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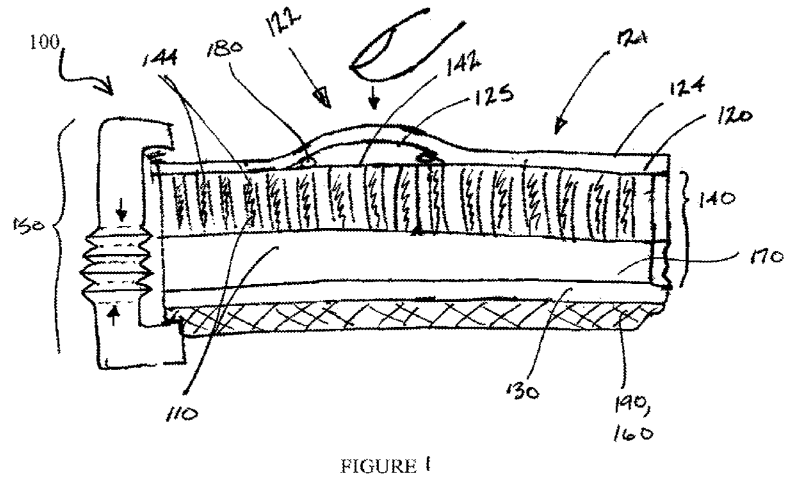

FIGURE 1

(57) **Abstract**: One embodiment of the user interface system comprises: a volume of fluid; a tactile layer; a retaining wall substantially impermeable to the fluid; a permeable layer; a displacement device; and a touch sensor. The tactile layer, with a back surface, defines a second region, operable between: a retracted state, wherein the second region is substantially flush with a first region; and an expanded state, wherein the second region is substantially proud of the first region. The permeable layer, joined to the back surface of the first region, includes a plurality of fluid ports that communicate a portion of the fluid through the permeable layer to the back surface of the second region. The displacement device directs the fluid through the fluid ports to the back surface to transition the second region from the retracted state to the expanded state. The touch sensor detects a user touch on the tactile layer.

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USER INTERFACE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of US Provisional Application number 61/405,140, filed 20-OCT-2010, which is incorporated in its entirety by this reference.

[0002] This application is related to U.S. application number 11/969,848 filed on 04 JAN 2008 and entitled "System and Method for Raised Touch Screens", U.S. application number 12/319,334 filed on 05 Jan 2009 and entitled "User Interface System", and U.S. application number 12/497,622 filed on 03 Jul 2009 and entitled "User Interface System", which are all incorporated in their entirety by this reference.

TECHNICAL FIELD

[0003] This invention relates generally to the user interface field, and more specifically to a new and useful user interface in the touch-based interface field.

BACKGROUND

[0004] Touch-sensitive displays (e.g., touch screens) allow users to input commands and data directly into a display, which may be particularly useful in a variety of applications. Common applications for touch screens include consumer products such as cellular telephones and user interfaces for industrial process control. Depending on the specific application, these touch-sensitive displays are commonly used in devices ranging from small handheld PDAs, to medium sized tablet computers, to large industrial implements. It is often convenient for a user to input and read data on the same display. Unlike a dedicated input device, such as a keypad with discrete well-defined keys, most touch-sensitive displays are generally flat. As a result, touch-sensitive screens do not provide significant tactile guidance for one or more control “buttons”. Instead, touch-sensitive displays rely on visual cues (e.g., displayed images) to guide user input.

[0005] Hence a serious drawback of touch-sensitive displays is the inherent difficulty a user faces when attempting to input data accurately because adjacent buttons are not distinguishable by feel. Improper keystrokes are common, which typically forces the user to focus both on the keypad (to properly input the next keystroke) and on the text input line (to check for errors); generally, the user is forced to keep his or her eyes on the display. The importance of tactile guidance is readily apparent in the competition between the Apple’s iPhone and RIM’s BlackBerry 8800. Touch-sensitive displays and physical hard buttons each have benefits and drawbacks, and digital devices generally incorporate one such component or the other.

[0006] Thus, there is a need in the touch-based interface field to create a new and useful interface, for a digital display, that incorporates tactile guidance for one or more control buttons.

BRIEF DESCRIPTION OF THE FIGURES

[0007] FIGURE 1 is a schematic representation of a preferred embodiment of the user interface system with a proximal reservoir;

[0008] FIGURE 2 is a schematic representation of an embodiment of the user interface system with in an expanded state;

[0009] FIGURE 3 is a schematic representation of an embodiment of the user interface system with a permeable layer defining a support surface with a concave contour proximal to the second region;

[0010] FIGURES 4A and 4B are schematic representations of an embodiment of the user interface system with a porous permeable layer and without and with a reservoir, respectively;

[0011] FIGURE 5 is a schematic representation of an embodiment of the user interface system with a with a proximal reservoir and a remote reservoir;

[0012] FIGURE 6 is a schematic representation of an embodiment of the user interface system with a proximal reservoir and a displacement device that is an electrical pump;

[0013] FIGURE 7 includes schematic representations of various operable states of the preferred embodiment of the user interface system;

[0014] FIGURE 8 is a perspective view of the preferred embodiment, incorporated into an electronic device with a digital display, and a flowchart of the operation of the preferred embodiment therein; and

[0015] FIGURE 9 is a perspective view of the preferred embodiment and a flowchart of the operation of the preferred embodiment therein.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] The following description of the preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

[0017] As shown in FIGURE 1, the user interface system 100 of the preferred embodiment includes: a volume of fluid 110; a tactile layer 120; a retaining wall 130; a permeable layer 140; a displacement device 150; and a touch sensor 160. The tactile layer 120 defines an outer tactile surface 124 touchable by a user and a back surface 125 opposite the tactile surface 124; the tactile layer 120 further includes a first region 121 and a second region 122, wherein the second region 122 is operable between: a retracted state, wherein the second region 122 is substantially flush with the first region 121; and an expanded state, wherein the second region 122 is substantially proud of the first region 121. The retaining wall 130 is substantially impermeable to the fluid 110. The permeable layer 140, interposed between the tactile layer 120 and the retaining wall 130, is joined to the back surface 125 of the first region 121 and defines a support surface 142 below the second region 122; the permeable layer 140 further includes a plurality of fluid ports 144 that communicate a portion of the fluid 110 through the permeable layer 140 to the back surface 125 of the second region 122. The displacement device 150 cooperates with the retaining wall 130 to direct a portion of the fluid 110 through the fluid ports 144 to the back surface 125 to transition the second region 122 from the retracted state to the expanded state. The touch sensor 160 is coupled to the retaining wall 130 and detects a user touch on the tactile surface 124. The user interface system

100 may further comprise: a reservoir 170 that contains a portion of the volume of fluid 110; a digital display 190 that transmits an image to the user; an attachment point 180 that joins the tactile layer 120 to the permeable layer 140; and/or a pressure sensor that detects ambient air pressure proximal to the user interface system 100.

[0018] The user interface system 100 functions to deform the second region 122 of the tactile layer 120 to provide the user with tactile guidance when operating a device to which the user interface is coupled. The user interface system 100 is substantially similar to the user interface system described in US Patent Application number 12/319,334 titled “User Interface System” and/or US Patent Application number 12/497,622 titled “User Interface System,” which are incorporated in their entirety by this reference. The user interface system 100 preferably cooperates with a visual guide (e.g., an image output by the digital display 190 and transmitted though the tactile surface 124) to provide a message, a choice, or any other suitable type of communication to the user, but may alternatively operate independently of a visual guide. The user interface system 100 preferably provides tactile guidance that is substantially adapted to a use of the device. The user interface system 100 may deform additional regions of the tactile layer 120, independently and/or concurrently with the second region 122, to provide further adaptability to the use of the device. FIGURE 7B and 7C depict a second region 122 and a third region 123 that are independently deformed. The user interface system 100 is preferably applied over an image that is static (e.g., a label) or dynamic (e.g., from the digital display 190); the user interface is preferably substantially transparent to permit transmission of the image through the user interface system 100.

However, any other suitable optical property of the user interface system 100 may suffice. As shown in FIGURE 8, the user interface system 100 of the preferred embodiment may be incorporated into an electronic device that includes a digital display, such as a vehicle console, a desktop computer, a laptop computer, a tablet computer, a television, a radio, a desk phone, a mobile phone, a smartphone, a PDA, a personal navigation device, a personal media player, a camera, or a watch. The user interface system 100 of the preferred embodiment may also be incorporated into an electronic device without a digital display, for example, onto a steering wheel of a vehicle, a remote control, or a keypad. The user interface system 100 may, however, be incorporated in any suitable device that tactilely and/or visually interfaces with a user.

[0019] The volume of fluid 110 of the preferred embodiment functions to transmit fluid pressure to the back surface 125 of the second region 122 to motivate a deformation of the second region 122. The fluid 110 preferably also functions to support the deformed (i.e., expanded) second region 122 when a user applies a force to the deformed second region 122. The fluid 110 is preferably a substantially incompressible fluid, such as oil, water, alcohol, and/or liquid paraffin, but may alternatively be a compressible fluid, such as air. However, the fluid 110 may be any other suitable type of fluid. A portion of the fluid 110 is preferably contained within the permeable layer 140, such as within the fluid ports 144 of the permeable layer 140 or within a cavity (e.g., reservoir) defined by the permeable layer 140. As shown in FIGURES 1 and 5, the user interface system 100 may also include a proximal and/or remote reservoir, respectively, that stores a portion of the fluid 110. However, the fluid may be arranged within the user interface system 100 in any other suitable arrangement. The fluid 110 is preferably substantially chemically inert in the presence of the tactile layer 120, the permeable layer 140, the displacement device 150, the touch sensor 160, the reservoir 170, and/or any other element of the user interface system 100 in contact with the fluid 110; specifically, the fluid 110 preferably does not corrode and is not corroded by any component of the user interface system 100 in contact with the fluid 110. Properties of the fluid 110 preferably remain substantially unchanged under normal operating conditions of the user interface system 100 or the device to which the user interface system 100 is applied. For example, if the user interface system 100 is used in an airplane, the properties of the fluid 110 preferably remain substantially unchanged between sea level and higher altitudes. However, the fluid 110 may have any other suitable chemical property.

[0020] As shown in FIGURES 2 and 5, the tactile layer 120 of the preferred embodiment functions to provide a tactile surface 124 that is touchable by the user and interfaces with a user in a tactile manner. The tactile layer 120 is preferably continuous, such that a user, when swiping a finger across the tactile surface 124, does not perceive any interruptions or seams therein. The tactile layer 120 is also preferably planar (i.e. flat) in the retracted state, but may alternatively form a non-planar (e.g., curved) surface. The tactile layer 120 may be arranged on a single plane, but may alternatively be arranged along a first plane and a second plane. For example, a portion of the tactile layer 120 may be arranged on a first surface of a device and a second portion of the tactile layer 120 may be arranged on a second surface of the device that is adjacent but not tangent to the first surface.

[0021] As shown in FIGURE 9, the tactile layer 120 further functions to define the second region 122 that outwardly deforms, from the retracted state to the expanded state, when fluid is displaced to the back surface 125 of the second region 122 (e.g., fluid pressure at the back surface 125 of the second region 122 increases above ambient air pressure); the second region 122 is preferably proud of the first region 121 in the expanded state and thus tactilely distinguishable, from the first deformable region 121, by the user. The tactile layer 120 also functions to define the first region 121 that remains substantially undeformed despite the state of the second region 122. The second region 122 preferably “relaxes” or “undeforms” back to the retracted state when the fluid 110 is drawn (or fluid pressure is released) from the back surface 125 of the second region 122; in the retracted state, the second region 122 is preferably flush with the first region 121 at the tactile surface 124. In a recessed state, the tactile layer 120 may also inwardly deform toward and/or conform to a concave contour defined by the permeable layer 140 (shown in FIGURE 3); fluid drawn away from the back surface 125 of the second region 122 preferably pulls the second region 122 into the concave contour. The recessed state preferably provides the user with additional tactile feedback that is distinguishable from the retracted state and the expanded state. The second region 122 is preferably operable between the expanded and the retracted states but may also be operable solely between the expanded and recessed states or between all of the expanded, retracted, and recessed states; the second region 122 may, however, be operable in any other state.

[0022] The tactile layer 120 is preferably elastic to permit deformation of the second region 122 in the various states. In a first variation, the tactile layer 120 is relatively more elastic in specific areas (e.g., proximal to the second region 122) and relatively less elastic in other areas (e.g., proximal to the first region 121); the tactile layer 120 is therefore preferably more capable of deformation at the relatively more elastic areas. In a second variation, the tactile layer 120 is generally uniformly elastic. In a third variation, the tactile layer 120 includes or is comprised of a smart material, such as Nickel Titanium (commonly referred to as "Nitinol"). The tactile layer 120 is also preferably substantially optically transparent, but may alternatively be translucent or opaque. The tactile layer 120 preferably has the following properties: high light transmission; low haze; wide viewing angle; minimal back reflectance (e.g., in the variation in which the user interface system 100 is applied to a digital display 190 that emits light); scratch resistance; chemical resistance; stain resistance; gas and/or liquid impermeability; and smoothness (i.e. not tacky or rough to the touch). Also or alternatively, the surface may include coatings that provide any of these desired properties. The tactile layer 120 is preferably of a suitable elastic material, such as a polymer and/or silicon-based elastomer. Such suitable materials include: poly-dimethylsiloxane (PDMS); RTV silicone (e.g., RTV silicone 615); polyurethanes; thermoset plastics (e.g., polymethyl methacrylate (PMMA)); and photocurable solvent-resistant elastomers (e.g., perfluropolyethers). The tactile layer 120 may, however, be made of any suitable material. In one variation, the tactile layer 120 is a single homogeneous (e.g., of the same material throughout) layer less than 1 mm thick, and in a preferred variation, the tactile layer 120 is between 50um and 200um in thickness. In another version, the tactile layer 120 may be constructed using multiple layers and/or coatings of the same or different suitable materials and thicknesses.

[0023] The tactile layer 120 is preferably adjacent the permeable layer 140, and the first region 121 of the tactile layer 120 is preferably selectively attached, adhered or otherwise joined to the permeable layer 140 such that the first region 121 of the tactile layer 120 is retained against the permeable layer 140. However, the tactile layer 120 may be joined to the permeable layer 140 with a portion of the touch sensor 160 (e.g., an electrode) interposed between the permeable layer 140 and the tactile layer 120. The touch sensor 160 may be joined to the tactile layer 120 and thus deform with the tactile layer 120 such that the distance between the tactile sensor and the tactile surface 124, is substantially maintained. This may be particularly important in the variation of the touch sensor 160 that is a capacitive touch sensor 160.

[0024] The first region 121 preferably defines a border with the second region 122. As fluid is displaced through the fluid ports 144 toward the tactile layer 120, only fluid that is directed toward a portion of the tactile layer 120 not adhered to the permeable layer 140 (i.e. the second region 122) exits the permeable layer 140 and outwardly expands the free portion of the tactile layer 120 to produce a deformed region of the surface; the deformed region is preferably the second region 122 and preferably forms a button. The first region 121 (which is joined to the permeable layer 140) preferably restricts the fluid 110 from exiting the fluid ports 144 adjacent to the first region 121; the first region 121 (and other regions joined to the permeable layer 140) is therefore preferably not deformed by fluid drawn through the fluid ports 144. Thus, the perimeter of the second region 122 is preferably partially defined by a portion of the back surface 125 of the tactile layer 120 that is attached to the permeable layer 140 (e.g., the first region 121).

[0025] The first region 121 of the tactile layer 120 is preferably retained against the permeable layer 140 via an attachment point 180 (or plurality of attachment points); the attachment point 180 may be a series of continuous points, such as a line, a curve, or area, but may alternatively be a series of non-continuous points. The attachment point 180 may be formed via adhesive bonding, chemical bonding, welding, diffusion bonding, or by any other suitable attachment material and/or method. The attachment point 180 may comprise a volume of adhesive or other material arranged between the tactile layer 120 and the permeable layer 140; alternatively, the attachment point 180 may be formed by a chemical bond substantially between the back surface 125 of the tactile layer 120 and the permeable layer 140. Methods and/or materials that form the attachment point 180 preferably result in an attachment point with optical properties substantially similar to the optical properties of the tactile layer 120 and/or the permeable layer 140. The attachment point 180 preferably define a border between the first region 121 and the second region 122, wherein the first region 121 is retained against the permeable layer 140 and the second region 122 remains free to deform under changes in fluid pressure at the back surface 125 of the second region 122.

[0026] The permeable layer 140 of the preferred embodiment functions to define a support surface 142 that supports the second region 122 and to further define a plurality of fluid ports 144 that communicate a portion of the fluid 110 through the permeable layer 140 to the back surface 125 of the second region 122. A portion of the fluid 110, directed through any of the fluid ports 144 and toward the tactile surface 124, preferably outwardly deforms the second region 122.

[0027] The fluid ports 144 of the permeable layer 140 are preferably substantially sealed from the ambient environment, such as by the retaining wall 130, tactile layer 120, and/or perimeter wall; the fluid ports 144 are also preferably substantially filled with the fluid 110, which preferably prevents contamination and undesired mixing of the volume of fluid 110 with another fluid. In an example in which the fluid 110 is liquid paraffin, the fluid ports 144 are substantially filled with paraffin and the permeable layer 140 is substantially sealed from the environment, by the retaining wall 130 and the permeable layer 140, in order to prevent entry of air into the fluid ports 144; such contamination of the fluid 110 may cause bubbles within the liquid paraffin, leading to decreased transparency and/or increased obstruction to light transmission (i.e. the image) through the user interface system 100. In the variation that includes a digital display 190 that outputs a dynamic image to the user, such reduction of transparency and increased obstruction may be particularly deleterious to the operation of the user interface system 100.

[0028] The permeable layer 140 may be one of several variations. In a first variation, shown in FIGURE 4, the permeable layer 140 is of a substantially porous material that defines a series of interconnected cavities that form the fluid ports 144; the cavities preferably contain a portion of the volume of fluid 110 and direct fluid through the permeable layer 140; the permeable layer 140 is therefore permeable to the fluid 110. In this variation of the permeable layer 140 that is porous, an electric field applied across a portion of the permeable layer 140 may effect a change in the porosity of the permeable layer 140; in this variation, the permeable layer 140 may thus perform the function of a valve in opening or closing flow of the fluid 110 toward or from the second region 122. However, a heating element may alternatively heat a portion of the permeable layer 140 to effect a change in the porosity of the portion of the permeable layer 140 and/or the viscosity of a portion of the fluid 110. In the variation that includes a reservoir 170 at least partially defined by the permeable layer 140, as shown in FIGURE 4B, cavities open to the reservoir 170 may communicate the fluid 110 between the reservoir 170 and the tactile layer 120. The permeable layer 140 of this variation may be substantially sponge-like. The user interface system 100 is preferably substantially transparent such that an image may be transmitted through the user interface system 100; thus, the permeable layer 140 of this variation is preferably of a substantially transparent porous material, such as transparent silica aerogel, a transparent polymer, and/or a transparent ceramic. However, the permeable layer 140 of this first variation may be any other suitable type of porous material.

[0029] In a second variation, shown in FIGURE 3, the permeable layer 140 defines a series of channels that form the fluid ports 144. The channels are preferably of a substantially cylindrical geometry; specifically the fluid ports 144 are preferably defined by channels that are substantially parallel bores of substantially circular cross-sections that pass fully through the permeable layer 140 substantially normal to the support surface 142. However, the channels (i.e. fluid ports 144) may be of any other geometry or cross-section. The channels are preferably substantially small enough to be substantially tactilely imperceptible to the user. The channel may also be optically invisible to the user, thus minimizing optical distortion of an image transmitted through the permeable layer 140, though the fluid 110 may have an index of refraction substantially similar to that of the permeable layer 140 to minimize such optical distortion. The channels may also be so small so as to be undetectable to the human eye, even when filled with the fluid (e.g., gas, air, liquid) of a different optical property (e.g, index of refraction) than that of the permeable layer 140. In the variation that includes substantially cylindrical channels, each channel if preferably of a diameter less than 500um, through each channel preferably has a maximum diameter of 100um, or less than the maximum feature size distinguishable to the touch or by unaided sight. The channels may be machined into the permeable layer 140, such as through laser ablation, bulk machining, conventional drilling, or etching. Alternatively, the channels may be formed during the manufacture of the permeable layer 140, such as by processing the permeable layer 140 with a mold that incorporates channel-forming features. Alternatively, the permeable layer 140 may comprise a series of individual channels (e.g., tubes) bundled together and retained by a holding material such as an adhesive. However, any other suitable method of forming the channels within the permeable layer 140 may be used. Because the user interface system 100 is preferably capable of transmitting an image to the user, the permeable layer 140 of the second variation preferably comprises a substantially transparent material, such as: glass; an elastomer; a silicon-based organic polymer, such as poly-dimethylsiloxane (PDMS), or other polymer; a thermoset plastic such as polymethyl methacrylate (PMMA); or a photocurable, solvent-resistant elastomer such as perfluropolyether. However, the permeable layer 140 may be of any other suitable material or geometry.

[0030] The permeable layer 140 of the preferred embodiment also functions to define a support surface 142 adjacent to the second region 122. The support surface 142 is preferably rigid, thus providing a 'hard stop' that limits inward deformation of the second region 122 due to a force applied to the tactile surface 124 by the user. The support surface 142 therefore prevents the user from "pressing too far" into the tactile surface 124. The support surface 142 may extend beyond the second region 122 to similarly support any other region or area of the tactile layer 120. In the variation in which the permeable layer 140 retains the first region 121 in a substantially planar form and the support surface 142 (below the second region 122) is also substantially planar, the support surface 142 may prevent inward deformation of the second region 122 beyond the plane of the first region 121 due to a force applied to the tactile surface 124 by the user. Furthermore, the permeable layer 140 preferably cooperates with the tactile layer 120 to substantially reduce the size and/or number of "divots" or interruptions felt by the user when swiping a finger across the tactile surface 124, particularly along the second region 122 in the retracted state. The divots are preferably defined by the fluid ports 144, and the tactile layer 120 is preferably of a thickness substantially greater than the cross-section of the fluid ports 144 such that the tactile layer 120 cannot noticeably deform into a opening of a fluid port; the fluid ports 144 may therefore be imperceptible by the user. However, any other suitable arrangement of the permeable layer 140 and tactile layer 120 may be used.

[0031] The retaining wall 130 of the preferred embodiment functions to support the permeable layer 140 and to prevent the fluid from escaping the user interface system 100 opposite the permeable layer 140. The retaining wall 130 of the preferred embodiment therefore preferably functions to cooperate with the displacement device 150 to direct a portion of the fluid 110 through the fluid ports 144 to the back surface 125 of the second region 122. Specifically the arrangement of the retaining wall 130 prevents the fluid 110, displaced into the permeable layer 140, from exiting the permeable layer 140 opposite the tactile layer; the retaining wall 130 therefore directs the fluid 110 closes a potential exit point for the fluid and directs the fluid 110 toward the tactile layer. The retaining wall 130 is substantially impermeable to the fluid 110 such that the fluid 110 may not pass through the retaining wall 130. In a first variation, the retaining wall 130 is joined directly to the permeable layer 140 opposite the support surface 142. In this variation, the retaining wall 130 closes the fluid ports 144 opposite the support surface 142 such that fluid may not escape the permeable layer 140 opposite the support surface 142 when the displacement device 150 increases the fluid pressure within the permeable layer 140; by closing the fluid ports 144 on this side of the permeable layer 140, an increase in fluid pressure within the permeable layer 140 directs the fluid 110 toward the support surface 142 and outwardly expands the second region 122. For example, in the second variation of the permeable layer 140, the fluid ports 144 defined by the permeable layer 140 do not function to substantially enclose a portion of the fluid 110; therefore, the retaining wall functions to provide a bottom wall to each of the fluid ports 144 defined by the permeable layer 140, thus preventing undesired flow of fluid out of the permeable layer 140 from the side opposite the support surface. The retaining wall 130 thus facilitates containment of a portion of the fluid 110 within the permeable layer 140. In a second variation, the retaining wall 130 is coupled to but offset from the permeable layer 140 opposite the support surface 142, thus cooperating with the permeable region to at least partially define a reservoir 170 between the permeable layer 140 and the retaining wall 130; the reservoir 170 may be further defined, in part, by the perimeter wall. In this second variation, the retaining wall 130 substantially resists deformation due to a fluid pressure increase within the reservoir 170 (generated by the displacement device 150) and prevents fluid from escaping past the retaining wall 130, thus directing fluid through the permeable layer 140 and toward the back surface 125 of the second region 122 to expand the second region 122. However, the retaining wall 130 may be of any other geometry and/or arrangement.

[0032] The retaining wall 130 may be a coating applied to the permeable layer 140 opposite the tactile layer 120, such as a substantially transparent sealant deposited thereon, but may alternatively be a separate layer of substantial thickness, such as a glass or polycarbonate substrate arranged over a digital display and adhered to the permeable layer 140. The retaining wall 130 may also include standoffs and/or pillars, joined to the permeable layer 140 and retaining the retaining wall 130 substantially offset from the permeable layer 140. However, the retaining wall 130 may be of any other geometry and coupled to the permeable layer 140 by any other method.

[0033] The displacement device 150 preferably functions to displace fluid within the fluid ports 144 and toward the back surface 125 of the second region 122 to outwardly deform the second region 122 in the expanded state. The displacement device 150 may be any of several variations, including a mechanical pump (e.g., a positive displacement, an impulse, or a velocity pump), an electrical (e.g., electroosmotic) pump, a clamp, a plunger-type displacement device (shown in FIGURE 9), or any other suitable device capable of displacing fluid. To transition the second region 122 from the retracted state to the expanded state, the displacement device 150 preferably generates an area of relatively high pressure within the permeable layer 140 substantially remote from the support surface 142; this preferably induces fluid flow toward a relatively low-pressure area proximal to the back surface 125 of the second region 122 (i.e. across a pressure gradient), thus expanding the second region 122. To transition the second region 122 from the expanded state to the retraced state (or from the retracted state to the recessed state), the displacement device 150 preferably generates an area of relatively low pressure within the permeable layer 140 substantially remote from the support surface 142; this preferably induces fluid flow away from the back surface 125 of the second region 122, thus retracting the second region 122. Therefore, the displacement device 150 directs a portion of the fluid 110 through the fluid ports 144 to the back surface 125 to transition the second region 122 from the retracted state to the expanded state, and the displacement device 150 directs a portion of the fluid 110 from the fluid ports 144 to transition the second region 122 from the expanded state to the retracted state and/or from the retracted state to the recessed state.

[0034] In a variation of the displacement device 150 that creates a fluid pressure gradient to motivate the fluid 110, the pressure gradient preferably dissipates as the second region 122 deforms to absorb a pressure change. Fluid pressure within the user interface system 100 preferably reaches a steady and constant state once the second region 122 is in the desired state (e.g., expanded, retracted, or recessed state); the displacement device 150 preferably maintains this fluid pressure within the system to retain the second region 122 in the desired state. In the variation of the user interface system 100 that includes a reservoir 170, the displacement device 150 may create a pressure gradient across the reservoir 170 and the fluid ports 144 to motivate the fluid 110 from the reservoir 170 to the fluid ports 144, or vice versa.

[0035] The displacement device 150 is preferably a positive displacement micro-pump, such as pump #MDP2205 from ThinXXs Microtechnology AG of Zweibrucken, Germany or pump #mp5 from Bartels Mikrotechnik GmbH of Dortmund, Germany. However, the displacement device 150 may be of any other suitable type. Suitable types of positive displacement pumps include rotary, reciprocating, gear, screw, progressing cavity, roots-type, peristaltic, plunger, diaphragm, or rope pumps. Suitable types of impulse pumps include hydraulic ram pumps, and suitable types of velocity pumps include radial- and axial-flow centrifugal pumps and educator-jet pumps.

[0036] Alternatively, in the variation of the user interface system 100 that includes a reservoir 170 interposed between the permeable layer 140 and the retaining wall 130, the mechanical pump may comprise a clamp coupled to the permeable layer 140 and the support surface 142, as shown in FIGURES 1 and 4, wherein the clamp modifies the orientation of a portion of the retaining wall 130 relative to the permeable layer 140. This preferably decreases (or increases) the volume of the reservoir 170, thus increasing (or decreasing) fluid pressure within the reservoir 170 and motivating fluid toward (or from) the fluid ports 144 to expand (or retract) the second region 122.

[0037] Similarly, the displacement device 150 may deform the permeable layer 140 to displace a portion of the fluid 110. For example, the displacement device 150 may compress a portion of the permeable layer 140, thus decreasing the volume of the permeable layer 140 and motivating fluid through the fluid ports 144 to outwardly deform the second region 122; the displacement device 150 may thus "squeeze" the fluid 110 out of the permeable layer 140 and toward the tactile layer 120. The permeable layer 140 may be deformed uniformly; for example, the displacement device 150 may be a clamp arranged substantially across the permeable layer 140 opposite the support surface 142, wherein the clamp compresses the permeable layer 140 by motivating the retaining wall 130 toward the tactile layer 120. Alternatively, the displacement device 150 may compress only a portion of the permeable layer 140, such as the portion of the permeable layer 140 substantially proximal to the second region 122. In this variation, the displacement device 150 may compress the permeable layer 140 in substantially one direction, but may alternatively compress the permeable layer 140 in more than one direction, such as vertically and horizontally, or may deform the permeable layer 140 by twisting. However, other suitable deformations of the permeable layer 140 that displaces a portion of the fluid 110 from the permeable layer 140 to deform the second region 122 are also possible.

[0038] The displacement device 150 may also be an electrical pump that provides a voltage gradient across a portion of the permeable layer 140 to induce electroosmotic fluid flow through the fluid ports 144. Because viscous forces substantially hinder fluid flow through substantially small channels, electroosmotic-driven fluid flow may be advantageous in variations of the user interface system 100 in which the fluid ports 144 are substantially small in cross-section. As shown in FIGURE 2, the displacement device 150 may generate a voltage gradient across the permeable layer 140 by generating a first voltage at a substantially transparent conductive trace 152 on the support surface 142 and a second (different) voltage on a transparent conductive trace on an opposite side of the permeable layer 140; the subsequent voltage gradient thus motivates fluid through the fluid ports 144. In the variation of the user interface system 100 in which the touch sensor 160 is a capacitive sensor arranged substantially between the permeable layer 140 and the tactile layer 120, within the permeable layer 140, or between the permeable layer 140 and the retaining wall 130, an electrode of the touch sensor 160 may also function as a portion of a conductive trace 152 of the electrical displacement device 150. However, the displacement device 150 may generate a voltage gradient across any other suitable portions or elements of the user interface system 100 to induce electroosmotic fluid flow.

[0039] Furthermore, the displacement device 150 may comprise a heating element that heats a portion of the fluid 110 (such as within the permeable layer 140) to expand the portion of the fluid 110 and thus expand the second region 122. In this example, a heat sink may also be included in the user interface system 100, wherein the heatsink draws heat out of the portion of the fluid 110 in order to cool the fluid and retract the second region 122.

[0040] The touch sensor 160 of the preferred embodiment functions to generate an output indicative of a user action proximal to the tactile surface 124. The output is preferably readable by a processor or other component within the device on which the user interface system 100 is arranged. The touch sensor 160 preferably recognizes a user action that is a finger touch on the tactile surface 124, but the touch sensor 160 may recognize contact by any other object, such as a stylus, a palm of the user, or multiple fingers of the user. Though the touch sensor 160 preferably detects a user action proximal to the tactile surface 124 at the second region 122 (e.g., wherein the user presses the expanded second region 122), the touch sensor 160 may also detect the user action proximal to any other region of the tactile layer 120.

[0041] The touch sensor 160 may detect the user action when the second region is solely in the retracted state, solely in the expanded state, solely in the recessed state. However, the touch sensor 160 preferably detects a user touch at the second region 122 regardless of the state of the second region 122, although the touch sensor 160 may also generate a unique output for a user touch proximate to the second region 122 in each of the retracted and expanded (and recessed) states. As explained above, the orientation of a portion of the touch sensor 160 may be manipulated in order to maintain the distance between the portion of the touch sensor 160 and the tactile layer 120 throughout the various states of the second region 122; this is preferably accomplished by joining a portion of the touch sensor 160 to the back surface 125 of the tactile layer 120, as shown in FIGURE 7: FIGURE 7A depicts the second region 122 in the retracted state with the portion of the touch sensor 160 adjacent to the support surface 142 of the permeable layer 140; FIGURE 7B depicts the second region 122 in the expanded state with the portion of the touch sensor 160 joined to and deformed with the back surface of the second region 122.

[0042] The touch sensor 160 is preferably a capacitive touch sensor 160, as shown in FIGURES 8 and 9, wherein the touch sensor 160 may be a first conductive trace 152A that is a driving line and a second conductive trace 152B that is a sensing line; a user touch on the tactile surface 124 is thus preferably captured by the traces 152A, 152B by the touch sensor 160. However, the touch sensor 160 may sense the user touch via any other suitable technology, such as optical, resistive, surface acoustic wave, infrared, dispersive signal, or acoustic pulse recognition sensor technology.

[0043] The touch sensor 160 is preferably joined to the retaining wall 130 opposite the permeable layer 140, wherein the touch sensor 160 detects the user action through the retaining wall 130, the permeable layer 140, and the tactile layer 120. However, any portion of the touch sensor 160 may be interposed between, joined to, and/or physically coextensive with any other component of the user interface system 100; the touch sensor 160 may therefore be directly or indirectly coupled to the retaining wall 130. In the variation of the touch sensor 160 that is a capacitive touch sensor 160 comprising at least one layer of electrodes (e.g., a self capacitance touch sensor 160), a portion of the touch sensor 160 may be arranged within the permeable layer 140. In a first example, the permeable layer 140 is injection molded around an electrode layer of the touch sensor 160; in a second example, the permeable layer 140 comprises two permeable sheets adhered, one on each side, to the electrode layer of the touch sensor 160, thus forming a physically coextensive permeable layer 140 and touch sensor 160 portion. The touch sensor 160 may also comprise a layer bonded to the retaining wall 130 on one side and the permeable layer 140 on the opposite, or the touch sensor 160 may be a touch-sensitive display (i.e. the touch sensor 160 and display 190 are physically coextensive) coupled to the retaining wall 130. In the above example, the electrode layer is preferably permeable to the fluid, such as incorporating through-bores, -holes, or -slots. However, the touch sensor 160 may be of any other type, geometry, or arrangement, such as in the sensing systems as described in U.S. Application Number 12/319,334 filed 05-JAN-2009 and entitled “User Interface System,” and U.S. Application Number 12/497,622 filed on 03-JUL-2009 and entitled “User Interface System and Method,” which are incorporated in their entirety by this reference.

[0044] The user interface system 100 may further comprise a display 190, coupled to the retaining wall 130, that visually outputs an image to the user. To provide visual guidance to the user, the image is preferably of an input key substantially aligned with the second region 122. The display 190 is preferably a digital display, such as an LCD, LED, ELP, or other type of digital display commonly arranged within any of a vehicle console, a desktop computer, a laptop computer, a tablet computer, a television, a radio, a desk phone, a mobile phone, a smartphone, a PDA, a personal navigation device, a personal media player, a camera, or a watch. The digital display 190 is preferably joined to the retaining wall 130 opposite the permeable layer 140, but may alternatively be physically coextensive with the retaining wall 130, the touch sensor 160, and/or the permeable layer 140. The display 190 preferably generates the image, and the permeable layer 140 and the tactile layer 120 cooperatively communicate the image from the display 190 to the user; the retaining wall 130 and/or the touch sensor 160 may also cooperate to communicate the image to the user. The permeable layer 140 and the tactile layer 120 (and the retaining wall 130 and/or the touch sensor 160) therefore are substantially transparent, are substantially non-obstructive to light, and have substantially minimal internal reflectance.

[0045] The user interface system 100 may further comprise a perimeter wall, substantially encompassing the perimeter of the permeable layer 140, cooperating with the retaining wall 130 and the tactile layer 120 to retain the fluid 110 substantially within the permeable layer 140. The tactile layer 120 and the retaining wall 130 preferably substantially enclose the fluid 110 between the opposing broad surfaces of the permeable layer 140, and the perimeter wall preferably encircles the permeable layer 140 to prevent fluid from leaking from the perimeter sides of the permeable layer 140. This may be particularly important in the first variation of the permeable layer 140 (which comprises a substantially sponge-like material with interconnected cavities, as shown in FIGURE 4): fluid directed toward an undeformable (first) region of the tactile layer 120 may be redirected substantially sideways through the interconnected cavities;

though the fluid 110 is thus beneficially motivated toward a deformable (second) region of the tactile layer 120, the fluid 110 may also be directed out of the perimeter sides of the permeable layer 140, thus releasing fluid pressure within the permeable layer 140 and limiting outward deformation of the deformable region of the tactile layer 120. (Beneficially, however, in this variation and any other variation in which fluid ports 144 communicate a portion of the fluid 110 in a direction substantially perpendicular to the support surface 142, the displacement device 150 may increase fluid pressure within the permeable layer 140 proximal to both the first region 121 and the second region 122 but draw the fluid 110 only toward the second region 122 and thus deform only the second region 122.) The perimeter wall thus prevents such release of fluid pressure and is preferably incorporated in this variation (and potentially other variations) of the permeable layer 140. In another variation, the perimeter wall cooperates with any of the retaining wall 130, the permeable layer 140, and the electronic device to define the reservoir 170. The perimeter wall may be substantially independent of the permeable layer 140 but may also be integral with the permeable layer 140 or physically coextensive with the retaining wall 130. However, the perimeter wall may also be physically coextensive with the tactile layer 120, retaining wall 130, or any other element of the user interface system 100. In the variation in which the displacement device modifies the orientation of a portion of the retaining wall 130, the perimeter wall preferably deforms where necessary to accommodate the change in orientation.

[0046] As described above, the user interface system 100 may include a reservoir 170 that contains a portion of the fluid 110. The reservoir 170 is preferably a proximal reservoir that is substantially adjacent to the permeable layer 140, as shown in FIGURES 1 and 5, but may also be a remote reservoir, as shown in FIGURE 5. As the fluid 110 is displaced toward the tactile layer 120, additional fluid is preferably provided to the permeable layer 140 by the reservoir 170; as the fluid 110 is displaced away from the tactile layer 120, the fluid 110 is preferably recollected by the reservoir 170. The reservoir 170 may also replenish fluid to the permeable layer 140, such as following a leak or other loss of the fluid 110, though the reservoir 170 may provide additional fluid for any other suitable function. The reservoir 170 is preferably coupled to the permeable layer 140 via the displacement device 150 (i.e. the displacement device 150 is arranged between the reservoir 170 and the permeable layer 140) such that the displacement device 150 draws fluid from the reservoir 170 and toward the permeable layer 140, and vice versa. Furthermore, the reservoir 170 may be substantially rigid such that the reservoir 170 does not substantially deform as the fluid 110 is drawn therefrom, but the reservoir 170 may alternatively be substantially deformable, such as in a variation of the reservoir 170 that is a pliable (e.g., plastic, silicone, or rubber) pouch that deforms as fluid is drawn from or into the reservoir 170. However, the reservoir 170 may be arranged in any other suitable fashion and take any other form.

[0047] The variation of the reservoir 170 that is a proximal reservoir 170 is preferably in direct fluid contact with the permeable layer 140, as shown in FIGURES 1 and 5. The proximal reservoir 170 may be coupled to (or partially defined by) the permeable layer 140 opposite the support surface 142, but may alternatively be a substantially large cavity within the permeable layer 140 and containing fluid accessible by any number of the fluid ports 144. The proximal reservoir 170 may also include support pillars 139 that support the proximal reservoir 170 and substantially maintain the shape of the reservoir 170, such as the support pillars 139 shown in FIGURE 5. In the variation of the permeable layer 140 that is porous, the permeable layer 140 may accept fluid from any side; thus, the proximal reservoir 170 may be arranged in any suitable orientation to communicate the fluid 110 to any side of the permeable layer 140. The variation of the reservoir 170 that is a remote reservoir is preferably coupled to the permeable layer 140 (or an additional proximal reservoir) via a channel, but may be coupled using any other suitable element or method.

[0048] The reservoir 170 may also include a second displacement device 150 that displaces the fluid 110 within the user interface system 100. This preferably decreases the load on the displacement device 150 and may be particularly useful in the variation that includes a remote reservoir, wherein the fluid 110 must be displaced over a substantial distance. For example, the remote reservoir may be coupled to a second displacement device 150 that is a clamp, wherein the clamp may be manually operated to displace fluid toward the permeable layer 140. In this example, the clamp may be a hinge and/or slider on a mobile phone or any other suitable device such that, when actuated, fluid is drawn from the remote reservoir and motivated toward the permeable layer 140 (or vice versa). However, any other suitable type of second displacement device 150 may be used and may or may not be substantially similar to the displacement device 150. The second displacement device 150 may also be used in place of the displacement device 150.

[0049] The user interface system 100 may further comprise a pressure sensor that detects ambient air pressure (or barometric or atmospheric pressure) proximal to the user interface system 100. The pressure sensor may be of any type of pressure sensor, such as a piezoresistive, capacitive, electromagnetic, piezoelectric, optical, or potentiometric pressure sensor. In the retracted state, the displacement device 150 preferably adjusts the fluid pressure at the back surface 125 of the second region 122 to substantially match the ambient air pressure such that the second region 122 does not deform undesirably (i.e. deviate from flush with the first region 121). For example, in the retracted state, the displacement device 150 preferably reduces the fluid pressure at the back surface 125 of the second region 122, when the user interface system 100 is transferred from substantially sea level to a substantially high altitude, such that the second region 122 does not outwardly deform in the presence of reduced ambient air pressure at higher altitudes. The pressure sensor may also serve as a reference for the displacement device 150, wherein, in the expanded (or recessed) state, the displacement device 150 increases (or decreases) the pressure at the back surface 125 of the second region 122 by a pre-specified pressure above (or below) the ambient air pressure such that the second region 122 deforms substantially identically at various ambient air pressures. However, the pressure sensor may function and/or cooperate with the displacement device 150 in any other way.

[0050] As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention as defined in the following claims.

CLAIMS

We Claim:

1. A user interface system comprising:
   - a volume of fluid;
   - a tactile layer, defining an outer tactile surface touchable by a user and a back surface opposite the tactile surface, the tactile layer including a first region and a second region, wherein the second region is operable between:
     - a retracted state, wherein the second region is substantially flush with the first region; and
     - an expanded state, wherein the second region is substantially proud of the first region;
   - a retaining wall, substantially impermeable to the fluid;
   - a permeable layer, interposed between the tactile layer and the retaining wall, joined to the back surface of the first region and defining a support surface below the second region, wherein the permeable layer includes a plurality of fluid ports that communicate a portion of the fluid through a portion of the permeable layer to the back surface of the second region;
   - a displacement device cooperating with the retaining wall to direct a portion of the fluid through the fluid ports to the back surface of the tactile layer to transition the second region from the retracted state to the expanded state; and
   - a touch sensor coupled to the permeable layer and detecting a user touch on the tactile surface of the tactile layer.

2. The user interface system of Claim 1, wherein the support surface is substantially rigid and provides a hard stop that limits inward deformation of the tactile layer due to a force applied to the tactile surface by the user.

3. The user interface system of Claim 1, wherein the displacement device draws a portion of the fluid from the fluid ports to transition the second region from the expanded state to the retracted state.

4. The user interface system of Claim 3, wherein the support surface defines a concave contour beneath the second region, wherein the second region is further operable in a recessed state, and wherein the displacement device draws a portion of the fluid from the fluid ports to pull the second region into the concave contour in the recessed state.

5. The user interface system of Claim 1, further comprising a reservoir containing a portion of the volume of fluid, wherein the displacement device displaces fluid from the reservoir to the fluid ports of the permeable layer.

6. The user interface system of Claim 5, wherein the reservoir is at least partially defined by the retaining wall on one side and by the permeable layer on an opposite side.

7. The user interface system of Claim 6, wherein the displacement device modifies the orientation of a portion of the retaining wall, relative to the permeable layer, to direct fluid from the reservoir to the fluid ports.

8. The user interface system of Claim 1, wherein the displacement device is an electrical pump that generates a voltage differential within the permeable layer to induce electroosmotic fluid flow through the fluid ports to outwardly expand the second region.

9. The user interface system of Claim 8, wherein the displacement device generates the voltage differential across a first conductive trace, arranged on the support surface, and a second conductive trace, arranged on the permeable layer opposite the support surface.

10. The user interface system of Claim 9, wherein the touch sensor is a capacitive sensor incorporating a portion of a conductive trace of the displacement device.

11. The user interface system of Claim 1, wherein the displacement device is a mechanical pump that increases fluid pressure in the permeable layer proximal to the retaining wall, and wherein the retaining wall resists deformation due to the

increase in fluid pressure and directs the fluid through a portion of the fluid ports to expand the second region.

12. The user interface system of Claim 1, further comprising an attachment point that joins a portion of the back surface of the tactile layer to the permeable layer.

13. The user interface system of Claim 12, wherein the permeable layer defines a substantially uniform density of fluid ports adjacent to the first and second regions, and wherein the attachment point blocks fluid flow through at least one fluid port adjacent to the first region.

14. The user interface system of Claim 12, wherein the first and second regions of the tactile layer are adjacent and form a substantially continuous tactile surface, and wherein the attachment point defines a border between the first and second region.

15. The user interface system of Claim 1, wherein the permeable layer defines the fluid ports that are substantially small in diameter such that the fluid ports are tactilely imperceptible to the user touching the tactile surface.

16. The user interface system of Claim 1, wherein the outward deformation of the second region of the tactile layer forms a button, and wherein the touch sensor detects a user touch substantially proximal to the button.

17. The user interface system of Claim 1, wherein the touch sensor is a capacitive touch sensor.

18. The user interface system of Claim 1, wherein the retaining wall is physically coextensive with the touch sensor.

19. The user interface system of Claim 1, further comprising a digital display, coupled to the retaining wall, that visually outputs an image to the user, wherein the image is of an input key substantially aligned with the second region.

20. The user interface system of Claim 19, wherein the digital display is physically coextensive with the retaining wall.

21. The user interface system of Claim 20, wherein a portion of the touch sensor is arranged substantially within the permeable layer.

22. The user interface system of Claim 19, wherein the fluid, the permeable layer, and the tactile layer cooperatively communicate the image from the display to the user.

23. The user interface system of Claim 1, wherein the tactile layer further defines a third region operable in a retracted state and an expanded state, wherein the displacement device cooperates with the retaining wall to direct a portion of the fluid through the fluid ports to the back surface to transition the third region, independently of the second region, from the retracted state to the expanded state.

24. The user interface system of Claim 1, further comprising a pressure sensor that detects ambient air pressure proximal to the user interface system, wherein, in the retracted state, the displacement device directs a portion of the fluid to substantially match fluid pressure at the back surface of the second region to ambient air pressure.

25. The user interface system of Claim 1, wherein the permeable layer is of a substantially porous material comprising a series of interconnected cavities that form the fluid ports.

26. The user interface system of Claim 1, wherein the permeable layer defines a plurality of fluid ports that are substantially parallel bores, substantially circular in cross-section, and passing fully through the permeable layer substantially normal to the support surface.

27. The user interface system of Claim 1, further comprising a perimeter wall that substantially encompasses the perimeter of the permeable layer and cooperates with the retaining wall and the tactile layer to retain the fluid substantially within the permeable layer.

28. The user interface system of Claim 27, wherein the perimeter wall and permeable layer further partially define a reservoir that contains a portion of the fluid.

29. The user interface system of Claim 1, wherein the fluid ports contain no fluid other than that of the volume of fluid, and wherein the fluid ports are substantially filled with the fluid.

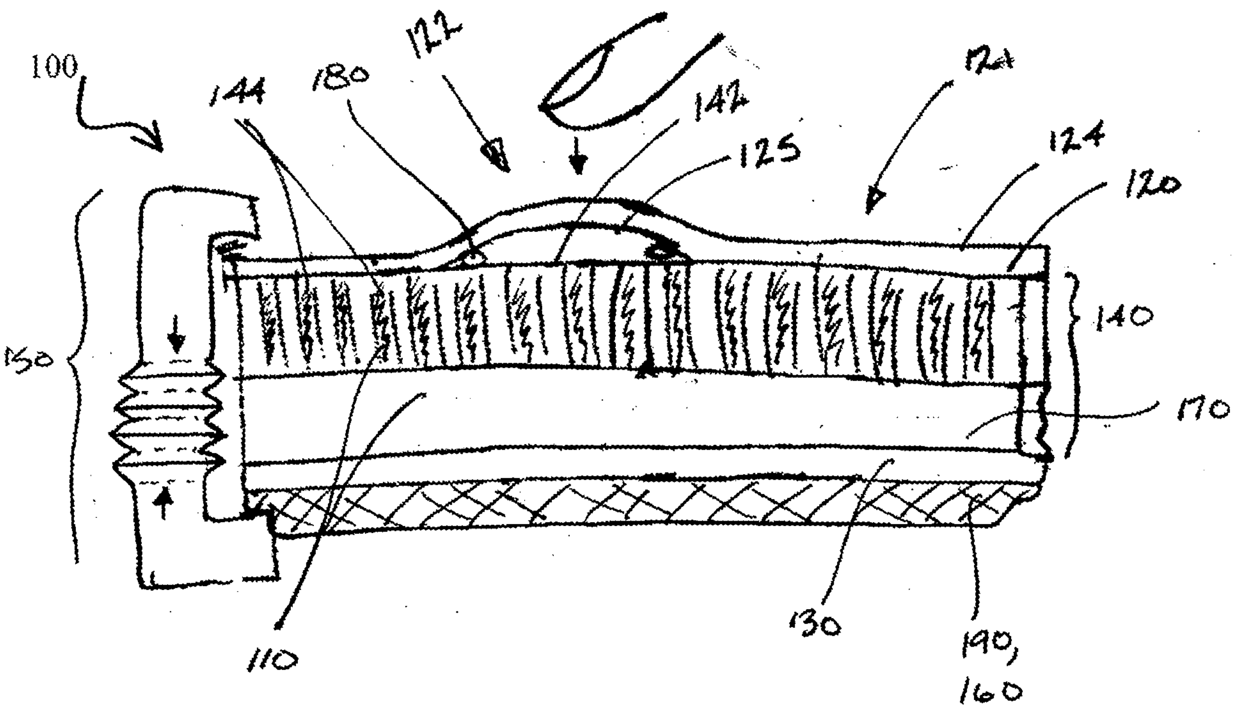

FIGURE 1

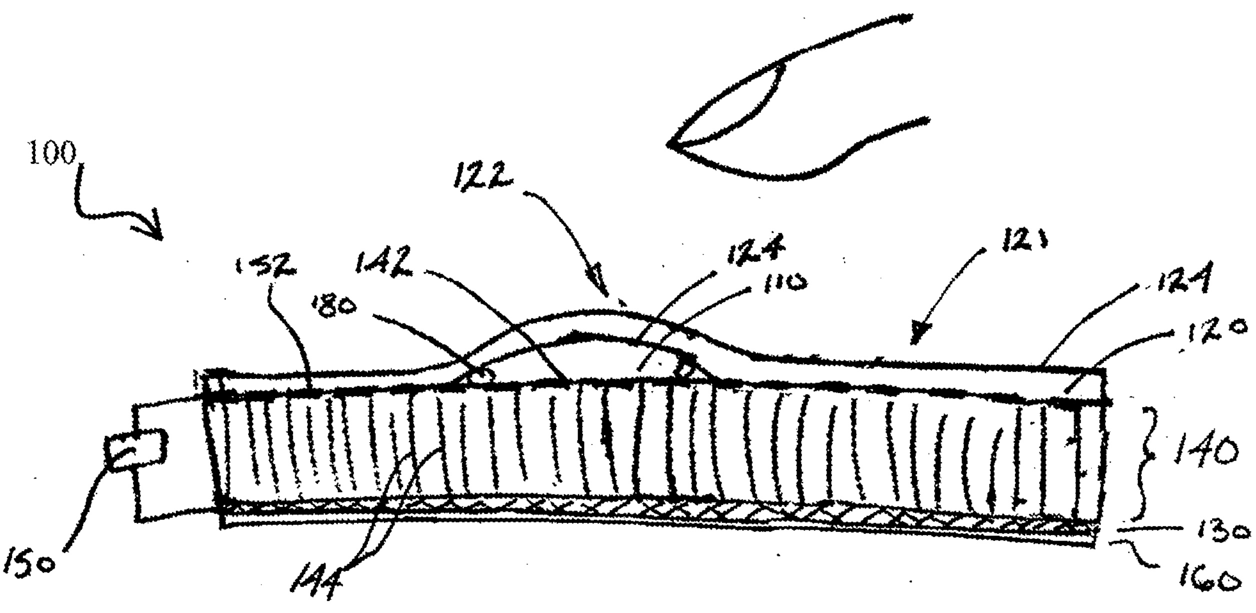

FIGURE 2

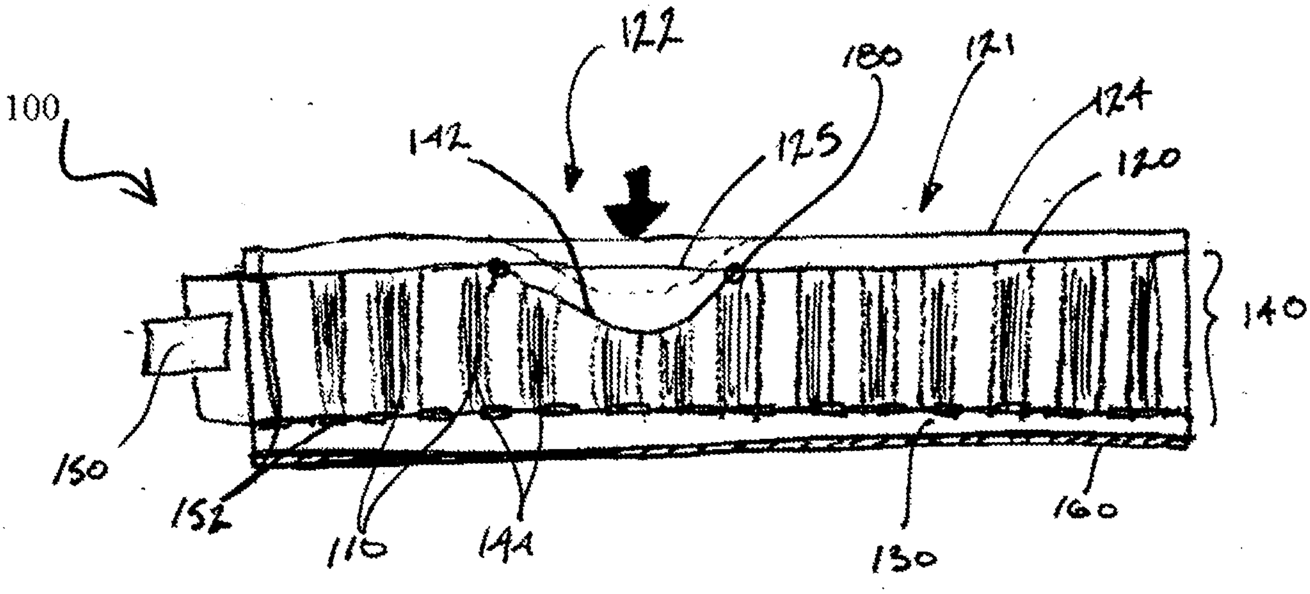

FIGURE 3

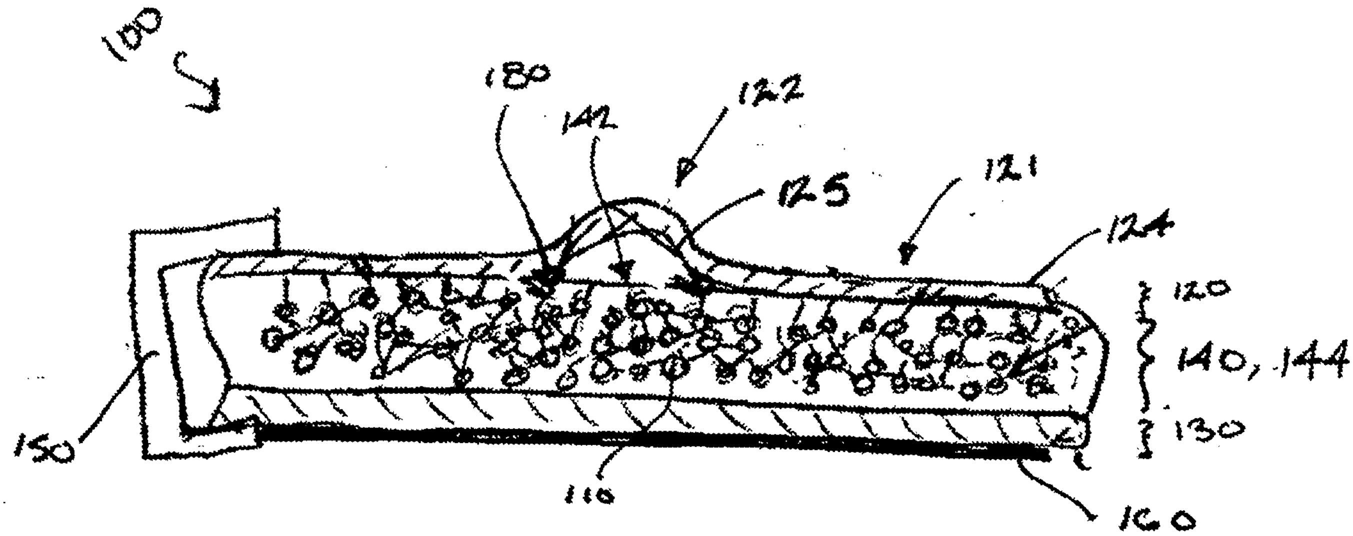
100
180
142
122
125
121
124
120
140, 144
130
150
110
160

FIG. 4A

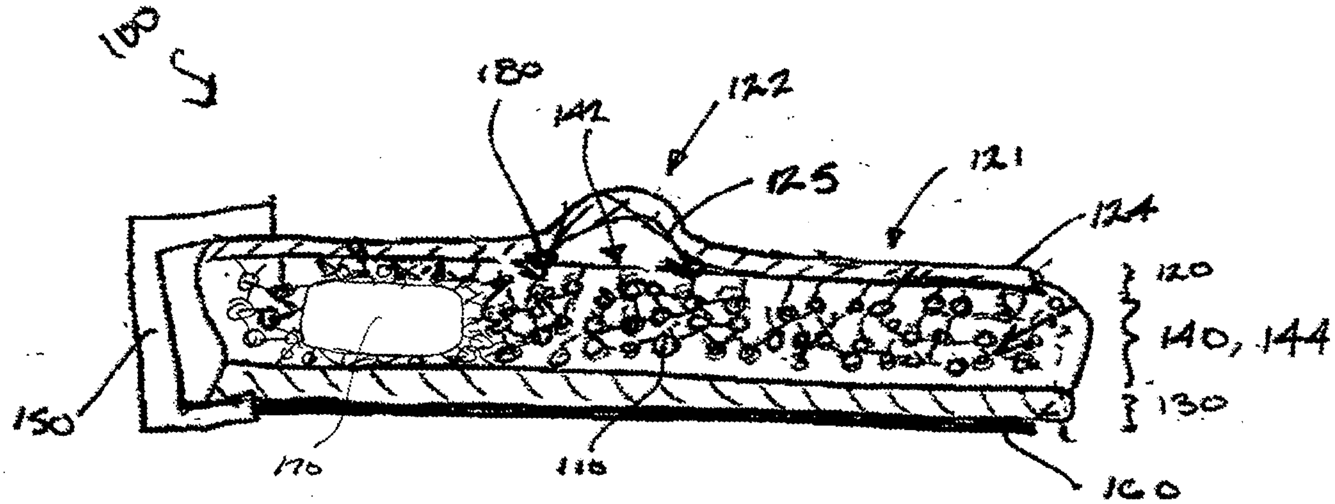
100
180
142
122
125
121
124
120
140, 144
130
150
170
110
160

FIG. 4B

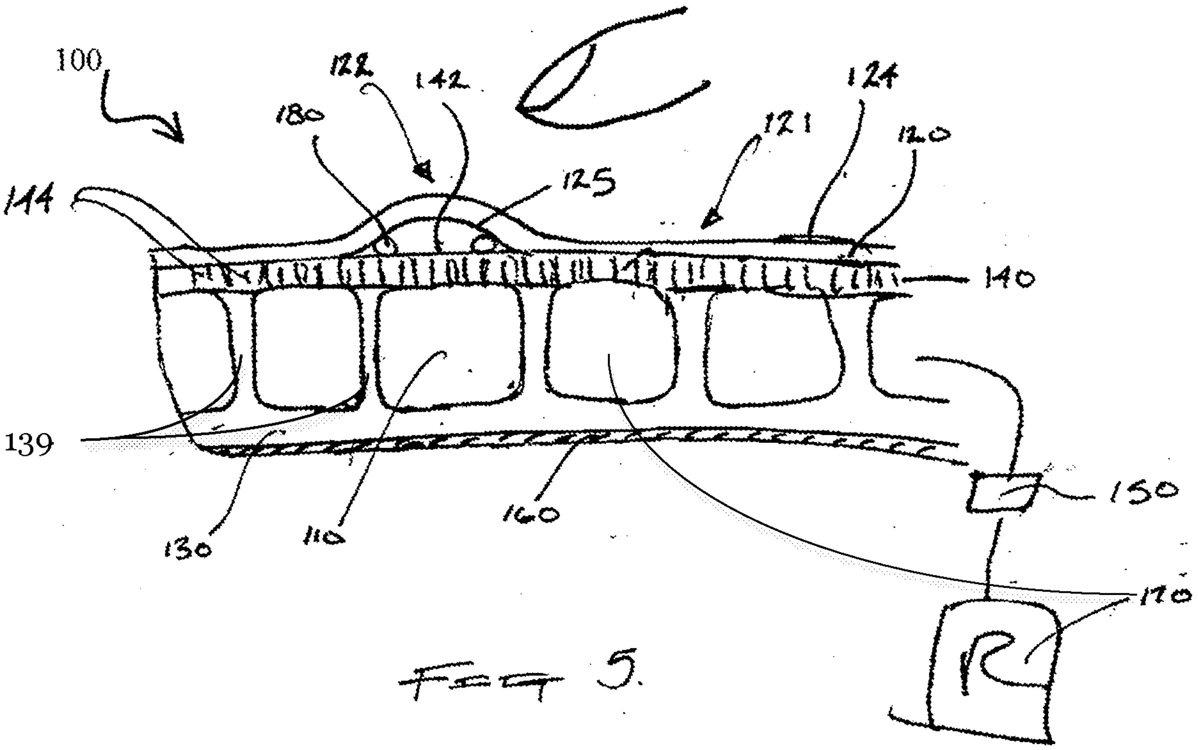

Fig 5.

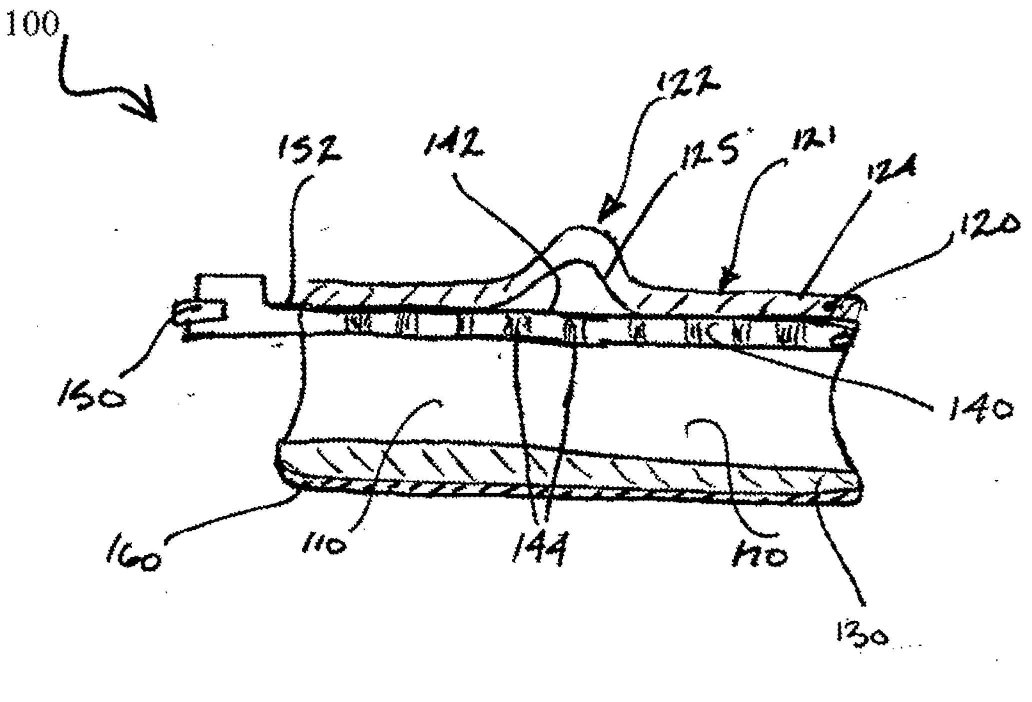

FIGURE 6

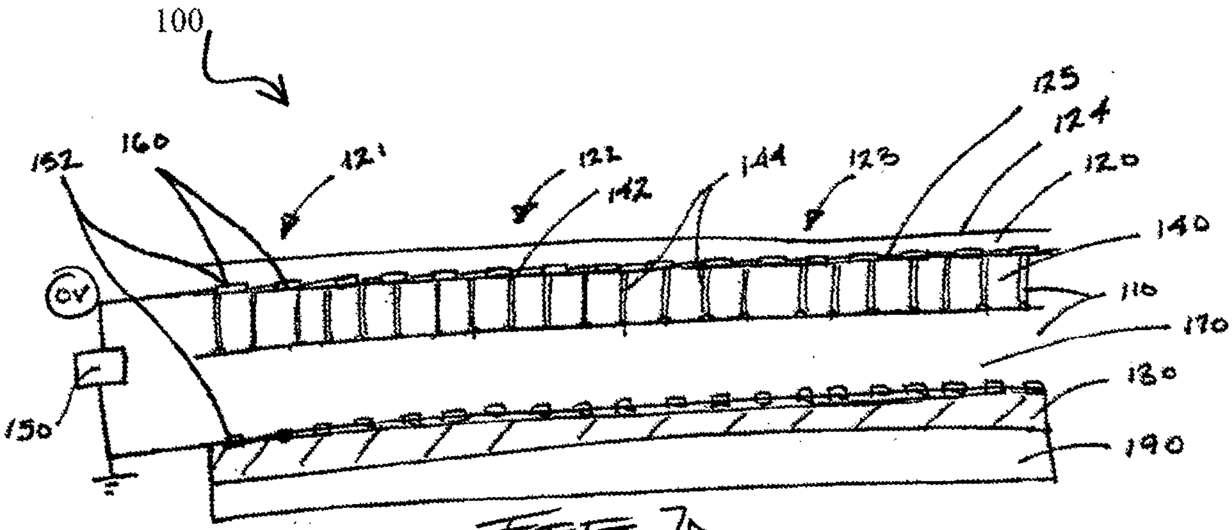

FIG 7A

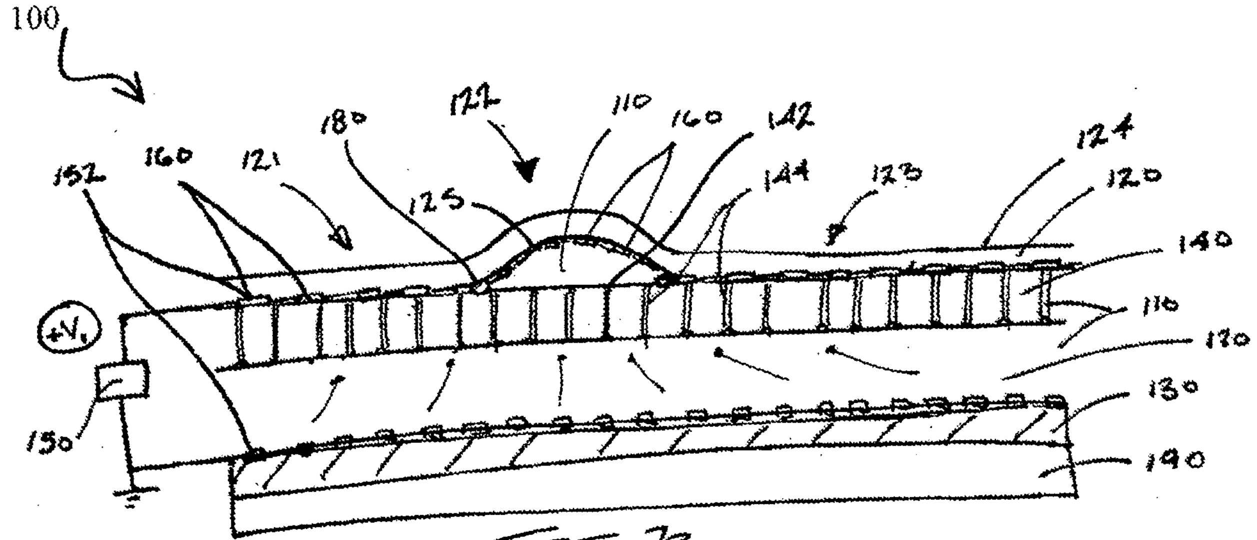

FIG. 7B

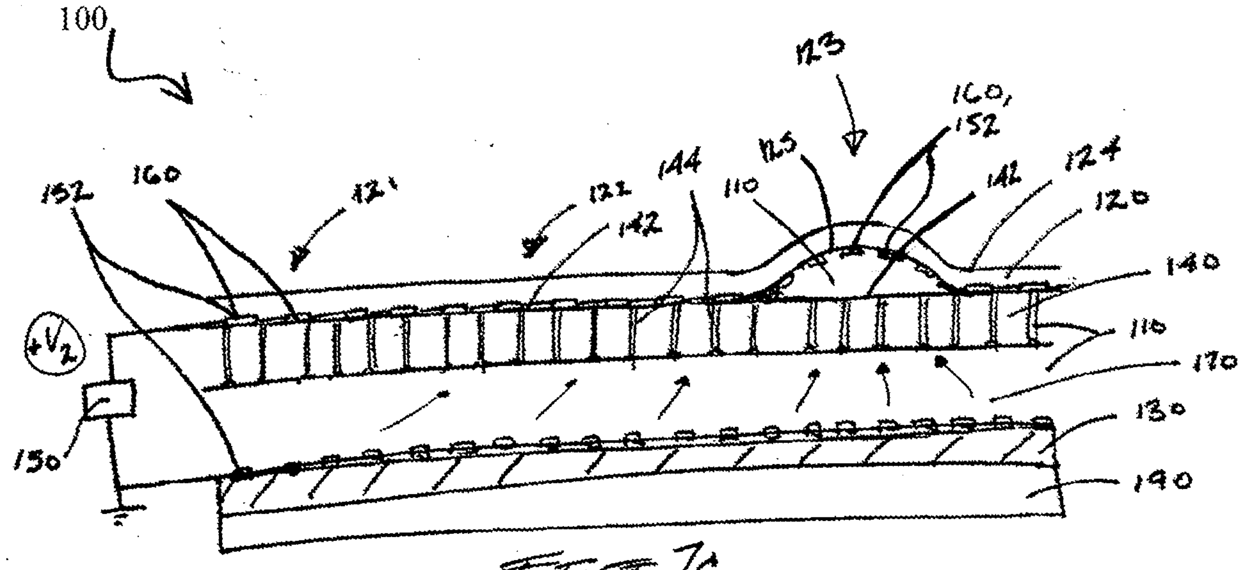

FIG 7C

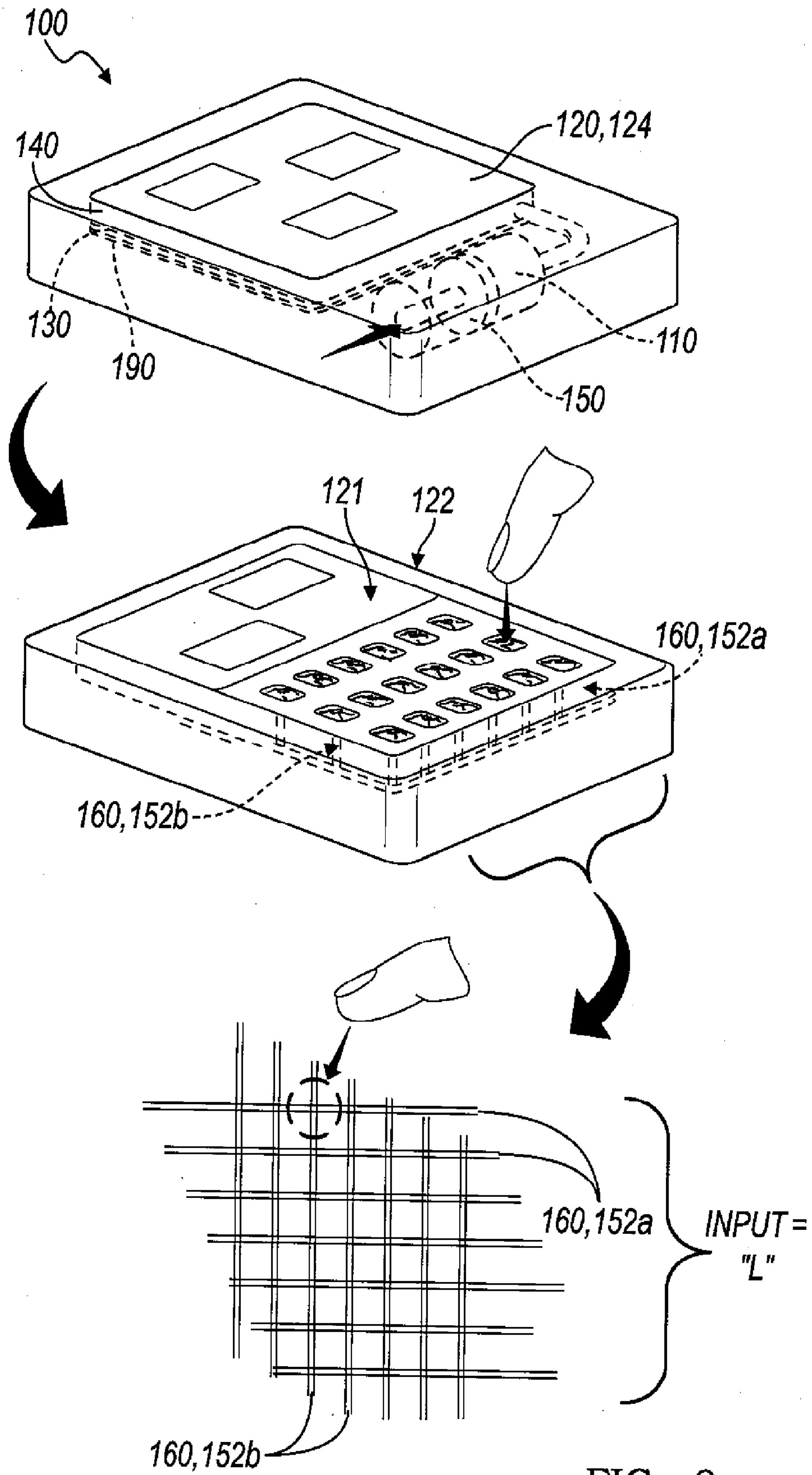
100
140
120,124
130
190
110
150
121
122
160,152a
160,152b
160,152a
INPUT =
"L"
160,152b

FIG. 8

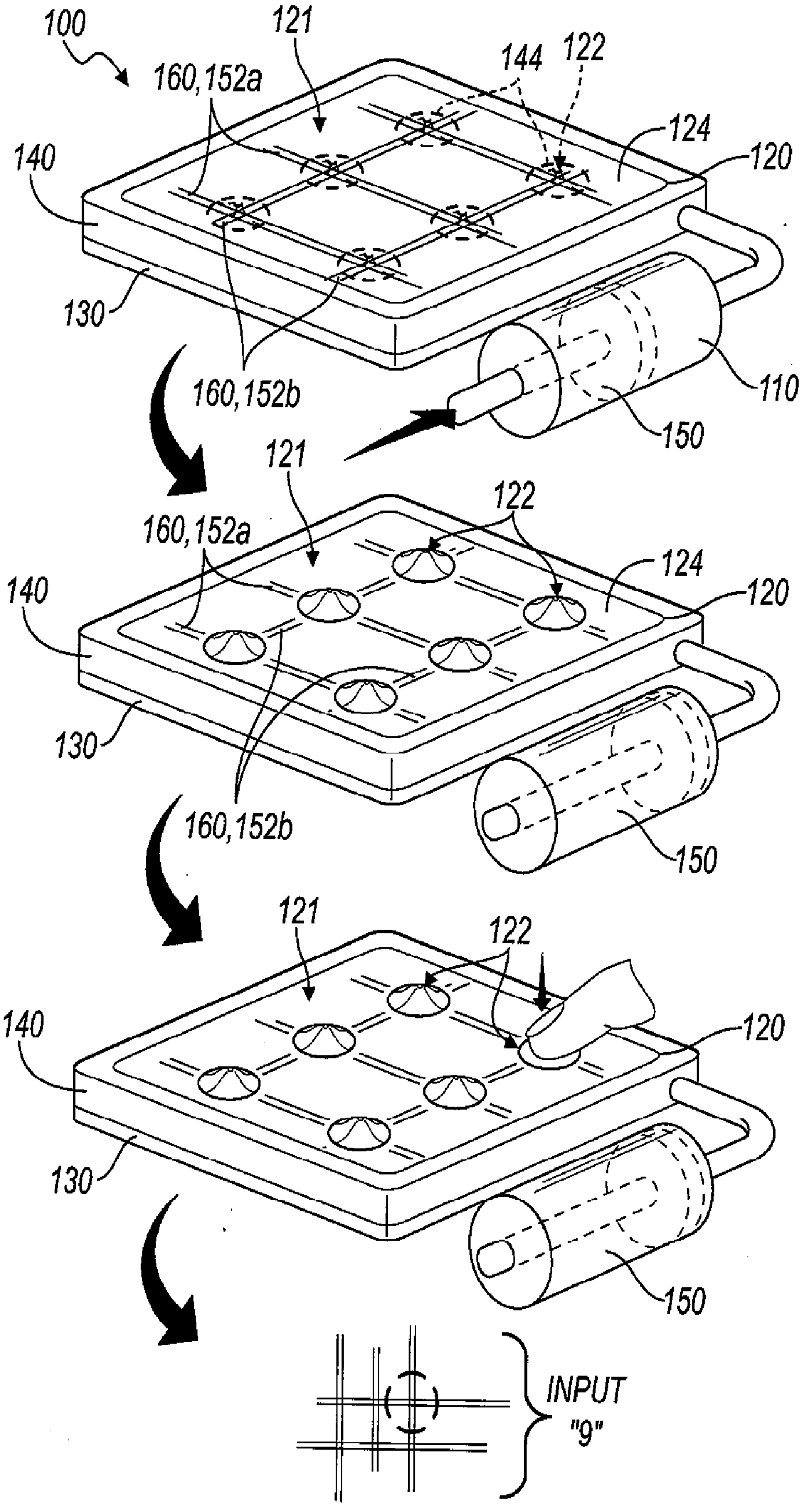
100
121
160,152a
144
122
124
120
140
130
160,152b
110
150
121
122
160,152a
124
120
140
130
160,152b
150
121
122
140
120
130
150
INPUT
"9"

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/057174

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G06F 3/045 (2012.01)
USPC - 345/174
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - G06F 3/03, 3/033, 3/041, 3/045 (2012.01)
USPC - 345/156, 162, 173, 174

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 practicable, search terms used)
MicroPatent; Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2009/0174687 A1 (CIESLA et al) 09 July 2009 (09.07.2009) entire document	1-7 and 11-29 ----- 8-10
Y	US 2007/0036492 A1 (LEE) 15 February 2007 (15.02.2007) entire document	8-10
A	US 2007/0236469 A1 (WOOLEY et al) 11 October 2007 (11.10.2007) entire document	1-29
A	US 2007/0122314 A1 (STRAND et al) 31 May 2007 (31.05.2007) entire document	1-29
A	US 2009/0174673 A1 (CIESLA) 09 July 2009 (09.07.2009) entire document	1-29
A	US 2010/0109486 A1 (POLYAKOV et al) 06 May 2010 (06.05.2010) entire document	1-29

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"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
21 February 2012	08 MAR 2012

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