF THE FIELD OF TECHNOLOGY

[0002] Liquid crystal display technology has reduced the size of displays from full screen sizes to minidisplays of less than 1.3 inches diagonal measurement, to microdisplays that require a magnification system. Microdisplays may be manufactured using semiconductor integrated circuit (IC) dynamic random access memory (DRAM) process technologies, *e.g.,* liquid crystal on silicon (LCOS). The LCOS microdisplays consist of a silicon substrate backplane with a reflective surface, a cover glass and an intervening liquid crystal layer. The LCOS microdisplays are arranged as a matrix of pixels arranged in a plurality of rows and columns, wherein an intersection of a row and a column defines a position of a pixel in the matrix. To incident light, each pixel is a liquid crystal cell above a reflecting mirror. By changing the molecular orientation of the liquid crystal in the layer, characterized by a tilt angle and a twist angle of the liquid crystal director at any point in the layer, the incident light can be made to change its polarization. The silicon backplane is an array of pixels, typically 7 to 20 micrometers (μm) in pitch. Each pixel has a mirrored surface that occupies most of the pixel area. The mirrored surface is also an electrical conductor that forms a pixel capacitor with the liquid crystal display cover glass electrode which is a transparent conductive coating on the inside face (liquid crystal side) of the cover glass. This transparent conductive coating is typically Indium Tin Oxide (ITO). As each pixel capacitor is charged to a certain voltage value, the liquid crystal fluid between the plates of the pixel capacitors changes its molecular orientation which affects the polarization state of the light incident to the pixels (reflections from the pixel mirrors).

[0003] The reflective LCOS microdisplays have a high aperture ratio, and therefore can provide greater brightness than transmissive liquid crystal displays. Major applications of these LCOS microdisplays are in home theater applications, *e.g.*, projectors, and front and rear projection televisions (large screen). For these applications, high contrast is very important. High contrast depends upon the liquid crystal optical mode being used in the liquid crystal display. Typically, a Vertically Aligned Nematic (VAN) mode is one of the optical modes that can achieve a very high contrast and many liquid crystal display manufacturers are beginning to use this particular optical mode in their displays.

[0004] The pretilt angle is defined as the tilt angle of the liquid crystal director at the boundary surface. In VAN mode liquid crystal displays, the pretilt angle is small, so the orientation of the molecules of the liquid crystal fluid are nearly perpendicular to the substrate surfaces when there is no electric field applied across the display. Therefore, incoming linearly polarized light, perpendicular to the display substrates, sees a small birefringence as it passes through the layer. Hence this normally incident linearly polarized light experiences little phase retardation when going through the liquid crystal fluid, including being reflected back from the bottom reflective substrate of the display. This provides a very dark "OFF" state when using crossed polarizers (*e.g.*, polarizing beam splitter - PBS), thus very high contrast is achieved. Upon application of an electric field across the liquid crystal fluid, the molecules in the bulk of the liquid crystal fluid orient themselves toward a direction defined by alignment layers on the substrate surfaces, thereby increasing the retardation of the layer of the liquid crystal fluid. Therefore, linearly polarized incident light starts to experience a phase retardation when going into the liquid crystal fluid and then being reflected back from the bottom reflective substrate of the display. As a result of this, the polarization state of the out-going light (reflected light) will be elliptical and some light starts to pass through the crossed polarizers. Increasing the electric field increases this effect until the brightest state is achieved.

[0005] In a typical VAN mode, the orientations of the molecules of the liquid crystal fluid at the substrate surfaces are defined by the alignment layers on each of the substrate surfaces. This orientation is described by a pretilt angle and a surface azimuthal direction, which is parallel to the projection of the liquid crystal director onto the plane of the substrate. The azimuthal direction of the molecules of the liquid crystal fluid proximate to the top alignment layer is opposite to the azimuthal direction of the molecules of the liquid crystal fluid proximate to the bottom alignment layer, *i.e.*, anti-parallel. The azimuthal directions defined by the alignment layers are at a 45 degree angle with the direction of polarization of the incoming linearly polarized incident light, as shown in Figures 1a and 1b. Usually the pretilt angle of the molecules in a VAN mode display needs to be kept small, *e.g.*, less than 4 degrees, to achieve a very dark "OFF" state, hence the high contrast. Although this pretilt angle is large enough to prevent reverse tilt domains in the display, it is not possible to overcome the defects that occur due to fringe fields between neighboring pixels. Fringe fields become very significant when the pixel size becomes small as is typical in LCOS microdisplays. For example, the size of an LCOS microdisplay may measure one inch diagonally and have a pixel size of approximately 12 μm x 12 μm. When high resolution is required, *e.g.*, digital cinema applications, pixel size may be further reduced to approximately 9 μm x 9 μm or even smaller. In such situations fringe fields are quite pronounced and the liquid crystals do not align along the direction defined by the tilt direction of the alignment layers. Ultimately this will create defects at the pixel boundaries, usually known as disclinations. This is quite apparent when one pixel is in an "ON" state and an adjacent pixel is in an "OFF" state, wherein the fringe fields are very strong.

[0006] Typical displays according to the prior art are disclosed, for example, in CH 661361A, US-A1-2001 0030723, EP-A-0793133, or US-A-6141074.

[0007] To overcome the above problem, it is necessary to increase the pretilt angle generated by the alignment layers on the substrate surfaces. Experimentally it has been determined that the pretilt angle has to be at least 8 degrees to overcome the fringe field effects. However, the dark state of a VAN mode liquid crystal display with a pretilt angle of this magnitude has a significant amount of light leakage through the crossed polarizers and the light contrast it can achieve is not that high. Therefore, the inherent property of VAN displays, the very dark "OFF" state, cannot be fully achieved. This is due to the non-zero birefringence seen by the linearly polarized incident light due to the high pretilt angle of the liquid crystal fluid. Heretofore, it has been necessary to use other methods such as attaching external retarders to stop this light leakage. Generally, this is the current method used by all the VAN liquid crystal display manufactures to solve the above problem.

SUMMARY OF THE INVENTION

[0008] The present invention overcomes the above-identified problems as well as other shortcomings and deficiencies of existing technologies by providing a method and apparatus as defined in the independent claims. Further enhancements are characterized in the dependent claims.

[0009] In the typical VAN optical mode, the surface azimuthal direction is 45 degrees to the direction of polarization of incoming linearly polarized incident light. Therefore, there is an effective birefringence as seen by the incoming incident light and it increases with increasing pretilt angle, hence the amount of light leakage.

[0010] If the display shown in figure 1a is rotated by 45 degrees with respect to the polarization direction of the incident linearly polarized light, *i.e.*, the surface azimuthal direction of the molecules of the liquid crystal fluid is either parallel or perpendicular to the direction of polarization of incoming incident linearly polarized light, then the light leakage is minimum because the effective birefringence as seen by the incoming incident linearly polarized light is zero and does not depend on the pretilt of the molecules of the liquid crystal fluid. However, this configuration cannot be applied to practical applications because the "ON" state is not bright due to the same reason explained above. But this feature is advantageously being used in the present invention, *i.e.*, surface azimuthal directions generated by the top and bottom substrates are set substantially perpendicular to each other. Also at the same time, the surface azimuthal direction generated by one substrate is perpendicular/parallel to the direction of polarization of incoming linearly polarized light while the surface azimuthal direction from the other substrate is parallel/perpendicular. Essentially this is a 90 degree twisted structure in the "OFF" state. Because the majority of the molecules of the liquid crystal layer do not have their azimuthal directions oriented at 45 degrees to the direction of polarization of incoming incident linearly polarized light, the effective birefringence as seen by the incoming incident linearly polarized light is minimal as compared to a VAN structure where all molecules have the same tilt angle and their surface azimuthal directions are all oriented at 45 degrees with respect to the polarization direction of the incoming linearly polarized light. Therefore, in the present invention, the light leakage is very small even though the pretilt angle is large enough to remove the disclinations due to fringe fields.

[0011] An important technical feature of the optical mode of the present invention takes place when in the "ON" state. In the "ON" state, the invention behaves differently from a conventional 90 degree twisted nematic (TN) mode, and the invention gives a very good bright state as is desired in liquid crystal display applications using a PBS. In a conventional 90 degree TN mode the linear polarized light is "guided" by the twisted structure, both in going in and coming out of the layer, which would give a dark state with a PBS. According to the present invention, the bright "ON" state is achieved without having to add chiral dopant in the liquid crystal fluid of the display.

[0012] Although the surface azimuthal directions of the molecules of the liquid crystal fluid at the bottom and top substrates produce a 90 degree twist, this optical mode does not behave as does a conventional 90 degree twisted nematic mode in the "ON" state. On the other hand, the present invention does not behave as a VAN mode display in the "OFF" state. The present invention produces a much darker state than that of a regular VAN mode display with the same pretilt angle. Therefore, the present invention is neither a VAN nor a conventional 90 degree twisted nematic mode display.

[0013] A gray scale, *e.g.*, a light intensity through the polarizer that is intermediate to the "ON" and "OFF" intensities may be obtained by controlling the voltage that is applied across the liquid crystal layer. In a crossed-polarizer (or PBS) configuration, increasing the voltage increases the light passing to the output up to a certain optimum bright-state voltage. The value of this optimum bright state voltage depends upon the liquid crystal material parameters, the cell gap, the pretilt and the light wavelength range of interest. This voltage can be determined experimentally. In addition, perceived gray scale can be controlled by controlling the time that the liquid crystal display is in the "ON" state and the time in the "OFF" state. In addition, color may be generated with methods known in the art such as color filters, use of three displays each for one color in a three-panel system, or with one microdisplay in a field sequential color (FSC) system.

[0014] The thickness (d) of the liquid crystal fluid (distance between the inside faces of the top and bottom substrates) may be, for example, about 3.5 μm +/- 0.2 μm. The birefringence (Δn) may be, for example, about 0.0830 at 45° C. Liquid crystal fluids that are being used in the present invention are nematic and have negative dielectric anisotropy $\Delta\varepsilon$ (= $\varepsilon_{//}$ - $\varepsilon_{\perp}$ < 0), where $\varepsilon_{//}$ and $\varepsilon_{\perp}$ are the parallel and perpendicular (to the liquid crystal molecule) components of the dielectric constant of the liquid crystal material. It is contemplated and within the scope of the present invention that any combination of thickness (d) and birefringence (Δn) may be used so long as the condition: $\Delta n \cdot d > \lambda/4$ is satisfied, where λ is wavelength of light incident on the display.

[0015] Any liquid crystal fluids developed for VAN displays may be used in the present invention. According to the present invention, it is not necessary to introduce a chiral dopant into the liquid crystal fluid. Typical liquid crystal fluids are for example but not limited to: MLC-6608, MLC-6609 and MLC-6610 manufactured by Merck. A physical property of liquid crystal materials used for VAN displays is negative dielectric anisotropy, *i.e.*, the perpendicular component of the dielectric constant is larger than that of the parallel component. Therefore, with an applied electric field, the molecules of the liquid crystal fluid will arrange themselves perpendicular to the direction of the electric field. For example, the dielectric anisotropy may range from about $\Delta\varepsilon$= -3.1 to -4.2. Birefringence may range from about 0.0777 to about 0.0996, and the nematic to isotropic phase transition temperature may be above 80° C.

[0016] A technical advantage of the present invention is that with this optical mode it is possible to have a much darker "OFF" state, hence high contrast, even with a relatively high pretilt angle compared to the VAN mode display with the same pretilt angle. Because of the high pretilt angle substantially no disclination defects will occur due to the fringe fields across the neighboring pixels at the pixel boundaries. Another technical advantage is that external retarders are not necessary to block the light leakage because of the very good dark state of the present invention.

[0017] In projection applications with McNeil type polarizing beam splitters, there is a system retarder, usually a quarter wave plate, for each and every color channel (RGB) to compensate the skew rays. When regular VAN mode displays are accommodated in such applications, then this system retarder can also be used to stop the light leakage. Essentially it is going to be a compromise state between the skew ray compensation and light leakage. However, this does not work well for the BLUE channel giving rise to a reasonable amount of light leakage. Therefore, contrast of the BLUE channel is generally lower than the other two channels (RED and GREEN). In fact the proper retarders to stop the light leakage are the ones with low retardation values of around 50 nanometers or less as shown by experiments. Such retarders with good uniformity are difficult to find and not easily available commercially. According to the present invention, this will not be a problem because of the very dark "OFF" state across the visible spectral region and the system retarders can be used solely to compensate for the skew rays. Also the BLUE channel will not suffer with low contrast either.

[0018] Some optical architectures do not require skew ray compensation. An example of this type of architecture are those where a wire-grid polarizing beamsplitter is used to separate input and output beam paths. Such wire-grid beamsplitters are manufactured by Moxtek Inc., of Orem, Utah. Therefore, for such applications the present invention is advantageous since the extra cost of attaching external retarders can be eliminated.

[0019] The present invention is directed to a reflective liquid crystal display, comprising: a first substrate that is substantially transparent; a second substrate that is substantially reflective and substantially parallel with said first substrate; and a liquid crystal fluid having a birefringence (Δn) and a negative dielectric anisotropy, wherein said liquid crystal fluid is between said first and second substrates; said first substrate having a first liquid crystal alignment layer proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the first liquid crystal alignment layer have a first pretilt angle from about 2 degrees to about 15 degrees and a first azimuthal direction; said second substrate having a second liquid crystal alignment layer proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the second liquid crystal alignment layer have a second pretilt angle from about 2 degrees to about 15 degrees and a second azimuthal direction, the second azimuthal direction being substantially perpendicular to the first azimuthal direction.

[0020] The polarization direction of the linearly polarized incident light may be approximately parallel with the first surface azimuthal direction. The polarization direction of the linearly polarized incident light may be approximately perpendicular with the first surface azimuthal direction.

[0021] Shades of gray may be produced by varying the electric field between said first and second substrates from substantially no electric field to an electric field having an optimum value.

[0022] The present invention is also directed to a reflective liquid crystal display, comprising: a first substrate that is substantially transparent; a second substrate that is substantially reflective and substantially parallel with said first substrate; and a liquid crystal fluid having a birefringence (Δn) and a negative dielectric anisotropy, wherein said liquid crystal fluid is between said first and second substrates; said first substrate having a first liquid crystal alignment layer proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the first liquid crystal alignment layer have a first pretilt angle from about 2 degrees to about 15 degrees and a first azimuthal direction; said second substrate having a second liquid crystal alignment layer proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the second liquid crystal alignment have a second pretilt angle from about 2 degrees to about 15 degrees and a second azimuthal direction, the second azimuthal direction being substantially perpendicular to the first azimuthal direction; wherein: when an electric field is applied between said first and second substrates, a substantial number of the molecules of said liquid crystal fluid increase their tilt angles, and when substantially no electric field is applied between said first and second substrates, a substantial number of the molecules of said liquid crystal fluid have their azimuthal direction substantially perpendicular to said first and second substrates; whereby when the electric field is applied between said first and second substrates, said liquid crystal fluid changes linear polarized incident light at said first substrate to approximately circularly polarized incident light when at said second substrate, wherein said second substrate reflects back the approximately circularly polarized incident light as approximately circularly polarized light of opposite handedness, wherein said liquid crystal fluid changes the approximately circularly polarized reflected light to approximately linear polarized reflected light when at said first substrate such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are approximately perpendicular, and whereby when substantially no electric field is applied between said first and second substrates, said liquid crystal fluid does not substantially change the polarization of light passing through the liquid crystal fluid and the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are approximately parallel.

[0023] The electric field may be applied between said first and second substrates for a plurality of first times and substantially no electric field may be applied for a plurality of second times, wherein the first and second times may be varied to produce shades of gray. The first and second times may also be varied to produce field sequential colors.

[0024] The present invention is directed to a method for a reflective liquid crystal display, said method comprising the steps of: providing a first substrate that is substantially transparent; providing a second substrate that is substantially reflective and substantially parallel with said first substrate; and providing a liquid crystal fluid having a birefringence (Δn) and a negative dielectric anisotropy between said first and second substrates; providing a first liquid crystal alignment layer on said first substrate, said first liquid crystal alignment layer being proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the first liquid crystal alignment layer have a first pretilt angle from about 2 degrees to about 15 degrees and a first azimuthal direction; providing a second liquid crystal alignment layer on said second substrate, said second liquid crystal alignment layer being proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the second liquid crystal alignment layer have a second pretilt angle from about 2 degrees to about 15 degrees and a second azimuthal direction, the second azimuthal direction being substantially perpendicular to the first tilt orientation direction; such that when substantially no electric field is applied between said first and second substrates, said liquid crystal fluid does not change the polarization state of light passing therethrough and the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are substantially parallel, when applying an electric field of an optimum value between said first and second substrates, said liquid crystal fluid changes linear polarized incident light at said first substrate to approximately circularly polarized incident light when at said second substrate, wherein said second substrate reflects back the approximately circularly polarized incident light as approximately circularly polarized light of opposite handedness, wherein said liquid crystal fluid changes the approximately circularly polarized reflected light to approximately linear polarized reflected light when at said first substrate such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are approximately perpendicular, and when applying an electric field less than the optimum value between said first and second substrates, said liquid crystal fluid changes the polarization state of the incident linearly polarized light to elliptically polarized light upon passing through said liquid crystal fluid and being reflected back from said second substrate.

[0025] Varying the electric field between said first and second substrates may be used to produce shades of gray by causing the polarization state of the incident light at said second substrate to vary from approximately linear polarization to elliptical polarization, and when there is substantially no electric field the polarization of the incident light at said second substrate is approximately linear.

[0026] The present invention is also directed to a method for a reflective liquid crystal display, said method comprising the steps of: providing a first substrate that is substantially transparent; providing a second substrate that is substantially reflective and substantially parallel with said first substrate; and providing a liquid crystal fluid having a birefringence (Δn) and a negative dielectric anisotropy, wherein said liquid crystal fluid is between said first and second substrates; providing a first liquid crystal alignment layer on said first substrate, said first liquid crystal alignment layer being proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the first liquid crystal alignment layer have a first pretilt angle from about 2 degrees to about 15 degrees and a first azimuthal direction; providing a second liquid crystal alignment layer on said second substrate, said second liquid crystal alignment layer being proximate to said liquid crystal fluid, wherein molecules of said liquid crystal fluid that are proximate to the second liquid crystal alignment layer have a second pretilt angle from about 2 degrees to about 15 degrees and a second azimuthal direction, the second azimuthal direction being substantially perpendicular to the first azimuthal direction; wherein: when substantially no electric field is applied between said first and second substrates, a substantial number of the molecules of said liquid crystal fluid have their orientation substantially perpendicular to said first and second substrates; and when applying an electric field between said first and second substrates, a substantial number of the molecules of said liquid crystal fluid change tilt towards parallel to the substrates; whereby when applying the electric field between said first and second substrates, said liquid crystal fluid changes linear polarized incident light at said first substrate to approximately circularly polarized incident light when at said second substrate, wherein said second substrate reflects back the approximately circularly polarized incident light as approximately circularly polarized light of opposite handedness, wherein said liquid crystal fluid changes the approximately circularly polarized reflected light to approximately linear polarized reflected light when at said first substrate such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are approximately perpendicular, and whereby when no electric field is applied between said first and second substrates, said liquid crystal fluid does not substantially change the polarization state of light passing through said liquid crystal fluid such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are approximately parallel.

[0027] The present invention is also directed to a reflective liquid crystal display assembly comprising: a first substantially transparent substrate; a second substantially reflective substrate located substantially parallel to said first substrate; a liquid crystal fluid having a birefringence (Δn) and a negative dielectric anisotropy, wherein said liquid crystal fluid is between said first and second substrates; first and second liquid crystal alignment layers on said first and second substrates, respectively, wherein molecules of said fluid proximate the first and second liquid crystal alignment layers have finite pretilt angles and are oriented in first and second azimuthal directions , respectively; wherein the assembly is configured such that (i) when substantially no electric field is applied between the substrates, a substantial number of fluid molecules are oriented substantially perpendicular to said substrates, (ii) when an electrical field of optimum value is applied between the substrates, tilt angles of a substantial number of fluid molecules increase, and (iii) when a less than optimum electric field is applied between said substrates, a substantial number of fluid molecules are oriented at intermediate tilt angles.

[0028] Other technical advantages of the present disclosure will be readily apparent to one skilled in the art from the following figures, descriptions, and claims. Various embodiments of the invention obtain only a subset of the advantages set forth. No one advantage is critical to the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] A more complete understanding of the present disclosure and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, wherein:

Figures 1a and 1b are schematic representations of a prior art VAN mode liquid crystal display in the "OFF" and "ON" states, respectively;

Figure 2 is a schematic elevational view of a portion of the liquid crystal display showing the azimuthal direction and pretilt angles of an exemplary molecule in a liquid crystal fluid;

Figures 3a and 3b are schematic representations of a liquid crystal display in the "OFF" and "ON" states, respectively, according to the present invention; and

Figure 4 is a collection of graphical representations of the tilt angles and azimuthal angles of liquid crystal fluid molecules as a function of the molecules' locations between the substrates in "OFF," and "ON" states, according to the present invention.

[0030] While the present invention is susceptible to various modifications and alternative forms, specific exemplary embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0031] The present invention is directed to a reflective liquid crystal microdisplay comprising a matrix of pixels of a liquid crystal fluid having light modifying properties controlled by voltage values stored in capacitors comprising the areas representing the pixels in the matrix of pixels of the liquid crystal microdisplay. The molecules of the liquid crystal fluid have a surface azimuthal direction that is either approximately parallel or perpendicular to the direction of polarization of incoming incident linearly polarized light.

[0032] According to the present invention, when in the "OFF" state (no electric field across the pixel capacitors), the molecules of the liquid crystal fluid have pretilt angles (measured from the perpendicular directions of the faces of the substrates) just sufficient to minimize disclinations due to fringe fields. The azimuthal direction of the molecules of the liquid crystal fluid at the transparent substrate is at approximately 90 degrees from the azimuthal direction of the molecules of the liquid crystal fluid at the reflective substrate. This configuration results in a very dark state when in the "OFF" state, resulting in high contrast.

[0033] Application of a voltage to the liquid crystal layer changes the tilt of the liquid crystal molecules in the bulk of the layer in a direction towards parallel to the substrates, due to the negative dielectric anisotropy of the material (see Figure 4).

[0034] Referring now to the drawings, the details of exemplary embodiments of the invention are schematically illustrated. Like elements in the drawings will be represented by like numbers, and similar elements will be represented by like numbers with a different lower case letter suffix.

[0035] Referring to Figures 1a and 1b, depicted are schematic representations of a prior art VAN mode liquid crystal display in the "OFF" and "ON" states, respectively. The azimuthal direction of the liquid crystal molecules defined by the alignment layers on the substrate surfaces 102, 104, are anti-parallel to each other, and are at a 45 degree angle with the direction of polarization of incoming incident linearly polarized light. In a VAN mode liquid crystal display, the pretilt angle θ needs to be kept small, *e.g.*, less than 4 degrees, to achieve a very dark "OFF" state, hence high contrast.

[0036] Referring now to Figure 2, depicted is a schematic elevational view of a portion of a liquid crystal display showing the azimuthal direction angle (Φ) and tilt angle (θ) of an exemplary molecule in a liquid crystal fluid. A glass (transparent) substrate 202 and a reflective (mirror) substrate 204 are parallel and have liquid crystal fluid, generally represented by the numeral 206, therebetween. The distance (thickness of liquid crystal fluid) between these parallel substrates is generally represented by "d." The distance (thickness), d, preferably may be about 3.5 μm +/-0.2 μm. The liquid crystal fluid 206 preferably may have a birefringence (Δn) of about 0.0830 at 45° C. Liquid crystal fluids that are being used in the present invention are nematic and have negative dielectric anisotropy $\Delta\varepsilon$ (= $\varepsilon_{//} - \varepsilon_{\perp} < 0$), where $\varepsilon_{//}$ and $\varepsilon_{\perp}$ are the parallel and perpendicular (to the nematic director) components of the dielectric constant of the liquid crystal fluid. It is contemplated and within the scope of the present invention that any combination of distance (thickness) (d) and birefringence (Δn) may be used with the condition: $\Delta n \cdot d > \lambda/4$ is approximately satisfied for an efficient bright state at a convenient voltage, (where λ is the wavelength of light incident on the display). For example, with a cell gap of approximately 3.5μm, using MLC-6608, and a pretilt of approximately 8 degrees from surface-normal, the optimum bright state voltage is approximately 4.0V for Red (640 nm), 3.5V for Green (540 nm) and 3.15V for Blue (470 nm).

[0037] A single molecule 206a of the liquid crystal fluid 206 is shown for exemplary purposes. The tilt angle θ is measured from the Z-axis which is perpendicular to the substrates 202 and 204. The azimuthal angle Φ is measured from the X-axis in the XY plane and is the angle between the X axis and the projection of the molecules of the liquid crystal fluid 206 on the XY plane. According to the present invention, polarization direction of the linearly polarized incident light at the glass substrate will be either approximately parallel or perpendicular to the azimuthal direction generated at the glass substrate 202.

[0038] Referring to Figures 3a, depicted is a schematic representation of a liquid crystal display in the "OFF" state, according to the present invention. The molecules of the liquid crystal fluid 206 are depicted in the "OFF" state wherein the pretilt angle θ (defined above) is only large enough to remove disclinations due to fringe fields. Preferably the pretilt angle θ may be from about 2 degrees to about 15 degrees. Most preferably the pretilt angle θ may be from about 5 degrees to about 15 degrees. The polarization state of the incident light 308 will not be affected substantially by the molecules of the liquid crystal fluid 206 and will be reflected back from the substrate 204 as substantially linearly polarized light with the polarization direction substantially parallel with that of the incident linearly polarized light.

[0039] Referring to Figures 3b, depicted is a schematic representation of a liquid crystal display in the "ON" state, according to the present invention. The configuration of the liquid crystal fluid 206, formed under optimum voltage drive, will cause the linearly polarized incident light entering the substrate 202 to become approximately circularly polarized light at the substrate 204. The approximately circularly polarized incident light at the substrate 204 will be reflected back as approximately circularly polarized light, but with opposite handedness, and when it reaches the substrate 202, this reflected light will be approximately linearly polarized with a polarization direction approximately perpendicular to that of the linearly polarized incident light.

[0040] Referring now to Figure 4, depicted are graphical representations of the tilt angles and azimuthal angles of molecules of the liquid crystal fluid 206 as a function of the location of these molecules located between the substrates in "OFF" and "ON" states, according to the present invention. Tilt angle θ is depicted on the left vertical axis from 0 to 90 degrees, and the azimuthal angle Φ is depicted on the right vertical axis from 0 to 90 degrees. The locations of the molecules of the liquid crystal fluid 206 between the substrates 202 and 204 are depicted on the horizontal axis from 0 to d. Curve 402 depicts the tilt angle θ of the molecules of the liquid crystal fluid 206 when they are in the "OFF" state. Curve 404 depicts the azimuthal angle Φ of the molecules of the liquid crystal fluid 206 when they in the "OFF" state. Curve 410 depicts the tilt angle θ of the molecules of the liquid crystal fluid 206 when they are in the "ON" state. Curve 412 depicts the azimuthal angle Φ of the molecules of the liquid crystal fluid 206 when they are in the "ON" state.

Corresponding tilt curves for an intermediate gray shade would fall between curves 402 and 410 and azimuthal curves would fall between curves 404 and 412.

[0041] The invention, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While the invention has been depicted, described, and is defined by reference to exemplary embodiments of the invention, such references do not imply a limitation on the invention, and no such limitation is to be inferred. The invention is capable of considerable modification, alternation, and equivalents in form and function, as will occur to those having ordinarily skills in the pertinent arts and having the benefit of this disclosure.

Claims

1. A reflective liquid crystal micro-display, comprising:

a first substrate (202) that is substantially transparent;
a second substrate (204) that is substantially reflective and substantially parallel with said first substrate;
a liquid crystal fluid (206) being free of a chiral dopant and having a birefringence (Δn) and a negative dielectric anisotropy, wherein said liquid crystal fluid (206) is between said first and second substrates (202, 204); and means for linearly polarizing light that enters said liquid crystal fluid (206);
said first substrate (202) having a first liquid crystal alignment layer proximate to said liquid crystal fluid (206), wherein the first liquid crystal alignment layer is designed such that it causes molecules of said liquid crystal fluid (206) that are proximate to the first liquid crystal alignment layer to have a first pretilt angle (θ) from about 2 degrees to about 15 degrees and a first azimuthal direction, wherein the first azimuthal direction is substantially parallel or substantially perpendicular to the polarization direction of the means for linearly polarizing light that enters said liquid crystal fluid;
said second substrate (204) having a second liquid crystal alignment layer proximate to said liquid crystal fluid (206), wherein the second liquid crystal alignment layer is designed such that it causes molecules of said liquid crystal fluid (206) that are proximate to the second liquid crystal alignment layer to have a second pretilt angle (θ) from about 2 degrees to about 15 degrees and a second azimuthal direction, the second azimuthal direction being substantially perpendicular to the first azimuthal direction.

2. The reflective liquid crystal micro-display according to claim 1, adapted such that shades of gray are produced by varying an electric field between said first and second substrates from substantially no electric field to an electric field having an optimum value.

3. The reflective liquid crystal micro-display according to one of the preceding claims, wherein a distance (d) between inside faces of said first and second substrates is from about 3.3 micrometers to about 3.7 micrometers, in particular 3.5 micrometers.

4. The reflective liquid crystal micro-display according to one of the preceding claims, wherein the birefringence (Δn) is from about 0.0777 to about 0.0996, in particular about 0.0830 at about 45 degrees Celsius.

5. The reflective liquid crystal micro-display according to one of the preceding claims, wherein the birefringence (Δn) times d is greater than λ/4 when an electric field having an optimum value is applied between said first and second substrates (202, 204), where d is the distance between inside faces of said first and second substrates and λ is the wavelength of light passing through said liquid crystal display.

6. The reflective liquid crystal micro-display according to one of the preceding claims, wherein the molecules of said liquid crystal fluid have a tilt angle (θ) of from about 5 degrees to about 15 degrees when substantially no electric field is applied between said first and second substrates.

7. The reflective liquid crystal micro-display according to one of the preceding claims 1-5, wherein the first pretilt angle (θ) is from about 5 degrees to about 15 degrees.

8. The reflective liquid crystal micro-display according to one of the preceding claims, wherein the second pretilt angle (θ) is from about 5 degrees to about 15 degrees.

9. The reflective liquid crystal micro-display according to claim 7, wherein the first pretilt angle (θ) is approximately 8 degrees.

10. The reflective liquid crystal micro-display according to claim 8, wherein the second pretilt angle (θ) is approximately 8 degrees.

11. A method for manufacturing a reflective liquid crystal micro-display, said method comprising the steps of:

providing a first substrate (202) that is substantially transparent;
providing a second substrate (204) that is substantially reflective and substantially parallel

with said first substrate (202);
providing a liquid crystal fluid (206) being free of a chiral dopant and having a birefringence (Δn) and a negative dielectric anisotropy between said first and second substrates (202, 204);
providing means for linearly polarizing light that enters said liquid crystal fluid (206);
providing a first liquid crystal alignment layer on said first substrate (202), said first liquid crystal alignment layer being proximate to said liquid crystal fluid (206), wherein molecules of said liquid crystal fluid (206) that are proximate to the first liquid crystal alignment layer receive a first pretilt angle (θ) from about 2 degrees to about 15 degrees and a first azimuthal direction only by said first liquid crystal alignment layer wherein the first azimuthal direction is substantially parallel or substantially perpendicular to the polarization direction of the means for linearly polarizing light that enters said liquid crystal fluid; and
providing a second liquid crystal alignment layer on said second substrate (204), said second liquid crystal alignment layer being proximate to said liquid crystal fluid (206), wherein molecules of said liquid crystal fluid that are proximate to the second liquid crystal alignment layer receive a second pretilt angle (θ) from about 2 degrees to about 15 degrees and a second azimuthal direction only by said second liquid crystal alignment layer, the second azimuthal direction being substantially perpendicular to the first azimuthal direction; such that
when substantially no electric field is applied between said first and second substrates (202, 204), said liquid crystal fluid (206) does not change the polarization state of light passing therethrough and the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are substantially parallel,
when applying an electric field of an optimum value between said first and second substrates (202, 204), said liquid crystal fluid (206) changes linear polarized incident light (308) at said first substrate to approximately circularly polarized incident light when at said second substrate (204), wherein said second substrate (204) reflects back the approximately circularly polarized incident light as approximately circularly polarized light (308) of opposite handedness, wherein said liquid crystal fluid (206) changes the approximately circularly polarized reflected light to approximately linear polarized reflected light when at said first substrate such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light (308) at said first substrate are approximately perpendicular, and
when applying an electric field less than the optimum value between said first and second substrates (202, 204), said liquid crystal fluid (206) changes the polarization state of incident linearly polarized light (308) to elliptically polarized light upon passing through said liquid crystal fluid (206) and being reflected back from said second substrate (204).

12. The method of claim 11, further comprising the step of varying the electric field between said first and second substrates so as to produce shades of gray by causing the polarization state of the incident light at said second substrate to vary from approximately linear polarization to elliptical polarization, and when there is substantially no electric field the polarization of the incident light at said second substrate is approximately linear.

13. The method of claim 11 or 12, wherein a distance (d) between inside faces of said first and second substrates is from about 3.3 micrometers to about 3.7 micrometers, in particular about 3.5 micrometers.

14. The method to one of the preceding claims 11-13, wherein said liquid crystal fluid (206) has a birefringence (Δn) from about 0.0777 to about 0.0996, in particular about 0.0830 at about 45 degrees Celsius.

15. The method to one of the preceding claims 11-14, wherein the birefringence Δn times d is greater than $\lambda/4$ when an electric field having an optimum value is applied between said first and second substrates (202, 204), where d is the distance between inside faces of said first and second substrates (202, 204) and λ is the wavelength of light passing through that liquid crystal display.

16. The method to one of the preceding claims 11-15, wherein the molecules of said liquid crystal fluid (206) have a tilt angle (θ) of from about 5 degrees to about 15 degrees when substantially no electric field is applied between said first and second substrates.

17. The method according to claim 12, wherein the first pretilt angle (θ) is about 8 degrees.

18. The method according to claim 12, wherein the second pretilt angle (θ) is about 8 degrees.

19. The method to one of the preceding claims 11-18, wherein:

when applying substantially no electric field between said first and second substrates (202, 204), a substantial number of the molecules of

said liquid crystal fluid (206) have their azimuthal direction substantially perpendicular to said first and second substrates (202, 204); and
when applying an electric field between said first and second substrates (202, 204), a substantial number of the molecules of said liquid crystal fluid (206) increase their tilt angles;
whereby when applying the electric field between said first and second substrates (202, 204), said liquid crystal fluid (206)changes linear polarized incident light at said first substrate (202) to approximately circularly polarized incident light when at said second substrate (204), wherein said second substrate (204) reflects back the approximately circularly polarized incident light as approximately circularly polarized light of opposite handedness, wherein said liquid crystal fluid (206) changes the approximately circularly polarized reflected light to approximately linear polarized reflected light when at said first substrate (202) such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate (202) are approximately perpendicular, and
whereby when applying substantially no electric field between said first and second substrates (202, 204), said liquid crystal fluid (206) does not substantially change the polarization state of light passing through said liquid crystal fluid (206) such that the polarization directions of the linearly polarized incident light and the linearly polarized reflected light at said first substrate are approximately parallel

Patentansprüche

1. Reflektierendes Flüssigkristallmikrodisplay, aufweisend:

ein erstes Substrat (202), das im Wesentlichen durchsichtig ist;
ein zweites Substrat (204), das im Wesentlichen reflektierend und im Wesentlichen parallel zu besagtem erstem Substrat angeordnet ist;
eine Flüssigkristallflüssigkeit (206), die frei von einem optisch aktiven Dotierungsmaterial ist und eine Doppelbrechung (Δn) und eine negative dielektrische Anisotropie aufweist, wobei besagte Flüssigkristallflüssigkeit (206) zwischen besagten ersten und zweiten Substraten (202, 204) angeordnet ist; und
Mittel zum linearen Polarisieren von Licht, das in besagte Flüssigkristallflüssigkeit (206) eintritt;
wobei besagtes erstes Substrat (202) eine erste Flüssigkristallausrichtungsschicht benachbart zu besagter Flüssigkristallflüssigkeit (206) aufweist, wobei die erste Flüssigkristallausrichtungsschicht so ausgeführt ist, dass sie bewirkt, dass Moleküle von besagter Flüssigkristallflüssigkeit (206), die benachbart zu der ersten Flüssigkristallausrichtungsschicht sind, einen ersten Anstellwinkel (θ) von etwa 2 Grad bis etwa 15 Grad und eine erste Azimutausrichtung aufweisen, wobei die erste Azimutausrichtung im Wesentlichen parallel oder im Wesentlichen senkrecht zu der Polarisierungsrichtung des Mittels zum linearen Polarisieren von Licht ist, das in besagte Flüssigkristallflüssigkeit eintritt,
wobei besagtes zweites Substrat (204) eine zweite Flüssigkristallausrichtungsschicht benachbart zu besagter Flüssigkristallflüssigkeit (206) aufweist, wobei die zweite Flüssigkristallausrichtungsschicht so ausgeführt ist, dass sie bewirkt, dass Moleküle von besagter Flüssigkristallflüssigkeit (206), die benachbart zu der zweiten Flüssigkristallausrichtungsschicht sind, einen zweiten Anstellwinkel (θ) von etwa 2 Grad bis etwa 15 Grad und eine zweite Azimutausrichtung aufweisen, wobei die zweite Azimutausrichtung im Wesentlichen senkrecht zu der ersten Azimutausrichtung ist.

2. Reflektierendes Flüssigkristallmikrodisplay gemäß Anspruch 1, so angepasst, dass Grauschattierungen erzeugt werden durch Variieren eines elektrischen Feldes zwischen besagten ersten und zweiten Substraten von im Wesentlichen keinem elektrischen Feld zu einem elektrischen Feld, das einen optimalen Wert aufweist.

3. Reflektierendes Flüssigkristallmikrodisplay gemäß einem der vorherigen Ansprüche, wobei ein Abstand (d) zwischen inneren Stirnflächen von besagten ersten und zweiten Substraten von etwa 3,3 Mikrometer bis etwa 3,7 Mikrometer, im Besonderen 3,5 Mikrometer ist.

4. Reflektierendes Flüssigkristallmikrodisplay gemäß einem der vorherigen Ansprüche, wobei die Doppelbrechung (Δn) von etwa 0,0777 bis etwa 0,0996 ist, im Besonderen etwa 0,0830 bei etwa 45 Grad Celsius.

5. Reflektierendes Flüssigkristallmikrodisplay gemäß einem der vorherigen Ansprüche, wobei die Doppelbrechung (Δn) multipliziert mit d größer ist als λ/4 wenn ein elektrisches Feld, das einen optimalen Wert aufweist, zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, wobei d der Abstand zwischen inneren Stirnflächen von besagten ersten und zweiten Substraten ist und λ die Wellenlänge von Licht ist, das durch besagtes Flüssigkristalldisplay hindurch tritt.

6. Reflektierendes Flüssigkristallmikrodisplay gemäß einem der vorherigen Ansprüche, wobei die Moleküle von besagter Flüssigkristallflüssigkeit einen Kippwinkel (θ) von etwa 5 Grad bis etwa 15 Grad aufweisen, wenn im Wesentlichen kein elektrisches Feld zwischen den besagten ersten und zweiten Substraten angelegt wird.

7. Reflektierendes Flüssigkristallmikrodisplay gemäß einem der vorherigen Ansprüche 1 bis 5, wobei der erste Anstellwinkel (θ) von etwa 5 Grad bis etwa 15 Grad ist.

8. Reflektierendes Flüssigkristallmikrodisplay gemäß einem der vorherigen Ansprüche, wobei der zweite Anstellwinkel (θ) von etwa 5 Grad bis etwa 15 Grad ist.

9. Reflektierendes Flüssigkristallmikrodisplay gemäß Anspruch 7, wobei der erste Anstellwinkel (θ) etwa 8 Grad ist.

10. Reflektierendes Flüssigkristallmikrodisplay gemäß Anspruch 8, wobei der zweite Anstellwinkel (θ) etwa 8 Grad ist.

11. Verfahren zur Herstellung eines reflektierenden Flüssigkristallmikrodisplays, wobei besagtes Verfahren die Schritte aufweist:

Bereitstellen eines ersten Substrats (202), das im Wesentlichen transparent ist;
Bereitstellen eines zweiten Substrats (204) das im Wesentlichen reflektierend und im Wesentlichen parallel zu besagtem erstem Substrat (202) ist;
Bereitstellen einer Flüssigkristallflüssigkeit (206), die frei ist von einem optisch aktiven Dotierungsmaterial und eine Doppelbrechung (Δn) und eine negative dielektrische Anisotropie zwischen besagten ersten und zweiten Substraten (202, 204) aufweist;
Bereitstellen von Mitteln zum linearen Polarisieren von Licht, das in besagte Flüssigkristallflüssigkeit (206) eintritt;
Bereitstellen einer ersten Flüssigkristallausrichtungsschicht auf besagtem erstem Substrat (202), wobei besagte erste Flüssigkristallausrichtungsschicht benachbart zu besagter Flüssigkristallflüssigkeit (206) ist, wobei Moleküle von besagter Flüssigkristallflüssigkeit (206), die benachbart zu der ersten Flüssigkristallausrichtungsschicht sind, einen ersten Anstellwinkel (θ) von etwa 2 Grad bis etwa 15 Grad und eine erste Azimutausrichtung nur durch besagte erste Flüssigkristallausrichtungsschicht erhalten, wobei die erste Azimutausrichtung im Wesentlichen parallel oder im Wesentlichen senkrecht ist zu der Polarisierungsrichtung des Mittels zum linearen Polarisieren von Licht, das in besagte Flüssigkristallflüssigkeit eintritt, und
Bereitstellen einer zweiten Flüssigkristallausrichtungsschicht auf besagtem zweitem Substrat (204), wobei besagte zweite Flüssigkristallausrichtungsschicht benachbart zu besagter Flüssigkristallflüssigkeit (206) ist, wobei Moleküle von besagter Flüssigkristallflüssigkeit, die benachbart zu der zweiten Flüssigkristallausrichtungsschicht sind, einen zweiten Anstellwinkel (θ) von etwa 2 Grad bis etwa 15 Grad und eine zweite Azimutausrichtung nur durch besagte zweite Flüssigkristallausrichtungsschicht erhalten, wobei die zweite Azimutausrichtung im Wesentlichen senkrecht zu der ersten Azimutausrichtung ist; so dass

wenn im Wesentlichen kein elektrisches Feld zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, besagte Flüssigkristallflüssigkeit (206) den Polarisationszustand von Licht nicht ändert, das dort hindurch tritt, und die Polarisationsrichtungen des linear polarisierten einfallenden Lichts und des linear polarisierten reflektierten Lichts bei besagtem erstem Substrat im Wesentlichen parallel sind,
wenn ein elektrisches Feld eines optimalen Werts zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, besagte Flüssigkristallflüssigkeit (206) linear polarisiertes einfallendes Licht (308) bei besagtem erstem Substrat in ungefähr kreisförmig polarisiertes einfallendes Licht ändert, wenn es bei besagtem zweitem Substrat (204) ist,
wobei besagtes zweites Substrat (204) das ungefähr kreisförmig polarisierte einfallende Licht als ungefähr kreisförmig polarisiertes Licht (308) entgegen gesetzter Händigkeit zurück reflektiert, wobei besagte Flüssigkristallflüssigkeit (206) das ungefähr kreisförmig polarisierte, reflektiert Licht in ungefähr linear polarisiertes, reflektiertes Licht umwandelt, wenn es bei besagtem erstem Substrat ist, so dass die Polarisationsrichtungen des linear polarisierten einfallenden Lichts und des linear polarisierten reflektierten Lichts (308) bei besagtem erstem Substrat ungefähr senkrecht zueinander sind, und
wenn ein elektrisches Feld mit weniger als dem optimalen Wert zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, besagte Flüssigkristallflüssigkeit (206) den Polarisationszustand von einfallendem linear polarisiertem Licht (308)

beim Hindurchtreten durch besagte Flüssigkristallflüssigkeit (206) und beim Zurückreflektieren von besagtem zweiten Substrat (204) in elliptisch polarisiertes Licht ändert.

12. Verfahren nach Anspruch 11, weiterhin aufweisend den Schritt des Variierens des elektrischen Feldes zwischen besagten ersten und zweiten Substraten, um so Grauschattierungen zu erzeugen durch Bewirken, dass an besagtem zweitem Substrat der Polarisationszustand des einfallenden Lichts von ungefähr linearer Polarisation zu elliptischer Polarisation variiert, und wenn im Wesentlichen kein elektrisches Feld anliegt die Polarisation des einfallenden Lichts bei besagtem zweitem Substrat ungefähr linear ist.

13. Verfahren nach Anspruch 11 oder 12, wobei ein Abstand (d) zwischen inneren Stirnflächen von besagten ersten und zweiten Substraten von etwa 3,3 Mikrometer bis etwa 3,7 Mikrometer, im Besonderen etwa 3,5 Mikrometer ist.

14. Verfahren nach einem der vorherigen Ansprüche 11 bis 13, wobei besagte Flüssigkristallflüssigkeit (206) eine Doppelbrechung (Δn) von etwa 0,0777 bis etwa 0,0996, im Besonderen etwa 0,0830 bei etwa 45 Grad Celsius aufweist.

15. Verfahren nach einem der vorherigen Ansprüche 11 bis 14, wobei die Doppelbrechung Δn multipliziert mit d größer ist als $\lambda/4$ wenn ein elektrisches Feld, das einen optimalen Wert aufweist, zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, wobei d die Entfernung zwischen inneren Stirnflächen von besagten ersten und zweiten Substraten (202, 204) ist und λ die Wellenlänge von Licht ist, das durch dieses Flüssigkristalldisplay hindurch tritt.

16. Verfahren nach einem der vorherigen Ansprüche 11 bis 15, wobei die Moleküle von besagter Flüssigkristallflüssigkeit (206) einen Kippwinkel (θ) von etwa 5 Grad bis etwa 15 Grad aufweisen, wenn im Wesentlichen kein elektrisches Feld zwischen besagten ersten und zweiten Substraten angelegt wird.

17. Verfahren gemäß Anspruch 12, wobei der erste Anstellwinkel (θ) etwa 8 Grad ist.

18. Verfahren gemäß Anspruch 12, wobei der zweite Anstellwinkel (θ) etwa 8 Grad ist.

19. Verfahren nach einem der vorherigen Ansprüche 11 bis 18,
wobei:

wenn im Wesentlichen kein elektrisches Feld zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, eine wesentliche Anzahl der Moleküle von besagter Flüssigkristallflüssigkeit (206) ihre Azimutausrichtung im Wesentlichen senkrecht zu besagten ersten und zweiten Substraten (202, 204) aufweisen; und
wenn ein elektrisches Feld zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, eine wesentliche Anzahl der Moleküle von besagter Flüssigkristallflüssigkeit (206) ihre Kippwinkel erhöht;
wodurch, wenn das elektrische Feld zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, besagte Flüssigkristallflüssigkeit (206) linear polarisiertes einfallendes Licht an besagtem erstem Substrat (202) in ungefähr kreisförmig polarisiertes einfallendes Licht ändert, wenn dieses bei besagtem zweitem Substrat (204) ist, wobei besagtes zweites Substrat (204) das ungefähr kreisförmig polarisierte einfallende Licht als ungefähr kreisförmig polarisiertes Licht von entgegen gesetzter Händigkeit zurück reflektiert, wobei besagte Flüssigkristallflüssigkeit (206) das ungefähr kreisförmig polarisierte reflektierte Licht in ungefähr linear polarisiertes reflektiertes Licht ändert, wenn dieses bei besagtem erstem Substrat (202) ist, so dass die Polarisationsrichtungen des linear polarisierten einfallenden Lichts und des linear polarisierten reflektierten Lichts bei besagtem erstem Substrat (202) ungefähr senkrecht sind, und
wodurch, wenn im Wesentlichen kein elektrisches Feld zwischen besagten ersten und zweiten Substraten (202, 204) angelegt wird, besagte Flüssigkristallflüssigkeit (206) den Polarisationszustand des Lichts, das durch besagte Flüssigkristallflüssigkeit (206) hindurch tritt, im Wesentlichen nicht ändert, so dass die Polarisationsrichtungen des linear polarisierten einfallenden Lichts und des linear polarisierten reflektierten Lichts bei besagtem erstem Substrat ungefähr parallel sind.

Revendications

1. Micro-afficheur à cristaux liquides réflexif, comprenant :

un premier substrat (202) qui est sensiblement transparent ;
un second substrat (204) qui est sensiblement réflexif et essentiellement parallèle audit premier substrat ;
un liquide de cristaux liquides (206) qui est exempt de dopant chiral et ayant une biréfringence (Δn) et une anisotropie diélectrique né-

gative, dans lequel ledit liquide de cristaux liquides (206) se trouve entre lesdits premier et second substrats (202, 204) ; et

des moyens servant à polariser linéairement la lumière qui entre dans ledit liquide de cristaux liquides (206) ;

ledit premier substrat (202) ayant une première couche d'alignement de cristaux liquides à proximité dudit liquide de cristaux liquides (206), dans lequel la première couche d'alignement de cristaux liquides est conçue de telle sorte qu'elle impose aux molécules dudit liquide de cristaux liquides (206) qui sont à proximité de la première couche d'alignement de cristaux liquides d'avoir un premier angle de pré-inclinaison (θ) d'environ 2 degrés à environ 15 degrés et une première direction azimutale, dans lequel la première direction azimutale est essentiellement parallèle ou essentiellement perpendiculaire à la direction de polarisation des moyens servant à polariser linéairement la lumière qui entre dans ledit liquide de cristaux liquides ;

ledit second substrat (204) ayant une seconde couche d'alignement de cristaux liquides à proximité dudit liquide de cristaux liquides (206), dans lequel la seconde couche d'alignement de cristaux liquides est conçue de telle sorte qu'elle impose aux molécules dudit liquide de cristaux liquides (206) qui sont à proximité de la seconde couche d'alignement de cristaux liquides d'avoir un second angle de pré-inclinaison (θ) d'environ 2 degrés à environ 15 degrés et une seconde direction azimutale, la seconde direction azimutale étant essentiellement perpendiculaire à la première direction azimutale.

2. Micro-afficheur à cristaux liquides réflexif selon la revendication 1, adapté de telle sorte que des nuances de gris sont produites par variation d'un champ électrique entre lesdits premier et second substrats allant de sensiblement aucun champ électrique jusqu'à un champ électrique ayant une valeur optimale.

3. Micro-afficheur à cristaux liquides réflexif selon l'une quelconque des revendications précédentes, dans lequel une distance (d) entre les faces internes desdits premier et second substrats est d'environ 3,3 micromètres à environ 3,7 micromètres, en particulier de 3,5 micromètres.

4. Micro-afficheur à cristaux liquides réflexif selon l'une quelconque des revendications précédentes, dans lequel la biréfringence (Δn) est d'environ 0,0777 à environ 0,0996, en particulier d'environ 0,0830 à environ 45 degrés Celsius.

5. Micro-afficheur à cristaux liquides réflexif selon l'une quelconque des revendications précédentes, dans lequel la ddes temps de biréfringence (Δn) est supérieure à λλ/4 lorsqu'un champ électrique ayant une valeur optimale est appliqué entre lesdits premier et second substrats (202, 204), où d est la distance entre les faces internes desdits premier et second substrats et λ est la longueur d'ondes de la lumière passant à travers ledit afficheur à cristaux liquides.

6. Micro-afficheur à cristaux liquides réflexif selon l'une quelconque des revendications précédentes, dans lequel les molécules dudit liquide de cristaux liquides ont un angle d'inclinaison (θ) d'environ 5 degrés à environ 15 degrés lorsque sensiblement aucun champ électrique n'est appliqué entre lesdits premier et second substrats.

7. Micro-afficheur à cristaux liquides réflexif selon l'une quelconque des revendications précédentes 1 à 5, dans lequel le premier angle de pré-inclinaison (θ) est d'environ 5 degrés à environ 15 degrés.

8. Micro-afficheur à cristaux liquides réflexif selon l'une quelconque des revendications précédentes, dans lequel le second angle de pré-inclinaison (θ) est d'environ 5 degrés à environ 15 degrés.

9. Micro-afficheur à cristaux liquides réflexif selon la revendication 7, dans lequel le premier angle de pré-inclinaison (θ) est d'approximativement 8 degrés.

10. Micro-afficheur à cristaux liquides réflexif selon la revendication 8, dans lequel le second angle de pré-inclinaison (θ) est d'approximativement 8 degrés.

11. Procédé de fabrication d'un micro-afficheur à cristaux liquides réflexif, ledit procédé comprenant les étapes consistant à :

fournir un premier substrat (202) qui est sensiblement transparent ;

fournir un second substrat (204) qui est sensiblement réflexif et essentiellement parallèle audit premier substrat (202) ;

fournir un liquide de cristaux liquides (206) qui est exempt de dopant chiral et ayant une biréfringence (Δn) et une anisotropie diélectrique négative entre lesdits premier et second substrats (202, 204) ;

fournir des moyens servant à polariser linéairement la lumière qui entre dans ledit liquide de cristaux liquides (206) ;

fournir une première couche d'alignement de cristaux liquides sur ledit premier substrat (202), ladite première couche d'alignement de cristaux liquides étant à proximité dudit liquide de cristaux liquides (206), dans lequel les molécules dudit liquide de cristaux liquides (206) qui sont à proximité de la première couche d'alignement de cristaux liquides reçoivent un premier angle de pré-inclinaison (θ) d'environ 2 degrés à environ 15 degrés et une première direction azimutale uniquement par ladite première couche d'alignement de cristaux liquides, dans lequel la première direction azimutale est essentiellement parallèle ou essentiellement perpendiculaire à la direction de polarisation des moyens servant à polariser linéairement la lumière qui entre dans ledit liquide de cristaux liquides ; et fournir une seconde couche d'alignement de cristaux liquides sur ledit second substrat (204), ladite seconde couche d'alignement de cristaux liquides étant à proximité dudit liquide de cristaux liquides (206), dans lequel les molécules dudit liquide de cristaux liquides qui sont à proximité de la seconde couche d'alignement de cristaux liquides reçoivent un second angle de pré-inclinaison (θ) d'environ 2 degrés à environ 15 degrés et une seconde direction azimutale uniquement par ladite seconde couche d'alignement de cristaux liquides, la seconde direction azimutale étant essentiellement perpendiculaire à la première direction azimutale ; de telle sorte que :

lorsque sensiblement aucun champ électrique n'est appliqué entre lesdits premier et second substrats (202, 204), ledit liquide de cristaux liquides (206) ne change pas l'état de polarisation de la lumière passant à travers celui-ci et les directions de polarisation de la lumière incidente polarisée linéairement et de la lumière réfléchie polarisée linéairement audit premier substrat sont essentiellement parallèles,
lorsqu'un champ électrique d'une valeur optimale est appliqué entre lesdits premier et second substrats (202, 204), ledit liquide de cristaux liquides (206) change la lumière incidente polarisée linéaire (308) audit premier substrat en lumière incidente polarisée approximativement circulairement quant audit second substrat (204),
dans lequel ledit second substrat (204) réfléchit la lumière incidente polarisée approximativement circulairement en lumière polarisée approximativement circulairement (308) de sens de rotation opposé, dans lequel ledit liquide de cristaux liquides (206) change la lumière réfléchie polarisée approximativement circulairement en lumière réfléchie polarisée approximativement linéairement quant audit premier substrat, de telle sorte que les directions de polarisation de la lumière incidente polarisée linéairement et de la lumière réfléchie polarisée linéairement (308) audit premier substrat sont approximativement perpendiculaires, et
lorsqu'un champ électrique inférieur à la valeur optimale est appliqué entre lesdits premier et second substrats (202, 204), ledit liquide de cristaux liquides (206) change l'état de polarisation de la lumière polarisée linéairement incidente (308) en lumière polarisée elliptiquement lors du passage à travers ledit liquide de cristaux liquides (206) et qui est réfléchie depuis ledit second substrat (204).

12. Procédé selon la revendication 11, comprenant en outre l'étape consistant à faire varier le champ électrique entre lesdits premier et second substrats de manière à produire des nuances de gris en imposant à l'état de polarisation de la lumière incidente au niveau dudit second substrat de varier d'une polarisation approximativement linéaire jusqu'à une polarisation elliptique, et lorsqu'il n'y a sensiblement aucun champ électrique, la polarisation de la lumière incidente au niveau dudit second substrat est approximativement linéaire.

13. Procédé selon la revendication 11 ou 12, dans lequel une distance (d) entre les faces internes desdits premier et second substrats est d'environ 3,3 micromètres à environ 3,7 micromètres, en particulier d'environ 3,5 micromètres.

14. Procédé selon l'une quelconque des revendications précédentes 11 à 13, dans lequel ledit liquide de cristaux liquides (206) a une biréfringence (Δn) d'environ 0,0777 à environ 0,0996, en particulier d'environ 0,0830 à environ 45 degrés Celsius.

15. Procédé selon l'une quelconque des revendications précédentes 11 à 14, dans lequel la d des temps de biréfringence Δn est supérieure à λ/4 lorsqu'un champ électrique ayant une valeur optimale est appliqué entre lesdits premier et second substrats (202, 204), où d est la distance entre les faces internes desdits premier et second substrats (202, 204) et λ est la longueur d'ondes de la lumière passant à travers cet afficheur à cristaux liquides.

16. Procédé selon l'une quelconque des revendications précédentes 11 à 15, dans lequel les molécules dudit liquide de cristaux liquides (206) ont un angle d'inclinaison (θ) d'environ 5 degrés à environ 15 degrés lorsque sensiblement aucun champ électrique n'est appliqué entre lesdits premier et second substrats.

17. Procédé selon la revendication 12, dans lequel le premier angle de pré-inclinaison (θ) d'environ 8 degrés.

18. Procédé selon la revendication 12, dans lequel le second angle de pré-inclinaison (θ) d'environ 8 degrés.

19. Procédé selon l'une quelconque des revendications précédentes 11 à 18, dans lequel :

lorsque sensiblement aucun champ électrique n'est appliqué entre lesdits premier et second substrats (202, 204), un nombre substantiel des molécules du liquide de cristaux liquides (206) a leur direction azimutale essentiellement perpendiculaire aux dits premier et second substrats (202, 204) ; et

lorsqu'un un champ électrique est appliqué entre lesdits premier et second substrats (202, 204), un nombre substantiel des molécules du liquide de cristaux liquides (206) augmente leurs angles d'inclinaison ;

moyennant quoi, lorsque le champ électrique est appliqué entre lesdits premier et second substrats (202, 204), ledit liquide de cristaux liquides (206) change la lumière incidente polarisée linéaire audit premier substrat (202) en lumière incidente polarisée approximativement circulairement quant audit second substrat (204), dans lequel ledit second substrat (204) réfléchit la lumière incidente polarisée approximativement circulairement en lumière polarisée approximativement circulairement de sens de rotation opposé,

dans lequel ledit liquide de cristaux liquides (206) change la lumière réfléchie polarisée approximativement circulairement en lumière réfléchie polarisée approximativement linéaire quant audit premier substrat (202), de telle sorte que les directions de polarisation de la lumière incidente polarisée linéairement et de la lumière réfléchie polarisée linéairement audit premier substrat (202) sont approximativement perpendiculaires, et

moyennant quoi, lorsque sensiblement aucun champ électrique n'est appliqué entre lesdits premier et second substrats (202, 204), ledit liquide de cristaux liquides (206) ne change sensiblement pas l'état de polarisation de la lumière passant à travers ledit liquide de cristaux liquides (206), de telle sorte que les directions de polarisation de la lumière incidente polarisée linéairement et de la lumière réfléchie polarisée linéairement audit premier substrat sont approximativement parallèles.

"OFF" state VAN mode

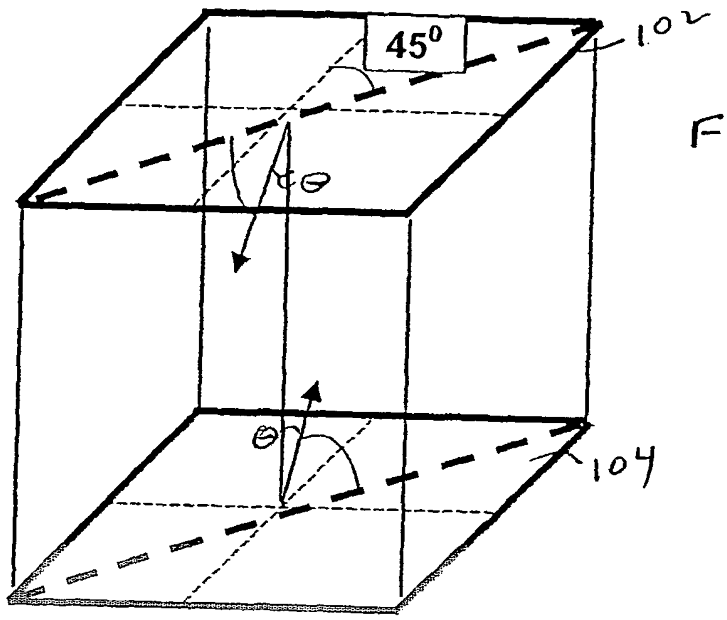
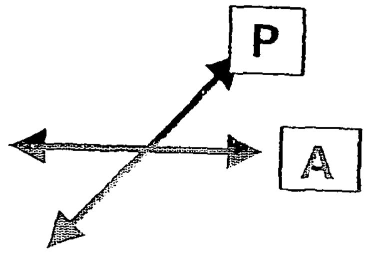


FIGURE 1a
(PRIOR ART)



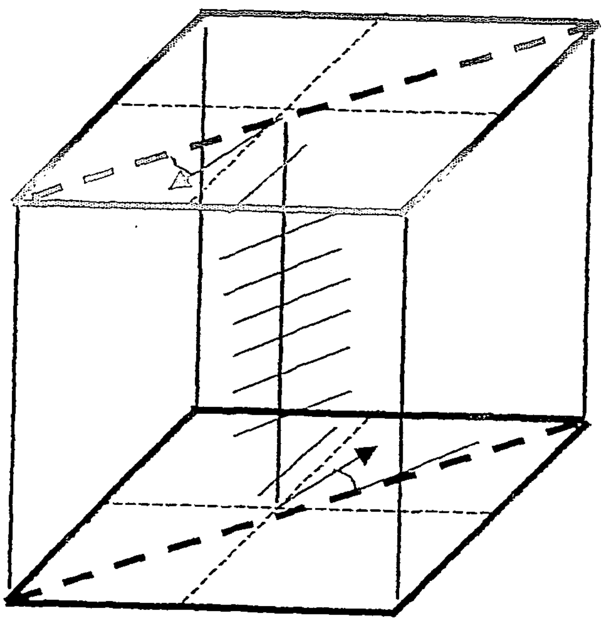


FIGURE 1b
(PRIOR ART)

"ON" state VAN mode

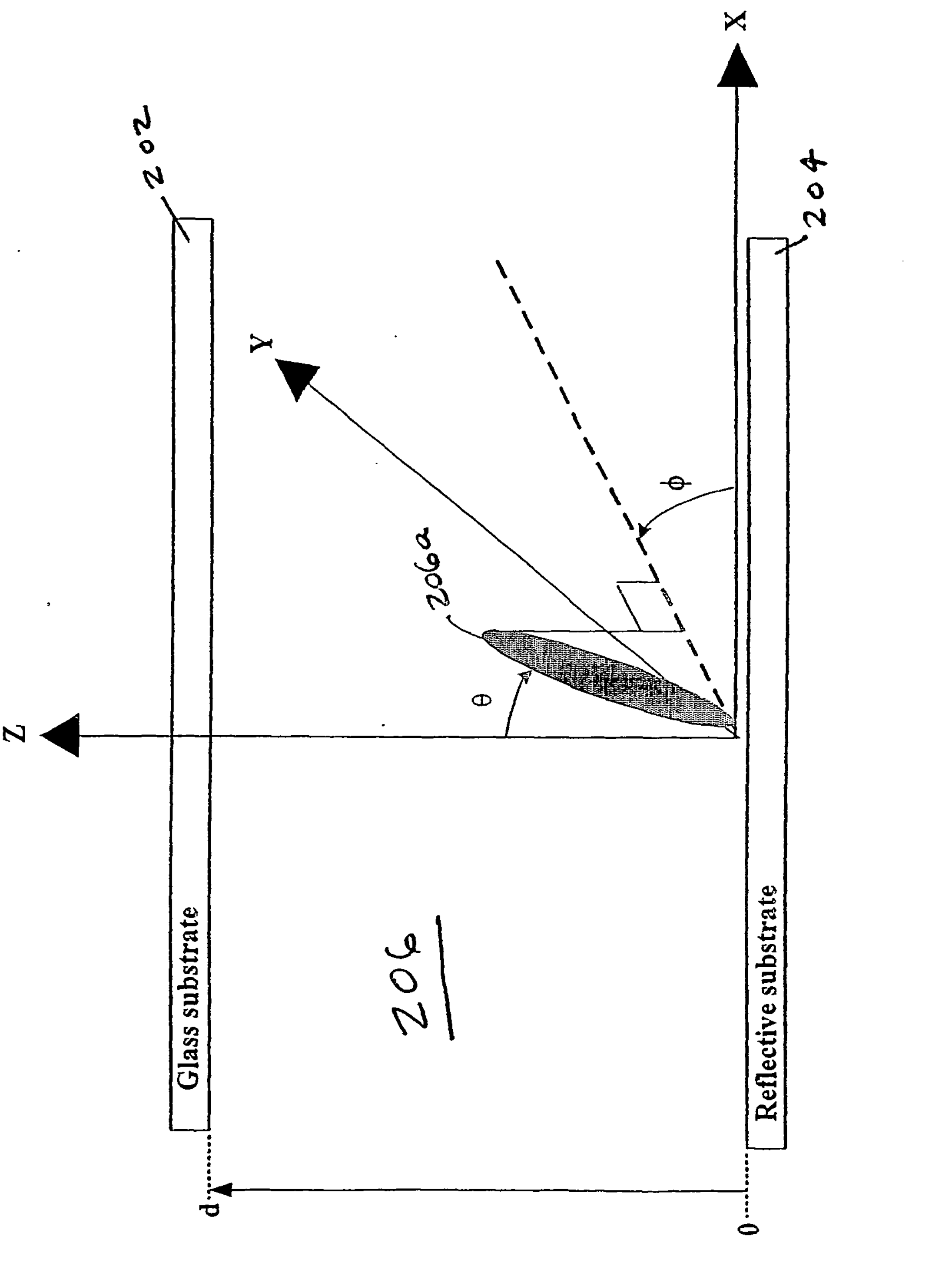

Glass substrate
Reflective substrate
202
204
206
206a
X
Y
Z
θ
φ
d
0

FIGURE 2

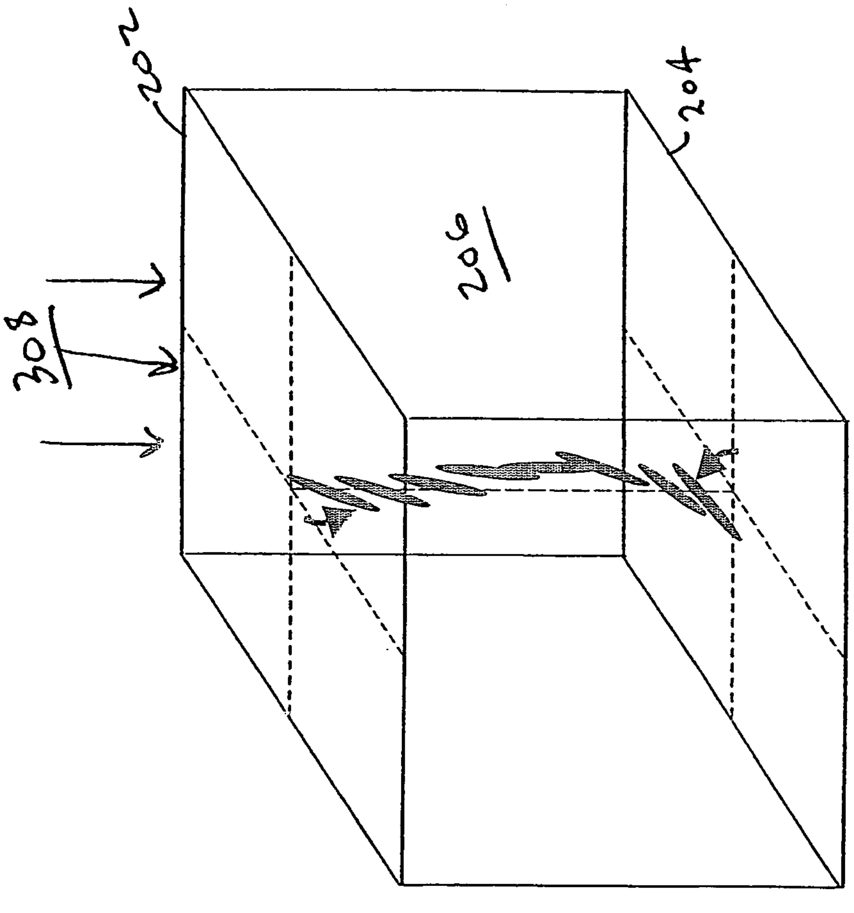


FIGURE 3a

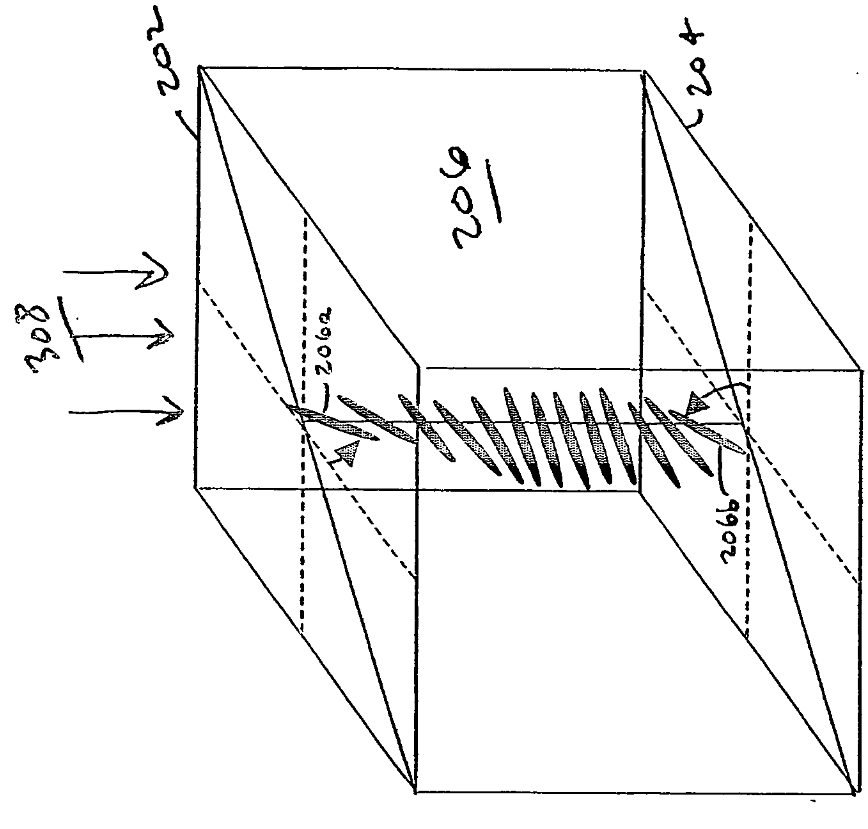


FIGURE 3b

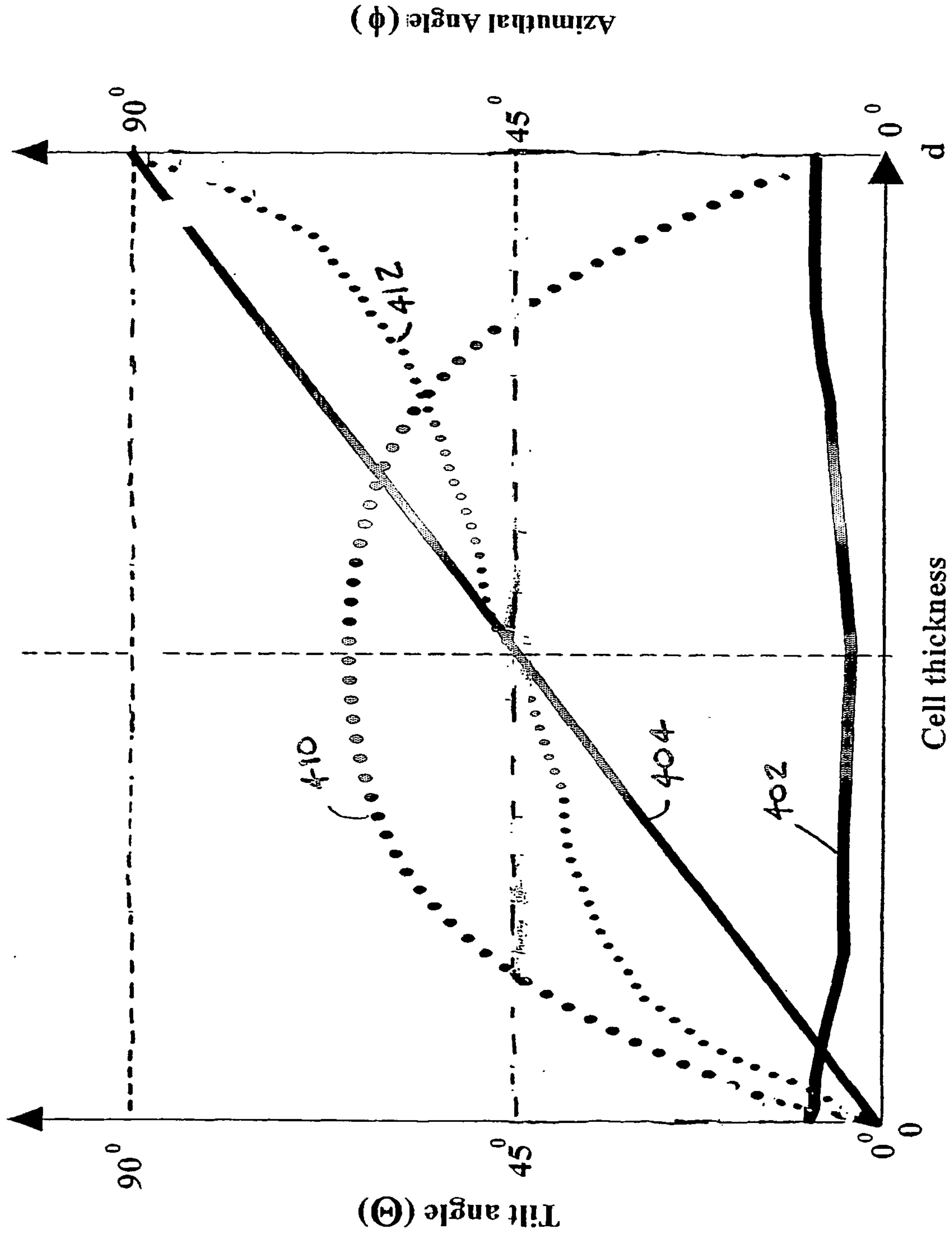

Azimuthal Angle (ϕ)
Tilt angle (Θ)
90°
45°
0°
0
d
Cell thickness
402
404
410
412

FIGURE 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CH 661361 A **[0006]**
- US 20010030723 A1 **[0006]**
- EP 0793133 A **[0006]**
- US 6141074 A **[0006]**

专利名称(译)	具有大倾斜角和高对比度的垂直对准向列模式液晶显示器		
公开(公告)号	[EP1599758B1](EP1599758B1)	公开(公告)日	2008-05-07
申请号	EP2004715065	申请日	2004-02-26
申请(专利权)人(译)	THREE-FIVE SYSTEMS INC.		
当前申请(专利权)人(译)	BRILLIAN CORPORATION		
[标]发明人	VITHANA HEMASIRI		
发明人	VITHANA, HEMASIRI		
IPC分类号	G02F1/139 G02F1/1337		
CPC分类号	G02F1/1337 G02F1/133528 G02F1/1393 G02F1/1396 G02F2001/133541 G02F2001/133742 G02F2001/133749 G02F2203/02		
代理机构(译)	GRUBERT，ANDREAS		
优先权	10/438511 2003-05-15 US 60/450370 2003-02-26 US		
其他公开文献	EP1599758A2		
外部链接	Espacenet		

摘要(译)

硅上反射液晶（LCOS）显示器包括透明基板，反射基板和基板之间的液晶流体。 LCOS显示器还包括以多个行和列排列的像素矩阵，其中行和列的交叉点定义矩阵中像素的位置。 LCOS显示器具有足以克服由于边缘场引起的向错的倾斜角，并且同时实现高对比度。液晶流体分子的表面方位角方向基本上平行于或垂直于入射的入射线性偏振光的偏振方向。光泄漏是最小的，因为入射入射线性偏振光所见的有效双折射基本上为零，并且不依赖于液晶流体分子的预倾角。在透明基板和反射基板之间，当处于“关闭”状态时，液晶流体分子的扭曲可以在约0度至约90度之间变化。