

3. Upon information and belief, Defendant Samsung Telecommunications America, L.P. is a Delaware limited partnership with its principal place of business at 1130 E. Arapaho Rd., Richardson, Texas 75081. Samsung Telecommunications America, L.P. may be served by delivery of summons to its registered agent of record, Corporation Service Company, 2711 Centerville Road, Suite 400, Wilmington, Delaware 19808. Samsung Telecommunications America, L.P. markets and develops wireless handsets and telecommunication products throughout North America.

4. Upon information and belief, Defendant Samsung SDI Co., Ltd. is a company organized under the laws of South Korea with its principal place of business at Samsung Life Insurance Building., 1502 2-ka Taepyung-Ro, Chung-Ku, Seoul, South Korea. Upon information and belief, Defendant Samsung SDI Co., Ltd. also has places of business in several locations throughout the United States, including at 1111 Plaza Drive, Suite 100, Schaumburg, Illinois 60173. Samsung SDI Co., Ltd. may be served by delivery of summons to any of its officers at 1111 Plaza Drive, Suite 100, Schaumburg, Illinois 60173. Samsung SDI Co., Ltd develops and manufactures LCD products.

5. Upon information and belief, Defendant Samsung SDI America, Inc. is a California corporation with its principal place of business at 18600 Broadwick Street, Rancho Dominguez, California 90220. Samsung SDI America, Inc. may be served by delivery of summons to any of its officers at 18600 Broadwick Street, Rancho Dominguez, California 90220. Samsung SDI America, Inc. imports and distributes finished LCD products to customers in the United States, Canada and Mexico.

6. Upon information and belief, Defendant Samsung Electronics Co. Ltd. is a company organized under the laws of South Korea with its principal place of business at 416

Maetan-3 Dong, Paldal-Gu, Suwon City, Kyungki-Do, Korea. Samsung Electronics Co., Ltd. may be served by delivery of summons to one of its subsidiaries based in the United States that is an agent of Samsung Electronics Co., Ltd. Samsung Electronics Co. Ltd. is a manufacturer of consumer and industrial electronic equipment and telecommunications equipment, including mobile telephones.

7. Upon information and belief, Defendant Samsung Electronics America, Inc. is a New York corporation with its principal place of business at 105 Challenger Road, Ridgefield Park, New Jersey 07660. Samsung Electronics America, Inc. may be served by delivery of summons to its registered agent of record, Corporate Service Company, 80 State Street, Albany, New York 12207. Samsung Electronics America, Inc. is a wholly-owned subsidiary of Samsung Electronics Co., Ltd. and oversees the operations of Samsung Telecommunications America, L.P.

JURISDICTION AND VENUE

8. Upon information and belief, Defendants regularly and continuously engage in substantial sales and other business transactions in this District and have committed acts of infringement in this District and nationwide. In particular, Defendants' "Model SPH-N400" mobile telephone has been sold and, upon information and belief, is currently being sold nationwide throughout the United States by numerous national retailers, including the Radio Shack Corporation. Defendants' SPH-N400 model mobile telephone has been sold and, upon information and belief, is currently being sold in this District, including at the following locations: (1) Radio Shack, 120 Eastpark SC, 120 East End Boulevard N, Marshall, Texas 75670 and (2) Price True Value, 302 N. Williams, Atlanta, Texas 75551.

9. This Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331 and 1338(a).

10. Venue is proper in this District pursuant to 28 U.S.C. §§ 1391(b), 1391(d), and 1400(b).

CLAIM FOR RELIEF

11. On June 24, 1986, the United States Patent and Trademark Office (the “PTO”) duly and legally issued U.S. Patent No. 4,596,446 (the “‘446 patent”), entitled “Liquid Crystal Devices With Particular Cholesteric Pitch-Cell Thickness Ratio.” On April 12, 1994, the PTO duly and legally issued Reexamination Certificate B1 4,596,446. On March 18, 1997, the PTO duly and legally issued Reexamination Certificate B2 4,596,446. Copies of the ‘446 patent and the Reexamination Certificates are attached hereto as Exhibit A and are made part of this Complaint.

12. QinetiQ is the owner of all right, title and interest in and to the ‘446 patent, including all right to recover for any and all past infringement thereof.

13. Defendants have made, used, offered for sale, and/or sold nationwide throughout the United States, and/or have imported into the United States, LCDs and LCD products such as mobile telephones, including “Model SPH-N400,” and/or components thereof, which are covered by one or more claims of the ‘446 patent, and currently continue to do so. Defendants’ past and present manufacture, use, offer for sale, sale and/or importation of those devices directly infringe one or more claims of the ‘446 patent.

14. Defendants also have infringed and continue to infringe one or more claims of the ‘446 patent by actively inducing and/or contributing to the infringement by others of one or more claims of the ‘446 patent.

15. Defendants' infringement of the '446 patent has been and continues to be willful, wanton, and deliberate, and carried out with full knowledge and awareness of QinetiQ's patent rights and without license from QinetiQ.

16. As a result of Defendants' infringing conduct, QinetiQ has suffered and will continue to suffer damages.

PRAYER FOR RELIEF

WHEREFORE, QinetiQ respectfully requests that the Court enter judgment in its favor and against Defendants as follows:

- (a) that Defendants have directly infringed, contributorily infringed, and actively induced infringement of one or more claims of the '446 patent;
- (b) that Defendants be ordered to compensate QinetiQ for their infringement of the '446 patent, and to pay enhanced damages, up to treble damages, as provided by 35 U.S.C. § 284 for the deliberate and willful nature of their infringement, and to pay interest thereon in the form of both pre-judgment and post-judgment interest;
- (c) that this case is exceptional within the meaning of 35 U.S.C. § 285;
- (d) that Defendants be ordered to pay QinetiQ's costs and expenses and its reasonable attorneys fees under 35 U.S.C. § 285; and
- (e) that QinetiQ be granted such other relief as the Court deems just and proper.

JURY TRIAL DEMANDED

QinetiQ respectfully demands a trial by jury on all issues triable to a jury.

Respectfully submitted,

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EXHIBIT “A”

United States Patent [19]

Waters et al.

[11] Patent Number: **4,596,446**[45] Date of Patent: **Jun. 24, 1986**[54] **LIQUID CRYSTAL DEVICES WITH PARTICULAR CHOLESTERIC PITCH-CELL THICKNESS RATIO**

[75] Inventors: Colin M. Waters; Edward P. Raynes, both of Malvern, England

[73] Assignee: The Secretary of State for Defence in Her Britannic Majesty's Government of the United Kingdom of Great Britain and Northern Ireland, London, England

[21] Appl. No.: 505,176

[22] Filed: Jun. 17, 1983

[30] Foreign Application Priority Data

Jun. 29, 1982 [GB] United Kingdom 8218821

[51] Int. Cl.⁴ G02F 1/13

[52] U.S. Cl. 350/346; 350/341; 350/349; 350/350 R

[58] Field of Search 350/346, 341, 349

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Ishibashi, T. et al., "On the Multiplexing of the Phase Change Type Color LCD," 1980 *Biennial Display Research Conference*, IEEE (Oct. 1980), pp. 186-188.

Primary Examiner—John K. Corbin

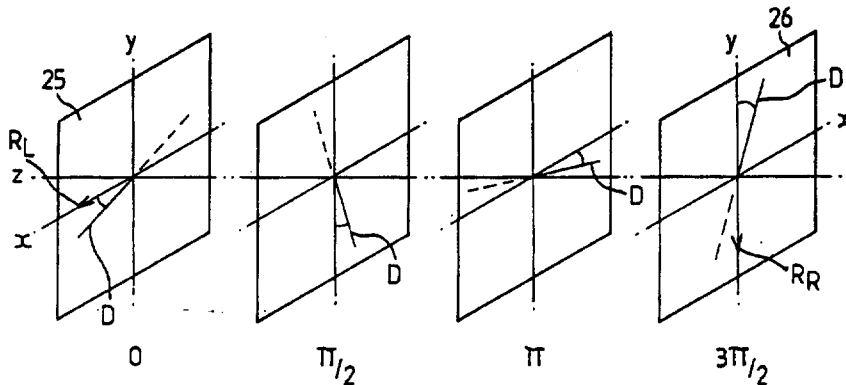
Assistant Examiner—Richard F. Gallivan

Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] ABSTRACT

A liquid crystal device comprises a layer of long pitch cholesteric liquid crystal material incorporating a pleochroic dye. The layer is contained between two cell walls surface treated to align liquid crystal molecules in a tilted homogeneous structure. The surface alignment and natural pitch of the cholesteric material are matched to provide a progressive molecular twist of between π and 2π , preferably about $3\pi/2$, with a uniform tilt direction. The ratio natural pitch P divided by thickness d of the liquid crystal layer is arranged to lie between 0.5 and 1.0, with a value of d less than $20\text{ }\mu\text{m}$. Both low tilt and high tilt surface alignment may be used separately or in combination. Polarizers may be used to enhance between ON and OFF states. The device has a sharp transmission/voltage characteristic which enables it to be used in large multiplex addressed matrix displays.

10 Claims, 10 Drawing Figures



EXHIBIT

A

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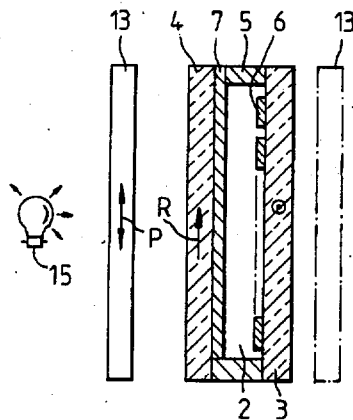
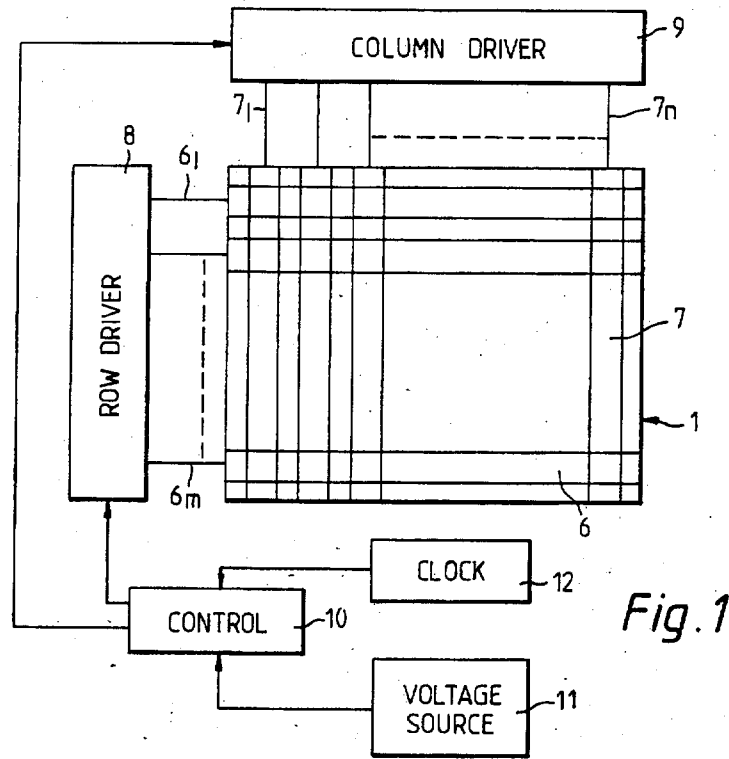


Fig. 2

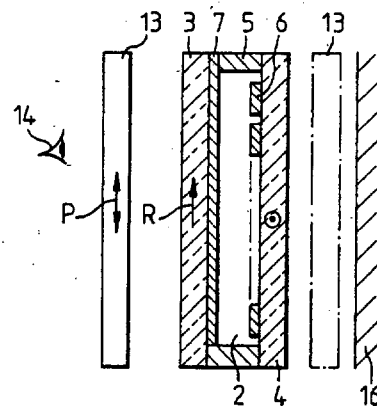


Fig. 3

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Fig. 4

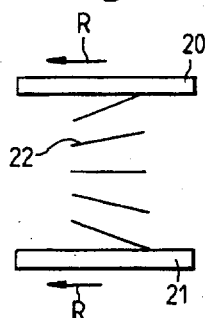


Fig. 5

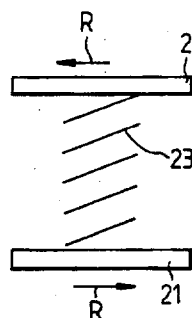


Fig. 6

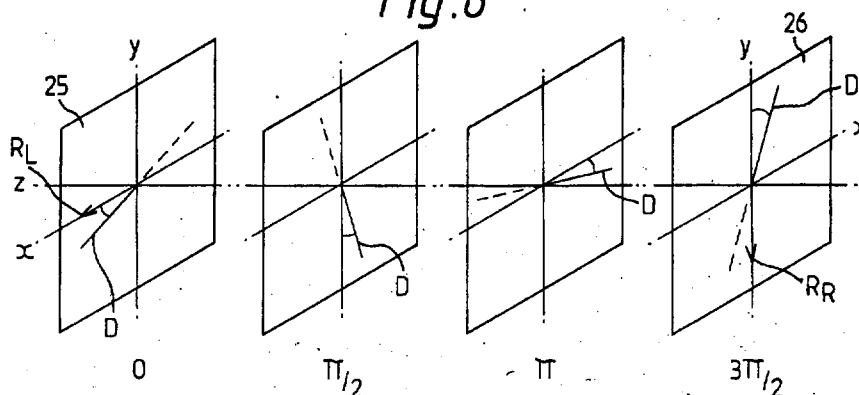
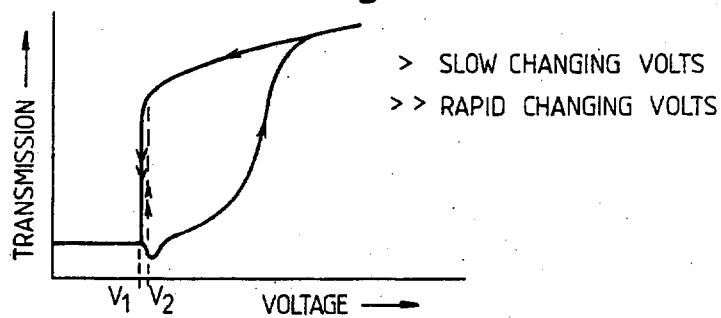


Fig. 7



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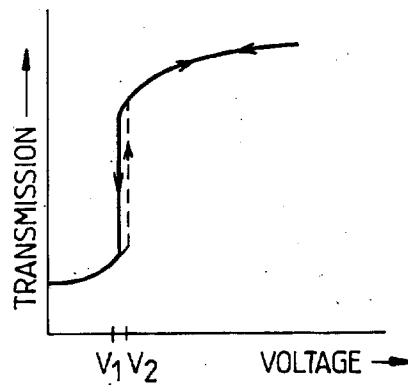


Fig. 8

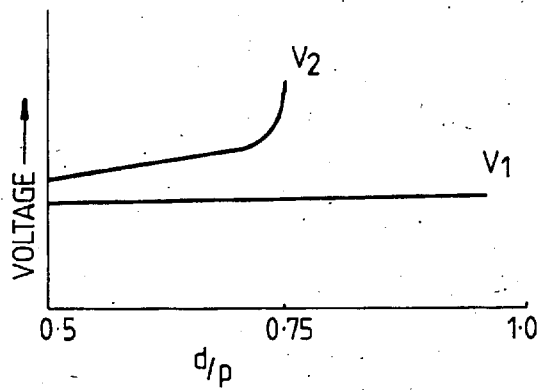


Fig. 9

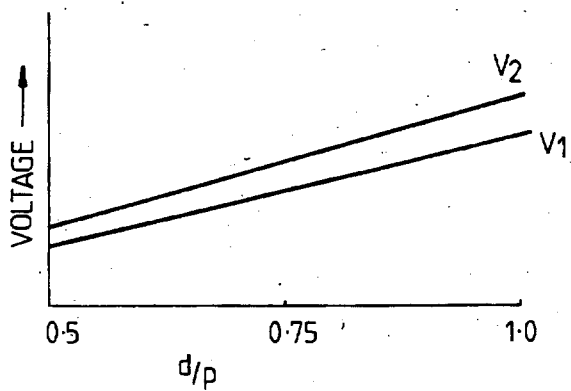


Fig. 10

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LIQUID CRYSTAL DEVICES WITH PARTICULAR CHOLESTERIC PITCH-CELL THICKNESS RATIO

BACKGROUND AND SUMMARY OF THE PRESENT INVENTION

This invention relates to liquid crystal devices. Such devices typically comprise a thin layer of a liquid crystal material contained between glass slides. Electrode structures on the slides allow an electric field to be applied across the layer causing a re-ordering of the liquid crystal molecules to an ON-state. On removing the electric field the molecules relax back to their OFF state.

There are three known types of liquid crystal material, nematic, cholesteric, and smectic each having a different molecular ordering.

The present invention utilises a long-pitch cholesteric mixture in which the molecules naturally adopt a helical structure with the helix axes normal to the plane of the layer. The long-pitch cholesteric mixture is formed by mixing typically a few percent of a cholesteric liquid crystal material with a nematic liquid crystal. The pitch of the cholesteric mixture can be controlled by adjusting the concentration of the cholesteric liquid crystal material.

One known device is the twisted nematic device which uses a thin layer of a nematic material between glass slides. The slides are unidirectionally rubbed and assembled with the rubbing directions orthogonal. The rubbing gives a surface alignment to the liquid crystal molecules resulting in a progressive 90° twist across the layer. When placed between polarisers, with their optical axis perpendicular or parallel to a rubbing direction the device rotates the plane of polarised light in its OFF state and transmits without rotation in the ON state. Small amounts of cholesteric have been added to the nematic material to ensure the 90° twist is of the same sense across the whole area of the device as explained in U.K. Pat. Nos. 1,472,247 and 1,478,592.

A known type of device employing short-pitch cholesteric material is the phase change device. In its OFF, zero applied voltage, state the material is scattering to light. The cholesteric pitch is very small in comparison to the layer thickness. When an above threshold voltage is applied across the layer its molecules rotate from their helical structure to lie parallel to the applied field. This is similar to the ON state of a positive nematic and is light transparent. On removing the voltage the material relaxes back to its light scattering OFF state. No cell wall surface alignment is necessary with this type of device. An advantage of this device is the fast turn OFF time compared with the twisted nematic device and wide angle of view.

Another type of cell utilises a cholesteric material whose pitch equals the layer thickness. With homogeneous boundary conditions a plan state is induced with a 2π rotation of the director across the layer. Inclusion of a pleochroic dye produces absorption of light in the OFF state. Application of a voltage re-orientates the liquid crystal and dye molecules giving higher transmission in the ON state. As the voltage is increased to just above threshold a scattering texture is formed, which clears after a further, substantial, increase of voltage to give the ON state. As the voltage is reduced there is a rapid reduction in transmission at the threshold voltage. The device therefore always shows significant hysteresis which is present irrespective of the rate of increase of

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voltage. This hysteresis limits the multiplexibility of this device. This device is described in I.E.E.E. Trans. on Electron Devices, Vol. ED 28 No. 6, June 1981, pp. 719-823.

It has now been found that certain cholesteric liquid crystal cells incorporating a pleochroic dye and having about a $3\pi/2$ twist exhibit a sharp transmission-voltage characteristic for rapidly increasing voltages, without hysteresis. A slow increase in voltage may still produce some hysteresis.

According to this invention a liquid crystal device comprises a layer of long pitch cholesteric liquid crystal material of positive dielectric anisotropy and incorporating an amount of a pleochroic dye contained between two cell walls bearing electrode structures and being surface treated to align liquid crystal molecules in a tilted homogeneous structure characterised in that the surface alignment and natural pitch p of the cholesteric material are matched to provide a progressive molecular twist of greater than π and less than 2π radians across the layer with a uniform tilt direction, the ratio of layer thickness d divided by pitch p lying between 0.5 and 1.0 with a value of d less than $20\text{ }\mu\text{m}$ whereby the device may be switched directly between a light transmissive ON state and a non transmissive OFF state with a sharp transmission/voltage characteristics without substantial hysteresis.

The amount of twist is preferably around $3\pi/2$. The surface alignment treatment results in a molecular tilt of between 0° and 30° or more but less than 90° (hemeotropic alignment). A tilt of less than say 5° e.g. 2° may be termed low tilt and between say 5° and 70° termed a high tilt. Both low and high tilt may be used singly or in combination.

The device may operate in a transmissive mode or with a reflector in a reflective mode both with or without neutral or coloured polarisers.

Two or more devices may be arranged in series. This arrangement may use different colour dyes in each device so that a total of three colours may be observed. Alternatively the dyes may be similar so that a single colour of enhanced contrast between OFF and ON states is obtained. Furthermore each cell may have a different absorption so that eight values of absorption or grey scale are obtained.

Usually the pitch of a cholesteric liquid crystal increases with increasing temperature. The device may be enhanced by either

- (i) choosing a liquid crystal material, or mixture of materials, with small or zero temperature dependence of pitch to maintain the optimum d/p over a wide temperature range; or
- (ii) choosing a liquid crystal whose pitch decreases with increasing temperature to partially or wholly compensate for variations in threshold voltage with temperature.

Additionally, or instead, the liquid crystal temperature may be sensed and the addressing voltage levels altered accordingly. One method of sensing is described in U.K. Pat. No. 2,012,093 B.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The invention will now be described by way of example only with reference to the accompanying drawings of which:

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FIG. 1 is a plan view of a matrix multiplex addressed liquid crystal display;

FIG. 2 is a cross section of a display such as FIG. 1 used in a transmissive mode;

FIG. 3 is similar to FIG. 2 but operates in a reflective mode;

FIGS. 4, 5 are schematic views of parallel aligned cell walls for explaining the matching of alignment;

FIG. 6 is a diagrammatic view showing matching surface alignment and cholesteric twist directions;

FIG. 7 is a graph showing transmissions of voltage characteristic for $3\pi/2$ single polariser dye display with low tilt surface alignment;

FIG. 8 is similar to FIG. 7 but for a high tilt cell;

FIG. 9 is a graph showing cell switching voltages against d/p ratio for a low tilt cell surface alignment;

FIG. 10 is a graph showing cell switching voltages against d/p ratio for a high tilt cell surface alignment.

DETAILED DESCRIPTION OF THE PREFERRED EXEMPLARY EMBODIMENTS

The display of FIGS. 1, 2 comprises a liquid crystal cell 1 formed by a layer 2 of cholesteric liquid crystal material contained between glass walls 3, 4. A spacer ring 5 maintains the walls typically $6\text{ }\mu\text{m}$ apart. Additionally numerous short lengths of $6\text{ }\mu\text{m}$ diameter glass fibre may be dispersed in the liquid crystal material to maintain an accurate wall spacing. Strip like row electrodes 6₁ to 6_m, e.g. of SnO_2 , are formed on one wall 3 and similar column electrodes 7₁ to 7_n formed on the other wall 4. With m-row electrodes and n-column electrodes this forms an m x n matrix of addressable elements. Each element is formed by the interaction of a row and column electrode.

A row driver supplies voltage to each row electrode 6. Similarly a column drive 9 supplies voltages to each column electrode 7. Control of applied voltages is from a control logic 10 which receives power from a voltage source 11 and timing from a clock 12.

In liquid crystal displays the ON and OFF states are visibly different. This is used for example to show digits as in watches, etc.

There are two conventional techniques for multiplex addressing displays, a so-called slow scan and a fast scan or r.m.s. mode. In the slow scan mode each element in a matrix is addressed with a voltage for a time sufficient to turn that element ON. This is repeated for each line of the matrix and then the whole matrix is re-addressed or refreshed repeatedly. In the fast scan mode each element required to be ON is addressed once per complete refresh cycle with a higher voltage level for a time less than the response time of the liquid crystal material and during the remainder of the refresh cycle receives a lower voltage. These voltages are set so that the r.m.s. level over many cycles is sufficiently high to maintain the required elements ON. Elsewhere the r.m.s. level is insufficient to cause elements to be in the ON state.

As an example of fast scan addressing an A.C. row voltage V_R is applied to each row in turn. As each row is addressed column voltages $\pm V_C$ are applied to appropriate column electrodes, the \pm signs refer to the phase of the A.C. signal e.g. at 1 KHz. This is repeated for each row until the whole cell is addressed. The process is repeated for the whole cell at a frame rate typically of 50 Hz for a 10 line matrix whilst information is to be displayed. Each element required to be ON receives $V_R + V_C$ for one time interval per complete addressing cycle, i.e. frame time, and $\pm V_C$ for other

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time intervals. The r.m.s. value of $V_R + V_C$ and $n - 1(\pm V_C)$ is arranged to equal a desired V_2 level. Elements not required to be ON receive V_C , or $V_R - V_C$ for all time periods. The r.m.s. value of V_C , $V_R - V_C$ is V_1 . The display is formed collectively by ON elements receiving V_2 volts on a background of OFF elements receiving V_1 volts.

Alternatively the display may be collectively formed by OFF elements on a background of ON elements.

To multiplex address a display having a large numbers of lines the ON/OFF transmission voltage characteristic must be very sharp, since the OFF elements in the display have to be held at a voltage V_1 which is only slightly lower than the ON voltage V_2 . The number of lines, n, (or level of multiplexing) that can be addressed can be related to the ratio of V_1 , V_2 voltages. For example for the optimised Alt and Pleschko addressing scheme (I.E.E.E. Trans. ED Vol. ED 21 1974 pp 146-155),

$$\left(\frac{V_2}{V_1}\right)^2 = \frac{\sqrt{n} + 1}{\sqrt{n} - 1}$$

Decreasing $V_2 - V_1$ increases the value of n.

Present displays using the twisted nematic or Schadt Helfrich effect without dyes can be multiplexed about 32 ways ($n=32$). However dyed displays have previously been limited to around $n=3$. As explained below displays of the present invention provide sharp ON/OFF transmission characteristics and hence high values of n.

The display of FIG. 1 has been arranged as an orthogonal m x n matrix but may be arranged in other layouts. For example an eight bar digit can be displayed by a three row by three column matrix and multiplex addressed. The digits can be extended to a row of digit by adding column electrodes in groups of three.

For a transmissive display FIG. 2 a polariser 13 may be arranged behind, or in front of the cell 1. The polarisation axis P of the polariser is parallel with the surface alignment direction R (see below) on the adjacent cell walls. An observer 14 views the display illuminated by e.g. a tungsten bulb 15.

FIG. 3 shows a display having a reflector 16 behind the cell. A polariser 13 is mounted in front of or behind the cell 1 with its polarisation axis P parallel to the alignment direction R of the adjacent wall.

As seen in FIG. 2, 3 the components are separated. In practice they are in contact with one another. For example the reflector 16 may be a layer of aluminum sprayed or evaporated onto the rear cell wall 4.

The cholesteric material used naturally forms a helical ordering in the layer 2 with the helical axis normal to the walls 3, 4.

Liquid crystal molecules can be aligned at the cell wall surface by various alignment techniques. For example coating the surface with polyvinyl alcohol and unidirectional rubbing with a soft tissue. This results in a molecular alignment along the rubbing direction and with a tilt of the molecules of about 2° to the surface. Alternatively, as described in U.K. Pat. Nos. 1,472,247, 1,478,592, 1,545,084, and 2,007,865 A MgF_2 may be evaporated onto the walls. Depending on the angle of evaporation, single or sequentially, the molecules are aligned and the angle of tilt may vary between zero and 30° or more.

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The cell is constructed to have a $3\pi/2$ molecular twist across the layer. Thus the two alignment directions on the assembled cell must be orthogonal. The cholesteric pitch p is chosen so that for a layer thickness d the molecules twist across the layer by $3\pi/2$ i.e. d/p is 0.75. such a value of d/p matches the natural cholesteric twist to the surface alignment twist. It has been found that values of d/p may lie between 0.5 to 1.0.

As noted above surface alignment by rubbing results in a surface molecules tilt of about 2° . The relative orientation of the two rubbing directions must be matched to the natural cholesteric rotation which may be left or right handed. The need for this matching is explained with reference to FIGS. 4, 5.

In FIG. 4 cell walls 20, 21 are unidirectionally rubbed and assembled with the rubbing R in the same directions. For this cell the liquid crystal material is a nematic material, it is not optically active i.e. has no twisted structure. The liquid crystal molecules 22 are splayed, they are inclined towards the centre of the layer. When a voltage is applied the molecules rotate to align normal to the walls. Some molecules rotate clockwise others anti-clockwise to the ON state. This is the problem of reverse tip referred to in the prior art. It gives rise to a patchy appearance to the display.

FIG. 5 is similar to FIG. 4 except that the rubbing directions are opposite. This results in liquid crystal molecules 23 all inclined in the same direction towards one wall in the OFF state. When a voltage is applied all molecules rotate in the same direction to give a uniform appearance.

FIG. 6 shows how the cholesteric twist and alignments are matched. Left plane 25 and right plane 26 have rubbing directions R_L and R_R respectively. Viewed from the left R_R is rotated anti-clockwise $3\pi/2$ from R_L . Passing from left to right the director is rotated clockwise by $3\pi/2$. The tilt angle across the centre of the layer is uniform. Intermediate planes are indicated for $\pi/2$ and π rotation. For a cholesteric that twists anticlockwise on passing through the layer the rubbing direction R_L is reversed. The orientation of the rubbing directions is critical. If one of the rubbing directions is opposite to that indicated in FIG. 6 then there is a significant degradation in the sharpness of the electro-optic transmission curve.

The transmission against applied voltage characteristic for a low tilt (e.g. 2°) $6\mu\text{m}$ cell with a $3\pi/2$ twist incorporating a dye and using a single polariser shown in FIG. 7. The lower curve shows transmission changes with a slowly increasing voltage, the upper curve shows transmission changes with a decreasing voltage. The decreasing voltage curve is obtained for both slow and fast reduction in voltage. A surprising effect is that for a rapid increase in voltage from V_1 to V_2 , marked by a broken line, the transmission change closely follows the upper curve. V_1 is below the steep ramp of the two closely spaced lines and V_2 is just above it. The display of FIG. 1 is operated using R.M.S. values of V_1 and V_2 for OFF and ON elements respectively.

In the OFF state very little light is transmitted whilst substantially all of the light is transmitted in the ON state. For a liquid crystal material having a reasonably high birefringence (e.g. $\Delta n \gtrsim 0.15$) there is guiding of polarised light in the OFF state. If light from a source enters the layer polarised along the molecular axis of the liquid crystal and dye molecules and in a direction normal to this axis, it is both guided and absorbed across the layer. When the birefringence is low (e.g. $\Delta n \lesssim 0.15$)

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there is less guiding of polarised light, and a larger fraction of unpolarised light may be absorbed by the dye molecules allowing the device to be operated without a polariser.

When the cell is in the ON state the liquid crystal and dye molecules are re-oriented towards the normal to the walls, provided the material has positive dielectric anisotropy ($\Delta\epsilon > 0$). In this condition little light is absorbed by the dye.

For high birefringence materials ($\Delta n \gtrsim 0.15$) it is preferable to use a single polariser to increase the absorption in the OFF state. For low birefringence ($\Delta n \lesssim 0.15$) it is preferable to use no polarisers to produce a brighter ON state.

For high birefringence materials and layers of $12\mu\text{m}$ or more a polarisation switch effect (c.f. the $\pi/2$ twisted nematic) is obtainable without a dye by using the cell between two polarisers.

FIG. 9 shows the effect of varying the ratio d/p in the low tilt cell whose transmission characteristics are shown in FIG. 7. As the layer thickness d to cholesteric pitch p increases above 0.5 the value of V_1 remains reasonably constant. However, the value of V_2 increases gradually up to about d/p of 0.75 and then increases markedly. Thus for low tilt cells the value of d/p is preferably within the range 0.5 to 0.75. The additional strain induced by the surfaces at values of $d/p < 0.75$ for a $3\pi/2$ twist, reduces the tendency of the cell to form a scattering texture just above the threshold voltage V_1 .

Cells of $3\pi/2$ twist with surface alignments having high tilts, e.g. 30° , have a transmission characteristic shown in FIG. 8. For applied voltages above V_1 the transmission changes rapidly with little hysteresis both for slowly and rapidly increasing and decreasing voltages. For this high tilt cell the variation of V_1 and V_2 with varying d/p is shown in FIG. 10. Both V_1 and V_2 increase steadily with increasing d/p . Similar results obtain when the tilts are different on the two cell walls. For example one tilt may be zero or 2° and the other 30° with alignment matched to the twist direction as in FIG. 6.

The invention may be operated as a multiplexed matrix array as described above with reference to FIG. 1 or as a fixed legend display.

This device may be operated in a two-frequency mode where the cell is switched ON by a low frequency signal f_l and switched OFF by a high frequency f_h . The signal $f_l < f_c < f_h$ where f_c is the frequency at which the dielectric anisotropy of the liquid crystal material changes sign being positive at low frequencies to negative at high frequencies.

Examples of suitable liquid crystal materials are: Catalogue Nos. E63, E70, E43, CB 15 available from B.D.H. Ltd., Poole, Dorset, England.

Biphenyl liquid crystal materials are described in U.K. Patent No. 1,433,130 and U.K. Patent Application No. 2,031,010 A. ZLI 1132 available from E. Merck, Darmstadt, W. Germany.

Suitable dyes are anthraquinone dyes described in U.K. Patent Applications Nos. 2,011,940 A, 2,082,196 A, 2,081,736 A, 2,093,475 A, available from I.C.I. Ltd., or from B.D.H. Chemicals Ltd. as D82, D86.

EXAMPLE 1

Material E63+1.5% by weight of CB 15+1% Dye D82 (B.D.H.)

Cell thickness $6\mu\text{m}$, low tilt alignment

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V_2/V_1 at temperature $T=20^\circ=1.165$
 Maximum number, n , of lines which may be multiplexed using the Alt & Pleshko technique: $n=40$

$$\frac{1}{V} \left(\frac{dV}{dT} \right) \approx 0.5\% \text{ per } ^\circ\text{C}.$$

Response time
 $t_{ON} \approx 500$ ms
 $t_{OFF} \approx 300$ ms
 Contrast ratio 4:1.
 The angle of view is extremely good with or without a polariser.

EXAMPLE 2

Liquid crystal cell thickness $8 \mu\text{m}$, low tilt alignment
 Materials ZLI 1289 (Merck)
 +ME 33 30% by weight (Merck)
 +CB 15 1% by weight (B.D.H.)
 +D 82 dye 1% by weight (B.D.H.)
 $(V_2/V_1)_{T=20^\circ}=1.160$
 $n=46$

EXAMPLE 3

Cell thickness $8 \mu\text{m}$ low tilt alignment
 Materials (B.D.H.) 3/5/7 CB
 +CB 15 1% by weight
 +D 82 dye 1% by weight
 $(V_2/V_1)_{T=20^\circ}=1.125$
 $n=72$

EXAMPLE 4

Cell thickness $8 \mu\text{m}$, low tilt alignment
 Material (B.D.H.) 3/5/7 CB 50% by weight
 +3/5/7 CNPYR 50% by weight
 $(V_2/V_1)_{T=20^\circ}=1.072$
 $n=200$

EXAMPLE 5

Cell thickness $8 \mu\text{m}$, low tilt alignment on one wall and high tilt alignment on the other wall.
 Material ZLI 1557 (Merck)
 +CB 15 0.9% by weight (B.D.H.)
 +D 82 dye 1% by weight (B.D.H.)
 $(V_2/V_1)_{T=20^\circ}=1.063$
 $n=268$

EXAMPLE 6

Cell thickness $8 \mu\text{m}$, low/high tilt alignment
 Material (B.D.H.) E 63
 +CB 15 1.1% by weight
 +D 82 dye 1% by weight
 $(V_2/V_1)_{T=20^\circ}=1.141$
 $n=58$

EXAMPLE 7

Cell thickness $8 \mu\text{m}$, low/high tilt alignment.
 Material (B.D.H.) 3/5/7 PECH
 +CB 15 1% by weight
 +D 82 dye 1% by weight
 $(V_2/V_1)_{T=20^\circ}=1.134$
 $n=64$

EXAMPLE 8

Cell thickness $8 \mu\text{m}$, high tilt alignment
 Material ZLI 1557 (Merck)

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+CB 15 0.9% by weight (B.D.H.)
 +D 82 dye 1% by weight (B.D.H.)
 $(V_2/V_1)_{T=20^\circ}=1.042$
 $n=590$

EXAMPLE 9

Cell thickness $8 \mu\text{m}$, high tilt alignment
 Material ZLI 1289 (Merck)
 +BCO Ester 30% by weight (B.D.H.)
 +CB 15 1.1% by weight (B.D.H.)
 +D 82 dye 1% by weight (B.D.H.)
 $(V_2/V_1)_{T=20^\circ}=1.075$
 $n=190$

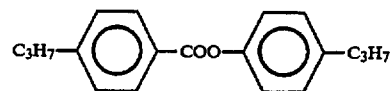
EXAMPLE 10

Cell thickness $8 \mu\text{m}$, high tilt alignment
 Material (B.D.H.) E 120
 +CB 15 0.75% by weight
 +D 82 dye 1% by weight
 $(V_2/V_1)_{T=20^\circ}=1.08$
 $n=170$

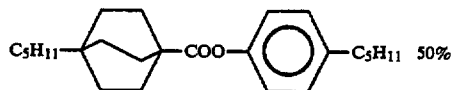
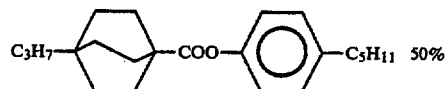
Table of properties of liquid crystal materials.

Material	$\frac{k_{33}}{k_{11}}$	$\frac{\Delta\epsilon}{\epsilon_1}$
ZLI 1289 (Merck)	2.01	2.28
ZLI 1289 + 30% ME 33	1.23	1.87
ZLI 1289 + 30% BCO Ester	1.30	2.0
E 120	1.01	1.09
3/5/7 CB	1.55	2.91
E 63	1.93	3.19
3/5/7 PECH	2.08	2.7

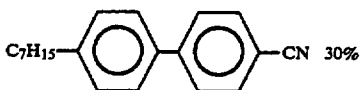
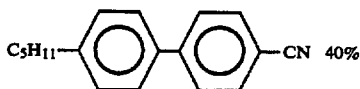
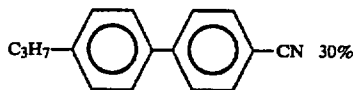
ME 33 is



BCO Ester is



3/5/7 CB is



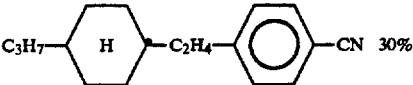
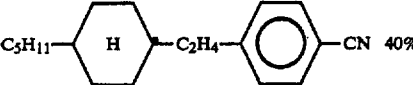
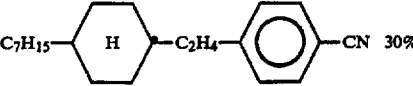
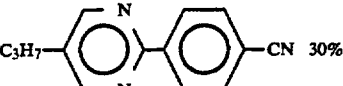
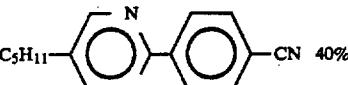
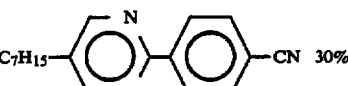
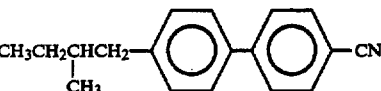
3/5/7 PECH is

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-continued

Material	$\frac{k_{33}}{k_{11}}$	$\frac{\Delta\epsilon}{\epsilon_1}$
		30%
		40%
		30%
3/5/7 CNPYR is		
		30%
		40%
		30%
CB 15 is		
		

We claim:

1. A liquid crystal display device comprising:
a layer of positive dielectric anisotropy cholesteric liquid crystal material of natural pitch p and thickness d less than $20 \mu\text{m}$ contained between two parallel spaced cell walls, electrode structures on both cell walls arranged to form a plurality of addressable elements, a surface treatment on both

cells wall in contact with the liquid crystal material to align liquid crystal molecules in a tilted homogeneous structure,

said surface alignment being matched to said cholesteric material to provide a progressive molecular twist of greater than π and less than 2π radians across said layer with a uniform tilt direction, the ratio of layer thickness d divided by pitch p laying between 0.5 and 1.0, said device further comprising means for selectively absorbing transmitted light depending on the molecular orientation of the liquid crystal material, two sets of driver circuits and a controlling logic circuit for repetitively applying voltage from a voltage source to the electrode structures in a multiplexed sequence, wherein each of said addressable elements may be switched directly between a light transmissive state and a nontransmissive state with a sharp transmission/voltage characteristic without substantial hysteresis.

2. The device of claim 1 wherein the means for selectively absorbing transmitted light is an amount of pleochroic dye incorporated in the liquid crystal material.

3. The device of claim 2 and further comprising at least one polariser.

4. The device of claim 1 wherein the means for selectively absorbing transmitted light is two polarisers arranged optically in front of and behind the layer of liquid crystal material.

5. The device of claim 1 wherein the molecular twist is about $3\pi/2$.

6. The device of claim 1 wherein the surface treatment provides a liquid crystal molecular tilt up to 5° and the ratio d/p lies between 0.5 and 0.75.

7. The device of claim 1 wherein the surface treatment provides a liquid crystal molecular tilt of between 5° and 70° on at least one cell wall.

8. The device of claim 1 and further comprising a reflector optically behind the cell.

9. The device of claim 1 arranged optically in series with at least one other device of claim 1 with different colour dyes in the different cells.

10. The device of claim 1 wherein the electrode structure on one cell wall is arranged in a first series of m separate electrodes and the electrode structure on the other cell wall is arranged in a second series of n separate electrodes to form an $m \times n$ matrix of separate addressable elements.

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US004596446B1

REEXAMINATION CERTIFICATE (2268th)

United States Patent [19] [11] **B1 4,596,446**

Waters et al. [45] Certificate Issued **Apr. 12, 1994**

[54] **LIQUID CRYSTAL DEVICES WITH PARTICULAR CHOLESTERIC PITCH-CELL THICKNESS RATIO**

[75] **Inventors:** Colin M. Waters; Edward P. Raynes, both of Malvern, England

[73] **Assignee:** The secretary of State for Her Defence in Her Britannic Majesty's Government the United Kingdom of Great Britain and Northern Ireland, London, United Kingdom

Reexamination Request:
No. 90/003,040, Apr. 30, 1993

Reexamination Certificate for:
Patent No.: **4,596,446**
Issued: **Jun. 24, 1986**
Appl. No.: **505,176**
Filed: **Jun. 17, 1983**

[30] **Foreign Application Priority Data**

Jun. 29, 1982 [GB] United Kingdom 8218821

- [51] **Int. Cl.⁵** G02F 1/1343; G02F 1/1337; G02F 1/13
- [52] **U.S. Cl.** 359/55; 359/75; 359/98; 359/101
- [58] **Field of Search** 359/101, 98, 102, 55, 359/75

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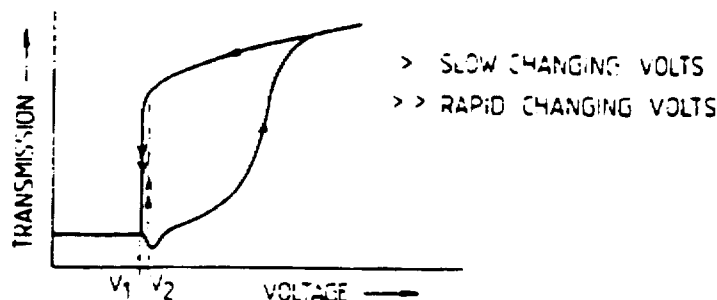
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Primary Examiner—Anita Pellman Gross

[57] **ABSTRACT**

A liquid crystal device comprises a layer of long pitch cholesteric liquid crystal material incorporating a pleochroic dye. The layer is contained between two cell walls surface treated to align liquid crystal molecules in a tilted homogeneous structure. The surface alignment and natural pitch of the cholesteric material are matched to provide a progressive molecular twist of between π and 2π , preferably about $3\pi/2$, with a uniform tilt direction. The ratio natural pitch P divided by thickness d of the liquid crystal layer is arranged to lie between 0.5 and 1.0, with a value of d less than 20 μm . Both low tilt and high tilt surface alignment may be used separately or in combination. Polarizers may be used to enhance between ON and OFF states. The device has a sharp transmission/voltage characteristic which enables it to be used in large multiplex addressed matrix displays.



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**REEXAMINATION CERTIFICATE
ISSUED UNDER 35 U.S.C. 307**

THE PATENT IS HEREBY AMENDED AS
INDICATED BELOW.

Matter enclosed in heavy brackets **[]** appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS
BEEN DETERMINED THAT:

The patentability of claims 1-10 is confirmed.

New claims 11, 12, and 13 are added and determined to be patentable.

11. *The device of claim 1, wherein said addressable elements are addressable in a r.m.s. mode.*

12. *The device of claim 1, wherein the liquid crystal material has a birefringence Δn approximately equal to or greater than 0.15.*

13. *The device of claim 1, wherein the liquid crystal material has induced strain.*

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REEXAMINATION CERTIFICATE (3157th)

United States Patent [19]

[11] B2 4,596,446
Waters et al.
[45] Certificate Issued Mar. 18, 1997

[54] **LIQUID CRYSTAL DEVICES WITH PARTICULAR CHOLESTERIC PITCH-CELL THICKNESS RATIO**

[75] Inventors: **Colin M. Waters; Edward P. Raynes,**
both of Malvern, England

[73] Assignee: **The Secretary of State for Her Defence in Her Britannic Majesty's Government of the United Kingdom of Great Britain and Northern Ireland, London, England**

Reexamination Request:

No. 90/004,198, Apr. 2, 1996

Reexamination Certificate for:

Patent No.: **4,596,446**
Issued: **Jun. 24, 1986**
Appl. No.: **505,176**
Filed: **Jun. 17, 1983**

Reexamination Certificate B1 4,596,446 issued Apr. 12, 1994

Certificate of Correction issued Jun. 19, 1996.

[30] **Foreign Application Priority Data**

Jun. 29, 1982 [GB] United Kingdom 8218821

[51] Int. Cl.⁶ **G02F 1/133; G02F 1/141;**
G02F 1/13

[52] U.S. Cl. **359/55; 359/75; 359/98;**
359/101

[58] Field of Search 359/101, 98, 102,
359/55, 75

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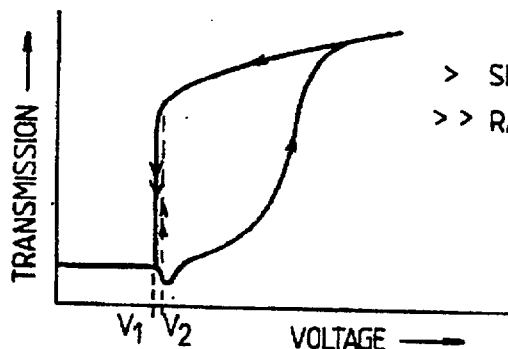
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Primary Examiner—Anita Pellman Gross

[57] **ABSTRACT**

A liquid crystal device comprises a layer of long pitch cholesteric liquid crystal material incorporating a pleochroic dye. The layer is contained between two cell walls surface treated to align liquid crystal molecules in a tilted homogeneous structure. The surface alignment and natural pitch of the cholesteric material are matched to provide a progressive molecular twist of between π and 2π , preferably about $3\pi/2$, with a uniform tilt direction. The ratio natural pitch P divided by thickness d of the liquid crystal layer is arranged to lie between 0.5 and 1.0, with a value of d less than 20 μm . Both low tilt and high tilt surface alignment may be used separately or in combination. Polarizers may be used to enhance between ON and OFF states. The device has a sharp transmission/voltage characteristic which enables it to be used in large multiplex addressed matrix displays.



> SLOW CHANGING VOLTS
>> RAPID CHANGING VOLTS

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REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS
INDICATED BELOW.

Matter enclosed in heavy brackets [] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

ONLY THOSE PARAGRAPHS OF THE SPECIFICATION AFFECTED BY AMENDMENT ARE PRINTED HEREIN.

Column 7, lines 34-40:

EXAMPLE 4

Cell thickness 8 μm , low tilt alignment
Material (B.D.H.) 3/5/7 CB 50% by weight
+3/5/7 CNPYR 50% by weight+CB15
(V_2/V_1)_{T=20°}=1.072
n=200

AS A RESULT OF REEXAMINATION, IT HAS BEEN
DETERMINED THAT:

The patentability of claims 1-13 is confirmed.

New claims 14-31 are added and determined to be patentable.

14. The device according to claim 13, wherein said induced strain is in a direction tending to twist the liquid crystal material to a shorter pitch.

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15. The device of claim 1, wherein the thickness d equals 6 μm .

16. The device of claim 1, wherein the thickness d equals 8 μm .

17. The device of claim 1, wherein n equals the number of lines that can be addressed and n is greater than 32.

18. The device of claim 17, wherein n is at least 40.

19. The device of claim 4, wherein said thickness d is 8 μm .

20. The device of claim 4, wherein said surface treatment provides a low liquid crystal molecular tilt.

21. The device according to claim 20, wherein said low liquid crystal molecular tilt is less than 5°.

22. The device according to claim 21, wherein said low liquid crystal molecular tilt is 2°.

23. The device of claim 4, wherein thickness d is greater than 12 μm .

24. The device of claim 23, wherein said liquid crystal is a high birefringence material.

25. The device of claim 24, wherein $\Delta n \geq 0.15$.

26. The device of claim 4, wherein said liquid crystal is a high birefringence material.

27. The device of claim 26, wherein $\Delta n \geq 0.15$.

28. The device according to claim 4, wherein n equals the number of lines that can be addressed and n equals 200.

29. The device according to claim 4, wherein for any pixel in the display, the ON voltage is V_2 and the OFF voltage is V_1 where the ratio of V_2 divided by V_1 at a liquid crystal temperature of 20° C. is 1.072.

30. The device of claim 7, wherein said liquid crystal molecular tilt is no greater than 30°.

31. The device of claim 30, wherein said liquid crystal molecular tilt is 30° on at least one cell wall.

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