

Description

The invention relates to smectic liquid crystal devices.

Liquid crystal devices commonly comprise a thin layer of a liquid crystal material contained between two glass plates or walls. A thin transparent electrode is deposited on the inner face of both walls. The combination of liquid crystal layer, walls, and electrode is often termed a liquid crystal cell. When an electric field is applied between the two electrodes, liquid crystal molecules rotate in the field to an ON state. On removal of the field the molecules rotate back to an OFF state, determined by a surface treatment applied to the walls before cell assembly and by the type of liquid crystal material. The optical transmission characteristics of the ON and OFF states are different. Some devices need one or two polarisers and/or dyes to visibly distinguish between ON and OFF states.

There are broadly three different types of liquid crystal material, nematic, cholesteric, and smectic, each distinguished by a different molecular ordering.

Such materials only show a liquid crystal phase over a limited temperature range between the solid and isotropic liquid phases. Within the liquid crystal phase temperature range a material may exhibit one or more of the nematic, cholesteric or smectic phase types. Normally a material is chosen such that it forms only one type of liquid crystal phase over its working temperature range.

The present invention concerns devices using smectic liquid crystal materials.

Displays have been made with the electrodes formed into rows on one wall and columns on the other wall. These collectively form an x, y matrix of separately addressable elements on a large display. One way of addressing such a display is by multiplexing i.e. addressing each row in sequence until the whole display has been addressed. This is repeated all the time that a display is needed. Another type of display uses the ON and OFF states to form an electrically switchable optical shutter. Yet another type of display is used as an optical storage device. Nematic cholesteric and smectic liquid crystal material have been used for such devices. A problem with many displays is the time taken to switch between the two states i.e. the response times. For many displays a fast response time is needed. A nematic material, arranged in a 90° twisted structure typically has a response time of 100 milliseconds.

Devices comprising smectic materials have not been used as widely as devices with nematic or cholesteric materials. Available display devices based on smectic materials did not have the necessary characteristics. Recently however ferro electric smectic devices with fast switching and bistability characteristics have become of interest. N. A. Clark & S. T. Lagerwall, App. Phys. Letters 36 (11) 1980 pp 899 - 901. Chiral liquid crystal materials in a tilted smectic phase, e.g. S_C^* , S_I^* , S_F^* , S_J^* , S_G^* , S_H^* are known to exhibit ferroelectric properties. This has been described by R. B. Meyer, L. Liebert, L. Strzelecki and P. Keller, J. de Physique (Lett), 36, L-69 (1975).

One known chiral smectic liquid crystal device is described in FR-A-2 567 533. This provides bistable switching and uniform mono domain molecular structure by a combination of material with a chiral smectic and cholesteric phases, a surface alignment treatment, and a slow cooling from the isotropic phase on manufacture.

According to this invention a method of making a liquid crystal display device comprises the steps recited in Claim 1

The heating step may be before or after introduction of the material to the space.

The liquid crystal material may be a single component or a mixture of components. The material may combine one or more chiral components with laevo (left hand) cholesteric twist sense with one or more chiral components with dextro (right hand) cholesteric twist sense. With such a mixture none of the laevo components can be the racemates of the dextro components. This chiral mixture may be a chiral smectic itself or may be used as an additive to a non-chiral and/or racemate tilted smectic liquid crystal host material. Alternatively the chiral component or components may have the same cholesteric twist sense providing the cholesteric pitch and P_s have the above values.

The smectic phase has at least one of the following chiral tilted smectic phases C^* , I^* , F^* , J^* , G^* , K^* , H^* depending on temperature and may include a smectic A phase between the cholesteric to chiral smectic phase transition.

The layer thickness may be up to 15 μm or more, but is typically 1 - 12 μm e.g. 2 μm and 6 μm .

The p/d ratio is large enough to prevent the material, in its cholesteric phase close to the cholesteric to smectic phase transition, adopting more than a 3π twist, ideally the pitch p is greater than 4d, so that less than π twist can occur in the cholesteric phase near the transition. Ideally this value of p is large over the whole cholesteric phase, preferably is large for 5° C above the smectic/cholesteric transition.

The pitch in the smectic phase is greater than 0.1 μm and preferably much greater, e.g. greater than layer thickness.

The value of P_s is at least 0.1 and preferably 1 or more nC/cm². All the chiral components may have substantial values of P_s and the same sense of P_s . Alternatively one or more components may have P_s values of opposite senses providing the net P_s is substantial.

For some mixtures the cooling is at a rate of between 0.05° and 2° C/minute within $\pm 5^\circ$ C of the cholesteric to smectic phase transition. The rate of cooling depends upon the amount of compensation in the cholesteric phase. For well compensated material the cell may be cooled as quickly as is convenient, e.g. 20° C/minute or more.

According to this invention a liquid crystal device comprises the features recited in claim 9. The device cell may be arranged between two polarisers arranged with their optical axes parallel or at a non zero angle to one another.

The device may further include means for applying two d.c. voltages of opposite polarity to the electrode structures whereby the molecules of the mixture are forced to lie in one of two different positions depending on the polarity of applied voltage and switch between these two positions as the polarity is changed.

The cell wall surface treatment may provide similar alignment, in the same or different directions, or different types of alignment, e.g. homogeneous and homeotropic, on the two walls. Alternatively one wall may be left cleaned but with no surface alignment.

According to this invention a liquid material mixture for use in a tilted chiral smectic liquid crystal device comprises a material having a tilted chiral smectic phase at normal device operating temperatures and a cholesteric phase at an elevated temperature, the mixture having a cholesteric pitch greater than 4 μ m in the cholesteric phase at least 0.1° C above a cholesteric to smectic transition temperature, and a substantial spontaneous polarisation coefficient P_s , in the smectic phase.

The device operating temperature typically falls within the range of 0° to 40° C, although for some devices mounted on equipment the upper operating temperature may be about 100° C or even higher.

Use of chiral components in nematic liquid crystal material is well known. The addition of a chiral component imparts a twist direction to the nematic material director and results in a cholesteric material. The direction of this twist can either be clockwise or anticlockwise, i.e. right or left rotation. Adding two different chiral materials of opposite twist can result in zero twist depending upon the composition and temperature of the mixture. Some compounds can have molecules with both right and left rotatory power, these are optical isomers when the optical isomers are present in equal amounts a racemic mixture is formed which is indistinguishable from ordinary non-chiral liquid crystalline materials.

Brief Description of the Drawings

One form of the invention will now be described, by way of example only, with reference to the accompanying drawings in which: -

Figures 1, 2, are plan and section views of a liquid crystal display device;

Figures 3, 4, 5, are stylised views of a layer of aligned liquid crystal material showing smectic A, smectic C and smectic C* material respectively;

Figure 6 is a plan view of a Sc* cell showing both P_s UP and P_s DOWN molecular alignment states.

Figures 7(a), (b), (c) are graphs of cholesteric pitch vs temperature for various mixtures;

Figure 8 is a graph showing variation of half cone angle between UP and

DOWN states for one material mixture;

Figure 9 is a graph showing variation of P_s with temperature for one material mixture.

Description of preferred embodiment

The cell 1 shown in Figures 1, 2 comprises two glass walls, 2, 3, spaced about 1-6 μ m apart by a spacer ring 4 and/or distributed spacers. Electrode structures 5, 6 of transparent tin oxide are formed on the inner face of both walls. These electrodes may be of conventional row and column shape or seven segment display. A layer 7 of liquid crystal material is contained between the walls 2, 3 and spacer ring 4. Polarisers 8, 9 are arranged in front of and behind the cell 1. The alignment of the optical axis of each polariser is discussed later. To an approximation the polarisers are crossed and the optical axis of one is nearly parallel or perpendicular to a liquid crystal molecular alignment direction. A d.c. voltage source 10 supplies power through control logic 11 to driver circuits 12, 13 connected to the electrode structures 5, 6, by lead wires 14, 15.

Prior to assembly the walls 2, 3 are surface treated by spinning on a thin layer of polyamide or polyimide, drying and where appropriate curing; then buffing with a soft cloth (e.g. rayon) in a single

direction R1, R2. This known treatment provides a surface alignment for liquid crystal molecules. The molecules align themselves along the rubbing direction R1, R2, and at an angle of about 2° to the surface. The directions R1, R2 may in the same or opposition directions. When R1, R2 are arranged in the same direction the contacting liquid crystal molecules tilt towards the layer centre and adopt a splayed configuration across the layer thickness. Surface alignment may be provided by the known process of obliquely evaporating silicon oxide onto the cell walls. As for rubbing alignment the alignment can be parallel in the same or opposite direction. Alternatively one wall may be either left uncoated, or coated with e.g. polyamide and not buffed. Alignment is then provided by the other, rubbed wall surface.

The device may operate in a transmissive or reflective mode. In the former light passing through the device e.g. from a tungsten bulb is selectively transmitted or blocked to form the desired display. In the reflective mode a mirror is placed behind the second polariser 9 to reflect ambient light back through the cell 1 and two polarisers. By making the mirror partly reflecting the device may be operated both in a transmissive and reflective mode.

Pleochroic dyes may be added to the material 7. In this case only one polariser is needed.

An idealised, and somewhat simplistic, arrangement of liquid crystal molecules within a cell is shown diagrammatically in Figures 3, 4, 5. In practice these arrangements may differ considerably from those illustrated, depending in part on cell wall surface effects.

Figure 3 shows a layer 7 of smectic A (S_A) material. Axes x, y, z, are used to define directions. The liquid crystal layer lies in x, y plane, layer thickness is in the z direction, rubbing directions R1, R2, are + x, and - x for the upper and lower wall respectively. For an S_A material with these alignments the individual molecules 21 align in the x direction in layers 20 parallel to the y, z plane.

Figure 4 shows a layer of smectic C (S_C) material. Surface alignment is + x and - x as in Figure 3.

As in Figure 3 the liquid crystal molecules 21 form into layers 20 parallel to the y, z plane. However S_C molecules 21 adopt a tilted formation within each layer. The tilt is in an x, y plane and at an angle θ to the x axis. Typically θ is $15^\circ - 25^\circ$ depending on material composition and temperature.

Figure 5 illustrates smectic pitch in a layer 7 of smectic C* (S_C^*) material. This material forms into layers 20n, with the molecules 21n in each layer lying at an angle $15 - 25^\circ$ to the x axis and with this angle $15 - 25^\circ$ varying in each layer 21. Collectively the molecules form into a twisted structure with the twist axis along the x axis. This is shown in Figure 5 where the molecular alignment in successive layers 21 is shown lying along the surface of a cone with a 45° change between each layer.

The structure of Figure 5 is termed a tilted chiral smectic phase. Such materials can be produced by the addition of a chiral material to a smectic material. The chiral additive may have either a clockwise or anticlockwise twist, some compounds may have molecules with both senses of twist direction, in which case the material can be racemate. Tilted chiral smectic materials can have a spontaneous polarisation and there are two opposing directions for this depending on the configuration of the molecule. In a racemate material the two spontaneous polarisation (Ps) directions are equal and cancel one another and there is no net Ps. With a mixture of chiral compounds of opposite twist directions Ps can either be additive or subtractive. Providing there is a net Ps the mixture will exhibit a ferroelectric characteristic.

One way of producing an aligned S_C^* layer 7 is heating the material into an S_A phase where it is aligned by the cell surface treatment, and then cooling to the S_C^* phase. Unfortunately this cooling can also form the material into a small focal conic structure; a state with layers of molecules lying in many planes at different angles to one another.

The present invention overcomes this problem by using a material having a cholesteric phase above the smectic phase and providing a suitable cholesteric pitch as follows:

The material is one having the following phases with increasing temperature;

solid - smectic X* - smectic A - cholesteric - isotropic

solid - smectic X* - cholesteric - isotropic

where X* is at least one of the following: - C*, I*, F*, J*, G*, K*, H*. For materials having more than one such smectic phase the phase varies with temperature.

The pitch p in the cholesteric phase is arranged to ensure that the maximum twist across the layer thickness d is not greater than 3π . A 3π twist can occur when p is about $2/3d$; a 2π twist when p is about d; a π twist when p is about $2d$; and zero twist when $p > 4d$. Preferably $p > 4d$.

This cholesteric pitch is necessary for a temperature range of 0.1°C above the smectic/cholesteric transition. Preferably this range is 5°C above the transition and ideally over the entire cholesteric phase.

There are a number of ways of achieving the above material. For example combining one or more chiral components with laevo (left) cholesteric twist sense with one or more chiral components with dextro (right) cholesteric twist sense, with the proviso that none of the laevo components are the racemates of the dextro components. Such a mixture may be used by itself if it has the necessary smectic phases. Alternatively the

chiral mixture may be added to a non-chiral or a racemate liquid crystal material, eg a smectic C host. Different chiral components may have different temperature/pitch characteristics. In this case it is necessary to ensure that the resultant pitch has the required value in the temperature range above the smectic/cholesteric phase transition.

When using chiral components of opposite twist sense it is necessary to ensure that the resultant mixture has the required spontaneous polarization value P_s . Thus all of the chiral components, regardless of their cholesteric twist sense, may have the same sense of S_C^* polarization, i.e. their P_s add. Alternatively one or more of the chiral components may have the opposite sense of P_s providing the net P_s has a sufficient value.

Another way of achieving the above material is to use one or more chiral components with the same cholesteric twist sense and S_C^* polarisation sense but still satisfying the cholesteric pitch values noted above. Such a mixture may be used alone or in combination with a non-chiral or a racemate liquid crystal material, eg a S_C host.

As a result of the long pitch in the cholesteric phase the material cools into the S_A phase with uniform alignment caused by the cell wall treatment. The result is alignment as in Figure 3. On further cooling the material adopts the S_C^* phase with alignment approximately as in Figure 6 for mixtures with sufficiently long S_C^* pitch such that the surface alignment unwinds the helical pitch, ie the S_C^* pitch is about d , or figure 5 for shorter pitch lengths. Materials without an S_A phase are cooled from the cholesteric to a chiral smectic phase. Providing the cholesteric pitch is sufficiently long the cell is well aligned in the S^* phase.

The pitch in the tilted smectic phase is arranged to be greater than about $1 \mu m$ and preferably very much greater.

The compensation of pitch in the cholesteric phase is illustrated in Figures 7(a), (b), (c). Figure 7(a) shows cholesteric pitch against temperature for a noncompensated material having a cholesteric to smectic transition. At this transition the pitch tends to infinity. The compensated material shown in Figure 7(b) shows a pitch increase to infinity a few degrees above the transition temperature with a pitch reduction below. In Figure 7c the compensation temperature where the pitch goes to infinity occurs just below the smectic to cholesteric transition temperature. By suitable selection of materials this pitch increase can be made to occur even closer to the transition temperature, but a few degrees difference does not seem to affect the end result.

Some dopants e.g. CC10, CC12 can be used alone in small amounts to give a characteristic shown in Figure 7(c). In this case the material is not compensated as in Figure 7(b) but inherently has a long pitch.

When a d.c. pulse of sufficient magnitude is applied to the electrodes 5, 6 the molecules adopt one of two different alignments, D1, D2, depending upon the polarity of the pulse. This is shown in Figure 8 at 21, 22. Note these alignments may not correspond to a zero field alignment. The two molecular directions D1, D2 represent two different P_s directions, i.e. UP and DOWN directions. The polarisers 7, 8 are arranged with their optical axis orthogonal and with the optical axis of one polariser 7 or 8 parallel to direction 21, or 22. Alternatively the polarisers 7, 8 axis may be at non parallel and non orthogonal directions. In each case a different effect is observed in the two switched states.

The cell is observed to change rapidly between a dark and a light state as the d.c. pulses are applied. The angle between directions 21, 22 depends upon the liquid crystal material. Ideally it will be about 45° . Alternatively, when a dye is incorporated into the liquid crystal material, the ideal angle between directions 21, 22 is about 90° with the single polariser aligned along or perpendicular to one of the two directions 21, 22. Figure 8 shows how the angle θ (half the angle between 21, 22) varies with temperature for one material mixture, example 5. The variation of P_s with temperature for this same example 5 is shown in Figure 9.

The cell 1 may also be used as a shutter when the electrodes 5, 6 are sheet electrodes. Light is blocked or transmitted in the cells of two different switched states. This shutter may also be combined with coloured polarisers to provide a colour switch, arranged in front of a monochrome cathode ray tube (C.R.T.).

A similar arrangement is described in G.B. 1,491,471. In this a C.R.T. emits light in two different wavelengths. The colour switch is switched to transmit the two different colours a frame at a time. This is synchronised to the C.R.T. emitting frame sequential images representing the two different colours. Providing the frame time is high enough an observer's eye integrates the two different colour images as one multicolour image.

The present invention provides a colour switch by using a neutral polariser on one side of the cell 1 and two different colour, e.g. red and blue, polarisers on the opposite side the cell. These coloured polarisers are arranged with their optical axis orthogonal. The axis of one coloured polariser is parallel to that of the neutral polariser. The cell is switched at the C.R.T. frame rate as in G.B. 1,491,471.

The cell may also be used as a 90° polarisation switch. In this case the polarisers are arranged with one parallel to the liquid crystal molecules in one of the switched states 21, 22. The second polariser is crossed with respect to the first polariser. The angle between the two directions 21, 22 is about 45° . Providing the birefringence Δn is suitably arranged, of the known expression $\Delta n d / \lambda$, the plane of polarisation of light is rotated by 90° .

Polarisation switches are useful for example in three dimensional (3-D) television. In this alternate left and right eye frames are displayed. An observer wears polarising glasses and a polarisation switch in front of the TV screen is switched in synchronism with the frame rate. This is described in G.B. 2,062,281 B. A similar effect is obtained if an observer wears glasses that have left and right eye liquid crystal shutters that are switched in synchronism with left and right eye frames on the TV screen.

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Examples of materials: -

Chiral Components

Code		Absolute configuration of chiral groups	Sense of cholesteric twist	Sense of spontaneous polarisation
CC1	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{COOC}^*\text{H}(\text{Me})\text{C}_6\text{H}_{13}$			
CC2	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{COOC}^*\text{H}(\text{Me})\text{C}_6\text{H}_{13}$	R	D	(-)
CC3	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{COO}-\text{O}(\text{F})-\text{O}-2\text{MB}^*$	S	D	(+)
CC4	$2\text{MB}^*-\text{O}-\text{O}-\text{COO}-\text{O}(\text{F})-\text{O}-2\text{MB}^*$	SS	D	(+)
CC5	$2\text{MB}^*-\text{O}-\text{COO}-\text{O}-\text{O}-2\text{MB}^*$	SS	D	(+)
CC6	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{COO}-\text{O}-2\text{MB}^*$	S	D	(+)
CC7	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{L}^*-\text{O}-\text{L}^*\text{C}_2\text{H}_5$	SS	L	(+)
CC8	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{L}^*\text{C}_2\text{H}_5$	S	L	(+)
CC9	$\text{C}_6\text{H}_{13}\text{C}^*\text{H}(\text{Me})\text{COO}-\text{O}-\text{O}-\text{COO}\text{C}^*\text{H}(\text{Me})\text{C}_6\text{H}_{13}$	SS	L	(+)
CC10	$\text{C}_9\text{H}_{19}-\text{O}-\text{O}-\text{CO}-\text{C}^*\text{H}(\text{CN})\text{CH}_3$	-	L	(+)
CC11	$\text{C}_3\text{H}_7-\text{O}-\text{O}-\text{O}(\text{F})-\text{O}-\text{OC}^*\text{H}(\text{Me})\text{CO}_2\text{C}_2\text{H}_5$	-	D	(+)
CC12	$\text{C}_9\text{H}_{19}-\text{O}-\text{O}-\text{O}(\text{Cl})(\text{Me})-\text{OC}^*\text{H}(\text{Me})\text{CO}_2\text{C}_2\text{H}_5$	-	D	(+)
CC13	$\text{C}_8\text{H}_{17}\text{O}-\text{O}-\text{O}-\text{CO}_2\text{C}^*\text{H}(\text{CN})(\text{Me})\text{CH}(\text{Me})$	-	D	(+)

where $2\text{MB}^*:-\text{CH}_2\text{C}^*\text{H}(\text{Me})\text{C}_2\text{H}_5$; and $\text{L}^* = -\text{COO}\text{C}^*\text{H}(\text{Me})\text{COO}-$

Sense of polarisation according to the convention by S. T. Lagerwall and I Dahl, Mol Cryst. Liq. Cryst. 114 p. 151 (1980).

Sense of cholesteric twist and absolute configuration of chiral group convention are described by G. W. Gray & D. G. McDonnell, Mol Cryst. Liq. Cryst. 34, p.211 (1977): -

5 D: Dextro
L: Laevo

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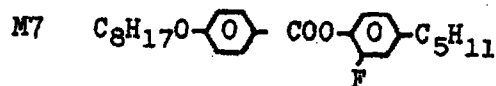
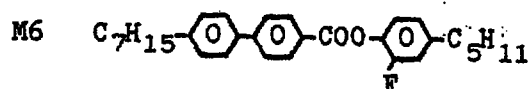
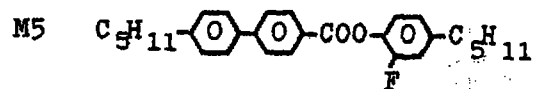
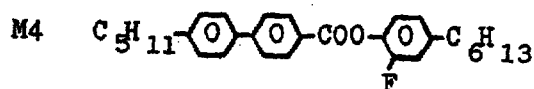
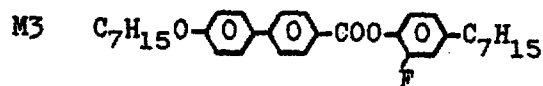
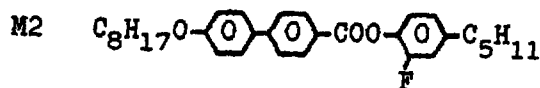
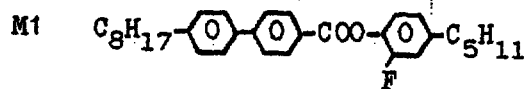
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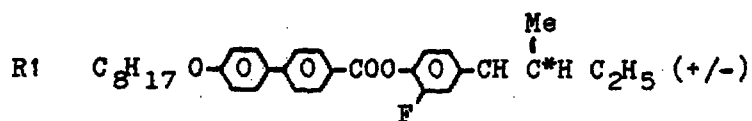
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Non-Chiral Materials



Racemate Materials



Sc Host Mixtures

Code	Composition	Transition Temperature °C
H1:-	M1 + M2 + M3 (1 : 1 : 1)	Is 151.7 N 112.7 S _A 107.3 S _C 27.8 S
H2:-	M2 + M3 + R1 (1 : 1 : 1)	
H3:-	M1 + M6 + M4 (1 : 1 : 1)	Is N 60 S _C
H4:-	M2 + M3 + M5 (1 : 1 : 1)	Is 155.8 N 89.7 S _C 15 Solid
Key: Is = isotropic, N = nematic, S = smectic, Ch = cholesteric Where no subscript is given to a smectic material the particular phase is unknown.		

Example 1:

- (a) 7.9 % R1
 (b) 2.2 % CC1
 (c) 90 % M6

This material had the following phases with increasing temperature solid - S_C^* - S_A - cholesteric - isotropic.

Materials (a), (b) have opposite senses of cholesteric twist, but the same sense of S_C^* polarization.

When tested in a cell having a 6 μm thick layer excellent alignment was achieved on cooling down to the S_A and then S_C^* phases. When tested in a cell with a 12 μm thick layer the mixture showed a π twist in the heated cholesteric phase. Providing the cooling rate was slow e.g. about 0.2 °C/min. good alignment was achieved and the device could be rapidly switched using the ferroelectric effect. The spontaneous polarization P_s was measured to be about 1 nC/cm².

The following Examples 2, 3, 4 use compensated chiral mixtures. These mixtures are composed of chiral components with opposite sense of cholesteric twist, but the same sense of S^* spontaneous polarisation.

Example 2

CD1: - 23% CC1 + 77% CC3.

This has the phase transition temperature of: -

Isotropic 114 °C Chol 93.4 °C S_A 71.5 °C S_C^* 50 °C Solid.

The cholesteric pitch/temperature curve is similar to Figure 7b, the compensation temperature (ie where the pitch is infinite) occurs at ~ 99 °C.

In a 2 μm cell, a π twist state can be maintained for up to 1 °C above the S_A to cholesteric phase transition temperature; with slow cooling good alignment can be achieved in the smectic phases. At 61.5 °C the mixture showed a P_s ~ 25 nC/cm² and a tilt angle (i.e. half cone angle) of ~ 18.5 °.

Example 3

CD3: - 22% CC1 + 78% CC3.

This has the following phase transition temperatures: -

Isotropic 115 °C Chol 94.6 °C S_A 72.6 °C S_C^* 47 °C Solid.

The cholesteric pitch/temperature curve is similar to Figure 7b; the compensation temperature (i.e. where the pitch is infinite) occurs at ~ 98 °C.

In a 2 μm cell, a zero twist state can be obtained, and a π twist can be maintained for up to ~ 6 °C above the S_A to cholesteric phase transition temperature.

Example 4

CD9: - 20% CC8 + 80% CC3.

This has the following phase transition temperatures: -

Isotropic 120.1 °C Chol 93.0 °C S_A 78.0 °C S_C^* 43 °C Solid. The cholesteric pitch/temperature curve is similar to Figure 7b, the compensation temperature (i.e. where the pitch is infinite) occurs at ~ 102 °C.

In a 6 μm cell, a 2 π twist state can be obtained for up to 0.5 °C above the S_A to cholesteric phase transition.

Examples 5, 6, 7, 8 use a compensated chiral mixture in an S_C host.

Example 5

CM6 = 43.5% CD3 + 56.5% H1.

This has phase - temperature values: -

Isotropic 132.8 °C Cholesteric 106.8 °C S_A 83.9 °C S_C^* 14 °C - solid.

The pitch/temperature curve is similar to Figure 7b; the mixture being compensated (i.e. infinite pitch) at ~ 113 °C. In a 2 μm and 6 μm cell, respectively, a zero twist state is obtained for up to 14 °C and up to 8 °C above the S_A to cholesteric phase transition temperature. Figures 8 and 9 show the tilt angle (ie. half cone angle) and spontaneous polarisation, P_s , as a function of temperature for CM6.

Example 6

CM8 19.6% (49% CC1 + 51% CC4) + 80.4% H1

This has phase-temperature values:-

Isotropic 126.1 °C Cholesteric 84 °C S_A 65 °C S_C^* 5 °C

The pitch/temperature curve is similar to Figure 7b; the mixture being compensated (i.e. infinite pitch) at ~ 119.5 °C. In a 2 μ m cell a zero twist state is obtained for a few °C above the smectic A to cholesteric phase transition temperature.

Example 7

CM3:- 40% (20% CC1 + 80% CC3) + 60% H3.

This has the following phase transition temperatures:-

Isotropic 127.5 °C Cholesteric 92.4 °C S_A 72 °C S_C^* 10 °C

The pitch/temperature curve is similar to Figure 7c.

In a 6 μ m cell a zero twist state is obtained for up to 3 °C above the smectic A to cholesteric phase transition temperature.

Example 8

CM11:- 25% CD9 + 75% H4.

This has the following phase transition temperatures:-

Isotropic 147.1 °C Chol 101.1 °C S_A 85.1 °C S_C^* 13 °C

The pitch/temperature curve is similar to Figure 7b; the compensation temperature (i.e. where the pitch is infinite) occurs at ~ 119 °C. In a 2 μ m cell, a zero twist state can be obtained just above the smectic A to cholesteric phase transition temperature.

Example 9

CM13:- 90% (90% H4 + 10% M7) + 10% (49% CC1 + 51% CC4)

Isotropic 135 °C Cholesteric 52.3 °C S_C^* -15 °C -25 °C

In a 6 μ m cell, a 0 ° twist state was obtained for up to ~ 10 °C above the smectic A to cholesteric phase transition temperature. At 30 °C the spontaneous polarisation of the mixture was 3.4 nC/cm² and the tilt angle (i.e. half the cone angle) was 21 °.

Example 10

CM 15:- 15.9% (31.4% CC9 + 68.6% CC4) + 94.1% H1.

Isotropic 135 °C Cholesteric 56.1 °C S_C^* 20 °C Solid.

In a 6 μ m cell, a π twist state was maintained for a few degrees Celsius above the smectic C* to Cholesteric transition. The alignment was poor after critically cooling into the S_C^* phase, however, by applying ~ 20 Vpk 10Hz square wave, zero twist alignment in the smectic C* could be induced. Heating back up to just into the cholesteric phase and cooling with a d.c. field of appropriate sign then gave the desired alignment.

At 50 °C and 30 °C the spontaneous polarisation of the mixture is 2nC/cm² and 6.2nC/cm², respectively.

Examples 11, 12 use a single cholesteric twist sense chiral component in an S_C host.

Example 11

LPC2:- 1% CC10 + 99% H1.

This mixture has the following phase transition temperatures:-

Isotropic 151 °C Cholesteric 113.5 °C S_A 104.5 °C S_C^* 28 °C

The cholesteric pitch/temperature curve is similar to Figure 7c.

In a 2 μ m cell, a zero twist state can be achieved for ~ 0.5 °C above the smectic A to cholesteric transition temperature.

The spontaneous polarisation of the mixture is 1.7nC/cm² and 4.2nC/cm² at 80 °C and 40 °C, respectively.

Example 12

LPC3: - 1% CC10 + 99% H4.

This mixture has the following phase transition temperatures: -

5 Isotropic 158° Cholesteric 91° S_A 89° S_C* 18° S 8° S.

The cholesteric pitch/temperature curve is similar to Figure 7c.

In a 2 μm cell, a zero twist state can be achieved for ~ 4° C above the smectic A to cholesteric phase transition temperature.

10 Example 13

LPC6: - 0.5% CC10 + 99.5% (95% H4 + 5% M7)

Isotropic 152° Cholesteric 76.8° S_C* < 0° S.

15 In a 6 μm cell, a zero twist state can be achieved for up to 0.2° C above the smectic C* to cholesteric transition temperature.

Example 14

UCM30: - 92.5% (85% H4 + 15% M7) + 7.5% CC12.

20 The mixture has the following phases -

Is 155.8° Ch 60.5° S_C* 15° S.The cholesteric pitch/temperature curve is similar to Figure 7(c). Ps = 4.4nC/cm² at 50.5° C and 8.4nC/cm² at 25° C. In a 6.2 μm thick cell a zero twist state can be achieved for ~ 7° C above the S_C* to cholesteric phase transition temperature.

25

Example 15

CM20: - 85% HI + 15% CD18

This mixture has the following phases: -

30 Is 133.7° Ch 92.8° S_A 63.2 S_C*.In a 2 μm thick cell a zero twist can be obtained just above the S_A to Ch transition temperature.Ps = 18nC/cm² at 25° C.

CD18 = 34% CC1 + 66% CC11

35 Example 16

LPM13: - 72.5% HI + 25% M7 + 2.5% CC13

Is 118° Ch 56.3 S_C* < 0 Solid.Ps = 10nC/cm² at 20° C and 5nC/cm² at 46° C.

40 This shows zero twist in a 2 μm cell in the cholesteric phase.

Claims

1. A method of making a liquid crystal display device comprising the steps:
 - 45 providing two cell walls (8,9) spaced apart by a spacer (4) to contain a layer of a liquid crystal material (7), the wall inner surfaces having formed thereon electrode structures (5,6) and at least one wall surface being treated to provide a liquid crystal alignment,
 - providing a tilted chiral smectic liquid crystal material having a cholesteric phase at an elevated temperature above ambient between the chiral smectic and isotropic phases with a cholesteric pitch p
 - 50 greater than twice the layer thickness d at a temperature at least 0.1° C above a cholesteric to smectic transition temperature and in the chiral smectic phase a spontaneous polarization Ps greater than 0.1 nC/cm² and a smectic pitch greater than the layer thickness d,
 - heating the mixture to the cholesteric phase,
 - introducing and sealing the mixture into the space between the walls, cooling the material to the tilted chiral smectic phase.
 - 55
2. The method of claim 1 comprising the further steps of reheating to above the smectic/cholesteric transition temperature and slowly cooling, whilst a unidirectional voltage pulse is applied.



Example 12

LPC3: - 1% CC10 + 99% H4.

This mixture has the following phase transition temperatures: -

Isotropic 158° Cholesteric 91° S_A 89° S_C* 18° S 8° S.

The cholesteric pitch/temperature curve is similar to Figure 7c.

In a 2 μm cell, a zero twist state can be achieved for ~ 4° C above the smectic A to cholesteric phase transition temperature.

10 Example 13

LPC6: - 0.5% CC10 + 99.5% (95% H4 + 5% M7)

Isotropic 152° Cholesteric 76.8° S_C* < 0° S.

15 In a 6 μm cell, a zero twist state can be achieved for up to 0.2° C above the smectic C* to cholesteric transition temperature.

Example 14

UCM30: - 92.5% (85% H4 + 15% M7) + 7.5% CC12.

The mixture has the following phases -

Is 155.8° Ch 60.5° S_C* 15° S.The cholesteric pitch/temperature curve is similar to Figure 7(c). Ps = 4.4nC/cm² at 50.5° C and 8.4nC/cm² at 25° C. In a 6.2 μm thick cell a zero twist state can be achieved for ~ 7° C above the S_C* to cholesteric phase transition temperature.

25 Example 15

CM20: - 85% HI + 15% CD18

This mixture has the following phases: -

30 Is 133.7° Ch 92.8° S_A 63.2° S_C*.In a 2 μm thick cell a zero twist can be obtained just above the S_A to Ch transition temperature.Ps = 18nC/cm² at 25° C.

CD18 = 34% CC1 + 66% CC11

35 Example 16

LPM13: - 72.5% HI + 25% M7 + 2.5% CC13

Is 118° Ch 56.3° S_C* < 0 Solid.Ps = 10nC/cm² at 20° C and 5nC/cm² at 46° C.

40 This shows zero twist in a 2 μm cell in the cholesteric phase.

Claims

1. A method of making a liquid crystal display device comprising the steps:
 - 45 providing two cell walls (8,9) spaced apart by a spacer (4) to contain a layer of a liquid crystal material (7), the wall inner surfaces having formed thereon electrode structures (5,6) and at least one wall surface being treated to provide a liquid crystal alignment,
 - providing a tilted chiral smectic liquid crystal material having a cholesteric phase at an elevated temperature above ambient between the chiral smectic and isotropic phases with a cholesteric pitch p
 - 50 greater than twice the layer thickness d at a temperature at least 0.1° C above a cholesteric to smectic transition temperature and in the chiral smectic phase a spontaneous polarization Ps greater than 0.1 nC/cm² and a smectic pitch greater than the layer thickness d,
 - heating the mixture to the cholesteric phase,
 - introducing and sealing the mixture into the space between the walls, cooling the material to the tilted
 - 55 chiral smectic phase.
2. The method of claim 1 comprising the further steps of reheating to above the smectic/cholesteric transition temperature and slowly cooling, whilst a unidirectional voltage pulse is applied.



3. The method of claim 1 wherein the material is cooled at a rate of less than $20^{\circ}\text{C}/\text{minute}$ within $\pm 5^{\circ}\text{C}$ of the cholesteric/smectic phase transition.
- 5 4. The method of claim 1 wherein the material is cooled at a rate of less than $2^{\circ}\text{C}/\text{minute}$ within $\pm 5^{\circ}\text{C}$ of the cholesteric/smectic phase transition.
5. The method of claim 1 wherein both walls are surface alignment treated and the cell is arranged with the alignment direction parallel in the same direction.
- 10 6. The method of claim 1 wherein both walls are surface alignment treated and the cell is arranged with the alignment direction parallel in opposite directions.
7. The method of claim 1 wherein the alignment is produced by unidirectional rubbing.
- 15 8. The method of claim 1 wherein the alignment is produced by oblique evaporation of silicon oxide.
9. A liquid crystal device comprising a layer (7) of a tilted chiral smectic liquid crystal material contained between two cell walls (2,3) each carrying electrode structures (5,6) and at least one wall surface being treated to give alignment to the liquid crystal molecules, a first linear polariser (8) and either a second polariser (9) or an amount of dichroic dye in the liquid crystal material, the liquid crystal material having a tilted chiral smectic phase at normal device operating temperatures and a cholesteric phase at a higher, above ambient, temperature, with a cholesteric pitch greater than twice the layer thickness d in the cholesteric phase for at least 0.1°C above the cholesteric to smectic transition temperature, a spontaneous polarisation $P_s > 0.1 \text{ nC}/\text{cm}^2$ in the smectic phase, and a smectic pitch greater than the layer thickness d .
- 25 10. The device of claim 9 wherein the cell walls are surface treated to align liquid crystal molecules in the same direction with a splayed configuration across the layer thickness.
- 30 11. The device of claim 9 wherein the electrodes are formed as strip electrodes arranged in a matrix format.
12. The device of claim 9 wherein the electrodes are formed as strip electrodes arranged in a segment format.
- 35 13. The device of claim 9 wherein the electrodes are formed as sheet electrodes.
14. The device of claim 9 wherein the liquid crystal layer thickness is up to $15\mu\text{m}$.
- 40 15. The device of claim 9 wherein the cholesteric pitch p is greater than $2d$ at a temperature at least 5°C above the transition temperature.
16. The device of claim 9 wherein one polariser is a neutral polariser and the second polariser is replaced by two differently coloured polarisers arranged with their optical axis orthogonal.
- 45 17. The device of claim 9 wherein one polariser is arranged with its optical axis parallel to the liquid crystal molecular alignment in one of its switched states, and the other polariser is arranged with its optical axis crossed with respect to the first polariser.
- 50 18. The device of claim 9 wherein the cholesteric pitch within 0.1°C of the cholesteric/smectic transition is greater than four times the liquid crystal layer thickness.
- 55 19. The device of claim 9 and further comprising means (10,11,12,13) for applying the two d.c. voltages of opposite polarity to the electrode structures to switch the liquid crystal material into its two different states.
20. A liquid crystal material mixture for use in the method of claim 1 comprising a material having a tilted chiral smectic phase at normal device operating temperatures and a cholesteric phase at an elevated



temperature, the mixture having a cholesteric pitch greater than $4\mu\text{m}$ in the cholesteric phase at least 0.1°C above a cholesteric to smectic transition temperature, a spontaneous polarisation coefficient P_s of at least 1.0 nC/cm^2 , in the smectic phase, and a smectic pitch greater than the layer thickness d .

- 5 21. The material of claim 20 wherein the material has the following phases with temperature: - isotropic $\Rightarrow$ cholesteric $\Rightarrow$ smectic A $\Rightarrow$ chiral smectic $\Rightarrow$ solid.
22. The material of claim 20 wherein the material has the following phases with temperature: - isotropic $\Rightarrow$ cholesteric $\Rightarrow$ chiral smectic $\Rightarrow$ solid.
- 10 23. The material of claim 20 wherein the pitch in the cholesteric phase is greater than $4\mu\text{m}$ over a temperature range up to 20 to 5°C above the cholesteric smectic phase transition.
24. The material of claim 20 wherein the smectic pitch is greater than $2\mu\text{m}$.
- 15 25. The material of claim 20 wherein the cholesteric/smectic phase transition is above 40°C .
26. The material of claim 20 wherein the cholesteric smectic phase transition is above 100°C .
- 20 27. The material of claim 20 and further including an amount of a dichroic dye.

Patentansprüche

1. Ein Verfahren zur Herstellung einer Flüssigkristall - Anzeigeeinrichtung, mit den Schritten:
 - 25 Vorsehen zweier Zellenwände (8, 9), die durch einen Abstandshalter (4) beabstandet sind, damit sie eine Schicht aus einem Flüssigkristallmaterial (7) enthalten können, wobei auf den Wandinnenflächen Elektrodenstrukturen (5, 6) ausgebildet sind und wenigstens eine Wandoberfläche behandelt ist, um eine Flüssigkristallausrichtung zu schaffen,
 - Vorsehen eines geeigneten, chiralen smektischen Flüssigkristallmaterials, das
 - 30 - zwischen der chiralen smektischen Phase und der isotropen Phase
bei einer erhöhten Temperatur oberhalb der Raumtemperatur eine cholesterische Phase mit einer cholesterischen Ganghöhe G , die größer als die doppelte Schichtdicke d bei einer Temperatur von wenigstens $0,1^\circ\text{C}$ oberhalb der Temperatur des Übergangs von der cholesterischen in die smektische Phase,
 - 35 - und in der chiralen smektischen Phase
eine spontane Polarisation P_s , die größer als $0,1\text{ nC/cm}^2$ und eine smektische Ganghöhe, die größer als die Schichtdicke d ist,
 - besitzt,
 - Erwärmen des Gemischs in die cholesterische Phase,
 - 40 Eingeben und Einschließen des Gemischs in den Raum zwischen den Wänden,
 - Abkühlen des Materials in die geeignete, chirale smektische Phase.
2. Das Verfahren von Anspruch 1, mit den weiteren Schritten des erneuten Erwärmens auf einen Wert oberhalb der Temperatur des Übergangs von der smektischen in die cholesterische Phase und des langsamen Abkühlens, während ein einsinniger Spannungsimpuls angelegt wird.
3. Das Verfahren von Anspruch 1, in dem das Material in einem Bereich von $\pm 5^\circ\text{C}$ des Übergangs von der cholesterischen in die smektische Phase mit einer Rate von weniger als 20°C/min abgekühlt wird.
- 50 4. Das Verfahren von Anspruch 1, in dem das Material in einem Bereich von $\pm 5^\circ\text{C}$ des Übergangs von der cholesterischen in die smektische Phase mit einer Rate von weniger als 2°C/min abgekühlt wird.
5. Das Verfahren von Anspruch 1, in dem beide Wände einer Oberflächenausrichtungsbehandlung unterzogen werden und die Zelle so beschaffen ist, daß die Ausrichtung in gleichem Richtungssinn parallel ist.
6. Das Verfahren von Anspruch 1, in dem beide Wände einer Oberflächenausrichtungsbehandlung unterzogen werden und die Zelle so beschaffen ist, daß die Ausrichtung in entgegengesetztem



Richtungssinn parallel ist.

7. Das Verfahren von Anspruch 1, in dem die Ausrichtung durch ein einsinniges Schleifen erzeugt wird.

8. Das Verfahren von Anspruch 1, in dem die Ausrichtung durch schräges Aufdampfen von Siliziumoxid erzeugt wird.

9. Eine Flüssigkristalleinrichtung, mit

einer Schicht (7) aus einem geneigten, chiralen smektischen Flüssigkristallmaterial, das zwischen zwei Zellenwänden (2, 3) enthalten ist, welche jeweils Elektrodenstrukturen (5, 6) tragen, wobei wenigstens eine Wandfläche behandelt ist, um dem Flüssigkristallmolekülen eine Ausrichtung zu verleihen,

einem ersten linearen Polarisator (8) und

entweder einem zweiten Polarisator (9) oder einer Menge eines dichroitischen Farbstoffs im Flüssigkristallmaterial,

wobei das Flüssigkristallmaterial eine geneigte, chirale smektische Phase bei normalen Betriebstemperaturen der Einrichtung und eine cholesterische Phase bei einer höheren Temperatur oberhalb der Umgebungstemperatur besitzt, wobei die cholesterische Ganghöhe in der cholesterischen Phase bei wenigstens $0,1^\circ\text{C}$ oberhalb der Temperatur des Übergangs von der cholesterischen in die smektische Phase größer als die doppelte Schichtdicke d ist, wobei das Flüssigkristallmaterial ferner eine spontane Polarisierung $P_s > 0,1 \text{ nC/cm}^2$ in der smektischen Phase und eine smektische Ganghöhe, die größer als die Schichtdicke d ist, besitzt.

10. Die Einrichtung von Anspruch 9, in der die Zellenwände einer Oberflächenbehandlung unterzogen werden, um die Flüssigkristallmoleküle in derselben Richtung mit einer schrägen Konfiguration über die Schichtdicke hinweg auszurichten.

11. Die Einrichtung von Anspruch 9, in der die Elektroden als Streifenelektroden ausgebildet sind, die matrixförmig angeordnet sind.

12. Die Einrichtung von Anspruch 9, in der die Elektroden als Streifenelektroden ausgebildet sind, die segmentförmig angeordnet sind.

13. Die Einrichtung von Anspruch 9, in der die Elektroden als Flächenelektroden ausgebildet sind.

14. Die Einrichtung von Anspruch 9, in der die Flüssigkristall-Schichtdicke bis zu $15 \mu\text{m}$ beträgt.

15. Die Einrichtung von Anspruch 9, in der die cholesterische Ganghöhe G bei einer Temperatur, die wenigstens 5°C oberhalb der Übergangstemperatur liegt, größer als $2d$ ist.

16. Die Einrichtung von Anspruch 9, bei der ein Polarisator ein neutraler Polarisator ist und der zweite Polarisator durch zwei verschieden gefärbte Polarisatoren ersetzt ist, welche so angeordnet sind, daß ihre optischen Achsen zueinander senkrecht sind.

17. Die Einrichtung von Anspruch 9, bei der ein Polarisator so angeordnet ist, daß seine optische Achse in einem seiner Schaltzustände parallel zur molekularen Ausrichtung des Flüssigkristalls ist, während der andere Polarisator so angeordnet ist, daß seine optische Achse in bezug auf den ersten Polarisator über Kreuz orientiert ist.

18. Die Einrichtung von Anspruch 9, bei der die cholesterische Ganghöhe innerhalb von $0,1^\circ\text{C}$ des Übergangs von der cholesterischen in die smektische Phase größer als die vierfache Flüssigkristall-Schichtdicke ist.

19. Die Einrichtung von Anspruch 9 und ferner mit Einrichtungen (10, 11, 12, 13) zum Anlegen von zwei Gleichspannungen von entgegengesetzter Polarität an die Elektrodenstrukturen, um das Flüssigkristallmaterial in seine zwei verschiedenen Zustände umzuschalten.



20. Ein Flüssigkristallmaterialgemisch zur Verwendung in dem Verfahren gemäß Anspruch 1, mit einem Material mit einer geneigten, chiralen smektischen Phase bei normalen Betriebstemperaturen der Einrichtung und einer cholesterischen Phase bei einer erhöhten Temperatur, wobei das Gemisch eine cholesterische Ganghöhe, die in der cholesterischen Phase wenigstens $0,1^\circ\text{C}$ oberhalb einer Temperatur des Übergangs von der cholesterischen in die smektische Phase größer als $4\text{ }\mu\text{m}$ ist, einen spontanen Polarisationskoeffizienten P_s von wenigstens $1,0\text{ nC/cm}^2$ in der smektischen Phase und eine smektische Ganghöhe, die größer als die Schichtdicke d ist, besitzt.
21. Das Material von Anspruch 20, wobei das Material in Abhängigkeit von der Temperatur die folgenden Phasen besitzt:
Isotropisch $\Leftrightarrow$ cholesterisch $\Leftrightarrow$ A-smektisch $\Leftrightarrow$ chiral-smektisch $\Leftrightarrow$ fest.
22. Das Material von Anspruch 20, wobei das Material in Abhängigkeit von der Temperatur die folgenden Phasen besitzt:
Isotropisch $\Leftrightarrow$ cholesterisch $\Leftrightarrow$ chiral-smektisch $\Leftrightarrow$ fest.
23. Das Material von Anspruch 20, bei dem die Ganghöhe in der cholesterischen Phase in einem Temperaturbereich von 20 bis 5°C oberhalb des Übergangs von der cholesterischen in die smektische Phase größer als $4\text{ }\mu\text{m}$ ist.
24. Das Material von Anspruch 20, bei dem die smektische Ganghöhe größer als $2\text{ }\mu\text{m}$ ist.
25. Das Material von Anspruch 20, bei dem der Übergang von der cholesterischen in die smektische Phase oberhalb von 40°C liegt.
26. Das Material von Anspruch 20, bei dem der Übergang von der cholesterischen in die smektische Phase oberhalb von 100°C liegt.
27. Das Material von Anspruch 20, das ferner eine Menge eines dichroitischen Farbstoffs enthält.

Revendications

- Procédé pour produire un dispositif d'affichage à cristaux liquides, comprenant les étapes consistant:
à fournir deux parois (2, 3) de cellule espacées par un élément d'espacement, ou entretoise, (4) pour que la cellule contienne une couche d'une matière (7) à propriétés de cristaux liquides, des structures (5, 6) d'électrodes étant formées sur les surfaces intérieures des parois et au moins une surface de paroi étant traitée pour permettre l'obtention d'un alignement des cristaux liquides,
à fournir une matière à propriétés de cristaux liquides et (capable de présenter une phase) smectique chirale inclinée, cette matière ayant une phase cholestérique à une température élevée, supérieure à la température ambiante, entre les phases smectique chirale et isotrope, avec un pas cholestérique p supérieur à deux fois l'épaisseur d de la couche à une température supérieure d'au moins $0,1^\circ\text{C}$ à la température de transition de la phase cholestérique à la phase smectique, et, dans la phase smectique chirale, une polarisation spontanée P_s supérieure à $0,1\text{ nC/cm}^2$ et un pas smectique supérieur à l'épaisseur d de la couche,
à chauffer le mélange jusqu'à son passage à la phase cholestérique,
à introduire et fermer de manière étanche le mélange dans l'espace situé entre les parois,
à refroidir la matière jusqu'à son passage à la phase smectique chirale inclinée.
- Procédé selon la revendication 1, comprenant les étapes supplémentaires consistant à réchauffer jusqu'au-delà de la température de transition smectique/cholestérique et à refroidir lentement, tout en appliquant une impulsion de tension (électrique) unidirectionnelle.
- Procédé selon la revendication 1, dans lequel la matière refroidit à une vitesse inférieure à 20°C/min à $\pm 5^\circ\text{C}$ de la phase de transition cholestérique/smectique.
- Procédé selon la revendication 1, dans lequel la matière est refroidie à une vitesse inférieure à 2°C/min à $\pm 5^\circ\text{C}$ de la transition de phase cholestérique/smectique.



5. Procédé selon la revendication 1, dans lequel les deux parois sont traitées pour assurer un alignement sur la surface, et la cellule est agencée de façon que la direction des alignements soit parallèle à la même direction.
- 5 6. Procédé selon la revendication 1, dans lequel les deux parois sont traitées pour assurer un alignement sur la surface et la cellule est agencée de façon que les alignements soient parallèles dans des directions opposées.
7. Procédé selon la revendication 1, dans lequel l'alignement est produit par frottement unidirectionnel.
- 10 8. Procédé selon la revendication 1, dans lequel l'alignement est produit par évaporation oblique d'oxyde de silicium.
- 15 9. Dispositif à cristaux liquides, comprenant une couche (7) d'une matière à propriétés de cristaux liquides, capable de présenter une phase smectique chirale inclinée, matière contenue entre deux parois (2, 3) de cellule, chacune portant des structures (5, 6) d'électrode et au moins une surface de paroi ayant été traitée pour conférer un alignement aux molécules à propriétés de cristaux liquides, un premier polariseur linéaire (8), et soit un second polariseur (9) soit une quantité de colorant dichroïque présent dans la matière à propriétés de cristaux liquides,
la matière à propriétés de cristaux liquides ayant, à des températures de fonctionnement normal du dispositif, une phase smectique chirale inclinée et ayant une phase cholestérique à une température supérieure, au-delà de la température ambiante, avec un pas cholestérique supérieur à deux fois l'épaisseur d de la couche en phase cholestérique à au moins 0,1 °C au-delà de la température de transition de phase cholestérique à phase smectique, une polarisation spontanée Ps supérieure à 0,1 nC/cm² en phase smectique, et un pas smectique supérieur à l'épaisseur d de la couche.
- 25 10. Dispositif selon la revendication 9, dans lequel les parois de la cellule sont traitées sur leur surface pour aligner les molécules des cristaux liquides dans la même direction, avec une configuration évasée ou conique sur l'épaisseur de la couche.
- 30 11. Dispositif selon la revendication 9, dans lequel les électrodes sont formées en tant qu'électrodes en ruban disposées en un format de matrice.
- 35 12. Dispositif selon la revendication 9, dans lequel les électrodes sont formées en tant qu'électrodes en ruban disposées en un format à segment(s).
13. Dispositif selon la revendication 9, dans lequel les électrodes sont formées en tant qu'électrodes en feuille.
- 40 14. Dispositif selon la revendication 9, dans lequel l'épaisseur de la couche à propriétés de cristaux liquides va jusqu'à un maximum de 15 µm.
15. Dispositif selon la revendication 9, dans lequel le pas p de la phase cholestérique est supérieur à 2d à une température supérieure d'au moins 5 °C à la température de transition.
- 45 16. Dispositif selon la revendication 9, dans lequel un polariseur est un polariseur neutre et le second polariseur est remplacé par deux polariseurs de coloration différente disposés en ayant leurs axes optiques perpendiculaires mutuellement.
- 50 17. Dispositif selon la revendication 9, dans lequel un polariseur est disposé avec son axe optique parallèle à l'alignement des molécules des cristaux liquides dans un de ses états de commutation, et l'autre polariseur est disposé avec son axe optique croisé par rapport au premier polariseur.
- 55 18. Dispositif selon la revendication 9, dans lequel le pas cholestérique à $\pm 0,1$ °C de la transition phase cholestérique/phase smectique est supérieur à quatre fois l'épaisseur de la couche à propriétés de cristaux liquides.



19. Dispositif selon la revendication 9, comprenant en outre des moyens (10, 11, 12, 13) pour appliquer deux tensions électriques continues de polarité opposée aux structures d'électrodes afin de faire passer par commutation la matière à propriétés de cristaux liquides à ses deux états différents.

5 20. Mélange constituant une matière à propriétés de cristaux liquides destinée à servir dans le procédé selon la revendication 1, ce mélange comprenant une matière ayant une phase smectique chirale inclinée à des températures normales de fonctionnement du dispositif et ayant une phase cholestérique à une température élevée, le mélange ayant un pas, en phase cholestérique, supérieur à $4 \mu\text{m}$ à $0,1$ °C au moins au-dessus de la température de transition cholestérique à smectique, un coefficient de polarisation spontanée P_s d'au moins $1,0 \text{ nC/cm}^2$, en phase smectique, et un pas de phase smectique supérieur à l'épaisseur d de la couche.

10 21. Matière selon la revendication 20, dans laquelle la matière présente les phases suivantes selon la température :
15 isotrope $\Rightarrow$ cholestérique $\Rightarrow$ smectique A $\Rightarrow$ smectique chirale $\Rightarrow$ solide.

22. Matière selon la revendication 20, dans laquelle la matière présente les phases suivantes selon la température :
20 isotrope $\Rightarrow$ cholestérique $\Rightarrow$ smectique chirale $\Rightarrow$ solide.

23. Matière selon la revendication 20, dans laquelle le pas en phase cholestérique est supérieur à $4 \mu\text{m}$ dans un intervalle de la température allant jusqu'à 20 à 5 °C au-delà de la transition de phase cholestérique/smectique.

25 24. Matière selon la revendication 20, dans laquelle le pas en phase smectique est supérieur à $2 \mu\text{m}$.

25. Matière selon la revendication 20, dans laquelle la transition des phases cholestérique/smectique se situe à une température supérieure à 40 °C.

30 26. Matière selon la revendication 20, dans laquelle la transition des phases cholestérique/smectique se situe à une température supérieure à 100 °C.

35 27. Matière selon la revendication 20, comprenant en outre une certaine quantité d'un colorant dichroïque.