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WO 2011/101649 A1

(54) Title: DISPLAY ELEMENTS

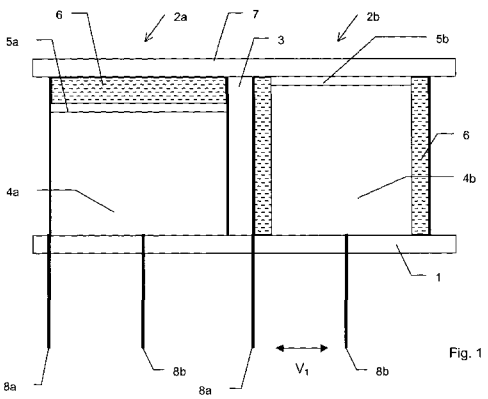



Fig. 1

(57) Abstract: A electrically actuable display element comprises a substrate, a display surface and an electrically actuable element disposed between the substrate and the display surface and electrically actuable so as to bring a portion thereof into proximity or contact with the display surface and thereby change the display state of the display element.

# Display Elements

## Field of the Invention

[0001] The present invention relates to display elements for visual and/or tactile displays, and particularly but not exclusively for touch-sensitive displays.

## Background of the Invention

[0002] At present, display technologies fall into 5 main types: LCD, plasma, CRT, OLED/LED and projection. These technologies can be further categorised as follows:

1. Shuttered technology, such as LCD and projection, which allows light to pass in predefined parts of the screen to form the required image.
2. Emissive technology, such as plasma, CRT and OLED/LED that emits light at predefined positions on the screen to render the required image.

[0003] Shuttered technologies suffer from poor efficiency, because the light provided by a backlight is partially blocked. Neither technology performs well under bright lighting conditions. Transreflective LCD technologies, which reflect bright illumination, suffer from narrow viewing angles.

[0004] For touch-sensitive applications, a touch-sensitive layer may be added to the display panel to enable user input using fingers or styli. For tactile applications, a tactile layer may be added that gives a textured or 3D representation.

[0005] All of the aforementioned technologies share similar drawbacks for touch-sensitive or tactile applications, in that an additional layer must be added directly over the visual display, therefore degrading the light output, clarity and contrast of the display panel. Moreover, the additional layer and associated components add to the cost of the display.

[0006] Additionally, some touch-sensitive technologies based on row and column sensing in a matrix are only able to detect a single touch at any one time. Other touch-sensitive technologies have poor spatial resolution.

## Statement of the Invention

[0007] According to one aspect of the present invention, there is provided an electrically actuable display element according to claim 1. According to another aspect of the present invention, there is provided a display element according to claim 14.

## Brief Description of the Drawings

**[0008]** There now follows, by way of example only, a detailed description of preferred embodiments of the present invention, with reference to the figures identified below.

Figure 1 is a schematic cross section of two adjacent pixels in respective non-actuated and actuated configurations, in a display panel according to the first embodiment of the invention.

Figure 2 is a schematic perspective view of the layers of the display panel of the first embodiment.

Figure 3 is a schematic cross section of two adjacent pixels in respective non-touch-sensitive and touch-sensitive configurations, in the display panel of the first embodiment.

Figure 4 is a schematic cross section of two adjacent pixels in respective non-tactile and tactile configurations, in the display panel of the first embodiment.

Figure 5 is a schematic cross section of two adjacent pixels in respective non-actuated and actuated configurations, in a display panel according to a second embodiment of the invention.

## Detailed Description of the Embodiments

**[0009]** In the following description, functionally similar parts carry the same reference numerals between different embodiments.

### First Embodiment

**[0010]** A first embodiment of the present invention comprises a visual display screen with touch-sensitive input and tactile output. The visual, touch-sensitive and tactile functions are all provided by the same electrically active material, such as piezoelectric material. As is known in the art, piezoelectric materials generate an electric field in response to mechanical stress and also exhibit the reverse piezoelectric effect, in which the application of an electric field produces stress in the material, resulting in expansion or contraction of the material if not constricted. The stress in the material may be proportional to the electric field. Piezoelectric materials may be ceramics or polymers such as PVDF. The mechanical and electrical properties of the piezoelectric material may be enhanced by providing several layers of the material. As an alternative to piezoelectric materials, other materials may be used which exhibit a shape or size change in response to an electric field, such as carbon nanotube materials currently proposed for use as artificial muscles (see for example 'Giant-

Stroke, Superelastic Carbon Nanotube Aerogel Muscles', Aliev A et. al. Science 20 March 2009, Vl. 323. no. 5921, pp. 1575 – 1578).

**[0011]** Figures 1 to 4 illustrate the constructional details of a display panel according to a first embodiment of the present invention. The visual display screen of the first embodiment comprises an insulating substrate 1 carrying a matrix of cells 2a, 2b corresponding to the pixel configuration of the display. The cells 2a, 2b may be formed integrally as holes in the surface of the substrate 6, or applied as a separate perforated layer as shown in Figure 2. In either case, the cells 2a, 2b have walls 3 formed between them. A piezoelectric actuating element 4a, 4b is fitted in each of these cells 2a, 2b, leaving a small void at the top of the cell 2a, 2b.

**[0012]** The insulating substrate 1 carries electrical connections 8a, 8b, for example as a layer formed on one or both sides thereof, which make an independently addressable electrical connection to each piezoelectric actuating element 4a, 4b. A display controller 10 is connected to the electrical connections, to drive the display as described in more detail below.

**[0013]** The upper surface 5a, 5b of each piezoelectric actuating element 4a, 4b is arranged to reflect and/or emit light when illuminated, according to the desired appearance of the corresponding pixel when switched on. In one example, the upper surface 5a, 5b comprises a coloured layer having the desired colour of that pixel. The coloured layer may be fluorescent.

**[0014]** The remaining space within each cell 2a, 2b is filled with a substantially opaque fluid 6, and the cells 2a, 2b are sealed by a substantially transparent front screen 7, fixed to the top ends of the walls 3. Hence, as shown in cell 2a with the pixel 'off', the fluid 6 fills the void above piezoelectric actuating element 4a and obscures the upper surface 5a of the piezoelectric actuating element 4a, so that only the fluid 6 is visible through the front screen 7. As shown in cell 2b, the piezoelectric actuating element 4b expands in height and contracts in width when a voltage $V_1$ is applied across it, so that the liquid 6 is expelled from between the upper surface of the piezoelectric actuating element 4b and the front screen 7, and is retained between the walls 3 and the sides of the piezoelectric actuating element 4b. The upper surface is now visible through the front screen and the pixel appears in its 'on' state. When the voltage is switched off, the piezoelectric actuating element returns to its rest position as shown in cell 2a.

**[0015]** The intensity of the displayed pixel may be controlled by varying the voltage $V_1$ applied to the piezoelectric actuating element 4a, 4b and therefore the thickness of the fluid 6 between the front screen 7 and the upper surface 5a, 5b.

**[0016]** Where the upper surface 5a, 5b is fluorescent, it may be illuminated by ultraviolet (UV) light from a light source forming part of the display screen. For example, the UV light may be introduced into one or more sides of the front screen 7, which acts as a light guide for the UV light.

**[0017]** One pole 8a of the electrical connection to the piezoelectric actuating element 4a, 4b may be made via the fluid 6, which is electrically conductive, for example by including a dissolved salt.

**[0018]** A touch-sensitive function of the display of the first embodiment is illustrated in Figure 3. The front screen 7 is flexible, so that pressure applied to the front screen 7 is transmitted to the piezoelectric actuating element 4b. As a result of the direct piezoelectric effect, a voltage $V_2$ is produced across the electrical connections 8a and 8b and is sensed by the display controller 10, which detects in which individual cells 2a, 2b pressure is applied. Since the detected voltage varies with pressure, the display controller 10 may determine the level of pressure applied to each pixel, thereby enabling a proportional touch-sensitive display. Each pixel effectively acts as a display element and individually addressable pressure transducer. This technology enables many new touch-sensitive display applications.

**[0019]** Where the piezoelectric actuating element 4b is energised by applying the voltage $V_1$, the voltage $V_2$ will oppose the applied voltage $V_1$. The spacing between the upper surface 5a in the 'off' state and the front screen 7 may be such that pressure cannot be sensed by the piezoelectric actuating element 4a in its 'off' state.

**[0020]** A tactile aspect of the first embodiment is illustrated in Figure 4. If a voltage $V_3$ higher than voltage $V_1$ is applied, the piezoelectric actuating element 4b expands further and causes outward deformation of the flexible front screen 7 at that point. This deformation causes a tangible bump as well as a visible pixel, so that the displayed image can be felt by a user.

**[0021]** Hence, the first embodiment provides visual, touch-sensitive and/or tactile functions by means of the same piezoelectric element, and the need for additional layers for touch-sensitive and/or tactile functions is avoided. It is not essential that all three of these functions be provided; for example, if the front screen 7 is rigid, only the visual display will be provided.

**[0022]** The piezoelectric elements 4a, 4b may comprise stacked multiple layers of piezoelectric material. The piezoelectric elements 4a, 4b may be arranged in a cantilever bending or beam configuration. The piezoelectric elements 4a, 4b may be arranged in an X-poled or Y-poled configuration.

**[0023]** The display panel may be used as an interactive indicator, point of sale display or other display. The applications of the first embodiment are not limited to flat display screens, but may include for example a 'skin' or surface layer for toys and other products, enhancing the user experience with two way visual and tactile communication between the product and the user.

## Second Embodiment

**[0024]** In a second embodiment of the invention, the visual and/or tactile display function is provided by electrically heated thermal expansion rather than piezoelectricity. However, piezoelectric elements may be included for touch-sensitivity. Similar parts to those of the first embodiment are shown with the same reference numerals and their description is not repeated, for brevity.

**[0025]** The constructional details are shown in Figure 5. Within each cell 2a, 2b is provided a thermally expanding sac 11a, 11b containing a fluid that is selectively heated by supply of current to an electric heater 9a, 9b under the control of the display controller 10. The upper surface 5a, 5b is thereby forced upwards into proximity or contact with the front screen 7 and becomes visible, and the pixel is switched 'on'. When the current supply is switched off, the sac 11a, 11b contracts and the pixel is switched 'off'. In this way, the display controller 10 may independently switch each pixel on and off.

**[0026]** The upper surface 5a, 5b may be flexible, so that the proportion of the upper surface 5a, 5b in contact with the front screen 7 increases as the sac 11a, 11b expands. In this way, the intensity of the displayed colour of the pixel may be controlled. The front screen 7 may be flexible, and may be distorted outwardly by the expansion of the sac 11a, 11b, thereby providing a tactile representation of the pixel when switched 'on'.

**[0027]** A piezoelectric sensing element 4a, 4b may be provided within the each sac 11a, 11b, and the front screen 7 may be flexible. In this way, when the sac 11a, 11b is expanded into contact with the front screen 7, pressure applied to the front screen 7 is hydraulically transferred to the piezoelectric sensing element 4a, 4b, which generates a voltage that is sensed by the display controller 10 and therefore provides independent touch sensitivity for each cell 2a, 2b.

**[0028]** In this embodiment, there is no liquid surrounding the sac 11a, 11b, as this would prevent the increase in volume of the sac 11a, 11b.

## Alternative Embodiments

**[0029]** Alternative electrically actuated means may be provided within each cell 2a, 2b to provide a similar effect to the piezoelectric elements 4a, 4b and/or the thermally expanding sacs 11a, 11b. For example, micromechanical actuators may be used.

**[0030]** The embodiments described above are illustrative of rather than limiting to the present invention. Alternative embodiments apparent on reading the above description may nevertheless fall within the scope of the invention.

## Claims

1. An electrically actuable display element, comprising:

    a. a substrate;

    b. a display surface; and

    c. an electrically actuable element disposed between the substrate and the display surface and electrically actuable so as to bring a portion thereof into proximity or contact with the display surface and thereby change the display state of the display element.

2. The display element of claim 1, wherein the display surface is substantially transparent, and bringing said portion of the electrically actuable element into proximity or contact with the display surface causes the portion to be visible through the display surface.

3. The display element of claim 2, wherein the electrically actuable element is disposed within a cell containing fluid.

4. The display element of claim 3 wherein the fluid is substantially opaque, and bringing said portion of the electrically actuable element into proximity or contact with the display surface displaces said fluid from the display surface.

5. The display element of claim 3 or claim 4, wherein the fluid is electrically conductive, and arranged to provide an electrical contact to the electrically actuable element.

6. The display element of any preceding claim, wherein the display surface is flexible.

7. The display element of claim 6, wherein bringing said portion of the electrically actuable element into proximity or contact with the display surface distorts the display surface to provide a tactile display.

8. The display element of claim 6 or claim 7, wherein the electrically actuable element is pressure sensitive and arranged to sense pressure on the display surface when brought into contact therewith.

9. The display element of any preceding claim, wherein the electrically actuable element comprises a piezoelectric element.

10. The display element of any preceding claim, wherein the electrically actuable element comprises a thermally expandable element and a heater.

**11.** The display element of any preceding claim, wherein the portion of the electrically actuable element is optically reflective.

**12.** The display element of any preceding claim, wherein the portion of the electrically actuable element is fluorescent.

**13.** The display element of claim 12, wherein the display surface is arranged to guide ultraviolet light onto said portion.

**14.** A display element, comprising an electrically actuable element for switching the display state thereof, the electrically actuable element being pressure sensitive so as to provide a touch-sensitive display.

**15.** A display comprising an array of individually electrically addressable display elements each as claimed in any preceding claim.

Fig. 1

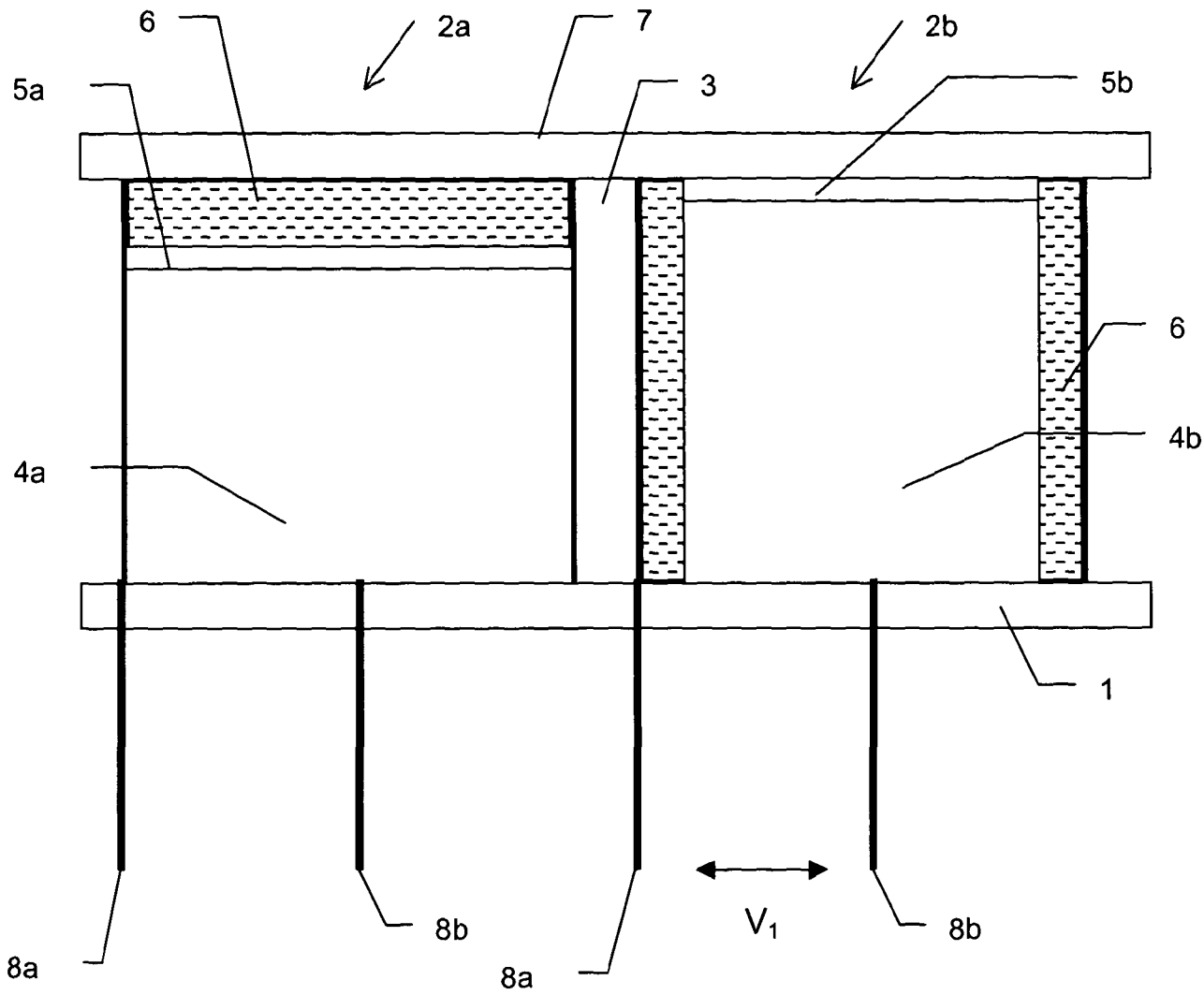


Fig. 2

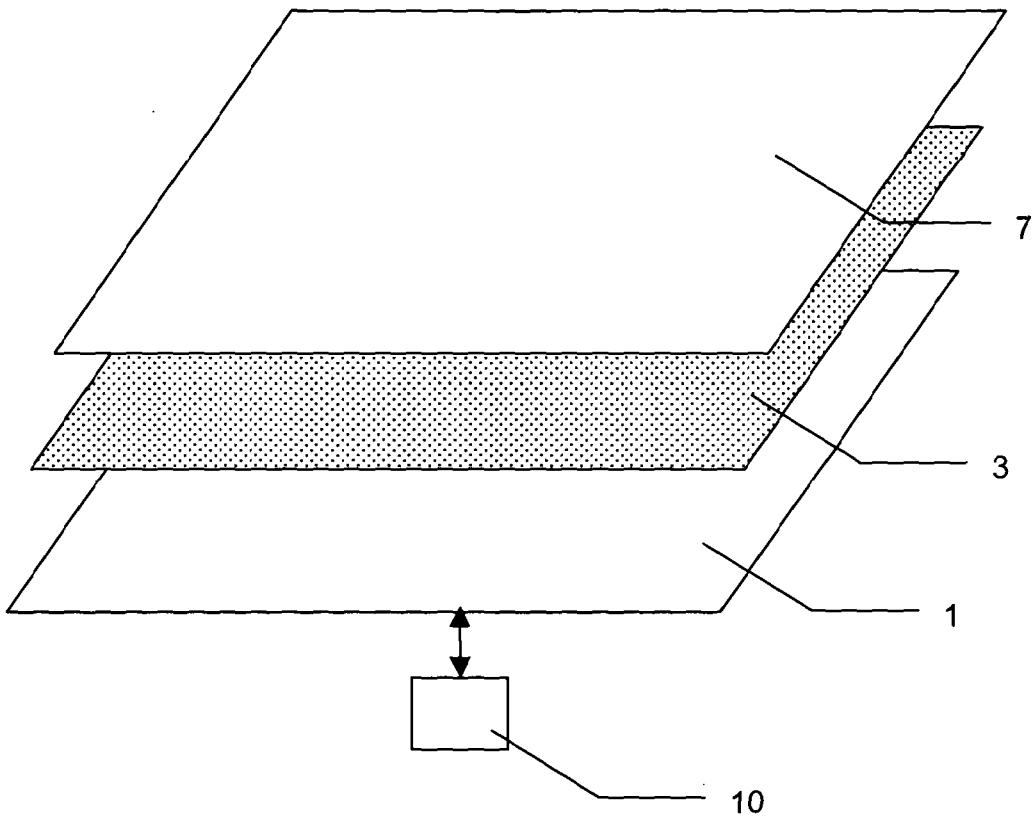


Fig. 3

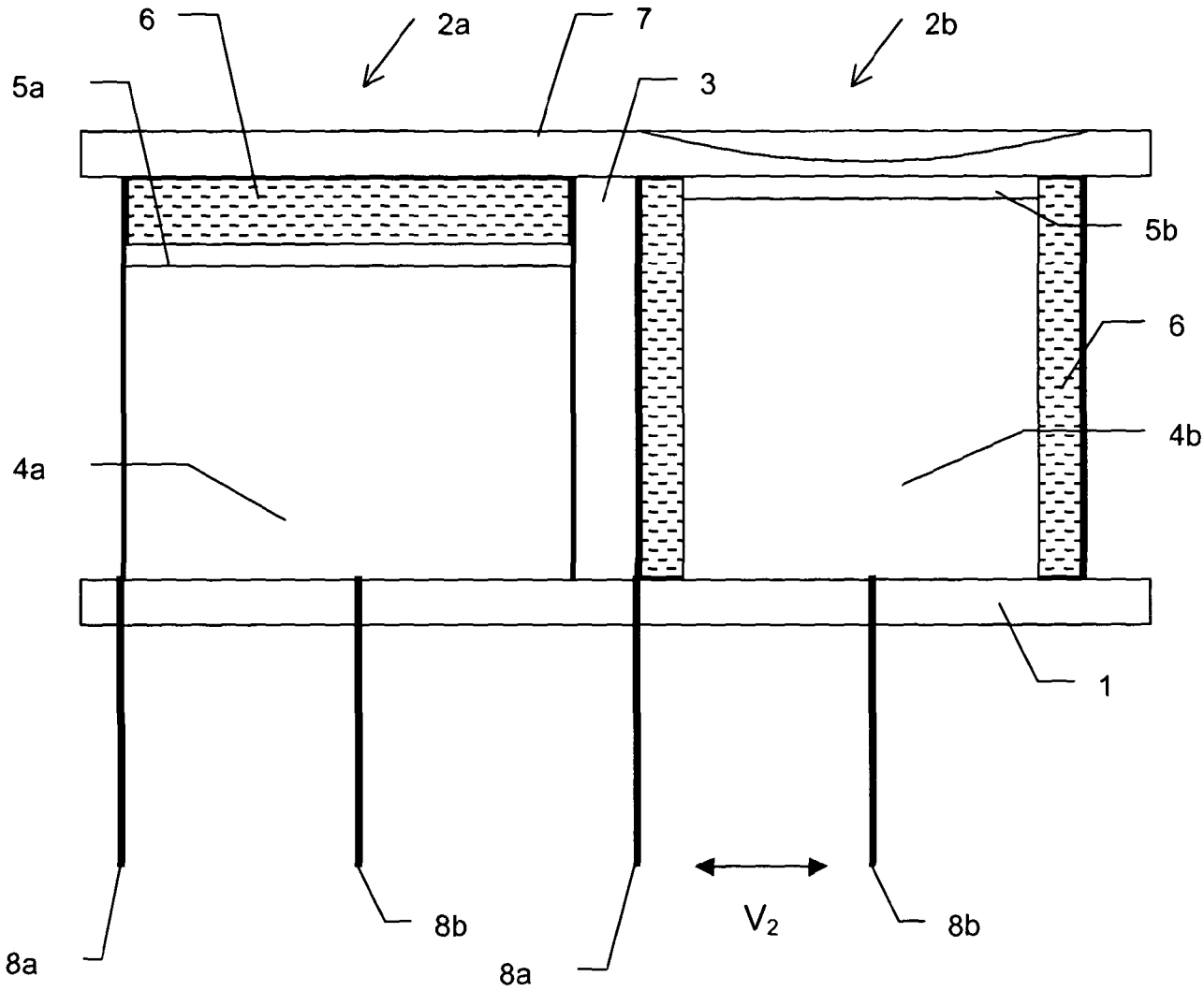


Fig. 4

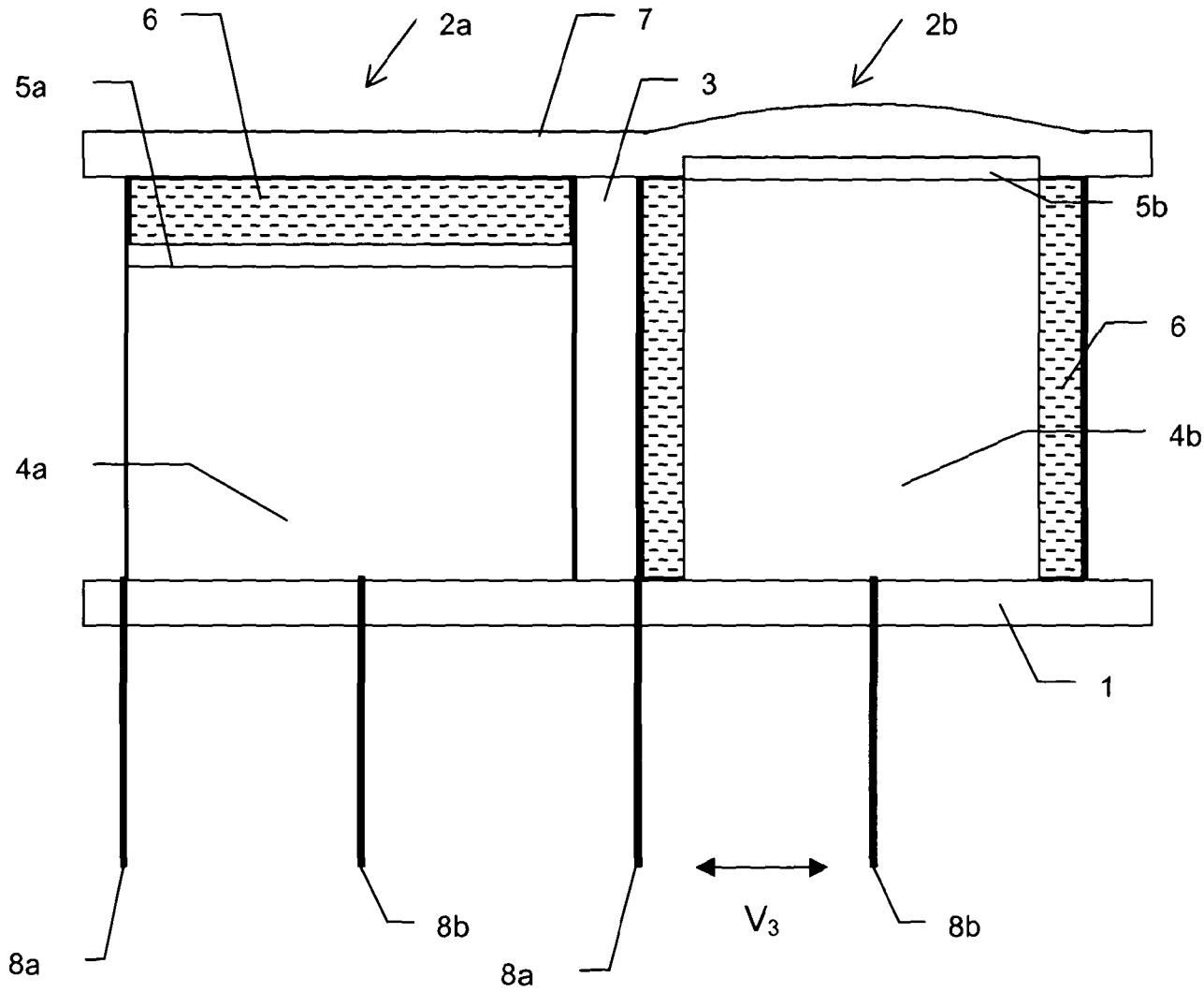
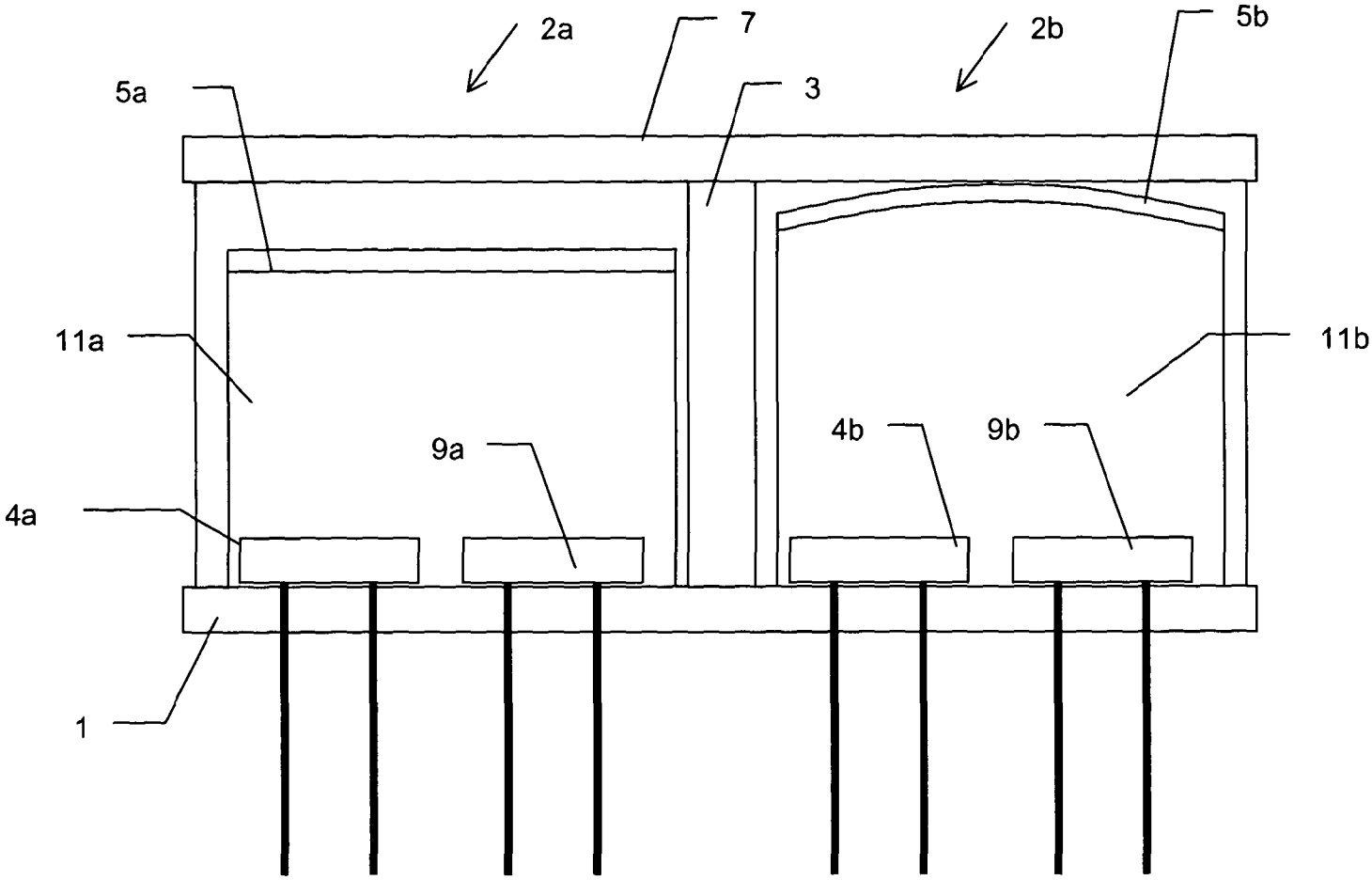


Fig. 5



# INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/000243

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B26/02 H03K17/96 G06F3/041
ADD.

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)
G02B H03K G06F

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, COMPENDEX, INSPEC, 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 1 199 696 A1 (NGK INSULATORS LTD [JP])<br>24 April 2002 (2002-04-24)<br>abstract<br>paragraph [0144] - paragraph [0145]<br>paragraphs [0094], [ 101]<br>figures 3,10 | 1-3,5,9,<br>11-13,15 |
| X | WO 2006/107174 A2 (DONGJIN SEMICHEM CO LTD [KR]; LEE CHUN-HYUK [KR])<br>12 October 2006 (2006-10-12)<br>abstract<br>paragraph [0057] - paragraph [0060] | 1-5,11,<br>15 |
| X | US 2004/179259 A1 (FUJII TAKAMICHI [JP] ET AL) 16 September 2004 (2004-09-16)<br>abstract<br>figure 5 | 1,2,15 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family 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 |
|---|---|
| 28 April 2011 | 26/07/2011 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Girardin, François |

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2011/000243

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-5, 9-13, 15

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/** 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5, 9-13, 15

   Electrically actuable display element (pixel) with a movable or deformable element which can be brought in contact with a substrate surface placed in front in order to change the state of the pixel.

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2. claims: 6-8

   Display element according to claim 1 having a flexible substrate such that the substrate surface is distorded depending on the pixel state, thereby providing a haptic display.

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3. claim: 14

   Display element comprising an electrically acutable element for switching the display state and being pressure sensitive to provide a touch-sensitive display.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2011/000243

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 1199696 A1 | 24-04-2002 | WO 0173730 A1 | 04-10-2001 |
| WO 2006107174 A2 | 12-10-2006 | CN 101288019 A | 15-10-2008 |
| | | EP 1877858 A2 | 16-01-2008 |
| | | JP 2008535033 A | 28-08-2008 |
| | | US 2008304129 A1 | 11-12-2008 |
| US 2004179259 A1 | 16-09-2004 | NONE | |