

these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

[0028] As shown in FIGS. 1 and 2, the user interface system 100 of the preferred embodiment includes: a layer 110 defining a surface 115, a substrate 120 supporting the layer and at least partially defining a cavity 125, a displacement device 130 coupled to the cavity 125 and adapted to expand the cavity 125 thereby deforming a particular region of the surface 115, a touch sensor 140 coupled to the substrate 120 and adapted to sense a user touch proximate the particular region of the surface 115, and a display 150 coupled to the substrate 120 and adapted to output images to the user.

[0029] The user interface system 100 of the preferred embodiments has been specifically designed to be incorporated into an electronic device, such as the display of an automotive console, a desktop computer, a laptop computer, a tablet computer, a television, a radio, a desk phone, a mobile phone, a PDA, a personal navigation device, a personal media player, a camera, or a watch. The user interface system may, however, be incorporated in any suitable device that interfaces with a user in both a visual and tactile manner.

1. The Layer and Substrate

[0030] As shown in FIG. 2, the layer 110 of the preferred embodiment functions to provide the surface 115 that interfaces with a user in a tactile manner. The surface 115 is preferably continuous, such that when swiping a finger across the surface 115 a user would not feel any interruptions or seams. The surface 115 is also preferably planar. The surface 115 is preferably arranged in a flat plane, but may alternatively be arranged in a curved plane. The layer 110 also functions to deform upon an expansion of the cavity 125, and to preferably “relaxes” or “un-deforms” back to a normal planar state upon retraction of the cavity 125. The layer 110 is preferably elastic. In one version, the layer 110 is relatively more elastic in specific areas and relatively less elastic in other areas and is deformed in the relatively more elastic areas. In another version, the layer 110 is generally uniformly elastic. In yet another version, the layer 110 includes or is made of a smart material, such as Nickel Titanium (commonly referred to as “Nitinol”), that has a selective and/or variable elasticity. The layer 110 is preferably optically transparent, but may alternatively be translucent or opaque. In addition to the transparency, the layer 110 preferably has the following properties: a high transmission, a low haze, a wide viewing angle, a minimal amount of back reflectance upon the display 150 (if the display 150 is coupled with the user interface), scratch resistant, chemical resistant, stain resistant, and relatively smooth (not tacky) to the touch. The layer 110 is preferably made from a suitable elastic material, including polymers and silicon-based elastomers such as poly-dimethylsiloxane (PDMS) or RTV Silicon (e.g., RTV Silicon 615). The layer 110 may, however, be made of any suitable material that provides the surface 115 and that deforms. In one version, the layer 110 is a single homogeneous layer less than 1 mm thick (preferably 50 to 200 microns). In another version, the layer 110 may be constructed using multiple layers or coatings from the same material or from different suitable materials.

[0031] The substrate 120 of the preferred embodiments functions to support the layer 110 and to at least partially define the cavity 125. In one version, as shown in FIGS. 3a and 3b, the layer 110 is directly attached to the substrate 120 using an adhesive, ultra-sonic bonding, oxygen plasma sur-

face treatment, or any other suitable techniques known to one skilled in the art. The substrate 120 and the layer 110, in this version, cooperately define the cavity 125 (with the substrate 120 defining a “container” and the layer 110 defining a “membrane” over the “container”). In another version, as shown in FIGS. 4a and 4b, the layer 110 is indirectly attached to the substrate 120 with another element, such as the touch sensor 140 and/or the display 150 located between the layer 110 and the substrate 120. The substrate 120 and the intervening element define the cavity 125 in this version. In yet another version, as shown in FIGS. 5a and 5b, the layer 110 and the substrate 120 are formed as a singular structure, which fully defines the cavity 125. In yet one more version, as shown in FIGS. 6a and 6b, the substrate 120 may include a lattice-like support member 160 under the particular region of the surface 115. When the cavity 125 is expanded and the deformation is present in the surface 115, the support member 160 functions to prevent a user from “pressing too far” into the deformation below the plane of the surface 115. When the cavity 125 is not expanded and the deformation is not present in the surface 115, the support member 160 functions to reduce (or potentially eliminate) the user from feeling “divots” in the surface 115 when swiping a finger across the surface 115. As shown in FIG. 6c, the support member 160 preferably includes holes or channels that allow for the expansion of the cavity 125 and the deformation of the surface 115. The support member 160 is preferably integrally formed with the substrate 120, but may alternatively be formed with the layer 110 or may be separately formed and later attached to the substrate 120. Finally, as shown in FIG. 6d, the support member 160 may alternatively partially define the cavity 125. The substrate 120 is preferably rigid, but may alternatively be flexible in one or more directions. The substrate 120—if located above the display 150 is preferably optically transparent, but may—if located below the display 150 or if bundled without a display 150 be translucent or opaque. The substrate 120 is preferably made from a material including polymers or glass, for example, elastomers, silicon-based organic polymers such as poly-dimethylsiloxane (PDMS), thermoset plastics such as polymethyl methacrylate (PMMA), and photocurable solvent resistant elastomers such as perfluoropolyethers. The substrate 120 may, however, be made of any suitable material that supports the layer 110 and at least partially defines the cavity 125. In the preferred version, the substrate 120 is a single homogenous layer approximately 1 mm to 0.1 mm thick and can be manufactured using well-known techniques for micro-fluid arrays to create one or more cavities and/or micro channels. In alternative versions, the substrate 120 may be constructed using multiple layers from the same material or from different suitable materials.

[0032] As shown in FIGS. 3a and 3b, the cavity 125 of the preferred embodiment functions to hold a fluid and to have at least two volumetric settings: a retracted volume setting (shown in FIG. 3a) and an extended volume setting (shown in FIG. 3b). The fluid is preferably a liquid (such as water, glycerin, or ethylene glycol), but may alternatively be a gas (such as air, nitrogen, or argon) or any other substance (such as a gel or aerogel) that expands the cavity 125 and deforms the surface 115. In the extended volume setting, the cavity 125 extends above the plane of the surface 115, thereby deforming a particular region of the surface 115. As explained above, the cavity 125 is preferably defined by the substrate 120 and the layer 110 (or an intervening element), or by the substrate 120 and layer 110 as a singular structure. In one