(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 December 2004 (02.12.2004)

PCT

(10) International Publication Number
WO 2004/104670 A1

(51) International Patent Classification[7]: G02B 26/02, 6/35

(21) International Application Number:
PCT/IB2004/050693

(22) International Filing Date: 13 May 2004 (13.05.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
03101479.8 22 May 2003 (22.05.2003) EP

(71) Applicant *(for all designated States except US)*: **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HAYES, Robert, A.** [AU/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **FEENSTRA, Bokke, J.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **HAGE, Leendert, M.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **WOLF, Ronald, M.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **MORKS, Ewout, V.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **JAULNEAU, Patrice, G., C.** [FR/FR]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **CAMPS, Ivo, G., J.** [BE/BE]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **SCHLANGEN, Lucas, J., M.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: **RAAP, Adriaan, Y.**; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

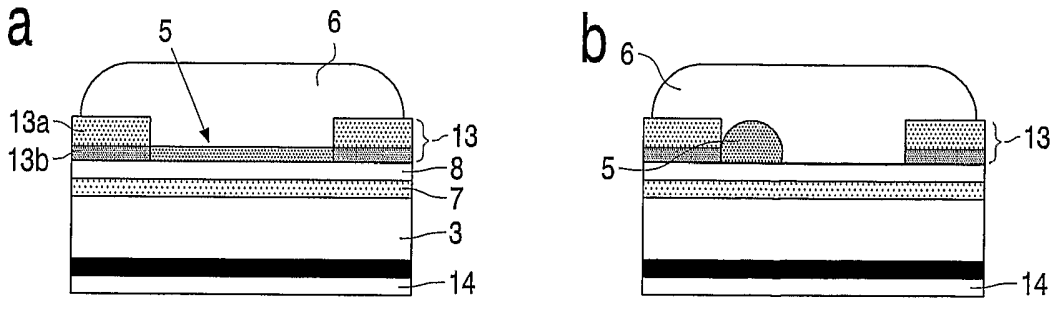
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DISPLAY DEVICE



(57) Abstract: An optical switch, e.g. a display device based on layer break up or layer displcement having at least two different states, in which one of the fluids (5) e.g oil in a first state adjoins at least a first support plate (3) and in the second state the other fluid (6) at least partly adjoins the first support plate, in which picture elements are separated by areas (13) having a hydrophilic surface.

WO 2004/104670 A1

Display device

The invention relates to an optical switch comprising at least one first fluid and a second fluid immiscible with each other within a space between a first transparent support plate and a second support plate, the second fluid being electroconductive or polar.

In particular the invention relates to a display device comprising picture elements (pixels) having at least one first fluid and a second fluid immiscible with each other within a space between a first transparent support plate and a second support plate, the second fluid being electroconductive or polar.

Optical switches may be used in shutter applications, diaphragms, but also in switchable color filters in e.g. display applications.

Display devices like TFT-LCDs are used in laptop computers and in organizers, but also find an increasingly wider application in GSM telephones. Instead of LCDs, for example, (polymer) LED display devices are also being used.

Apart from these display effects that are well established by now other display techniques are evolving like electrophoretic displays, which are suitable for paper white applications.

The invention is based on a principle called electro-wetting. The invention provides new ways of using this principle in which one of the fluids in a first state adjoins a greater part of the first support plate and in the second state the other fluid at least partly adjoins the first support plate.

If for instance a (first) fluid is a (colored) oil and the second (the other) fluid is water (due to interfacial tensions) a two layer system is provided which comprises a water layer and an oil layer. However, if a voltage is applied between the water and an electrode on the first support plate the oil layer moves aside or breaks up due to electrostatic forces. Since parts of the water now penetrate the oil layer the picture element becomes partly transparent.

Display devices based on this principle have been described in PCT-Application WO 03/00196 (PH – NL 02.0129). In most of the embodiments shown in this Application a picture element corresponds to a defined space (e.g. a substantially closed

space) and in the second state the other fluid substantially completely adjoins the first support plate. In one embodiment shown in this Application picture elements are described in which the pixel walls do not extend across the whole pixel thickness.

In practice however these pixel walls have a certain wall height of about 80 μm or more which has severe implications for the optical performance of small pixels in particular. The presence of such pixel walls results in an effectively reduced pixel area, since the area close to the walls does not contribute to the pixel brightness at the higher incoming angles. As a result, the total pixel will become less bright. This reduction of brightness will be more severe for smaller pixels. At a wall height of about 80 μm, the loss of brightness is about 10 – 15 % for a 500 μm x 500 μm pixel.

Moreover the walls are generally glued to the underlying surface. This underlying surface is often a fluoropolymer surface so the bonding is rather weak mechanically due to the fact that the fluoropolymer is very hydrophobic. Also the glue in between the walls and the fluoropolymer surface tends to move into the pixel area. In this case, the oil will not cover this part of the pixel, since the oil is repelled from the glue surface. These areas cause a considerable increase in reflectivity in the "black" off-state, thereby reducing the optical contrast.

It is one of the objects of the present invention to overcome at least partly the above mentioned problems.

To this end an optical device according to the invention comprises at one support plate within said space a surface area less wettable for the second fluid, the less wettable surface area being surrounded by areas having a more wettable surface area.

Although not strictly necessary the less wettable surface area is preferably separated by more wettable surfaces provided on walls.

By lowering the walls to 20 μm thickness, or less, the device can be operating in a range where the oil height upon contraction is in fact larger than the actual wall height. The inventors have experimentally confirmed that the oil remains within the pixel, due to the pinning of the oil/water interface at the bottom of the wall. In display applications the possibility of oil in adjacent pixels mixing when both pixels are switched can be avoided by incorporating a controlled oil motion e.g. by electromagnetic forces.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

In the drawings:

Figure 1 is a diagrammatic cross-section of a part of a display device, to show the principle on which a display device according to the invention is based,

Figure 2 is another diagrammatic cross-section of a part of a display device according to the invention,

Figure 3 is a diagrammatic cross-section of a part of a display device according to the invention, while

Figure 4 is a plan views of a part of a further display device according to the invention and

Figure 5 is a diagrammatic cross-section along line V –V in Figure 4

The Figures are diagrammatic and not drawn to scale. Corresponding elements are generally denoted by the same reference numerals.

Fig. 1 shows a diagrammatic cross-section of a part of a display device 1 which shows the principle on which a display device according to the invention is based. Between two transparent substrates or support plates 3, 4 a first fluid 5 and a second fluid 6 are provided, which are immiscible with each other. The first fluid 5 is for instance an alkane like hexadecane or as in this example a (silicone) oil. The second fluid 6 is electroconductive or polar, for instance water or a salt solution (e.g. a solution of KCl in a mixture of water and ethyl alcohol).

In a first state, when no external voltage is applied (Fig. 1a) the fluids 5, 6 adjoin the first and second transparent support plates 3, 4 of e.g. glass or plastic. On the first support plate 3 a transparent electrode 7, for example indium (tin) oxide is provided and an intermediate less wettable (hydrophobic) layer 8, in this example an amorphous fluoropolymer (AF1600).

When a voltage is applied (voltage source 9) via interconnections 20, 21 the layer 5 moves aside or breaks up into small droplets (Fig. 1b). This occurs when the electrostatic energy gain is larger than the surface energy loss due to the creation of curved surfaces. As a very important aspect it was found that reversible switching between a continuous film 5 covering the support plate 3 and a film adjoining the wall 2 is achieved by means of the electrical switching means (voltage source 9).

Figure 2 shows an embodiment of a display device according to the invention, in which walls between separate picture elements have been omitted for the greater part for the sake of clarity. In this embodiment the pixel walls 13 do not extend across the whole pixel thickness. Such walls may be obtained by offset printing or other printing techniques known in the art. It appears that the oil film 5 is very stable, which is enhanced even further as the pixel size decreases. So during switching the oil remains confined in each area. The other reference numerals have the same meaning as those in Figure 1.

The layer 13 in this example is approximately 20 μm thick or less and consists of a lower part 13^b, more wettable to the first fluid (hydrophobic) and an upper less wettable (hydrophilic) part 13^a (see Figure 3). In this way the wetting of the lower part of the pixel wall by the oil ensures a homogeneous optical off –state. Then when the pixel is activated the reversibility of oil movement due to the less wettable (hydrophilic) upper part is also maintained. Especially the less wettable (hydrophilic) part (or a surface part) has been found to be essential for good switching.

The layer thickness of approximately 20 μm or less is a significant improvement with respect to the 80 μm layer, leading to an improved brightness and speed. Furthermore, due to the absence of glue, the oil covers the entire pixel area, improving the optical contrast. The layer 13 or layer parts 13^a, 13^b in this example are printed. A printing process is very simple and flexible, thereby facilitating the fabrication of electrowetting displays at high resolutions significantly. In such a printing process it may be advantageous to use a pre-treatment of the substrate, such as a reactive ion-etching step using O_2 to make it more hydrophilic.

In the display of Figures 4, 5 the separating area between pixel areas has been integrated into the substrate by making interpixel areas 13'of the substrate less wettable to the first fluid (hydrophilic) for instance by means of laser radiation, a UV-ozone treatment or an oxygen-plasma treatment. The further reference numerals in Figures 4, 5 have the same meaning as those in the other examples. The possibility of oil in adjacent pixels mixing when both pixels are switched to the transparent state is avoided by incorporating a controlled oil motion by electromagnetic control, in this case by leaving apertures 17 in the electrodes 7.

Several variations to the principle are possible. Although a transmissive device has been described, the display may be made reflective by adding a reflector as shown by dashed lines 14 in Figure 3. The electrode configuration chosen here is merely an example. Other electrode configurations can be chosen, such as a circular geometry. Such a circular geometry is used in e.g. shutter applications and diaphragms.

The invention resides in each and every novel characteristic feature and each and every combination of characteristic features. Reference numerals in the claims do not limit their protective scope. Use of the verb "to comprise" and its conjugations does not exclude the presence of elements other than those stated in the claims. Use of the article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

CLAIMS:

1. An optical switch comprising at least one first fluid (5) and a second fluid (6) immiscible with each other within a space between a first transparent support plate (3) and a second support plate (4), the second fluid being electroconductive or polar, the device on at least one of the support plates comprising within said space a surface area less wettable to the second fluid, the less wettable surface area being surrounded by areas having a more wettable surface area.

2. An optical switch according to Claim 1 in which the less wettable surface area is separated by more wettable surfaces (13^a) provided on walls (13).

3. An optical switch according to Claim 2 in which the lower parts of the walls are more wettable by the first fluid.

4. An optical switch according to Claim 2 in which the walls have a height of at most 20 μm

5. A display device comprising picture elements having at least one first fluid and a second fluid immiscible with each other within a space between a first transparent support plate and a second support plate, the second fluid being electroconductive or polar, a picture element having an optical switch according to Claim 1 or 2.

6. A method for manufacturing an optical device according to claims 1 or 2 in which at least part of the one support plate is made less wettable by means of laser radiation, a UV-ozone treatment or an oxygen-plasma treatment.

7. A method for manufacturing an optical device according to claim 6 in which the one support plate is provided with walls by means of a mold.

8. A method for manufacturing an optical device according to claims 1 or 2 in which the less wettable part of the one support plate is made by means a printing method.

9. A method according to claim 8 in which the substrate is pre-treated by means of reactive ion-etching.

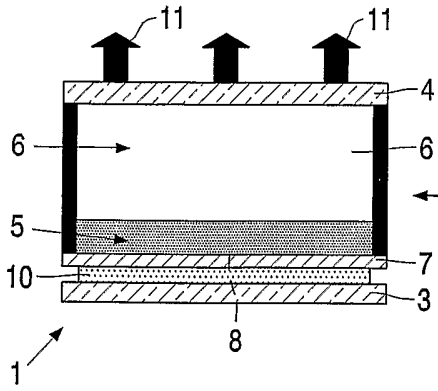


FIG. 1a

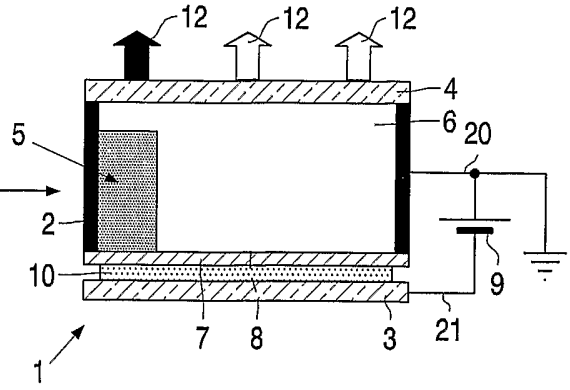


FIG. 1b

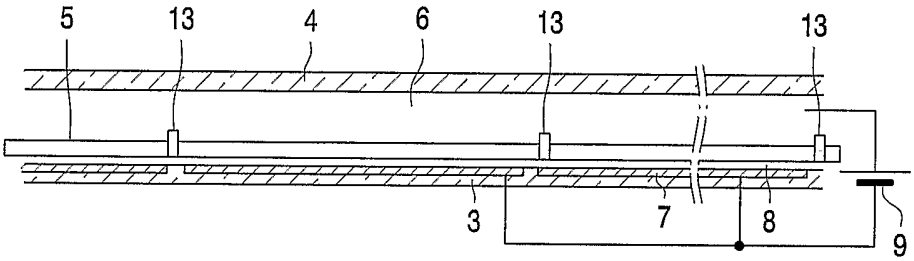


FIG. 2

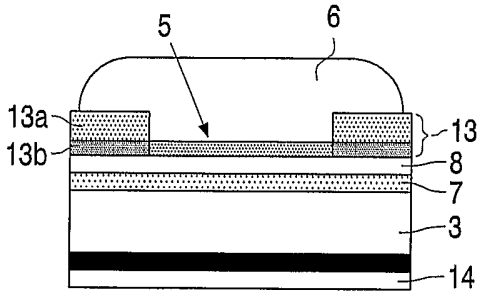


FIG. 3a

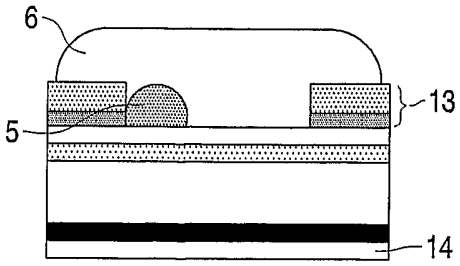


FIG. 3b

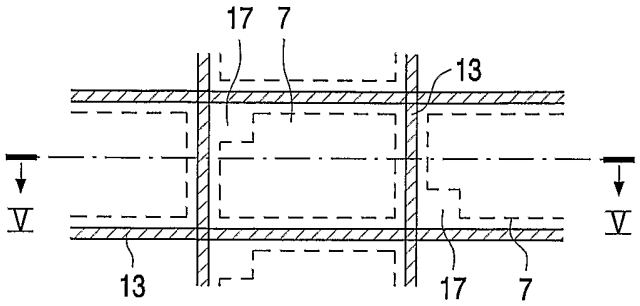


FIG. 4

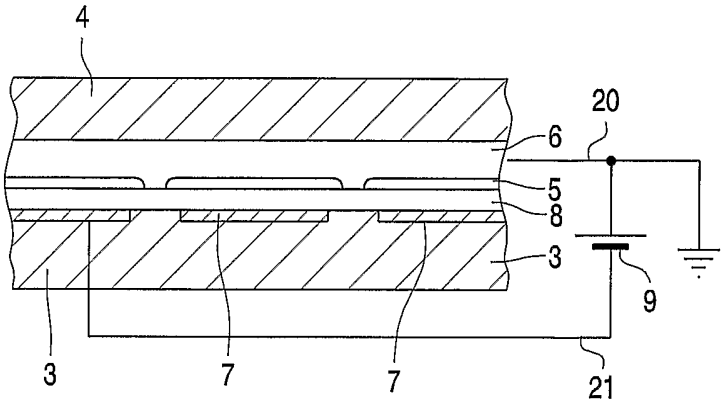


FIG. 5

INTERNATIONAL SEARCH REPORT

onal Application No
IB2004/050693

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B26/02 G02B6/35

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 069 450 A (CANON KK) 17 January 2001 (2001-01-17) paragraph '0005! - paragraph '0007! paragraph '0018! - paragraph '0022! -----	1-9
X	US 6 369 954 B1 (BERGE BRUNO ET AL) 9 April 2002 (2002-04-09) column 3, line 3 - line 39 column 6, line 3 - line 58 figure 1 -----	1-9
X	US 4 079 368 A (DISTEFANO THOMAS HERMAN) 14 March 1978 (1978-03-14) column 2, line 22 - column 3, line 8 column 4, line 38 - line 46 figure 1A ----- -/--	1-9

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"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 when the document is taken alone

"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

Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2004	06/09/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	THEOPISTOU, P

INTERNATIONAL SEARCH REPORT

onal Application No
IB2004/050693

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 582 391 A (LEGRAND JACQUES) 15 April 1986 (1986-04-15) column 2, line 66 - column 4, line 30; figure 1	1-9
A	WO 03/034748 A (KONINKL PHILIPS ELECTRONICS NV) 24 April 2003 (2003-04-24) page 4, line 17 - page 5, line 16 figure 3	1-9
A	PATENT ABSTRACTS OF JAPAN vol. 0182, no. 68 (C-1202), 23 May 1994 (1994-05-23) & JP 6 041337 A (MASUHIRO KOKOMA; others: 02), 15 February 1994 (1994-02-15) abstract	6-9
A	PATENT ABSTRACTS OF JAPAN vol. 0144, no. 75 (C-0770), 17 October 1990 (1990-10-17) & JP 2 196834 A (RIKAGAKU KENKYUSHO; others: 01), 3 August 1990 (1990-08-03) abstract	6-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

onal Application No
IB2004/050693

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1069450 A	17-01-2001	JP 2000356751 A	26-12-2000
		JP 2000356792 A	26-12-2000
		EP 1069450 A2	17-01-2001
		US 6449081 B1	10-09-2002
US 6369954 B1	09-04-2002	FR 2769375 A1	09-04-1999
		AT 214164 T	15-03-2002
		CA 2306249 A1	15-04-1999
		DE 69804119 D1	11-04-2002
		DE 69804119 T2	28-11-2002
		EP 1019758 A1	19-07-2000
		ES 2171041 T3	16-08-2002
		WO 9918456 A1	15-04-1999
		JP 2001519539 T	23-10-2001
US 4079368 A	14-03-1978	DE 2719505 A1	08-12-1977
		FR 2352364 A1	16-12-1977
		GB 1573165 A	13-08-1980
		JP 52140233 A	22-11-1977
US 4582391 A	15-04-1986	FR 2524658 A1	07-10-1983
		EP 0090723 A1	05-10-1983
WO 03034748 A	24-04-2003	EP 1438865 A1	21-07-2004
		WO 03034748 A1	24-04-2003
		TW 563984 Y	21-11-2003
		US 2003085850 A1	08-05-2003
JP 6041337 A	15-02-1994	JP 2542750 B2	09-10-1996
		JP 1896149 C	23-01-1995
		JP 6013615 B	23-02-1994
		JP 62235339 A	15-10-1987
JP 2196834 A	03-08-1990	JP 1858351 C	27-07-1994
		JP 5077692 B	27-10-1993