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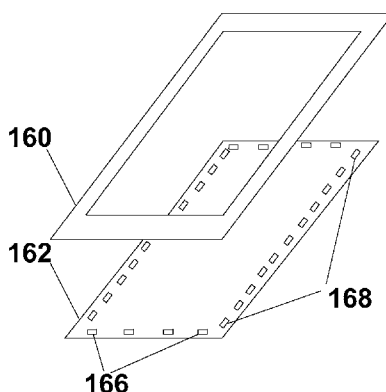


Fig. 16

(57) Abstract: An electro-optic display comprises, in order, a light-transmissive electrically-conductive layer; a layer of a solid electro-optic material; and a backplane (162) bearing a plurality of pixel electrodes, a peripheral portion of the backplane extending outwardly beyond the layer of solid electro-optic material and bearing a plurality of radiation generating means (166) and a plurality of radiation detecting means (168), the radiation generating means and radiation detecting means together being arranged to act as a touch screen.

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## **ELECTRO-OPTIC DISPLAYS WITH TOUCH SENSORS**

**[Para 1]** This application is related to:

- (a) U.S. Patents Nos. 6,473,072 and 6,738,050;
- (b) U.S. Patents Nos. 7,030,854; 7,312,784; and 7,705,824;
- (c) U.S. Patent No. 6,392,786;
- (d) U.S. Patent No. 7,110,164; and
- (e) U.S. Patents Nos. 6,473,072 and 6,738,050.

**[Para 2]** This application relates to electro-optic displays provided with touch sensors and/or tactile feedback. This invention is primarily directed to such electro-optic displays which use solid electro-optic media, as that term is defined below.

**[Para 3]** The background nomenclature and state of the art regarding electro-optic displays is discussed at length in U.S. Patent No. 7,012,600 to which the reader is referred for further information. Accordingly, this nomenclature and state of the art will be briefly summarized below.

**[Para 4]** The term "electro-optic", as applied to a material or a display, is used herein in its conventional meaning in the imaging art to refer to a material having first and second display states differing in at least one optical property, the material being changed from its first to its second display state by application of an electric field to the material. Although the optical property is typically color perceptible to the human eye, it may be another optical property, such as optical transmission, reflectance, luminescence or, in the case of displays intended for machine reading, pseudo-color in the sense of a change in reflectance of electromagnetic wavelengths outside the visible range.

**[Para 5]** The terms "bistable" and "bistability" are used herein in their conventional meaning in the art to refer to displays comprising display elements having first and second display states differing in at least one optical property, and such that after any given element has been driven, by means of an addressing pulse of finite duration, to assume either its first or second display state, after the addressing pulse has terminated, that state will persist for at least several times, for example at least four times, the minimum duration of the addressing pulse required to change the state of the display element.

**[Para 6]** Some electro-optic materials are solid in the sense that the materials have solid external surfaces, although the materials may, and often do, have internal liquid- or gas-filled spaces. Such displays using solid electro-optic materials may hereinafter for convenience be referred to as "solid electro-optic displays". Thus, the term "solid electro-optic displays"

includes rotating bichromal member displays, encapsulated electrophoretic displays, microcell electrophoretic displays and encapsulated liquid crystal displays.

**[Para 7]** Several types of electro-optic displays are known, for example:

(a) rotating bichromal member displays (see, for example, U.S. Patents Nos. 5,808,783; 5,777,782; 5,760,761; 6,054,071 6,055,091; 6,097,531; 6,128,124; 6,137,467; and 6,147,791);

(b) electrochromic displays (see, for example, O'Regan, B., et al., *Nature* 1991, 353, 737; Wood, D., *Information Display*, 18(3), 24 (March 2002); Bach, U., et al., *Adv. Mater.*, 2002, 14(11), 845; and U.S. Patents Nos. 6,301,038; 6,870,657; and 6,950,220);

(c) electro-wetting displays (see Hayes, R.A., et al., "Video-Speed Electronic Paper Based on Electrowetting", *Nature*, 425, 383-385 (25 September 2003) and U.S. Patent Publication No. 2005/0151709);

(d) particle-based electrophoretic displays, in which a plurality of charged particles move through a fluid under the influence of an electric field (see U.S. Patents Nos. 5,930,026; 5,961,804; 6,017,584; 6,067,185; 6,118,426; 6,120,588; 6,120,839; 6,124,851; 6,130,773; and 6,130,774; U.S. Patent Applications Publication Nos. 2002/0060321; 2002/0090980; 2003/0011560; 2003/0102858; 2003/0151702; 2003/0222315; 2004/0014265; 2004/0075634; 2004/0094422; 2004/0105036; 2005/0062714; and 2005/0270261; and International Applications Publication Nos. WO 00/38000; WO 00/36560; WO 00/67110; and WO 01/07961; and European Patents Nos. 1,099,207 B1; and 1,145,072 B1; and the other MIT and E Ink patents and applications discussed in the aforementioned U.S. Patent No. 7,012,600).

**[Para 8]** There are several different variants of electrophoretic media. Electrophoretic media can use liquid or gaseous fluids; for gaseous fluids see, for example, Kitamura, T., et al., "Electrical toner movement for electronic paper-like display", IDW Japan, 2001, Paper HCS1-1, and Yamaguchi, Y., et al., "Toner display using insulative particles charged triboelectrically", IDW Japan, 2001, Paper AMD4-4); U.S. Patent Publication No. 2005/0001810; European Patent Applications 1,462,847; 1,482,354; 1,484,635; 1,500,971; 1,501,194; 1,536,271; 1,542,067; 1,577,702; 1,577,703; and 1,598,694; and International Applications WO 2004/090626; WO 2004/079442; and WO 2004/001498. The media may be encapsulated, comprising numerous small capsules, each of which itself comprises an internal phase containing electrophoretically-mobile particles suspended in a liquid suspending medium, and a capsule wall surrounding the internal phase. Typically, the capsules are

themselves held within a polymeric binder to form a coherent layer positioned between two electrodes; see the aforementioned MIT and E Ink patents and applications. Alternatively, the walls surrounding the discrete microcapsules in an encapsulated electrophoretic medium may be replaced by a continuous phase, thus producing a so-called polymer-dispersed electrophoretic display, in which the electrophoretic medium comprises a plurality of discrete droplets of an electrophoretic fluid and a continuous phase of a polymeric material; see for example, U.S. Patent No. 6,866,760. For purposes of the present application, such polymer-dispersed electrophoretic media are regarded as sub-species of encapsulated electrophoretic media. Another variant is a so-called "microcell electrophoretic display" in which the charged particles and the fluid are retained within a plurality of cavities formed within a carrier medium, typically a polymeric film; see, for example, U.S. Patents Nos. 6,672,921 and 6,788,449.

**[Para 9]** An encapsulated electrophoretic display typically does not suffer from the clustering and settling failure mode of traditional electrophoretic devices and provides further advantages, such as the ability to print or coat the display on a wide variety of flexible and rigid substrates. (Use of the word "printing" is intended to include all forms of printing and coating, including, but without limitation: pre-metered coatings such as patch die coating, slot or extrusion coating, slide or cascade coating, curtain coating; roll coating such as knife over roll coating, forward and reverse roll coating; gravure coating; dip coating; spray coating; meniscus coating; spin coating; brush coating; air knife coating; silk screen printing processes; electrostatic printing processes; thermal printing processes; ink jet printing processes; and other similar techniques.) Thus, the resulting display can be flexible. Further, because the display medium can be printed (using a variety of methods), the display itself can be made inexpensively.

**[Para 10]** Although electrophoretic media are often opaque (since, for example, in many electrophoretic media, the particles substantially block transmission of visible light through the display) and operate in a reflective mode, many electrophoretic displays can be made to operate in a so-called "shutter mode" in which one display state is substantially opaque and one is light-transmissive. See, for example, the aforementioned U.S. Patents Nos. 6,130,774 and 6,172,798, and U.S. Patents Nos. 5,872,552; 6,144,361; 6,271,823; 6,225,971; and 6,184,856. Dielectrophoretic displays, which are similar to electrophoretic displays but rely upon variations in electric field strength, can operate in a similar mode; see U.S. Patent No. 4,418,346.

**[Para 11]** Other types of electro-optic media may also be useful in the present invention.

**[Para 12]** U.S. Patent No. 6,982,178 describes a method of assembling a solid electro-optic display (including an encapsulated electrophoretic display) which is well adapted for mass production. Essentially, this patent describes a so-called "front plane laminate" ("FPL") which comprises, in order, a light-transmissive electrically-conductive layer; a layer of a solid electro-optic medium in electrical contact with the electrically-conductive layer; an adhesive layer; and a release sheet. Typically, the light-transmissive electrically-conductive layer will be carried on a light-transmissive substrate, which is preferably flexible, in the sense that the substrate can be manually wrapped around a drum (say) 10 inches (254 mm) in diameter without permanent deformation. The term "light-transmissive" is used in this patent and herein to mean that the layer thus designated transmits sufficient light to enable an observer, looking through that layer, to observe the change in display states of the electro-optic medium, which will normally be viewed through the electrically-conductive layer and adjacent substrate (if present); in cases where the electro-optic medium displays a change in reflectivity at non-visible wavelengths, the term "light-transmissive" should of course be interpreted to refer to transmission of the relevant non-visible wavelengths. The substrate will typically be a polymeric film, and will normally have a thickness in the range of about 1 to about 25 mil (25 to 634  $\mu\text{m}$ ), preferably about 2 to about 10 mil (51 to 254  $\mu\text{m}$ ). The electrically-conductive layer is conveniently a thin metal or metal oxide layer of, for example, aluminum or ITO, or may be a conductive polymer. Poly(ethylene terephthalate) (PET) films coated with aluminum or ITO are available commercially, for example as "aluminized Mylar" ("Mylar" is a Registered Trade Mark) from E.I. du Pont de Nemours & Company, Wilmington DE, and such commercial materials may be used with good results in the front plane laminate.

**[Para 13]** Assembly of an electro-optic display using such a front plane laminate may be effected by removing the release sheet from the front plane laminate and contacting the adhesive layer with the backplane under conditions effective to cause the adhesive layer to adhere to the backplane, thereby securing the adhesive layer, layer of electro-optic medium and electrically-conductive layer to the backplane. This process is well-adapted to mass production since the front plane laminate may be mass produced, typically using roll-to-roll coating techniques, and then cut into pieces of any size needed for use with specific backplanes.

**[Para 14]** It is known (see the patents and application mentioned above) to provide electro-optic displays with touch screens. Many display applications benefit from touch sensitivity. In many cases, touch sensitivity in a limited number of fixed areas can be used for elements of the user interface. Alternatively, applications such as drawing, underlining, or complex and changeable user interfaces benefit from a full touch screen. Touch sensing capabilities also offer the possibility of producing an electronic paper-like display which mimics not only the readability but also the writeability of conventional paper. The ability to detect, at frequent intervals, the position of a finger or stylus on a display screen, enables a display to use the position information to effect selection of menu items or to capture handwriting as “digital ink”.

**[Para 15]** Although touch sensing is not strictly a display function, the touch sensor is typically considered part of the display because it must be co-located with the display (either above or below the display surface). Unfortunately, most touch screen technologies are not suitable for use with portable products using electrophoretic displays. Of the types of touch screen which are inexpensive, compact, and sufficiently low in power demand to address such displays, many require multiple layers and/or interfaces to be stacked on top of the display medium. Since electrophoretic displays are reflective, optical performance is reduced by each additional layer and interface interposed between the electro-optic layer and the user. Many types of touch screen also add excessive thickness to the display stack, and require multiple additional processing steps to form the complete display panel.

**[Para 16]** Inductive touch screens can be placed behind the backplane layer (i.e., on the opposed side of the backplane to both the user and the electro-optic medium), and thus do not affect optical performance. Such inductive touch screens also add minimal thickness, but they are expensive and require use of a special stylus.

**[Para 17]** Surface capacitive touch screens are a promising avenue for use with electro-optic displays. This type of touch screen is typically laminated or positioned over the front of a finished display. As shown in Figure 1A of the accompanying drawings, a typical form of such a touch screen has a substrate 1, typically formed of poly(ethylene terephthalate) (PET) having a thickness in the range of about 50 to about 250  $\mu\text{m}$ . A light-transmissive, electrically-conductive layer 2 is formed on the surface of the substrate 1. The layer 2 may be formed of indium tin oxide (ITO) or any other light-transmissive electrical conductor, for example PEDOT, carbon nanotubes or other inorganic conductors. The touch screen actually works better if the resistance of the layer 2 is not too low, a preferred range being about 1 to 5

Kohm/square, a range which can be achieved by ITO or various polymeric conductors. A low sheet resistance material 3 (typically screen printed silver ink) is formed and patterned in contact with the conductive layer 2. As discussed below, the various parts of the material 3 serve several functions.

**[Para 18]** As illustrated in Figure 1B, the material 3 includes corner electrodes 4 that make good electrical contact with the corners of the layer 2 and which are in electrical contact with a touch screen controller (not shown) via connector points 6. The corner electrodes 4 are the primary points the controller uses to inject measurement signals and sense changes in capacitance in order to detect touches on the screen. The material 3 also provides a linearization pattern 5, which selectively shorts out sections at the edges of the sheet conductor and causes the electrical field distribution to spread out over the screen more linearly than it otherwise would. Without the pattern 5, the electrical field would be subject to severe pincushion distortion and it would be difficult to implement a useful touch sensor. The connector points 6 are, as already noted, used to form connections from the touch screen to the controller; usually, these connections are provided in the form of a small flexible circuit tail ACF or conductive adhesive bonded to the connector points 6. Finally, the material 3 forms a proximity sensing electrode 7, which is needed in small surface capacitance screen to detect when a user approaches the screen. The proximity sensing electrode 7 can be a ring electrode encircling the screen, as illustrated in Figure 1B, or may be formed as a separate layer (for example, an aluminized polymeric film in the form of a die cut ring) laminated to the peripheral portion of the screen to reduce the footprint of the touch sensor features at the edge of the display.

**[Para 19]** In one aspect, this invention provides several methods for integrating capacitive touch sensors into a front plane laminate to produce a single film ready for assembly into a display. Electrophoretic and other bistable electro-optic media allow tighter integration of touch screens than is possible in liquid crystal displays because the bistable nature of the electro-optic medium potentially allows multiplexing of various electrode structures within the display between driving the display and sensing user input. This is not possible in liquid crystal displays; since such displays need to be driven continuously, no opportunity exists for using any display structures for touch sensing.

**[Para 20]** Another aspect of the present invention provides a display provided with a proximity sensing device which detects when a user is in close proximity to the display or, more specifically, to the screen thereof.

**[Para 21]** A third aspect of the present invention relates to incorporation of resistive touch sensors into electro-optic displays.

**[Para 22]** A fourth aspect of the present invention relates to integration of a display and a key input device in an electro-optic display.

**[Para 23]** More specifically, in one aspect this invention provides an electro-optic display comprising, in order:

- a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;

- a layer of a solid electro-optic material; and

- a backplane bearing a plurality of pixel electrodes,

the electro-optic display further comprising means for controlling the potential of the plurality of conductive members, such that the plurality of conductive members and the light-transmissive electrically-conductive layer can serve as a touch screen.

**[Para 24]** In another aspect, this invention provides an article of manufacture (a front plane laminate) comprising, in order:

- a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;

- a layer of a solid electro-optic material;

- a layer of a lamination adhesive; and

- a release sheet.

**[Para 25]** In another aspect, this invention provides an electro-optic display comprising, in order:

- a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;

- a light-transmissive electrically insulating layer;

- a light-transmissive electrically-conductive layer;

- a layer of a solid electro-optic material; and

- a backplane bearing a plurality of pixel electrodes,

the electro-optic display further comprising means for controlling the potential of the plurality of conductive members, such that the plurality of conductive members and the light-transmissive electrically-conductive layer can serve as a touch screen.

**[Para 26]** In another aspect, this invention provides an article of manufacture (a front plane laminate) comprising, in order:

- a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;

- a light-transmissive electrically insulating layer;

- a light-transmissive electrically-conductive layer;

- a layer of a solid electro-optic material; and

- a layer of a lamination adhesive; and

- a release sheet.

**[Para 27]** In another aspect, this invention provides an electro-optic display comprising, in order:

- a light-transmissive electrically-conductive layer;

- a layer of a solid electro-optic material;

- a backplane bearing a plurality of pixel electrodes; and

first and second electrically conductive layers spaced apart from another but capable of being deformed towards one another, the first and second electrically conductive layers forming a touch screen.

**[Para 28]** In another aspect, this invention provides an electro-optic display comprising, in order:

- a light-transmissive electrically-conductive layer;

- a layer of a solid electro-optic material; and

- a backplane bearing a plurality of pixel electrodes, a peripheral portion of the backplane extending outwardly beyond the layer of solid electro-optic material, the peripheral portion of the backplane bearing a plurality of radiation generating means and a plurality of radiation detecting means, the plurality of radiation generating means and plurality of radiation detecting means together being arranged to act as a touch screen.

**[Para 29]** As already mentioned, Figure 1A is a schematic cross-section through a prior art touch screen.

**[Para 30]** Figure 1B is a schematic top plan view of the touch screen shown in Figure 1A.

**[Para 31]** Figure 2 is a schematic cross-section through a first electro-optic display of the present invention having a touch screen incorporated into the front electrode of the display.

**[Para 32]** Figure 3 is a schematic cross-section through a modified form of the first electro-optic display shown in Figure 2.

**[Para 33]** Figure 4 is a schematic cross-section through a second electro-optic display of the present invention having a front touch screen spaced from the front electrode of the display.

**[Para 34]** Figure 5 is a schematic cross-section through a modified form of the second electro-optic display shown in Figure 4.

**[Para 35]** Figures 6 and 7 are schematic cross-sections through two different electro-optic displays of the present invention having front resistive touch screens.

**[Para 36]** Figure 8 is an exploded view of a display of the present invention having an array of switches that are operated by physical deformation of the display under pressure.

**[Para 37]** Figure 9 shows the appearance of the display shown in Figure 8 when it is running a cellular telephone program.

**[Para 38]** Figure 10 shows the arrangement of bus lines in a non-rectangular display of the present invention.

**[Para 39]** Figures 11 and 12 show the arrangement of bus lines in displays of the present invention provided with cut-outs to accommodate various display components.

**[Para 40]** Figure 13 shows the appearance of a display of the present invention running a program in which large buttons extend over multiple pixels of the display.

**[Para 41]** Figure 14 is a schematic cross-section through a display of the present invention provided with a rear resistive touch screen.

**[Para 42]** Figure 15 is an exploded view of a prior art display using an optical touch screen.

**[Para 43]** Figure 16 is an exploded view, similar to that of Figure 15, of an optical touch screen of the present invention.

**[Para 44]** As indicated above, in one aspect the present invention provides several methods for integrating capacitive touch sensors into a front plane laminate to produce a single film ready for assembly into a display.

**[Para 45]** As illustrated in Figure 2, the most straightforward way to effect such integration is to make a single conductive layer 21 serve as both the conductive layer of the touch screen and the top electrode of the display. In the structure of Figure 2, a front substrate 22, which serves as both the substrate of the touch screen and the front substrate of the display, faces a

viewer 24. The low sheet resistance material 23 (similar to the material 3 in Figures 1A and 1B) lies adjacent an electro-optic layer (illustrated as a microencapsulated electrophoretic layer 25) provided with pixel electrodes 26 on a backplane 27. (Although not shown in Figure 2, there is normally a layer of lamination adhesive between the electro-optic layer 25 and the pixel electrodes 26; there may also be a second layer of lamination adhesive between the electro-optic layer 25 and the conductive layer 21.) The backplane may be of a direct drive or active matrix type, and may be rigid or flexible. Connections to the conductive layer 21 and the material 23 are effected by edge connections using conductive adhesive, as illustrated at 28, although it should be noted that instead of the single connection to the front electrode normally needed in prior art displays, the device illustrated in Figure 2 needs five independent connections, one to the front electrode and four to the touch sensor, as described above with reference to Figures 1A and 1B.

**[Para 46]** The display illustrated in Figure 2 can be produced by only minor modification of the process for constructing an electrophoretic display using a front plane laminate, as described in the aforementioned U.S. Patent No. 6,982,178. As previously described, the prior art FPL process involves coating an ITO/PET film (available commercially) on its ITO surface with the electrophoretic medium. Separately, a lamination adhesive is coated on to a release sheet, and the resulting sub-assembly is laminated to the electrophoretic medium, with the lamination adhesive in contact with the electrophoretic medium, to form a finished FPL. Removal of the release sheet and lamination of the remaining layers to a backplane bearing pixel electrodes completes the display. To produce the display illustrated in Figure 2, a closely similar process may be used, except that the low sheet resistance material 23 is printed on to the ITO surface of the ITO/PET film before the electrophoretic medium is coated thereon. The present invention extends to such a modified front plane laminate.

**[Para 47]** Alternatively, the display shown in Figure 2 can be produced using an inverted front plane laminate as described in U.S. Patent Application Publication No. 2007/0109219 and/or a double release film as described in U. S. Patent No. 7,561,324. A double release film of the appropriate time essentially comprises an electro-optic layer sandwiched between two layers of lamination adhesive, with at least one, and preferably both, of the surfaces of the lamination adhesive layers remote from the electro-optic layer being covered by release sheets. To produce a display as shown in Figure 2 using such a double release film, first modifies the ITO/PET (or similar) film to provide the low sheet resistance material 23 thereon. Next, one of the two release sheets is peeled from the double release film, and the

surface of the lamination adhesive thus exposed is laminated (typically under heat and pressure) to the low sheet resistance material 23 and the conductive layer 21, thus forming an inverted front plane laminate. The remaining release sheet is then peeled from the sub-assembly so produced, and the surface of the lamination adhesive thus exposed is laminated (typically under heat and pressure) to the pixel electrodes 26 on the backplane 27 to produce the final display. This second lamination can also form the connection 28. The order of the two laminations can be reversed if desired, although the order just described is generally the most convenient for large scale production.

**[Para 48]** The use of a double release film in this manner reduces the difficulty and/or inconvenience of coating an electrophoretic medium on to the heterogeneous surface formed by printing the low sheet resistance material 23 on to the ITO surface of the ITO/PET film, since laminating an adhesive layer on the heterogeneous surface is typically easier than coating an electrophoretic medium thereon. Also, the double release film/inverted front plane laminate process provides alternative ways of effecting electrical connections between the front electrode 21 and the backplane 27. If a sufficiently low resistivity conductive pathway could be formed around the entire edge of the active display area, the touch sensor could alternatively be formed in the backplane as part of the pixel electrode layer 10.

**[Para 49]** Figure 3 illustrates a touch screen display of the present invention closely resembling that of Figure 2 but including a color filter array 29. This color filter array is formed on the front substrate 21 and then overcoated with a clear electrically conductive layer 22. As in the display shown in Figure 2, the only additional step needed in the display manufacturing process is printing the low sheet resistance material 23 on to the electrically conductive layer 22. It will be appreciated that the display shown in Figure 3 can be produced using a double release film/inverted front plane laminate process exactly analogous to that already described with reference to Figure 2.

**[Para 50]** Figure 3 also illustrates an alternative method of establishing electrical connections to the low sheet resistance material 23 and to the electrically conductive layer 22. Instead of the edge connections shown in Figure 2, the display of Figure 3 uses a flexible circuit tail 30 bonded or adhered to the connection pads 6 (see Figure 1B) of the touch screen. The flexible circuit tail 30 connects to the touch screen controller independently from the backplane (although it could alternatively terminate on the backplane itself, and thence be connected to the controller). The circuit tail 30 thus eliminates the need for a separate

connection between the front electrode of the display and the backplane, thus potentially simplifying display construction.

**[Para 51]** The displays shown in Figures 2 and 3 add touch screen functionality to the display with very little additional cost and no impact to optical performance or thickness. The size of the peripheral region between the active area and the physical edge of the display is, however, increased. In both displays, the sensing and display driving phases are distinct in time. During display driving, a common driver circuit would have priority and would be connected to the front electrode, possibly through the touch screen components. When display driving is completed, the common driver circuit can be disabled or disconnected and the touch screen controller connected to the display. Some provision, using analog or transistor switches, will be required to isolate each of the two parts of the circuit when they are not active.

**[Para 52]** In displays such as those illustrated in Figures 2 and 3, where the same front electrode serves as both a driving and a sensing electrode, one potential issue is perturbation of the electro-optic layer by the sensing signals on the top electrode during the touch sensing phase of operation. Sensing signal levels are typically in the 2-3 V range at the corners, which is enough to cause problems in electrophoretic electro-optic layers, either by partial driving or by more subtle degradations of image stability. There are several ways to minimize or eliminate this problem.

**[Para 53]** Sensing signal frequencies are typically of the order of 10 kHz range, and may thus be high enough not to affect many electro-optic media. It may also be advantageous to have the sensing signal centered around 0 V, so that it is DC balanced. This could be done by changing the output stage of the touch sensor controller, dereferencing the ground of the controller, or by AC coupling the signals through relatively large capacitors between the controller and the panel electrodes.

**[Para 54]** Another approach is to allow the pixel electrodes to float (i.e., not apply any driving voltage) during the sensing phase. In an active matrix display, this can be done by keeping one rail of the gate drivers on during the sensing phase, thus keeping the transistors non-conductive and allowing the pixels to float individually, and limiting the electric field experienced by the electro-optic layer. Alternatively, the source lines of the array (or the drive lines in a direct drive case display) can be driven with the sensing waveform with the gate drivers all turned on, but implementation of this approach poses practical difficulties.

**[Para 55]** If the difficulties posed by electrical interference between display driving and touch sensing are deemed too great, or if concurrent or overlapping display driving and touch sensing are necessary to allow for rapid response, as for example in a drawing operation or during fast typing of text input with rapid updating of the display, other forms of integration of a touch sensor into an electro-optic display may be used.

**[Para 56]** Figure 4 illustrates one form of such integration, in which the touch screen components are placed on the opposite side of the front substrate from the electro-optic layer, thus separating the sheet conductor 22 of the touch screen from the front electrode of the display. This allows the touch screen sheet conductor can use a material to higher sheet resistance than is desirable for the front electrode of a display, so that the touch screen sheet conductor can be formed of an inexpensive, highly light-transmissive material such as very thin ITO or a conductive polymer. Such a conductive polymer may, in some cases, be applied inexpensively, prior to coating of the electro-optic medium, on to the non-ITO-coated surface of the ITO/PET film in roll form used to prepare front plane laminates, as discussed above, without significant reduction in the light transmission by the film. After a front plane laminate prepared in this manner has been severed into pieces required for a particular size of display, the layer 23 required for the touch screen can be applied.

**[Para 57]** Figure 4 illustrates the connections to the touch screen being made via a flexible circuit tale 30, which connects to both the touch screen and the front electrode, thus eliminating the need for a separate connection from the front electrode to the backplane. Alternatively, multilayer screen printing techniques with vias could be used to provide connections between the touch screen and the backplane.

**[Para 58]** Figure 4 also illustrates a protective sheet 31 which is typically laminated on top of the front substrate using optically clear adhesive (not shown). The protective sheet 31 is designed to give the display the mechanical durability required for its intended use, and can incorporate ultra violet barriers and diffuse reflective hard coats to provide an attractive and durable front surface on the display. In the display of Figure 4, the protective sheet also serves to encapsulate and protect the touch screen layers.

**[Para 59]** The display shown in Figure 4 can be produced using a modified front plane laminate or a modified double release film/inverted FPL process exactly analogous to those previously described in connection with the display of Figure 2. To produce the display of Figure 2, the substrate used to produce the front plane laminate, or the substrate to which the double release film is laminated, may be modified to provide the front electrically-conductive

layer 22 and the low sheet resistance material 23 thereon. The protective sheet 31 may also be attached to the substrate at this point, but is typically more conveniently attached at a later stage in the production process.

**[Para 60]** An alternative to the structure shown in Figure 4 uses a multilayer conductive coating with intervening dielectric layers on one side of the front substrate 21; within this multilayer conductive coating, a conductive layer closer to the viewing surface of the display can be used as part of the touch screen, while a conductive layer closer to the electro-optic medium would serve as the front electrode of the display. Even a thin dielectric layer interposed between these two conductive layers would block direct current transmission and, at least to some extent, isolate the display driving and touch sensing electrical signals from one another.

**[Para 61]** Finally, Figure 5 illustrates a modification of the display of Figure 4 in which the layer 23 of the touch screen is disposed on the inward surface of the protective sheet 31. In such a display, it will typically be advantageous for the front electrode to connect to the backplane via an edge connector 28, while the touch screen connections pass through a flexible tail 30. Note that the display of Figure 5 can be produced by modifying only the protective sheet used in the display, and thus may provide a relatively easy path to retrofit an existing design of electro-optic display with a touch sensor when desired.

**[Para 62]** As already mentioned, a second aspect of the present invention relates to a display provided with a proximity sensing device which detects when a user is in close proximity to the display or, more specifically, to the screen thereof. When a surface capacitive touch sensor is used with a small to medium format display, a proximity sensor is typically needed to determine when the user approaches the display screen and to provide a common mode signal to assist in filtering of the signals from the four corner sensors which, as described above with reference to Figure 1B, form part of the touch screen. Also, if a battery-driven display uses a bistable electro-optic medium, it is desirable, in order to extend battery life, to shut down power to most parts of the display when the user is not interacting with the display and the display is not being rewritten. A method to detect an approaching user is thus a useful input.

**[Para 63]** As indicated above in the discussion of the display shown in Figures 1A and 1B, a proximity sensing electrode is a standard feature of most surface capacitive touch screens. This second aspect of the present invention relates to methods for providing proximity sensing as part of the backplane of an electro-optic display, or making use of existing

backplane features to provide this capacity, together with ways for using proximity sensing in a portable display system using a bistable electro-optic medium. Using a backplane feature to provide proximity sensing in combination with a touch screen provided on the front plane of the display can lead to a smaller border size for the touch screen, and potentially a lower construction cost. (The term “front plane” of a display is used herein in its conventional meaning in the art to refer to the electro-optic layer and all layers of the display between the electro-optic layer and the viewing surface.)

**[Para 64]** Many electro-optic displays include a border or peripheral electrode, a directly driven electrode positioned around the active area of the display and usually 1 to 3 mm in width. This border electrode serves as a single pixel which ensures that the entire edge of the display is in the same optical state. Without such a border pixel, the address lines extending across the peripheral portion of the display can capacitively switch the electro-optic material above them, producing distracting visual effects. The border electrode also provides some tolerance in positioning the display screen relative to a bezel of a housing.

**[Para 65]** In a display using a bistable electro-optic medium, the border electrode can be used, by time division multiplexing, both to address the overlying peripheral portion of the electro-optic medium and as a proximity sensing device. Switches, either analog or field effect transistor, could be used to isolate the circuits for these two functions from one another, or it may be possible to design the relevant circuits so that they do not interfere with one another.

**[Para 66]** Alternatively, dedicated electrodes for the proximity sensor could be provided on backplane. Although such dedicated electrodes might increase the optically inactive areas at the periphery of the backplane, including such dedicated electrodes would be inexpensive since there are already multiple patterned conductor layers on commercial backplanes.

**[Para 67]** The foregoing proposals assume that a touch screen is built into the front plane of the display. If only proximity sensing is desired and not touch screen capability, the front electrode of the display can be time division multiplexed between driving the display and sensing proximity. Figure 1B and the related description above describe this approach to providing both proximity sensing and touch screen capabilities, but if only proximity detection is desired, no additional physical features are needed in the display beyond those inherently present; in other words, additional circuitry on the display controller can provide any electro-optic display with proximity sensing capability when the electro-optic medium is not being driven.

**[Para 68]** Proximity sensing has uses in bistable displays other than those for which such sensing is employed in non-bistable displays. It is desirable that a battery-driven portable bistable display device shut down power to most of the internal systems (i.e., enter a deep sleep mode) when the image on the display is static and there is other device activity. However there is often a significant latency time associated with waking up from a deep sleep mode, especially when powering up a display controller and charging bias supplies is required. Using any of the above techniques, the device use proximity sensing to detect a user approaching and begin the wakeup process expecting that the user will soon wish to interact with the device. Another use could be to refresh an image long present on a screen, and hence somewhat faded, as a user approaches.

**[Para 69]** Such a sensor could also form a one bit input device for device's user interface; for instance a prompt could say "tap screen to accept", or in an electronic book reader tapping the screen could advance the page. Many display device designs provide two separate connections to the common front electrode, and appropriate control circuits can use the two separate connections as a rudimentary differential proximity sensor. Such a sensor could be used so that, for example, a tap on one side of the screen advances a page and on the other side moves back a page.

**[Para 70]** As already noted, a third aspect of the present invention relates to incorporation of resistive touch sensors into electro-optic displays. In a conventional resistive touch sensor, two continuous conductive films are separated by an air gap; the spacing between the conductive films is maintained by mechanical spacers placed between them. One film (typically called the "bottom film") is placed on a rigid support, while the other ("top") film is on a deformable substrate. Voltages are applied to the bottom film by means of electrodes along its edges, creating a voltage gradient across the film. When the top film is physically deformed by applied pressure, it comes into contact with the bottom film, creating an electrical circuit between the two layers. By detecting the voltages on the top film by means of electrodes placed at the edges of the top film, the location of the contact in the x and y dimensions can be determined. More elaborate arrangements of electrodes can improve the accuracy of the sensing, especially for larger panels. In some cases, it may even be possible to measure the force of the touch, to the degree that it affects the size of the contact area between the films.

**[Para 71]** Resistive touch screens have several key advantages over other competing technologies, including low cost, robustness, and sensitivity to any kind of mechanical touch

(some other touch sensors only respond to a special stylus, or a human finger). One major disadvantage, however, is the loss in brightness and contrast of the display, as in a reflective display the presence of a resistive touch sensor requires that light reflected from the electro-optic medium make two passes through two additional films. Other disadvantages are the thickness and weight added by the resistive touch system, in which the rigid support must be rigid enough not to deflect when pressure is applied to the front film. This is especially important in liquid crystal displays, the optical properties of which are markedly affected by pressure.

**[Para 72]** It has been found that, in an electro-optic display, the rigid support of prior art resistive touch sensors can be replaced by a thin and possibly flexible polymeric film, with the rigidity necessary for the operation of the touch sensor being provided by a rigid display backplane underlying this thin polymeric film.

**[Para 73]** An electro-optic display of the present invention having this type of resistive touch sensor is illustrated in schematic cross-section in Figure 6 of the accompanying drawings. This display comprises (in order from the backplane to the viewing surface), a rigid substrate 40, a thin film transistor active matrix backplane 42, a layer 44 of a solid electro-optic medium (illustrated as an encapsulated electrophoretic medium), a front electrode 46, a transparent substrate 48, a transparent conductive layer 50, which acts as the bottom film of the resistive touch sensor, an air gap 52 defined by spacers 54, a transparent conductive layer 56, which acts as the top film of the resistive touch sensor, and an optically transparent flexible substrate or protective layer 58, which serves to prevent mechanical damage to both the resistive touch sensor and the electro-optic medium.

**[Para 74]** A further electro-optic display having a resistive touch sensor is illustrated in Figure 7 of the accompanying drawings. The display of Figure 7 may be regarded as a modification of that shown in Figure 6, the single transparent substrate 48 shown in Figure 6 being replaced by two such substrates 48A and 48B adhered to each other by a thin, optically clear adhesive layer 60. It will be seen from Figure 7 that each of the substrates 48A and 48B bears only a single transparent conductive layer, thus avoiding the need for providing transparent conductive layers on both sides of a single sheet.

**[Para 75]** The displays shown in Figures 6 and 7 can readily be produced using a modified form of the front plane laminate described above with reference to U.S. Patent No. 6,982,178, in which the front substrate of the front plane laminate is modified to include a second light-transmissive electrically-conductive layer on the opposed side of the front substrate from the

release sheet. To produce the electro-optic display of Figure 7, the modified front substrate may be produced by adhesively securing together two separate substrates each provided with one light-transmissive electrically-conductive layer. The second light-transmissive electrically-conductive layer may optionally be patterned, by screen printing or other process, to provide features needed for its eventual role as the bottom film of the resistive touch sensor. This conductive layer may also be provided with an array of mechanical spacers which will form the spacers 54 in the final display.

**[Para 76]** The displays shown in Figures 6 and 7 can also be modified to use a somewhat flexible backplane, one that can be curved with a large radius of curvature, but still provides enough resistance to mechanical deformation to allow proper operation of the resistive touch sensor. Such a backplane may be based upon a thin metallic foil, as described for example in U.S. Patent No. 6,825,068 and Publication No. 2004/0180476.

**[Para 77]** The displays with resistive touch sensors provided by this aspect of the present invention possess cost advantages since they remove one or more of the components and manufacturing steps necessary to incorporate a conventional resistive touch sensor into an electro-optic display, and also possess improved optical performance since elimination of one or more of the layers of a conventional resistive touch sensor improves the optical transparency of the display and decreases the haze thereof, thus improving the dark state of the display. Finally, the displays of the present invention offer reduced thickness and weight of the display by removing the need for the conventional thick heavy bottom substrate.

**[Para 78]** As already mentioned, a fourth aspect of the present invention relates to integration of a display and a key input device in an electro-optic display. It has long been realized that the type of dedicated, permanently marked keyboard traditionally used in desktop and laptop computers is, by virtue of its size, weight and permanent markings, disadvantageous for use in small portable electronic devices. Accordingly, many electronic devices are now available in which a key-based input function is integrated into the display. For example, Apple's iPhone (Registered Trade Mark) eliminates the traditional keypad in favor of a liquid crystal display equipped with a resistive touch screen. Phone numbers, text messages and other data are entered by contacting an area of the screen delineated by a portion of an image, and interpreted by software.

**[Para 79]** This kind of "soft" or "virtual" keyboard offers distinct advantages over a traditional keypad, in that the indicia on and/or the locations of the virtual keys can be easily changed by software, this allowing the device to transform the function of the various keys

depending on factors such as the local language (different character sets), vision of the user (large text), or the application being used (for example, letters for text entry, numbers for dialing, and special sets of glyphs for particular programs, as for instance when audio or video programs mimic the glyphs conventionally used on dedicated audio or video equipment). In addition, since in conventional cellular telephones and similar portable electronic devices, the display and the keypad each take up about one-half of the usable surface area of the device, elimination of the dedicated keypad in favor of a virtual keyboard enables one to roughly double display size without increasing the overall size of the device.

**[Para 80]** However, many users complain of the lack of tactile feedback from virtual keyboards. If a user is trying to dial a telephone number while accomplishing another task, such as driving, the flat surface of the display does not offer any clue, other than visual, as to the locations of the keys, or any tactile or audible feedback to indicate when a key has been pressed. This makes it more difficult to dial a telephone number quickly and accurately on a featureless touch screen, and similar difficulties are encountered with other types of input sequences. It is almost impossible to touch type on a virtual keyboard without tactile feedback.

**[Para 81]** U.S. Patent Application Publication No. US 2003/0058223 describes a deformable display that is placed over an array of membrane switch “popples”. Mechanical pressure on the display surface is transmitted through the display to activate the underlying switches, which exhibit a nonlinear force profile as they are deformed (a “click”) However, the specific embodiments describe only a keypad equipped with a segmented display capable of displaying a limited set of key labels by direct drive of electrodes.

**[Para 82]** The present invention provides an electro-optic display comprising an active matrix display overlying an array of switches (keys) that are operated by physical deformation of the display under pressure. The active matrix display displays not only indicia for the keys by also all other data required to be displayed by the application being run, and thus serves as the main screen of the electro-optic display.

**[Para 83]** Figure 8 of the accompanying drawings is an exploded view of one embodiment of such a display. As seen in that Figure, the display comprises a rear substrate 80 provided with an array of pressure-sensitive switches 82. Overlying the rear substrate is a flexible membrane 84 having raised areas 86 aligned with the switches 82. The next, optional, layer of the display comprises an array of square keys 88 which assist in ensuring that pressure on any area of the display is transmitted to the closest switch 86. Overlying the keys 88 is a

flexible TFT array 90, a front plane 92 (comprising an adhesive layer, electro-optic layer and front electrode layer, none of which are shown separately in Figure 8) and an (optional) protective sheet 94.

**[Para 84]** Figure 9 shows the appearance of the display shown in Figure 8 when it is running a cellular telephone program. A U-shaped area extending around the side edges and the top edge of the display shows the digit 0-9. The central portion of the display shows a list of memorized telephone numbers. The lower portion of the display shows icons for dialing a highlighted telephone number from the list and for other functions common to cellular telephones.

**[Para 85]** Typically, the display itself would comprise a rectilinear array of pixels, each connected to a data bus line by an individual thin film transistor (TFT), controlled by a gate bus line. The TFT array should be constructed on a material that can deform under pressure to activate the underlying keys, for example, PET, polyimide, PEN, or a thin metal substrate, e.g. stainless steel foil.

**[Para 86]** Prior art TFT arrays are typically square or rectangular since this form of array has the advantage of allowing the display area to be addressed with as few bus lines as possible. However, it may be desirable for design reasons to create a display that includes cut-outs for a microphone or speaker, rounded edges, or other non-rectangular designs. Accordingly, the present invention extends to displays in which the pixel array is non-rectangular and/or includes interior holes. Figure 10 illustrates a non-rectangular display, in which data lines 100 are successively dropped as the width of the display decreases upwardly (as illustrated), while the lengths of the gate bus lines 102 are successively decreased to match the decreasing width. Figures 11 and 12 show two examples of displays with through-holes 110. In Figure 11 source lines 112 are routed around the hole 110 to activate non-contiguous sections of the same column, and separate gate lines are provided for the left and right sides of the display where the gate lines are divided by the hole 110. Similarly, in Figure 12 gate lines 114 are routed around the hole 110 to activate non-contiguous sections of the same row, and separate source lines are provided for areas above and below the hole 110 where the source lines are divided by the hole.

**[Para 87]** In some displays of the present invention, the user interface may require only one or two coarse inputs (for example, yes/no). In such a case, it may be convenient to provide an operating mode of the device where activation of any one of the keys within a pre-defined area produces the same result. Furthermore, the image on the display may outline the physical

boundaries of the set of keys that are mapped to the same result. A display of this type is illustrated in Figure 13, where large “YES” and “NO” buttons 130 and 132 respectively each extend over four of the underlying pixels 134.

**[Para 88]** Since the present invention eliminates the need for a keypad separate from the display, the display can cover the majority of the device surface. In the case of a so-called “candy bar” cellular telephone, which is long, thin and not hinged, the display may cover one entire major surface of the telephone. In the case of a clamshell telephone, which folds in half along the short axis of the phone, the display/keyboard may be split into two units, each covering one half of the face. Alternatively, the display itself may be made of flexible material and incorporate a bend window that allows it to fold in half along a line coincident with the telephone’s hinge, thus giving the appearance, when the telephone is opened, of a single large display covering the face of the telephone.

**[Para 89]** The touch screen displays shown in Figures 6 and 7 above use an air gap front touch screen (i.e., a touch screen which relies upon an air gap between two conductive layers and which is positioned between the electro-optic layer and the viewing surface of the display). Resistive touch sensors can also be constructed of two patterned electrically conductive films separated by a variably resistive material. When the variably conductive material is deformed by applied pressure, its resistance changes; detection of the location and magnitude of this change in resistance by a controlling device will indicate the location and intensity of touch applied to the system. Also, when the appearance of the electro-optic medium used is not significantly affected by manual pressure (as in encapsulated and especially polymer-dispersed electrophoretic media), the touch screen can be placed behind the electro-optic layer (i.e., on the opposed side of the electro-optic layer from the viewing surface of the display).

**[Para 90]** An example of such a touch screen display is shown in Figure 14. In this display, the substrate 40, the backplane 42, the electro-optic layer 44, the front electrode 46 and the front substrate 48 are all essentially identical to the corresponding parts of the displays shown in Figures 6 and 7. However, the display shown in Figure 14 further comprises an upper conductor 150 of a resistive touch sensor, this upper conductor being patterned into columns, a variably resistive material 152 (typically a liquid), a lower conductor 154 and a lower substrate 156. Although not shown in Figure 14, the lower conductor 154 is patterned into rows running perpendicular to the columns of upper conductor 150.

**[Para 91]** Resistive touch sensors that incorporate a variably resistive material typically do not require a large amount of deflection to activate, and thus can be placed behind the backplane of the electro-optic display. In this position, the touch sensor may be activated with pressure applied through the electro-optic display stack as shown in Figure 14. Advantages of this configuration are that the optically lossy film of the resistive touch sensor is not present between the electro-optic layer and the user viewing the display, so that the contrast ratio and reflectivity of the "naked" display (i.e., the display without the touch sensor) are maintained.

**[Para 92]** Another touch screen technology which can usefully be used with electro-optic displays is optical touch screen technology, usually in the form of infra-red touch screen technology. (Since optical touch screen technology involves passing beams of radiation across the viewing surface of the display, it is desirable that the radiation used be outside the visible range in order to ensure that no visible streaks of radiation are present on the viewing surface.) However, hitherto the implementation of such optical touch screen technology in electro-optic displays has been rather cumbersome and costly.

**[Para 93]** As illustrated in Figure 15, the prior art implementation of optical touch screen technology has typically involved providing the display with a light-deflecting bezel 160, an electro-optic module 162 (which includes the electro-optic layer itself, the front substrate, front electrode and backplane), and a separate rectangular circuit board 164. The circuit board 164 extends outwardly beyond the electro-optic module 162 so that a peripheral portion of the circuit board 164 is exposed, and along two edges of this peripheral portion are arranged infra-red light emitting diodes (LED's) 166, while the other two edges of the peripheral portion carry photodiodes 168 sensitive to the radiation emitted by the LED's 166. The light-deflecting bezel 160 bears light-deflecting surfaces (not shown) such that radiation emitted from the LED's 166 travels perpendicular to the plane of the circuit board 164, is deflected by the bezel 160 so that it travels across and parallel to the viewing surface (the upper surface as illustrated in Figure 15) of the electro-optic module 162, and it again deflected by the bezel downwardly on to the photodiodes 168. Thus, any object which obstructs the radiation passing across the viewing surface will result in the IR radiation failing to reach at least two of the photodiodes 168, thereby enabling the position of the object to be detected in two dimensions.

**[Para 94]** Figure 16 shows an IR optical touch screen display of the present invention. This display has a light-deflecting bezel 160 identical to that shown in Figure 15. However, the display of Figure 16 does not require a discrete circuit board; instead, the backplane of the

electro-optic module 162 is made larger than the corresponding module in Figure 15. More specifically, although not shown in Figure 16, the backplane of the electro-optic module is made larger than the electro-optic layer itself, so that a peripheral portion of the backplane is exposed, on this peripheral portion of the backplane bears LED's 166 and photodiodes 168 which function in the same manner as the corresponding integers in Figure 15.

**[Para 95]** The LEDs 166 and photodiodes 168 in Figure 16 can be mounted directly on the electro-optic module and are adhered to the glass or other backplane using a z-axis conductive adhesive. Electrical connections to the LEDs and photodiodes can be deposited on the backplane using traditional TFT metal layer deposition techniques already used for forming other connection on the backplane, for example those use to connect the row and column drivers of a backplane to the row and column electrodes of an active matrix backplane.

**[Para 96]** Photodiodes can be constructed such that they have a single wire serial interface whereby one diode sends its data to the next who then appends its own data to that received from the previous photodiode. In this manner the number of connections to the photodiode array can be minimized.

## CLAIMS

1. An electro-optic display comprising, in order:  
a light-transmissive electrically-conductive layer;  
a layer of a solid electro-optic material; and  
a backplane bearing a plurality of pixel electrodes, a peripheral portion of the backplane extending outwardly beyond the layer of solid electro-optic material, the peripheral portion of the backplane bearing a plurality of radiation generating means and a plurality of radiation detecting means, the plurality of radiation generating means and plurality of radiation detecting means together being arranged to act as a touch screen.
2. An electro-optic display according to claim 1 wherein the radiation generating means comprises a plurality of light emitting diodes emitting in the infra-red region.
3. An electro-optic display according to claim 1 wherein the radiation detecting means comprises a plurality of photodiodes.
4. An electro-optic display according to claim 1 further comprising a light-deflecting bezel arranged to deflect radiation from the radiation generating means across the light-transmissive electrically-conductive layer, and thence on to the radiation detecting means.
5. An electro-optic display according to claim 1 wherein the electro-optic material comprises an electrophoretic material comprising a plurality of electrically charged particles disposed in a fluid and capable of moving through the fluid under the influence of an electric field.
6. An electro-optic display according to claim 5 wherein the electrically charged particles and the fluid are confined within a plurality of capsules or microcells.
7. An electro-optic display according to claim 5 wherein the electrically charged particles and the fluid are present as a plurality of discrete droplets surrounded by a continuous phase comprising a polymeric material.
8. An electro-optic display according to claim 5 wherein the fluid is gaseous.
9. An electro-optic display comprising, in order:

a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;  
a layer of a solid electro-optic material; and  
a backplane bearing a plurality of pixel electrodes,  
the electro-optic display further comprising means for controlling the potential of the plurality of conductive members, such that the plurality of conductive members and the light-transmissive electrically-conductive layer can serve as a touch screen.

10. An article of manufacture comprising, in order:

a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;  
a layer of a solid electro-optic material;  
a layer of a lamination adhesive; and  
a release sheet.

11. An electro-optic display comprising, in order:

a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;  
a light-transmissive electrically insulating layer;  
a light-transmissive electrically-conductive layer;  
a layer of a solid electro-optic material; and  
a backplane bearing a plurality of pixel electrodes,  
the electro-optic display further comprising means for controlling the potential of the plurality of conductive members, such that the plurality of conductive members and the light-transmissive electrically-conductive layer can serve as a touch screen.

12. An article of manufacture comprising, in order:

a light-transmissive electrically-conductive layer, a peripheral portion of which bears a plurality of conductive members having a conductivity higher than that of the electrically-conductive layer;

a light-transmissive electrically insulating layer;  
a light-transmissive electrically-conductive layer;  
a layer of a solid electro-optic material; and  
a layer of a lamination adhesive; and  
a release sheet.

13. An electro-optic display comprising, in order:  
a light-transmissive electrically-conductive layer;  
a layer of a solid electro-optic material;  
a backplane bearing a plurality of pixel electrodes; and  
first and second electrically conductive layers spaced apart from another but capable of being deformed towards one another, the first and second electrically conductive layers forming a touch screen.

14. An electro-optic display according to claim 13 wherein the electro-optic material comprises an electrophoretic material comprising a plurality of electrically charged particles disposed in a fluid and capable of moving through the fluid under the influence of an electric field.

15. An electro-optic display according to claim 14 wherein the electrically charged particles and the fluid are confined within a plurality of capsules or microcells.

16. An electro-optic display according to claim 14 wherein the electrically charged particles and the fluid are present as a plurality of discrete droplets surrounded by a continuous phase comprising a polymeric material.

17. An electro-optic display according to claim 5 wherein the fluid is gaseous.

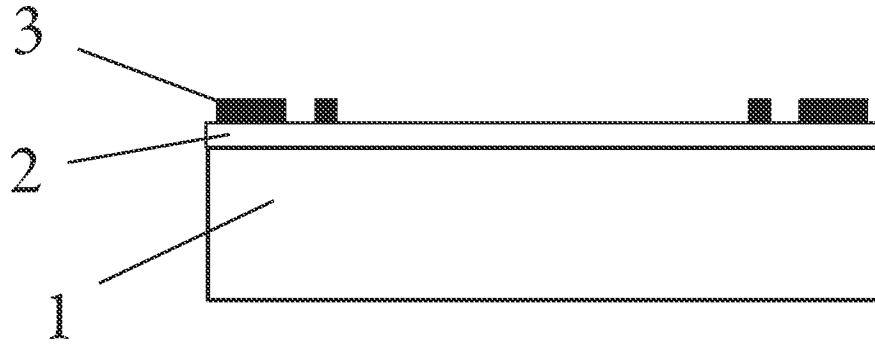


Fig. 1A (Prior Art)

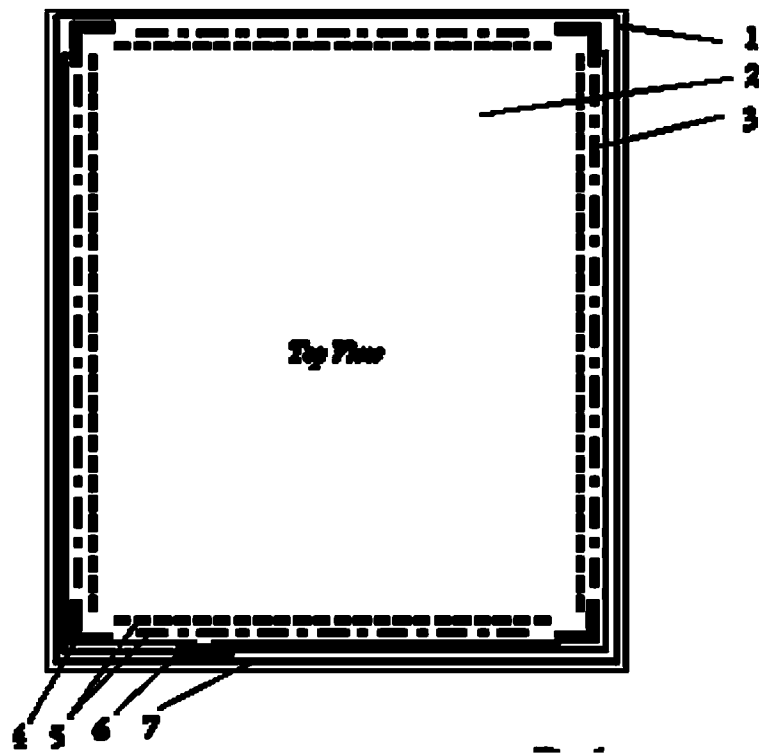


Fig. 1B (Prior Art)

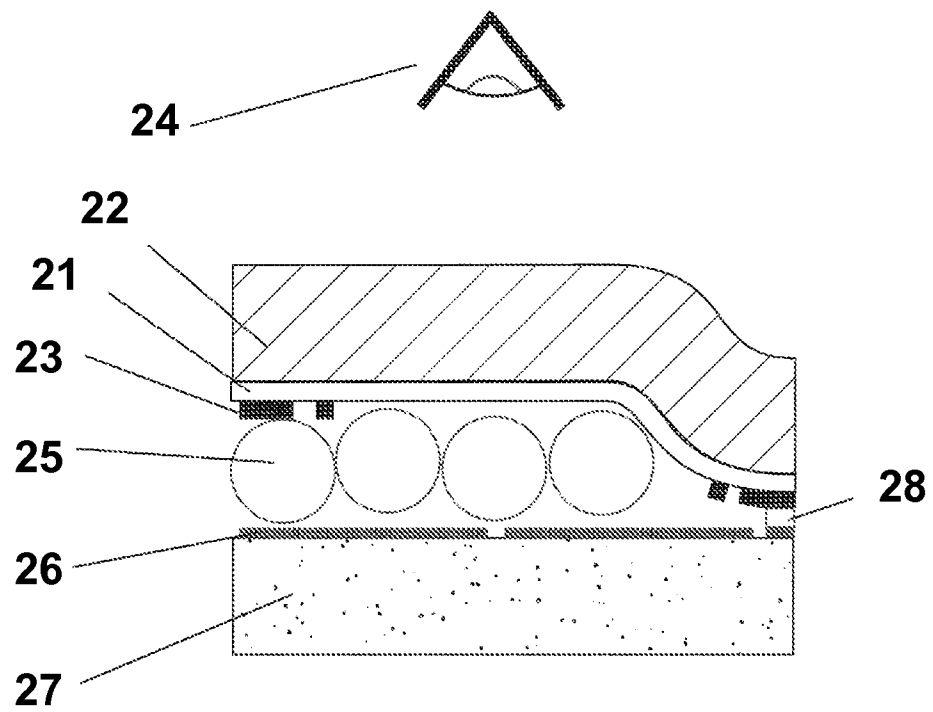


Fig. 2

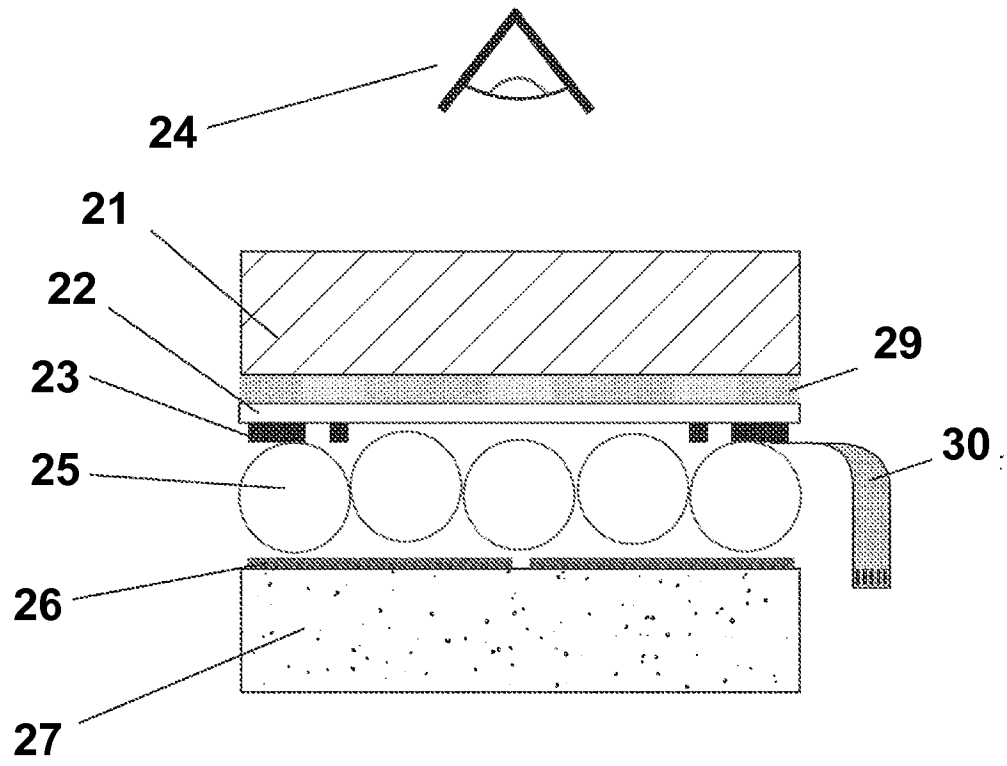


Fig. 3

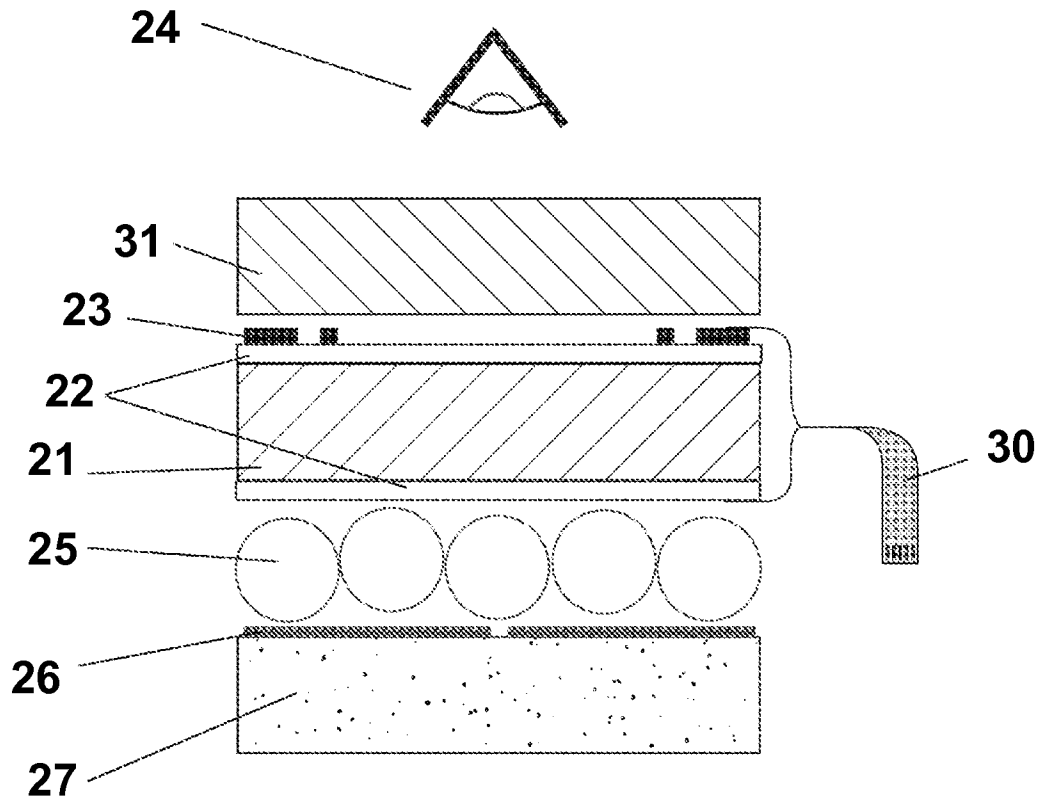


Fig. 4

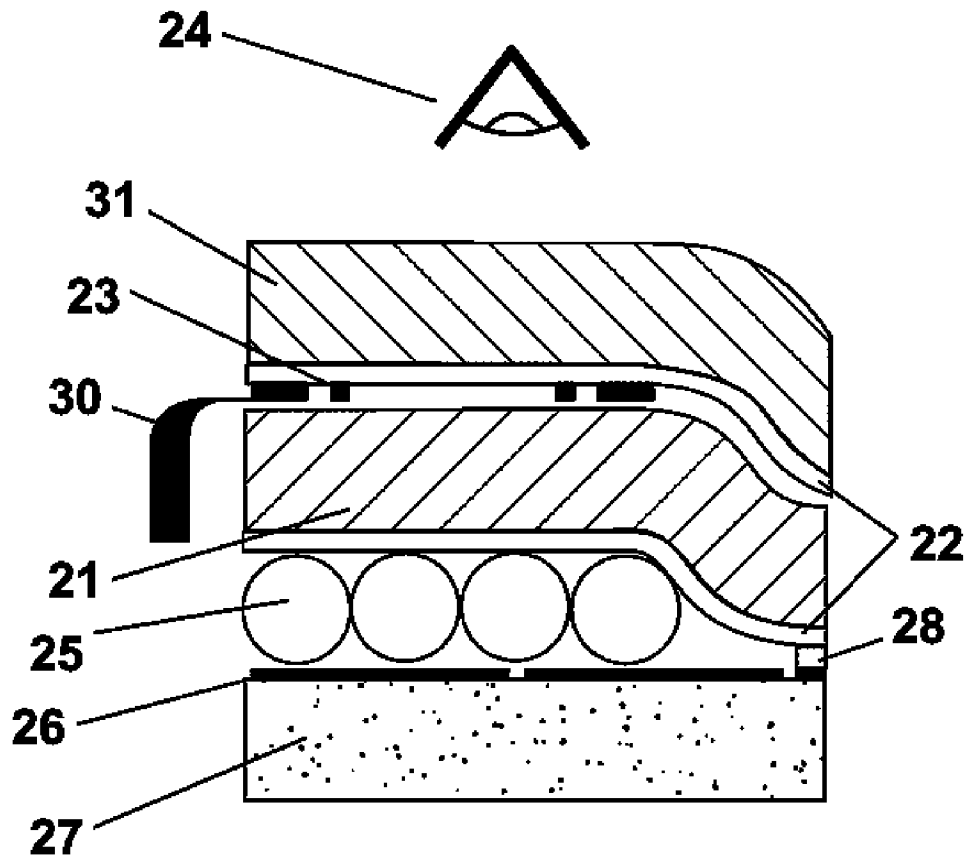


Fig. 5

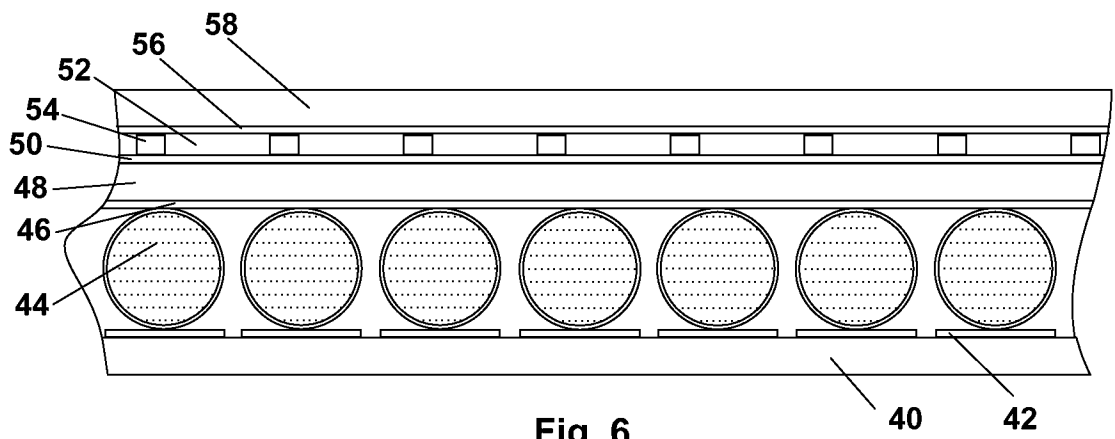


Fig. 6

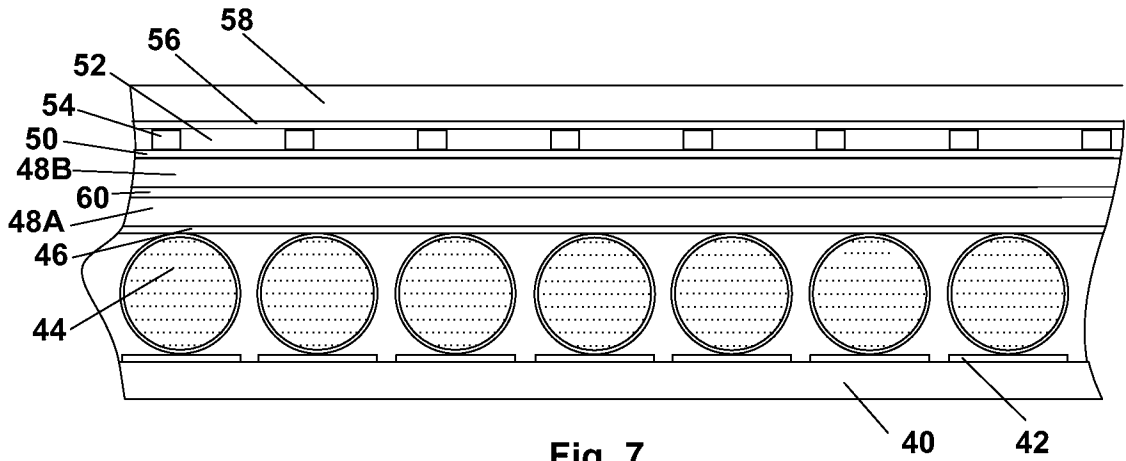


Fig. 7

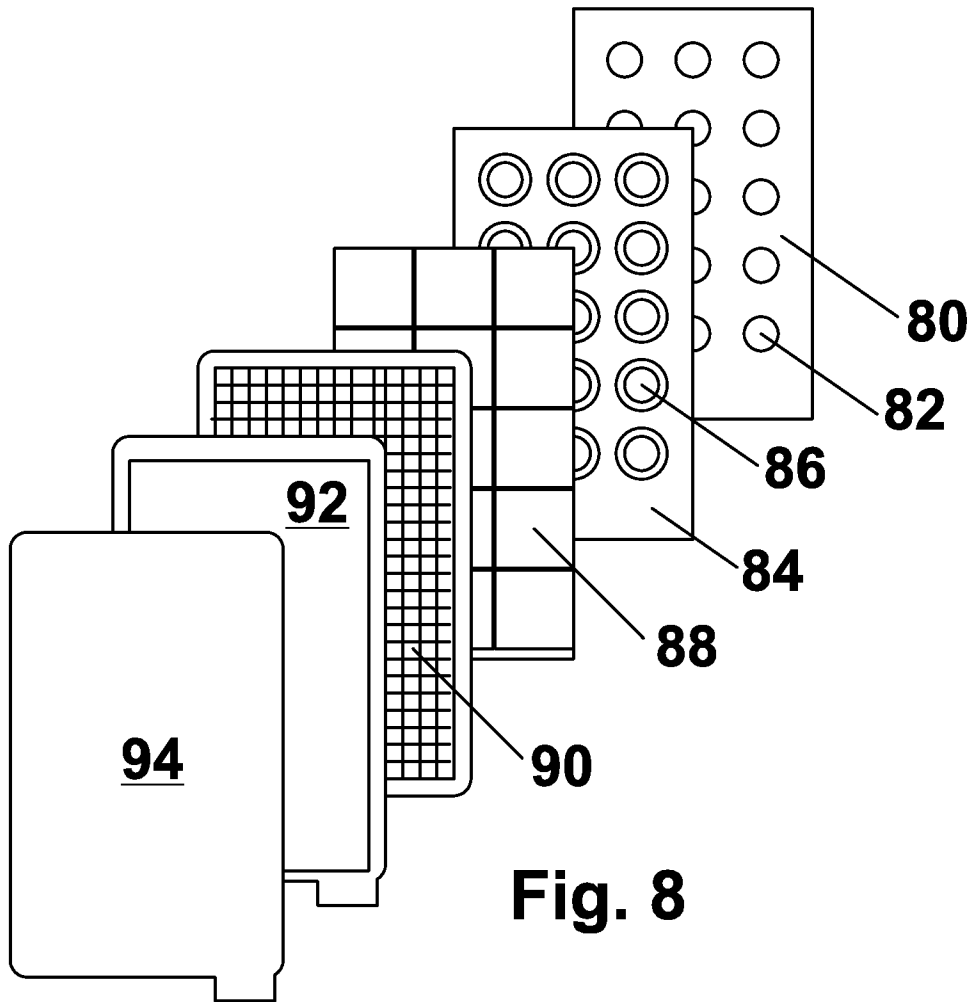
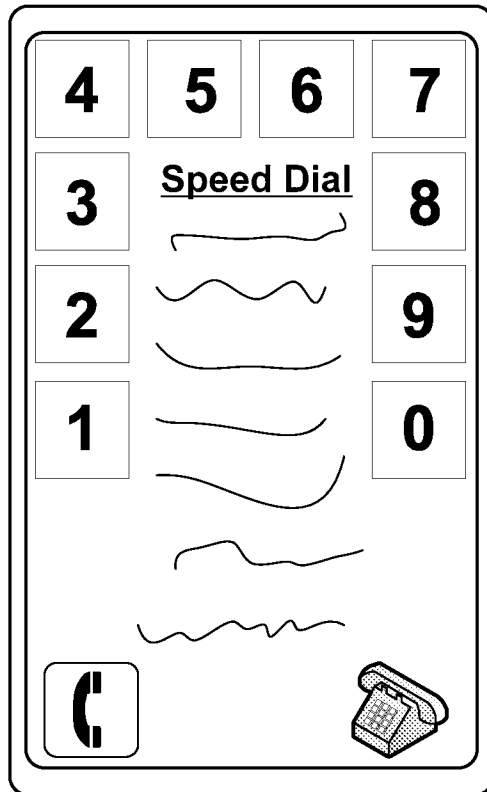
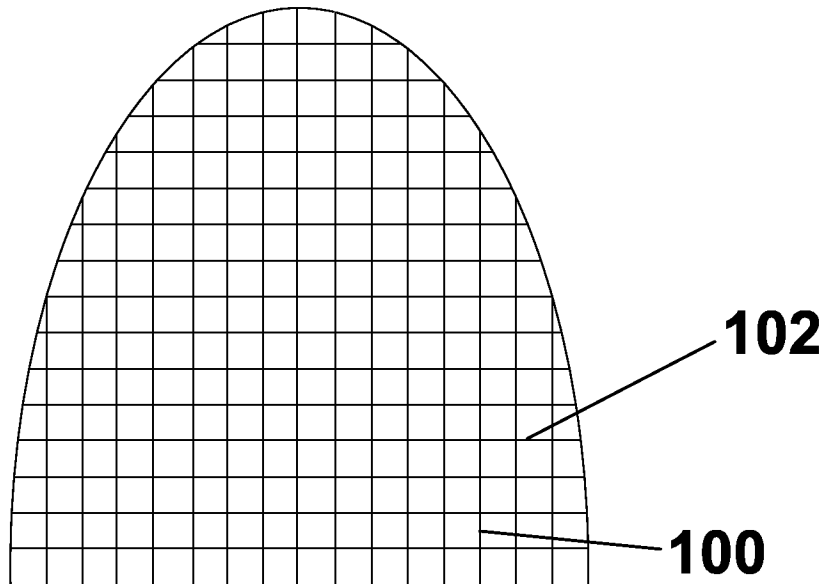


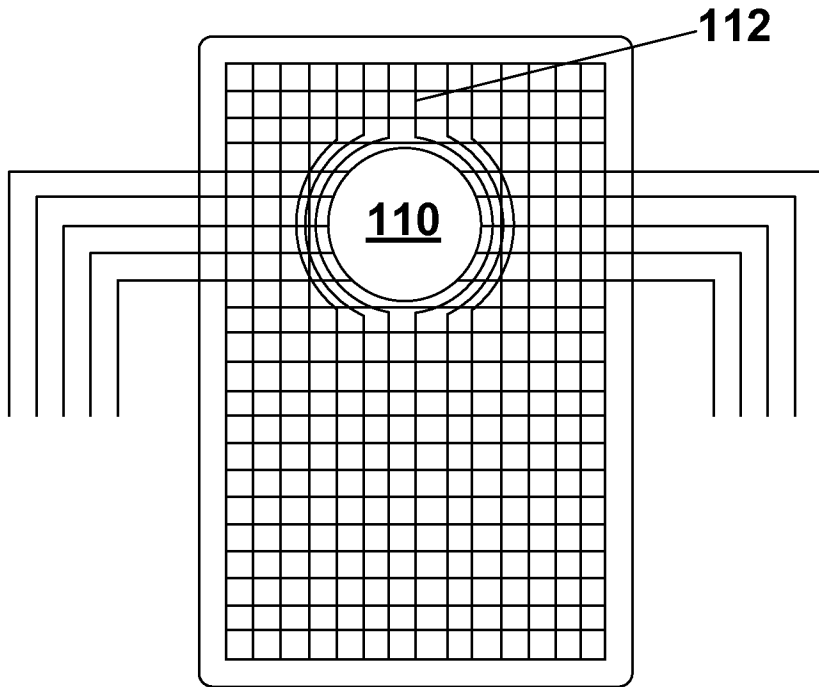
Fig. 8



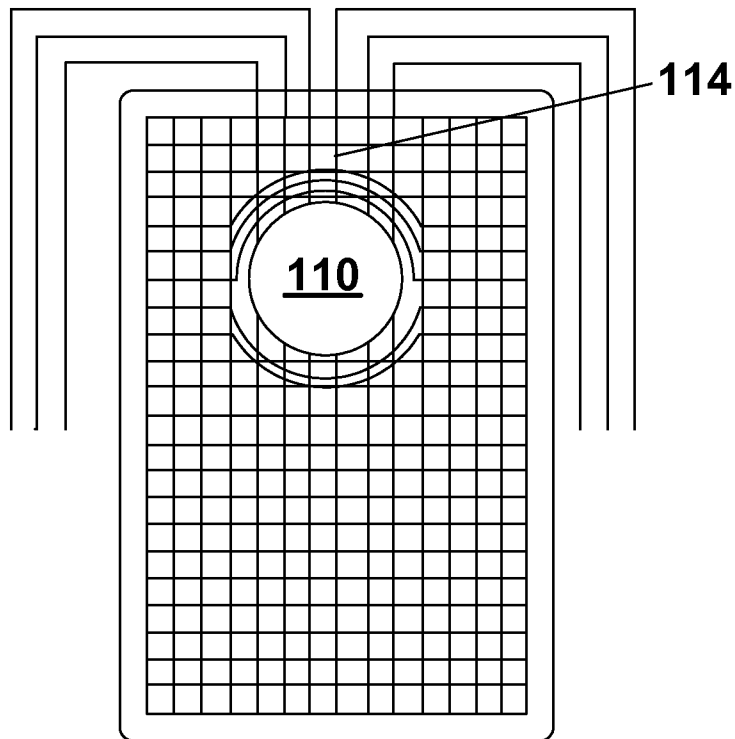
**Fig. 9**



**Fig. 10**



**Fig. 11**



**Fig. 12**

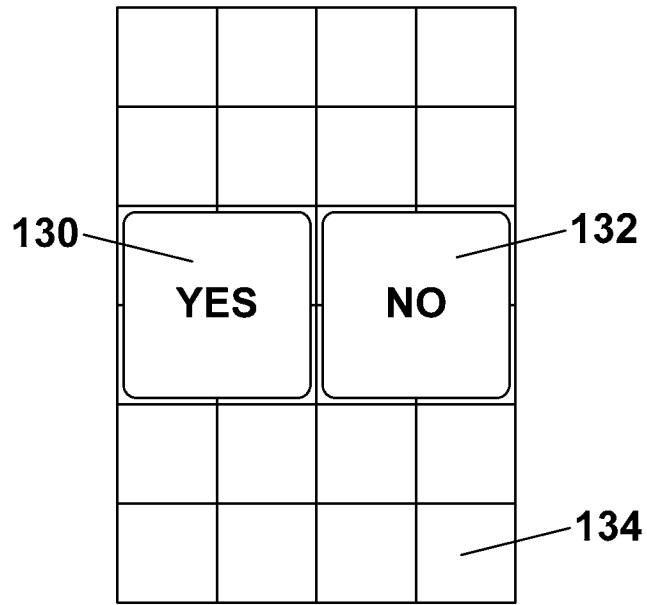


Fig. 13

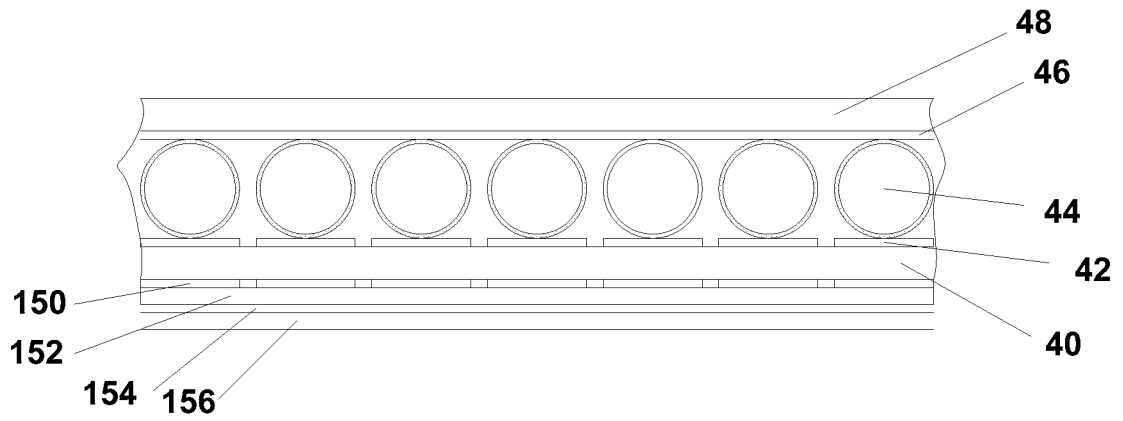
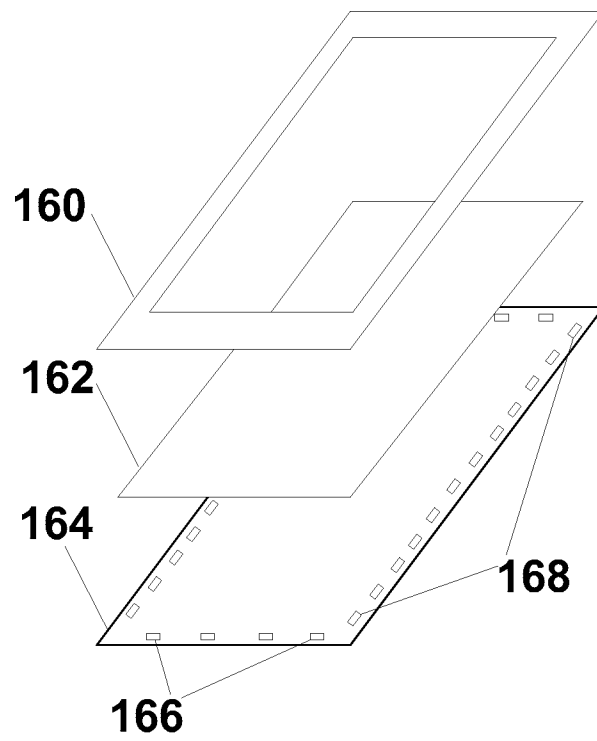


Fig. 14



**Fig. 15 (Prior Art)**

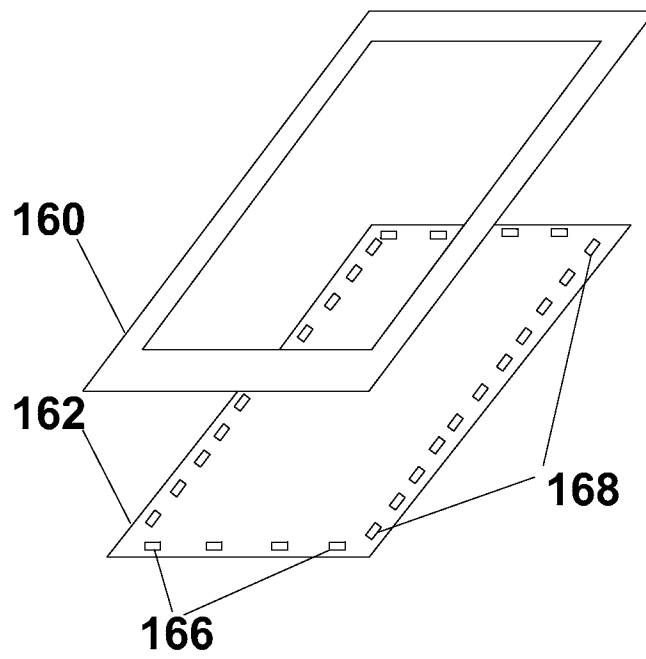


Fig. 16