

SPECIFICATION

Liquid crystal materials and devices

This invention relates to liquid crystal materials and to devices incorporating such materials.

Liquid crystal devices are commonly formed by enclosing a thin, typically 7 to 12 μm thick, layer of a liquid crystal material between glass slides. Electrode structures on the slides enable a voltage to be applied across the layer and change the molecular alignment of the liquid crystal molecules. This causes an observable effect which can be used in displays of various types, for example, digital watches, small calculators, voltage meters, etc. There are a number of different types of liquid crystal devices, for example, phase change effect, dynamic scattering, twisted nematic devices, etc.

This invention is concerned with the so-called twisted nematic device which in its OFF, zero applied voltage, state is optically active i.e. it rotates the plane of plane polarised by usually 90° (determined by surface treatment to the slides e.g. unidirectional rubbing to provide molecular alignment along the rubbing direction). Such a device loses its optical activity i.e. its rotary power on application of a suitable voltage to provide an ON state. Thus when placed between crossed, or parallel, polarisers the device can be used as an optical shutter to display information as determined by the electrode pattern and applied voltage.

One method of applying voltages is called multiplexing and involved application of different voltages in a predetermined sequence. This can result in the liquid crystal layer receiving two non zero voltage levels; one such level must be below and the other above a device threshold voltage at which the device changes from an OFF to an ON state.

A problem common to some displays is that at normal viewing incidence a display may appear OFF but at say a 45° incidence the display appears ON thus giving ambiguous readings on digital displays.

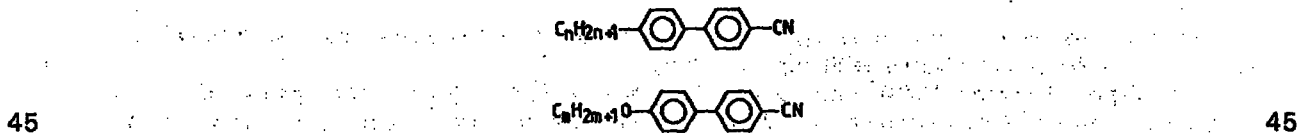
Another problem with some displays is that the threshold voltage changes with temperature. Thus a display may be adequate at one temperature but inoperable at a different temperature. One way of reducing this threshold voltage change with temperature is to mix different types of liquid crystal materials as, for example, taught in U.K. P.A. No. 45,627/77. This discloses mixtures of a material having crystalline nematic-isotropic phases with a material having crystalline-nematic-smectic-nematic-isotropic phases. The resulting mixture does not show a smectic phase.

Yet another problem in small displays, e.g. wrist watches, is the provision of an adequate voltage level. It is an advantage for the device threshold voltage to be as low as possible e.g. below 3 volts so that standard 1.5 voltage batteries may be used. Co-pending application No. 37,956/77 discloses various mixtures of materials having low threshold voltages. Examples of such mixtures are cyano biphenyls

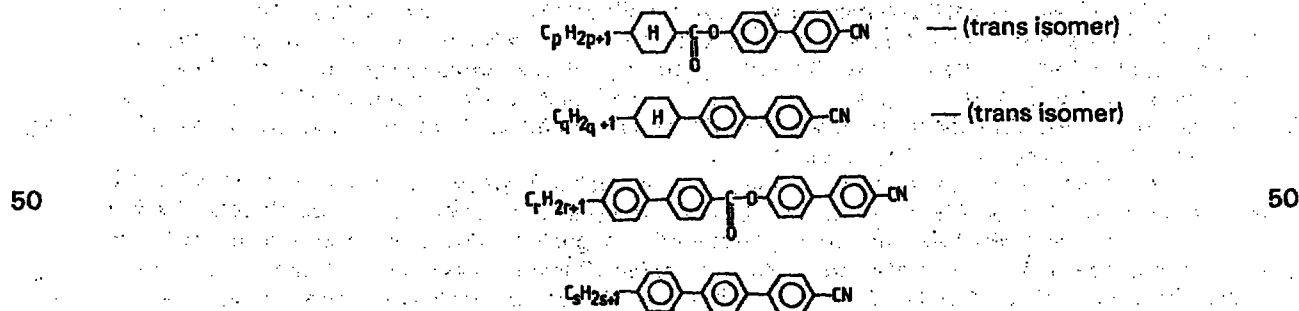
where x is a short n-alkyl group $\text{C}_n\text{H}_{2n+1}$ (n is an even integer) and X is a short n-alkoxy group $\text{C}_m\text{H}_{2m+1}$ (m is an odd integer). Preferably $n \leq 6$, $m \leq 5$.

Ideally a liquid crystal mixture used in multiplexed displays would show no angular ambiguity, no threshold voltage variation with temperature, and a low operating voltage. Inevitably a material cannot meet all these criteria and is a compromise. An object of this invention is to provide a material which is an improvement on some presently available materials.

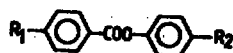
According to this invention a liquid material for use in liquid crystal displays comprising at least one material from a group 1 liquid crystal material comprising:—



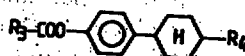
at least one of the group 1 materials having $n = 2$, or 4 or $m = 3$; at least one liquid crystal material from a group 2 liquid crystal material comprising



p, q, r, and s being integers, and a group 3 ester selected from at least one of the following



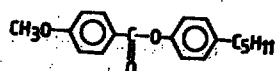
R_1 and R_2 are alkyl or alkoxy



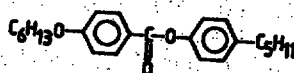
5 R_3 and R_4 are both alkyl with the group 3 ester material forming between 10% and 90% by weight of the total mixture and with the group 2 material forming between 5% and 30% by weight of the total mixture, all the alkyl and alkoxy being unbranched.

R_1 may be an alkyl group having between 1 and 5 carbon atoms. Alternatively R_1 may be an alkoxy group having between 1 and 6 carbon atoms. R_2 may be an alkyl group having between 3 and 7 carbon atoms.

10 Preferably the amount of ester material is between 30% and 70% by weight of the total mixture. The group 3 ester may be the mixture.



$\frac{2}{3}$ by weight



$\frac{1}{3}$ by weight

15 obtainable from E. Merck Co., Darmstadt as ZLI 1052.

The biphenyl materials may additionally have integer $n = 0, 2, 4, 6$, inclusive, and odd integers of $m = 1, 3, 5$, inclusive.

For some applications the biphenyl materials may have low values of $n = \text{even integer i.e. } n = 0, 2, 4, 6$ and $m = \text{odd integer i.e. } m = 1, 3, 5$ as a mixture whose average value of n, m is low, i.e. below 6.

20 The biphenyls may also include values of $n = 1, 3, 5, m = 2, 4, 6$.

For some applications n and m may include low values e.g. $n = 1, 3, 5$ and $m = 2, 4$ in combinations where the average value n, m is low i.e. less than 5.

According to an aspect of this invention a liquid crystal display device comprises a liquid crystal mixture according to this invention formed into a layer contained between two slides, at least one of which is transparent, both carrying electrode structures and both surface treated to provide a progressive liquid crystal molecular twist across the layer.

25 The device may be arranged between crossed, or parallel, linear polarisers. A reflector may be located adjacent to one polariser so the display may be observed by reflected light. The reflector may be partly reflecting and a tungsten light (or other suitable light source) arranged to illuminate the display through the reflector as required.

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

Figure 1 is a sectional view of a digital display;

Figure 2 is a sectional view of Figure 1;

35 Figure 3 shows a rear electrode configuration for Figure 1;

Figure 4 shows a front electrode configuration for Figure 1;

Figures 5, 6, 7 show schematic views of the device of Figures 1 to 4 with typical addressing voltages;

40 Figure 8 is a graph showing how light transmission through a twisted nematic cell arranged between crossed polarisers varies with applied voltage.

The display of Figures 1 to 4 comprises a cell 1, formed of two, front and back, glass slides 2, 3 respectively, spaced $7 \mu\text{m}$ apart by a spacer 4, all held together by an epoxy resin glue. In front of the front glass slide 2 is a front polariser 5 arranged with its axis of polarisation axis horizontal. A reflector 7 is arranged behind the back polariser.

45 Electrodes 8, 9 of tin oxide typically $100\text{\AA}$ thick are deposited on the inner faces of the slides 2, 3 as a complete layer and etched to the shapes shown in Figures 3, 4. The display has seven bars per digit 10 plus a decimal point 11 between each digit. As shown in Figure 3 the rear electrode structure is formed into three electrodes x_1, x_2, x_3 . Similarly the front electrode structure is formed into three electrodes per digit and decimal point $y_1, y_2, y_3, \dots$. Examination of the six electrodes per digit show that each of the eight elements can independently have a voltage applied thereto by application of suitable voltage to appropriate x, y electrodes.

50 Prior to assembly the inner faces of slides 2, 3 are cleaned then eg dipped in a solution of 0.2% by weight of poly vinyl alcohol (PVA) in water. When dry, the slides are rubbed in a single direction with a soft tissue then assembled with the rubbing direction orthogonal and parallel to the optical axis of the adjacent polariser. When a nematic liquid crystal material 12 is introduced between the slides 2, 3 the molecules at the slide surface lie along the rubbing direction with a progressive twist between the

slides.

When zero voltage is applied to the cell 1 light passes through the front polariser 5, through the cell 1 (whilst having its plane of polarisation rotated 90°) through its rear polariser 6 to the reflector 7 where it is reflected back again to an observer. When a voltage above a threshold value is applied between two electrodes 8, 9 the voltage crystal layer 12 loses its rotary power. Thus light at that position does not reach the reflector 7 and does not reflect back to the observer who sees a dark display of one or more bars of a digit 10. 5

10 Voltages are applied as follows as shown in Figures 5, 6 and 7 for three successive time intervals. A voltage of 3V/2 is swept down each x electrode in turn whilst — V/2 is applied to the remaining x electrodes. Meanwhile — 3V/2 or V/2 is applied to the y electrodes. A coincidence of 3V/2 and — 3V/2 at an intersection results in 3V across the liquid crystal layer. Elsewhere the voltage is V or — V. Thus by applying — 3V/2 to approximate y electrodes as the 3V/2 is swept down the x electrodes selected intersections are turned ON as indicated by solid circles. The electric voltage V is an a.c. signal of e.g. 100 Hz square wave, and the sign indicates the phase. 10

15 Each OFF intersection receives V for all three time periods whilst each ON intersection receives 3V followed by V then V for the three time period making an r.m.s. value of $1.91V = V_{ON}$: $V_{OFF} = V$. 15

20 The voltage at which a display is OFF and ON may be defined as follows and with reference to Figures 1 and 8. Mutually perpendicular axes X, Y, Z are shown in Figure 1 to lie in the surface and normal respectively to the slide 2, 3 surface. Light is shone through a transmissive display (i.e. as in Figure 2 without the reflector) along the Z axis and observed along this axis. The voltage is increased until only 10% of the maximum possible light is transmitted, this is an ON state and designated $V_{10}(0^\circ)$ i.e. 10% transmission at 0° incidence. The OFF state may be defined as when at least 90% of the maximum possible light is transmitted. 20

25 If light is transmitted and observed at 45° to the X, Y, Z axes (45° to a rubbing direction) a different transmission curve is seen as shown in Figure 8. The OFF state i.e. 90% transmission, $V_{90}(45^\circ)$ occurs at a lower voltage than at normal incidence. Of the four possible directions which are at 45° to both rubbing directions, the direction is chosen which has the lowest value of $V_{90}(45^\circ)$. 25

30 Therefore, for an unambiguous display V OFF must be below $V_{90}(45^\circ)$ and V ON must be above $V_{10}(0^\circ)$. Ideally the ratio $V_{10}(0^\circ)/V_{90}(45^\circ)$ should be unity but this is not obtainable. Liquid crystal mixtures according to this invention provide low values of $V_{10}(0^\circ)/V_{90}(45^\circ)$. Another characteristic is variation in the V OFF, V ON with temperature. One useful parameter is 30

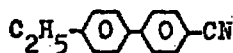
$$\frac{1}{V} \left(\frac{\Delta V}{\Delta T} \right)_{0^\circ-40^\circ}$$

where ΔV is the voltage change over a temperature range ΔT of 0° to 40°C and V is the average voltage. Both V and ΔV are measured for 90° transmission (i.e. OFF) at normal (0°) (or 45°) incidence. 35

35 Examples of liquid crystal mixtures follow with their characteristics listed in Table 1. 35

Example 1

weight %



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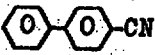


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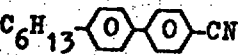
ZLI 1052

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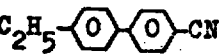
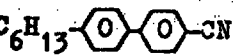
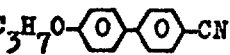
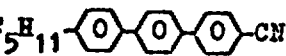
Example 2

	weight %
	5
	15
	10
	10
	10
ZLI 1052	50

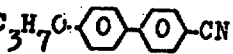
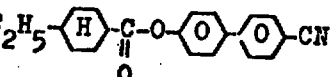
Example 3

	weight %
	35
	10
	10
ZLI 1052	45

Example 4

	weight %
	5
	25
	10
	10
ZLI 1052	50

Example 5

	weight %
	15
	15
	10
	15
ZLI 1052	45

Example 6

weight %

5



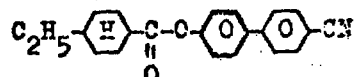
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ZLI 1052

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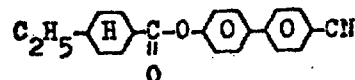
Example 7

weight %

30



10



15

ZLI 1052

45

Example 8

weight %

15



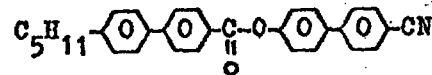
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ZLI 1052

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Examples 9 - 19

Biphenyl

weight %

45



11

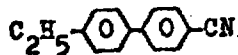
ZLI 1052

44

Example No.

biphenyl

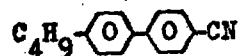
9



10



11



12



13



14



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16



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18



19

Example 20

weight %



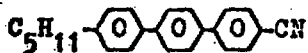
5



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10



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ZII 1052

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Example 21

weight %

22



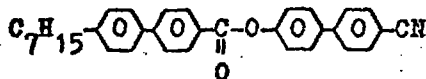
13



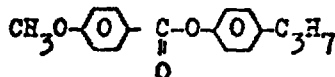
30.5



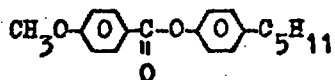
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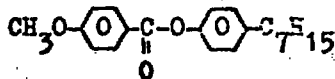
3.5



17



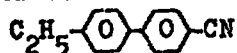
17



9

Examples 22-27

weight %



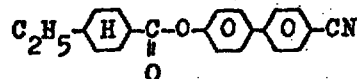
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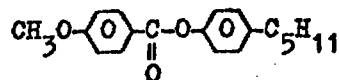
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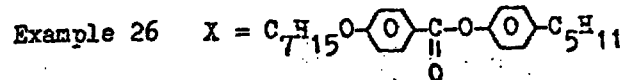
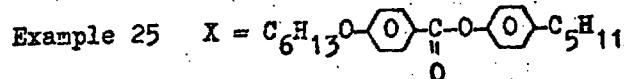
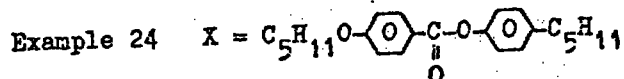
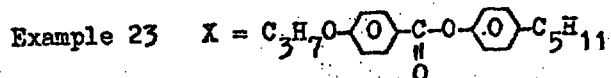
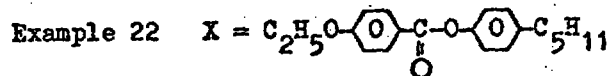
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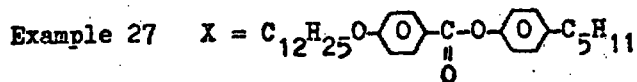
20

X

25



23

Example 28

	weight %
$\text{C}_2\text{H}_5-\text{O}-\text{O}-\text{CN}$	15
$\text{C}_4\text{H}_9-\text{O}-\text{O}-\text{CN}$	15
$\text{C}_3\text{H}_7\text{O}-\text{O}-\text{O}-\text{CN}$	10
$\text{C}_2\text{H}_5-\text{H}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{O}-\text{CN}$	15
$\text{CH}_3\text{O}-\text{O}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{C}_5\text{H}_{11}$	25
$\text{CH}_3\text{O}-\text{O}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{C}_7\text{H}_{15}$	20

Example 29

	weight %
$\text{C}_6\text{H}_{13}-\text{O}-\text{O}-\text{CN}$	45
$\text{C}_5\text{H}_{11}-\text{O}-\text{O}-\text{O}-\text{CN}$	10
$\text{CH}_3\text{O}-\text{O}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{C}_5\text{H}_{11}$	25
$\text{CH}_3\text{O}-\text{O}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{C}_7\text{H}_{15}$	20

Example 30

	weight %
$\text{C}_6\text{H}_{13}-\text{O}-\text{O}-\text{CN}$	35
$\text{C}_3\text{H}_7\text{O}-\text{O}-\text{O}-\text{CN}$	10
$\text{C}_5\text{H}_{11}-\text{O}-\text{O}-\text{O}-\text{CN}$	10
$\text{CH}_3\text{O}-\text{O}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{C}_5\text{H}_{11}$	25
$\text{CH}_3\text{O}-\text{O}-\text{C}(=\text{O})-\text{O}-\text{O}-\text{C}_7\text{H}_{15}$	20

24

Example 31

<chem>CCOc1ccc(Oc2ccc(C#N)cc2)cc1</chem>	weight % 15
<chem>CCCCOc1ccc(Oc2ccc(C#N)cc2)cc1</chem>	15
<chem>CCCCCOc1ccc(Oc2ccc(C#N)cc2)cc1</chem>	10
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	10
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	5
<chem>CCOc1ccc(C(=O)Oc2ccc(Cc3ccc(C#N)cc3)cc2)cc1</chem>	20
<chem>CCCCCc1ccc(C(=O)Oc2ccc(Cc3ccc(C#N)cc3)cc2)cc1</chem>	25

Example 32

<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	weight % 10
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	5
<chem>COc1ccc(C(=O)Oc2ccc(Cc3ccc(C#N)cc3)cc2)cc1</chem>	40
<chem>CCCCCc1ccc(C(=O)Oc2ccc(Cc3ccc(C#N)cc3)cc2)cc1</chem>	45

Example 33

<chem>CCOc1ccc(Oc2ccc(C#N)cc2)cc1</chem>	weight % 15
<chem>CCCCOc1ccc(Oc2ccc(C#N)cc2)cc1</chem>	15
<chem>CCCCCOc1ccc(Oc2ccc(C#N)cc2)cc1</chem>	10
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	15
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	5
<chem>COc1ccc(C(=O)Oc2ccc(Cc3ccc(C#N)cc3)cc2)cc1</chem>	20
<chem>CCCCCc1ccc(C(=O)Oc2ccc(Cc3ccc(C#N)cc3)cc2)cc1</chem>	20

Example 34

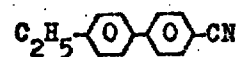
	weight %
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	16
<chem>CCCCOc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	10
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	10
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	4
<chem>CCOc1ccc(C(=O)Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	20
<chem>CCCCCc1ccc(C(=O)Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	25

Example 35

	weight %
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	10
<chem>CCOc1ccc(C(=O)Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	35
<chem>CCCCCc1ccc(C(=O)Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	40

Examples 36, 37

	Example 36 weight %	Example 37 weight %
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15	15
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15	10
<chem>CCCCOc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	10	10
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	10	10
<chem>CCCCCc1ccc(Oc2ccc(C(=O)Oc3ccc(Oc4ccc(C#N)cc4)cc3)cc2)cc1</chem>	10	10
<chem>CCOc1ccc(C(=O)Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	20	20
<chem>CCCCCc1ccc(C(=O)Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	20	25

Examples 38, 39

Example 38

weight %

10

Example 39

weight %

5

26



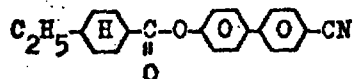
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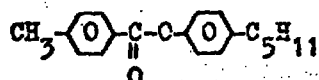
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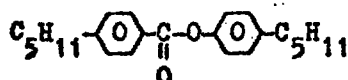
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Example 40

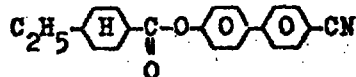
weight %



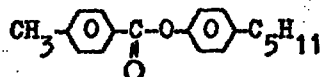
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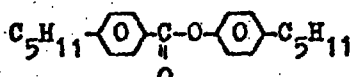
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Examples 41, 42

Example 41

weight %

Example 42

weight %



15

15



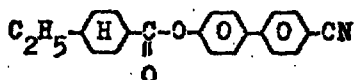
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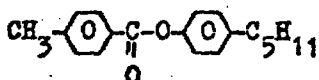
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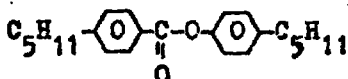
12

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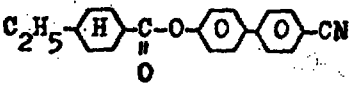
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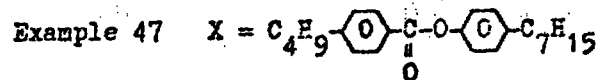
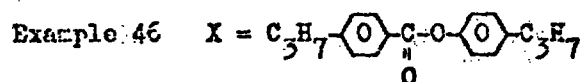
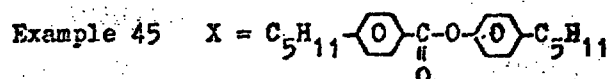
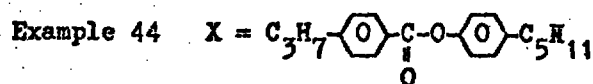
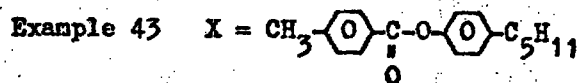


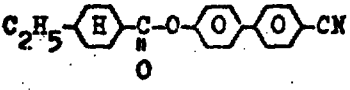
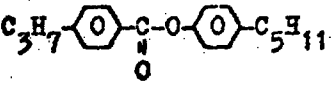
23

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Examples 43 to 47

	weight %
C_2H_5 - 	15
C_4H_9 - 	23
C_5H_{11} - 	10
C_2H_5 - 	12
X	40

Examples 48, 49

	Example 48 weight %	Example 49 weight %
C_2H_5 - 	15	15
C_4H_9 - 	22	20
C_5H_{11} - 	11	12
C_2H_5 - 	12	12
C_3H_7 - 	40	41

EXAMPLE 50

A mixture as for example 48 but with 0.5% of C 15 (formula given later) added to remove reverse twist; this is maximum suggested amount.

Example 51

	weight %
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15
<chem>CCCCOc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	10
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	45

5 The last detailed compound is a Merck compound designated ZLI 1305 and may replace the group 3 ester material used in previous examples. 5

Examples 10, 12 to 19, 29, 32, and 35 do not form part of this invention and are included for comparative purposes only.

TABLE 1A

Example	Melting Point °C	Clearing (isotropic) Point °C	Viscosity cSt		Birefringence Δn	$V_{90}(45^\circ)$	$V_{10}(0^\circ)$	$\frac{V_{10}(0^\circ)}{V_{90}(45^\circ)}$	$\frac{1}{V} \left(\frac{\Delta V}{\Delta T} \right)_{0-40^\circ}$
			20°C	0°C		volts 20°C	volts		%/°C
1	-4	60	57	276	0.194	1.07	1.87	1.75	0.57
2		54	55	265	0.188	1.0	1.78	1.78	0.74
3		60	62	316	0.193	1.21	2.07	1.71	0.67
4		60	64	311	0.191	1.175	2.01	1.71	0.67
5	-4	64	63	315	0.185	1.07	1.82		0.44
6		60				1.04	1.80		0.6
7		69				1.22	2.06		0.54
8		77				1.13	1.92		0.46
9						0.9	1.60	1.78	
10						1.10	1.92	1.75	
11						1.05	1.81	1.72	
12						1.21	2.08	1.72	
13						1.19	2.03	1.70	
14						1.37	2.33	1.70	
15						1.35	2.28	1.69	
16						1.45	2.49	1.72	
17						1.45	2.46	1.70	
18						1.50	2.52	1.68	
19						1.50	2.54	1.69	

TABLE 1 B

Example	Melting Point °C	Clearing (isotropic) Point °C	Viscosity cP		Birefringence Δn	$V_{90}(45^\circ)$ volts	$V_{10}(0^\circ)$ volts	$\frac{V_{10}(0^\circ)}{V_{90}(45^\circ)}$	$\frac{1}{V} \left(\frac{\Delta V}{\Delta T} \right)$ 0-40° %/°C
			20°C	0°C					
20	- 4	63	61	298	0.193	1.16	1.94	1.67	0.64
21	- 10	63	64			1.12	1.90	1.70	0.60
22		68	60			1.07	1.76	1.64	0.36
23		60	65			1.06	1.73	1.63	0.57
24		53	66			1.10	1.81	1.65	0.60
25		63	66			1.11	1.87	1.68	0.35
26		64	66			1.11	1.85	1.67	0.52
27						1.19	2.01	1.69	0.68
28		62	48			1.00	1.73	1.73	0.53
29	- 3					1.12	1.90	1.70	0.67
30	- 3	61				1.14	1.91	1.67	0.73
31		61	37	168		1.09	1.88	1.72	0.80
32	19	51				1.91	3.07	1.60	0.60
33		74	40	186	0.188	1.04	1.82	1.75	0.50
34		62	37	153	0.192	1.06	1.77	1.67	0.68
35	- 4	68				1.77	2.85	1.61	0.56*
36	- 8	64	45	198	0.182	1.07	1.82	1.70	0.49
37	- 12	61				1.12	1.87	1.67	0.49
38	- 6	65	47	214	0.163	1.30	2.12	1.63	0.62
39	- 2	55				1.36	2.24	1.65	0.62
40	- 2	60	41	163	0.148	1.43	2.31	1.62	0.64
41	- 4	63	43	168	0.172	1.08	1.81	1.68	0.46
42		57			0.172	1.02	1.73	1.70	0.56
43		61				1.03	1.74	1.69	0.46
44	- 10	59	46	178	0.171	1.03	1.70	1.65	0.55
45		63				1.08	1.81	1.68	**
46		60				1.01	1.70	1.68	0.62
47		59				1.13	1.87	1.65	***

TABLE 1B (continued)

Example	Melting Point °C	Clearing (isotropic) Point °C	Viscosity cP		Birefringence Δn	$V_{90}(45^\circ)$	$V_{10}(0^\circ)$	$\frac{V_{10}(0^\circ)}{V_{90}(45^\circ)}$	$\frac{1}{V} \left(\frac{\Delta V}{\Delta T} \right)$
			20°C	0°C		volts	volts		0-40° %/°C
48	-11	62	45	178	0.173	1.03	1.73	1.68	0.49
49	-11	66	46	185	0.174	1.08	1.83	1.69	0.53
50						1.05	1.80	1.71	0.56
51	-3	55	28	122	0.152	1.08	1.83	1.69	0.77

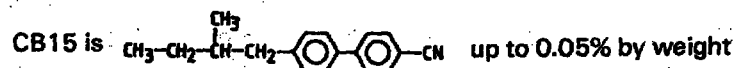
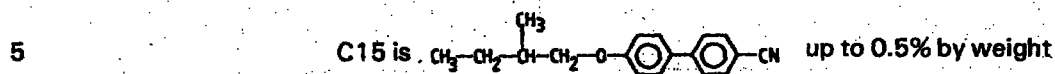
* smectic (S_A) to nematic at + 2°C.** S_A at ~ 0°C.*** S_A at ~ 10°C.

As a comparison of properties, Table 2 shows characteristics of commercially available mixtures of bisphenyls/terphenyls.

TABLE 2

	E7	E25M
$V_{90}(45^\circ)$	1.08	0.95
$V_{10}(0^\circ)$	1.96	1.75
$V_{10}(0^\circ)/V_{90}(45^\circ)$	1.81	1.84
$\frac{1}{V_{90}(0^\circ)} \left(\frac{\Delta V}{\Delta T} \right)_{90(0^\circ)} 0.-40^\circ$	0.85	0.85
E7 is		
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	weight %	
	51	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	25	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	16	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	8	
E25M is		
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	weight %	
	35	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	30	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	10	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	15	
<chem>CCCCCc1ccc(Oc2ccc(Oc3ccc(C#N)cc3)cc2)cc1</chem>	10	

Small amounts of a cholesteric material may be added to the nematic material to induce a preferred twist in the molecules in the liquid crystal layer. This and the use of appropriate slide surface treatment removes the problems of display patchiness as taught in U.K. Patent Serial Numbers 1,472,247 and 1,478,592. Suitable cholesteric materials are:

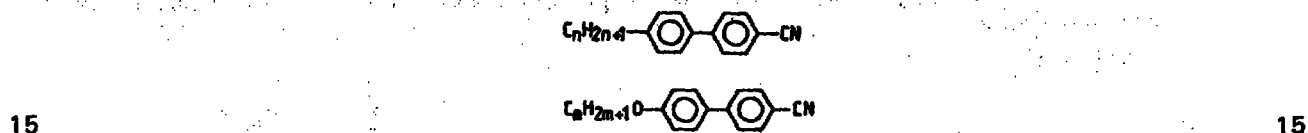


Other cholesteric materials may be used to provide a cholesteric pitch in the complete mixture between 1500 and 300 microns.

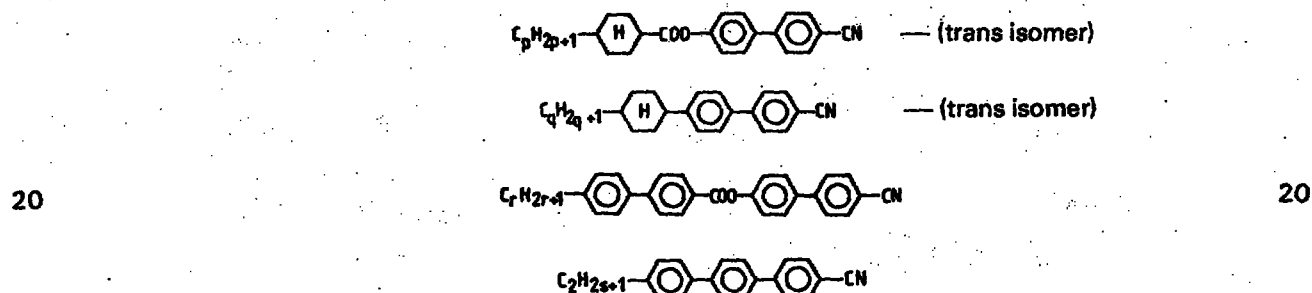
10 Small amounts of pleochroic dye may be added to enhance the display contrast, e.g. the dye described in U.K. Patent Application No. 42,810/77. 10

CLAIMS

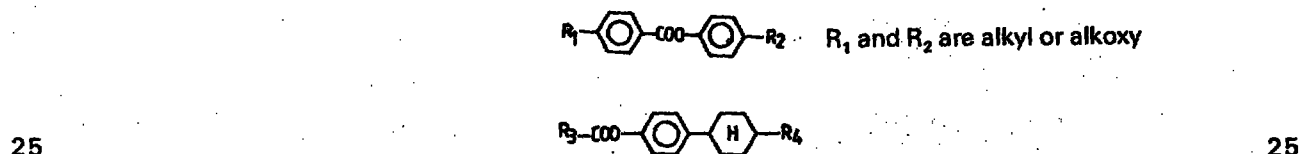
1. A liquid crystal material for use in liquid crystal displays comprising at least one material from a group 1 liquid crystal material comprising:—



at least one of the group 1 materials having $n = 2$, or 4 or $m = 3$; at least one liquid crystal material from a group 2 liquid crystal material comprising:—

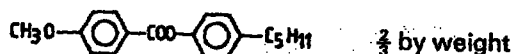


p, q, r, and s being integers, and a group 3 ester selected from at least one of the following

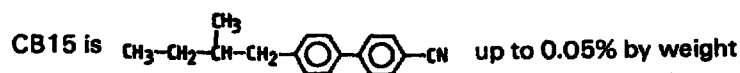
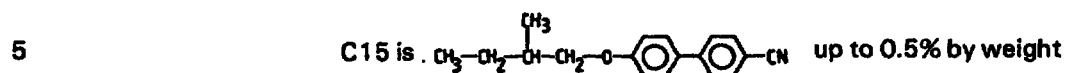


R₃ and R₄ are both alkyl with the group 3 ester material forming between 10% and 90% by weight of the total mixture and with the group 2 material forming between 5% and 30% by weight of the total mixture, all the alkyl and alkoxy being unbranched.

2. A liquid crystal material as claimed in claim 1 wherein both R₁ and R₂ are alkyl. 30
3. A liquid crystal material as claimed in claim 1 wherein R₁ is an alkyl group having between 1 and 5 carbon atoms. 30
4. A liquid crystal material as claimed in claim 1 wherein R₂ is an alkyl group having between 3 and 7 carbon atoms.
5. A liquid crystal material as claimed in claim 1 wherein R₁ is an alkoxy group having between 1 and 6 carbon atoms. 35
6. A liquid crystal material as claimed in claim 1 wherein the amount of ester is between 30% and 70% by weight of the total material.
7. A liquid crystal material as claimed in claim 1 wherein the ester material is



Small amounts of a cholesteric material may be added to the nematic material to induce a preferred twist in the molecules in the liquid crystal layer. This and the use of appropriate slide surface treatment removes the problems of display patchiness as taught in U.K. Patent Serial Numbers 1,472,247 and 1,478,592. Suitable cholesteric materials are:



Other cholesteric materials may be used to provide a cholesteric pitch in the complete mixture between 1500 and 300 microns.

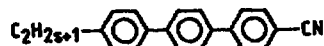
10 Small amounts of pleochroic dye may be added to enhance the display contrast, e.g. the dye described in U.K. Patent Application No. 42,810/77. 10

CLAIMS

1. A liquid crystal material for use in liquid crystal displays comprising at least one material from a group 1 liquid crystal material comprising:—



at least one of the group 1 materials having $n = 2$, or 4 or $m = 3$; at least one liquid crystal material from a group 2 liquid crystal material comprising:—



p, q, r , and s being integers, and a group 3 ester selected from at least one of the following



R_3 and R_4 are both alkyl with the group 3 ester material forming between 10% and 90% by weight of the total mixture and with the group 2 material forming between 5% and 30% by weight of the total mixture, all the alkyl and alkoxy being unbranched.

2. A liquid crystal material as claimed in claim 1 wherein both R_1 and R_2 are alkyl.

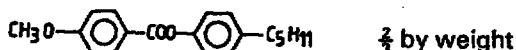
30 3. A liquid crystal material as claimed in claim 1 wherein R_1 is an alkyl group having between 1 and 5 carbon atoms. 30

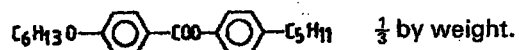
4. A liquid crystal material as claimed in claim 1 wherein R_2 is an alkyl group having between 3 and 7 carbon atoms.

5. A liquid crystal material as claimed in claim 1 wherein R_1 is an alkoxy group having between 1 and 6 carbon atoms. 35

6. A liquid crystal material as claimed in claim 1 wherein the amount of ester is between 30% and 70% by weight of the total material.

7. A liquid crystal material as claimed in claim 1 wherein the ester material is





8. A liquid crystal material as claimed in claim 1 wherein R_3 and R_4 are C_3H_7 .

9. A liquid crystal material as claimed in claim 1 and further including an amount of the material

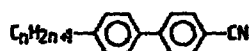


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where the value of m , or n is not more than 6.

10. A liquid crystal material as claimed in claim 1 and further including an amount of the material



whose value of n is any of the number, 0, 2, 4, or 6.

10 11. A liquid crystal material as claimed in claim 1 wherein $p = 2$. 10

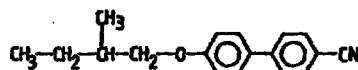
12. A liquid crystal material as claimed in claim 1 wherein $q = 5$.

13. A liquid crystal material as claimed in claim 1 wherein $r = 5$, or 7.

14. A liquid crystal material as claimed in claim 1 wherein $s = 5$.

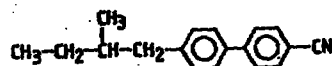
15 15. A liquid crystal material as claimed in claim 1 wherein a small amount of a cholesteric liquid crystal material is added to the mixture to provide a cholesteric pitch between 1500 and 300 microns. 15

16. A liquid crystal material as claimed in claim 15 wherein up to 0.5% by weight of the cholesteric material



is added to the mixture.

20 17. A liquid crystal material as claimed in claim 18 wherein up to 0.05% by weight of the cholesteric material 20



is added to the mixture.

25 18. A liquid crystal display device comprising a layer of a liquid crystal material as claimed in claim 1 formed into a layer contained between two slides, at least one of which slides is transparent, both carrying electrode structures and both surface treated to provide a progressive liquid crystal molecular twist across the layer. 25

