[0040] The structure and operation of the capacitive touch sensor of the present invention provides enhanced durability over previous technologies. Under normal operation, the conductive layers **210**, **220** are not flexed to the point of contact. Contact between the conductive layers may be prevented by coating the protective layer with a nonconductive material, or by using spacers, a filler material, or other methods to keep the conductive layers apart. This reduces the occurrence of rubbing, sticking or flaking of the conductive layers. Additionally, because no contact between conductive layers **210**, **220** is required, one or both conductive layers **210**, **220** can optionally be coated with a protective layer or multilayer **212**, **218**. The protective layer **212**, **218** may be a hard coat of low surface energy material to reduce sticking, for example. The protective layers **212**, **218** physically isolate the conductive layers from other sensor material, thereby mitigating degradation of the conductive layers due to chemical reaction and ion diffusion.

[0041] When the upper conductive layer **210** is pushed towards the lower conductive layer **220**, the capacitive current flowing between the two conductive layers **210** and **220** is locally increased at that portion of the upper conductive layer **210** that approaches more closely towards the lower conductive layer **220**. It will be appreciated that, because of this local rise in capacitive current between the two conductive layers, the touch screen may be operated with any object or stylus that depresses the upper conductive layer **210**. This mode of operation contrasts with conventional capacitive touch screen that require the use of a conductive stylus.

[0042] The optional protective layers **212**, **218**, may also function as a transparent, antireflective coating for the conductors **210**, **220**. For example, the protective layers **212**, **218** may be formed of SiO_2 and may have a thickness in the range of 0.05 μm-10 μm, although the protective layers **212**, **218** may have a thickness outside this range. The bottom protective layer **218** may also be formed of SiO_2, and may have a thickness greater than the thickness of the protective layer **212**. In addition to protecting the conductive layers, an advantage of using protective layers is that high reflective losses at the interface between the gap and the conductive layer, which typically has a high refractive index, may be reduced.

[0043] Other embodiments of the touch sensor of the present invention are schematically illustrated in **FIGS. 2B and 2C**. The touch sensor may be configured with only one protective layer **212** as shown in **FIG. 2B**, or may be configured without protective layers as illustrated in **FIG. 2C**. Spacers **216** may be interposed between the two conductive layers **210** and **220**, with spacers designed to prevent contact between the layers, to set a uniform gap between the layers, or to provide a desired activation force.

[0044] The gap **215** may optionally be filled with a deformable material. Upon application of a touch, the gap material allows movement of one conductive layer toward the other conductive layer. When the touch is removed, the sensor layers return to their original positions. The gap material may be a liquid, or a deformable elastic material. Protective layers **212** and **218** and spacers **216** may or may not be used when a gap material is disposed between the conductive layers. The addition of gap filling material may improve display durability by dissipating the energy applied during a touch, making the sensor more resistant to damage.

[0045] Where transparency through the sensor is important, the gap filler material may be a deformable material with appropriate optical properties to increase overall transmission through the sensor. The gap filler material preferably deforms without the creation of air pockets that cause the material to become optically lossy. For example, the gap filler material may be polyurethane epoxy, silicone, a rubbery material, or a gel. Furthermore, the gap filler material may have a refractive index similar to that of the surrounding materials, so as to reduce reflective losses at the material interfaces.

[0046] In addition, the gap filler may be composed of a material that changes dielectric properties when compressed, further enhancing the change in capacitance induced by a touch. One type of material that changes electrical properties under pressure is a deformable material that is loaded with conductive particles. The conductive particles may be particles of metal, metal oxide, or a conductive polymer. In addition, the particles may be coated with a conductive material, for example, a metal, a metal oxide, or conductive polymer. The refractive index of the particles may be selected to increase optical transmission through the sensor. For example, the scattering and reflection losses due to the particles in a matrix are reduced when the difference in the refractive index between the particles and the matrix is reduced.

[0047] The gap filler may also be composed of a material that exhibits a change in electrical properties with pressure, such as a piezoelectric material. A configuration incorporating pressure sensitive materials as the gap filler material may provide a signal indicating the force as well as the location of the touch, e.g. giving z-axis sensitivity. A piezoelectric gap filler material may be used as a force transducer, wherein a force applied to the surface of the sensor causes a corresponding change in the voltage across the gap. The magnitude of the touch force may be determined by measuring the voltage across the piezoelectric material. Suitable piezoelectric materials include poled polyvinylidene fluoride (PDVF) and ferroelectric liquid crystal.

[0048] Another embodiment of the invention, illustrated in **FIG. 3A**, includes a top structure **340** with a supporting layer **305**, a first conductive layer **310**, and an optional protective layer **312** as previously discussed. In this embodiment, the bottom structure **345** includes an optional substrate **330**, a bottom conductive layer **320** and a protective layer **318** provided with integrated spacers **316**. Alternatively, the top protective layer **312** may include the integrated spacers **316**. The protective layer **318** integrated with the spacers **316** can be formed, for example, by standard microreplication methods using a UV curable material such as an acrylate or methacrylate composition. The spacers may vary in density and dimensions to alter the physical stiffness of the sensor to control the touch activation force. For example, the spacers may have a diameter between 5 μm and 250 μm, a height between 2 μm and 50 μm and be spaced apart by 0.5 mm to 5 mm, although they may have dimensions outside these ranges. The material used to form the protective layer **318** integrated with the spacers **316** may be loaded with silica or other particles, with dimensions in the range of 10 nm to 10 μm to increase hardness, if desired.

[0049] Optionally, a roughened surface **317** may be superimposed on the spacers **316** and protective layer **318** to