PCT
WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : G02F 1/13, C09K 19/60 — A1

(11) International Publication Number: WO 89/ 00712

(43) International Publication Date: 26 January 1989 (26.01.89)

(21) International Application Number: PCT/GB88/00585

(22) International Filing Date: 20 July 1988 (20.07.88)

(31) Priority Application Number: 8717362

(32) Priority Date: 22 July 1987 (22.07.87)

(33) Priority Country: GB

(71) Applicant (*for all designated States except US*): THE GENERAL ELECTRIC COMPANY, PLC [GB/GB]; 1 Stanhope Gate, London W1A 1EH (GB).

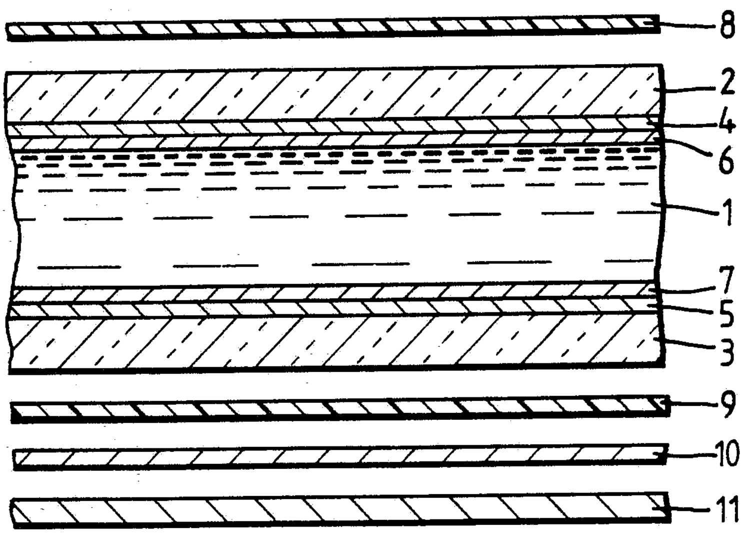
(72) Inventors; and
(75) Inventors/Applicants (*for US only*) : WILTSHIRE, Michael, Charles, Keogh [GB/GB]; 3 The Brackens, High Wycombe, Buckinghamshire HP11 1EB (GB). MOSLEY, Alan [GB/GB]; 6 Chiltern Park Avenue, Berkhamsted, Herts HP4 1EU (GB).

(74) Agent: GEORGE, Sidney, Arthur; The General Electric Company, p.l.c., Central Patent Department (Wembley Office), Hirst Research Centre, East Lane, Wembley, Middlesex HA9 7PP (GB).

(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

**Published**
*With international search report.*

(54) Title: LIQUID CRYSTAL DISPLAYS




(57) Abstract

A liquid crystal display comprises a body of a nematic liquid crystal host material (1) which contains a pleochroic fluorescent dye and which is supertwisted. Parameters of the display are selected such that the display has a transmission wavelength spectrum which encompasses the emission spectrum of the fluorescent dye. In a backlit mode, the display operates in transmission and the light from an electroluminescent panel (11) excites the fluorescent dye in the liquid crystal. In high ambient light levels, the display operates in a reflective mode and the fluorescence is excited by ambient blue or ultraviolet light. The absorption and the fluorescence of the dye are anisotropic, so that switched segments appear dark. In unswitched regions of the display, however, the fluorescence is excited and gives a bright background to the display. Hence, the effect of the fluorophor is to improve the brightness of the display.

*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | |
|---|---|---|---|---|---|
| AT | Austria | GA | Gabon | MR | Mauritania |
| AU | Australia | GB | United Kingdom | MW | Malawi |
| BB | Barbados | HU | Hungary | NL | Netherlands |
| BE | Belgium | IT | Italy | NO | Norway |
| BG | Bulgaria | JP | Japan | RO | Romania |
| BR | Brazil | KP | Democratic People's Republic of Korea | SD | Sudan |
| CF | Central African Republic | | | SE | Sweden |
| CG | Congo | KR | Republic of Korea | SN | Senegal |
| CH | Switzerland | LI | Liechtenstein | SU | Soviet Union |
| CM | Cameroon | LK | Sri Lanka | TD | Chad |
| DE | Germany, Federal Republic of | LU | Luxembourg | TG | Togo |
| DK | Denmark | MC | Monaco | US | United States of America |
| FI | Finland | MG | Madagascar | | |
| FR | France | ML | Mali | | |

# Liquid Crystal Displays

This invention relates to liquid crystal displays (LCDs), and particularly to displays comprising liquid crystal cells which can be operated in a multiplexing mode.

There is a widespread and increasing demand for displays which can present large quantities of complex information. This requires that the display should be multiplexed to quite high levels; over 100-way multiplexing is commonly needed. Moreover, in many applications, the display is also required to consume little power, to operate at low voltages and to be portable. An example of such a requirement is the monitor for a portable personal computer.

Liquid crystal displays fulfil the second set of requirements well, in that they require low driving voltages (1-2V) and consume very little power. However, their visual appeal, particularly when multiplexed, is poor. Conventional twisted nematic devices can be multiplexed only to a limited extent (typically fewer than 64 ways), and at the high levels of multiplexing the contrast of the display falls considerably and the viewing angle is greatly restricted. Furthermore, the appearance of the display, even at low levels of multiplexing, tends to be dull because polarisers are required for its operation. The dullness is accentuated in dim ambient lighting, and some form of subsidiary light source is then required.

Displays have recently been developed which use supertwist liquid crystal devices. These displays provide greatly improved multiplexability while maintaining good contrast and good range of viewing angle. A sharp voltage threshold is required for the high level of multiplexing in these displays, and this is achieved by increasing the twist in the liquid crystal layers to about 270° and by stabilising the twisted structure by increasing the surface tilt. There are various types of supertwist displays. Examples are described in an article by C.M. Waters, V. Brimmel and E.P.Raynes (1983) in Japan Display 83, pages 396-399, and later (1985) by the same authors in Mol. Cryst. Liq. Cryst., 123, pages 303-319. The described displays incorporate absorbing pleochroic dyes in a liquid crystal host. Such displays may be operated either with a host having high birefringence and a single polariser (the so-called Heilmeier type) or with a host having a low birefringence and no polariser (operating in the so-called White-Taylor mode).

The most common supertwist display relies on birefringence interference effects in an undyed liquid crystal, and was first demonstrated by T.J.Scheffer and J. Nehring (1985) in J. Appl. Phys., 58, pages 3022-3031. Like the twisted nematic display, these supertwist birefringence effect (SBE) displays require two polarisers, and so have an inherently dull appearance, tending to be rather darker than the twisted nematic LCD. In one method of operation of a conventional SBE display, the selected or switched segments appear dark against a bright background. The colour of the background, typically green or yellow, is determined by the display construction.

A fluorescent LCD has recently been disclosed by Van Ewyk et al in an article "Anistropic fluorophors for liquid crystal displays" in Displays, October 1986, pages 155-160. This display combines the visual attributes of emissive displays with the desirable electrical characteristics of liquid crystal technology. The device described is a guest-host nematic (Heilmeier type) display containing an anisotropic fluorescent dye, particularly a perylene diester. The fluorescence may be excited either directly by light absorbed by the dye, or indirectly by light which is absorbed in the liquid crystal host and the energy of which is subsequently transferred to the dye.

By virtue of the anisotropy of the fluorescence, liquid crystal segments can be switched on or off by the guest-host effect in the liquid crystal. Van Ewyk et al preferred the indirect excitation process for a back-lit display, using ultraviolet light, since this gave dark segments on a green background, whereas a directly-excited display had an unacceptable (blue on green) colour contrast. The indirectly-excited display possesses a hemispherical viewing angle, is uniformly bright, has good contrast and is driven by low (1-2v) voltages. Moreover, the displayed information is not washed out (as it is in other emissive displays) in high ambient light levels.

An object of the present invention is to provide an improved supertwist liquid crystal display.

According to the invention there is provided a liquid crystal display comprising a body of a nematic liquid crystal host material which contains a pleochroic fluorescent dye and which is supertwisted; and wherein parameters of the display are selected such that the display has a transmission wavelength spectrum which encompasses the emission spectrum of the fluorescent dye.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawing, which shows a partly-exploded schematic cross section through a liquid crystal cell in accordance with the invention.

The cell comprises a body 1 of liquid crystal material contained between glass plates 2 and 3, spaced apart by, for example, 6.5 $\mu$m. The inner surface of each plate is provided with a respective thin transparent electrically conductive layer 4, 5 formed of, for example, indium tin oxide. Each conductive layer is patterned to provide a desired electrode configuration. On each plate is deposited a respective thin surface alignment layer 6, 7 which acts to produce a tilted alignment of the liquid crystal. Such a layer may comprise a rubbed polyimide. Laminated on the outer surface of each plate 2, 3 is a respective polarising film 8, 9 of high efficiency and brightness, the films being suitably orientated so that the transmission wavelength spectrum of the display encompasses the emission spectrum of the fluorescent dye and so that the display has a high contrast ratio. On the outer surface of the film 9 is a transflective layer 10, and located thereover is an electroluminescent panel 11 for backlighting the cell via the layer 10. The electroluminescent panel 11 may provide green light, with a peak output at 500nm.

The body 1 of liquid crystal material comprises a liquid crystal mixture designated 14954, supplied by BDH Ltd., to which are added a sufficient quantity of an anisotropic pleochroic fluorescent dye to obtain adequate fluorescence without reaching a solubility limit, for example 1% by weight of di(4-pentyl bicyclo [2.2.2] oct-1-yl) perylene dicarboxylate, together with a sufficient quantity of a compound designated CB15, supplied by BDH Ltd., to give a helical pitch of approximately 11.6 μm.

In a backlit mode, the display operates in transmission and the light from the panel 11 also excites the fluorescent dye in the liquid crystal. In high ambient light levels, the display operates in a reflective mode and the fluorescence is excited by ambient blue or ultraviolet light. Because the absorption and the fluorescence of the dye are anisotropic, switched segments appear dark. In unswitched regions of the display, however, the fluorescence is excited and gives a bright background to the display. The parameters of the display are chosen such that its transmission spectrum matches the emission spectrum of the fluorophor. Light which would be absorbed in a conventional display designed according to the prior art is, in the present invention, used to excite the fluorescence. Hence, the effect of the fluorophor is to improve the brightness and visual appeal of the display.

In an alternative embodiment (not shown), the display may be constructed to operate in the Heilmeier mode. In that case, approximately 1% of the above-mentioned dye is added to a nematic liquid crystal having a high birefringence, such as the materials E7 or E63 which are available from BDH Ltd., doped with the required amount of the compound CB15. The display then requires a single polariser on its front surface and operates by indirect excitation of the fluorescent dye by an ultraviolet backlight.

In another embodiment, which operates in the White-Taylor mode, a low birefringence host, such as a mixture of cyclohexyl cyclohexane compounds, to which may be added a small amount of

4-n-pentyl 4"-cyanoterphenyl to promote energy transfer, is used, In this case, no polariser is required and the display may be front or back-lit by ultraviolet light.

In the latter alternative embodiments, the need to provide ultraviolet light for excitation precludes use of the display in a battery-operated equipment, such as a portable personal computer, but it may, of course be used in any suitable mains-powered configuration.

It will be appreciated that any of the embodiments described above could be operated with the fluorescence excited either directly or indirectly (or both) depending on the particular application.

In all cases, the display parameters, such as the cell thickness, the surface tilt and the liquid crystal properties, are chosen so that the transmission wavelength spectrum of the display encompasses the absorption and emission spectrum of the fluorescent dye. The parameters will be optimised, as will be apparent to those skilled in the art.

Although in the above-described embodiments a green fluorophor is employed, the display could equally well be constructed with any other suitable dye.

The present invention enables the desirable features of an SBE display to be combined with the visual impact of an emissive display by incorporating a fluorescent dye in the liquid crystal. Because the display incorporates supertwist liquid crystal devices, a high degree of multiplexing is possible.

## CLAIMS

1. A liquid crystal display, comprising a body (1) of a nematic liquid crystal host material which contains an anisotropic pleochroic fluorescent dye and which is supertwisted; and wherein parameters of the display are selected such that the display has a transmission wavelength spectrum which encompasses the emission spectrum of the fluorescent dye.

2. A liquid crystal display as claimed in Claim 1, wherein the fluorescent dye is caused to fluoresce by impingement of light directly thereon.

3. A liquid crystal display as claimed in Claim 1, wherein the fluorescent dye is caused to fluoresce by impingement of light on the liquid crystal host material.

4. A liquid crystal display as claimed in Claim 2 or Claim 3, wherein the light is received from the viewing side of the display.

5. A liquid crystal display as claimed in Claim 2 or Claim 3, wherein the light is received from the side of the display opposite to the viewing side.

6. A liquid crystal display as claimed in any one of Claims 3-5, wherein the light is ultraviolet light.

7. A liquid crystal display as claimed in Claim 5,including an electroluminescent panel (11) attached to said opposite side of the display for producing the light.

8. A liquid crystal display as claimed in any preceding claim, wherein the dye is di(4-pentyl bicyclo [2.2.2] oct-1-yl) perylene-3, 9 or 10-dicarboxylate.

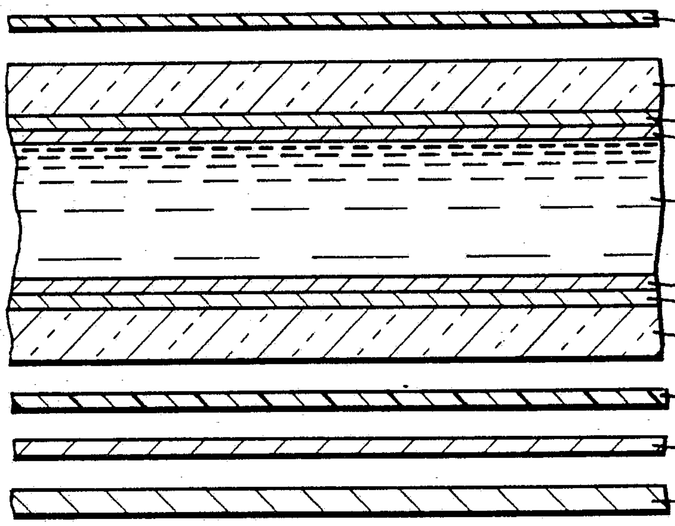
9. a liquid crystal display as claimed in any preceding claim, wherein the twist of the liquid crystal host material is in the range 120-360°.

10. A liquid crystal display as claimed in any preceding claim, comprising a pair of spaced-apart glass (2,3) between which the body (1) of liquid crystal host material is contained; a layer (4,5) of

patterned, electrically-conductive material on the inner surface of each glass plate; and an unpatterned surface alignment layer (6,7) over the conductive material layer.

11. A liquid crystal display, comprising a body of a high birefringence nematic liquid crystal host material which contains an anisotropic pleochroic fluorescent dye and which is supertwisted; and polarising means at a viewing side of the display; the display being operative in response to ultraviolet light impinging thereon from the side opposite to the polarising means.

12. A liquid crystal display, comprising a body of low birefringence nematic liquid crystal host material which contains an anisotropic pleochroic fluorescent dye and which is supertwisted; the display being operative in response to ultraviolet light and/or ambient light, suitable to excite the dye fluorescence, impinging thereon.


8
2
4
6
1
7
5
3
9
10
11

# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB88/00585

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

$IPC^4$ G 02 F 1/13, C 09 K 19/60

**II. FIELDS SEARCHED**

Minimum Documentation Searched [7]

| Classification System | Classification Symbols |
|---|---|
| $IPC^4$ | G 02 F, C 09 K |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [9]

| Category [*] | Citation of Document, [11] with indication, where appropriate, of the relevant passages [12] | Relevant to Claim No. [13] |
|---|---|---|
| Y | EP, A1, 0186970 (THE GENERAL ELECTRIC COMPANY) 9 July 1986, Whole document | 1,3,6,10 |
| A | | 8 |
| | --- | |
| Y | US, A, 4337999 (FUNADA et al.) 6 July 1982, see column 5, line 3 - column 7, line 44 | 1,2,4,6,10 |
| | --- | |
| Y | ELECTRONICS LETTERS vol 22, no. 18, 28 August 1986, (R van Ewyk et al.) "Fluorescent liquid crystal displays" Whole document | 1,4,8 |
| | --- | |
| Y | US, A, 4244636 (BAUR et al.) 13 January 1981 Whole document | 1,11,12 |
| | --- | |
| P | WO, 87/05617 (THE GENERAL ELECTRIC COMPANY) 24 September 1987 Whole document | |
| X | | 3,4,8 |
| | --- | |

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 16th September 1988 | 11 NOV 1988 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| EUROPEAN PATENT OFFICE | P.C.G. VAN DER PUTTEN |

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
|---|---|---|
| Y | EP, A1, 0168757 (ROGERS CORPORATION) 22 January 1986, Abstract | 5, 7 |
| | -- | |
| Y | MOL.CRYSR.LIQ.CRYST. vol 123, pp. 303-319 1985, (C.M. Waters, E.P. Raynes and V Brimell) "Design of Highly Multiplexed Liquid Crystal Dye Displays" whole document | 9 |
| | -------------- | |

# ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 01/09/88
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

PCT/GB 88/00585
SA 23276

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP-A- 0186970 | 09-07-86 | JP 61144629 | 02-07-86 |
| | | GB 2169092 | 02-07-86 |
| US-A- 4337999 | 06-07-82 | DE 2837218 | 08-03-79 |
| | | DE 2837257 | 22-03-79 |
| | | JP 54048690 | 17-04-79 |
| | | CH 636637 | 15-06-83 |
| | | CH 637261 | 29-07-83 |
| | | US 4556287 | 03-12-85 |
| | | JP 54151580 | 28-11-79 |
| | | JP 55003466 | 11-01-80 |
| US-A- 4244636 | 13-01-81 | NL 7801665 | 17-08-78 |
| | | FR 2380566 | 08-09-78 |
| | | DE 2706372 | 17-08-78 |
| | | BE 863988 | 29-05-78 |
| | | JP 53101997 | 05-09-78 |
| | | GB 1585754 | 11-03-81 |
| | | CA 1106479 | 04-08-81 |
| | | AT 368295 | 27-09-82 |
| | | SE 7801773 | 15-08-78 |
| WO-A- 87/05617 | 24-09-87 | GB 2189502 | 28-10-87 |
| | | EP 0261165 | 30-03-88 |
| EP-A- 0168757 | 22-01-86 | JP 61039085 | 25-02-86 |

EPO FORM P0479