lenges with regard to maintaining a uniform layer thickness. The various embodiments of the invention involve touch sensing devices and methods of manufacturing touch sensing devices having both high transparency and high sheet resistance.

[0017] **FIG. 1A** illustrates a resistive touch sensor **100** in accordance with one embodiment of the invention. The resistive touch sensor **100** shown in **FIG. 1A** includes a top substrate **140** that forms the touch surface of the sensor **100**. Top substrate **140** is preferably formed of a material that is dimensionally stable and resistant to abrasion and chemicals. In one configuration, a base layer **142** comprising a polyester material, such as polyethylene terephthalate (PET) is used as a component of the top substrate **140**. The top substrate **140** may optionally incorporate one or more additional layers **141**, **143**, such as hard coats to improve the structural characteristics and scratch resistance of the top layer as well as antireflective or antiglare coatings to improve viewability through the touch sensor.

[0018] The touch sensor **100** includes first and second conductive layers **110**, **120** separated by a gap **130**. The first conductive layer **110** is disposed on the top layer **140**, which may optionally incorporate a number of layers, such as hardcoat layers and/or antireflective or antiglare coatings as described above. A substrate layer **150**, comprised of a suitable transparent material, such as glass or plastic, supports the second conductive layer **120**. One or more spacers **160** may be positioned within the gap layer **130** to maintain an appropriate spacing between the conductive layers **110**, **120**. The conductive layers **110**, **120** may be formed, for example, by depositing a transparent conductive metal oxide layer, such as ITO, ATO, TO, or other transparent conductive materials on the top layer **140** and substrate **150**.

[0019] The resistive touch sensor **100** may be energized by an electrical drive signal produced by controller circuitry (not shown) and applied to one or more of the conductive layers **110**, **120** of the resistive touch sensor. A touch applied to the surface of the touch sensor **100** deflects the first conductive layer **110** towards the second conductive layer **120**, causing the contact between the conductive layers **110**, **120**. The location of the touch is determined as a function of the point of contact between the conductive layers **110**, **120**.

[0020] The controller may alternate the electrical signal between the first and second conductors **110**, **120** to determine the x and y coordinates of the touch. Alternatively, one of the conductors can be driven from all four corners, for example, while the other is held at ground or another constant potential.

[0021] **FIG. 1B** illustrates a capacitive touch sensor **101** in accordance with an embodiment of the invention. In this example, a conductive layer **175** is formed on a transparent substrate **170** of a suitable material, such as glass or plastic. As previously discussed, the transparent conductive layer may be formed of a transparent metal oxide, such as ITO, ATO, or TO.

[0022] A controller (not shown) is coupled to the conductive layer **175** and provides an electrical drive signal to the conductive layer **175**. Optionally, a resistor pattern may be screen printed on the conductive layer **175** to linearize the electric field supplied by the touch sensor controller across the surface of the touch sensor **101**. In this example, a dielectric layer **180** is coupled to the conductive layer **175**. The dielectric layer **180** may incorporate several layers including one or more layers to protect the touch sensor and/or reduce glare, for example.

[0023] **FIGS. 1A and B** illustrate examples of resistive and capacitive touch sensors incorporating transparent layers. Other configurations of touch sensors employing transparent conductive layers are also possible and are considered to be within the scope of the invention.

[0024] The high index of refraction of the metal oxide to air interface causes a significant reduction in light transmitted from a display through the transparent touch sensor. Also, metal oxide transparent conductors tend to absorb visible light preferentially in the blue region of the spectrum, resulting in a yellowed appearance, especially in thicker layers. High temperature annealing may improve the optical properties of the metal oxide, but may also result in a lower than desired sheet resistance, or may not be possible due to the temperature sensitivity of other layers or materials present (for example, use of a polymeric substrate).

[0025] Touch sensors arranged according to the various embodiments of the invention improve the optical transmission of the touch sensor by removing selected areas of one or more of the conductive layers of the touch sensor. Removal of the conductive material increases the optical transmission through the touch sensor.

[0026] Furthermore, a desired sheet resistance of the metal oxide layer may be achieved during deposition by maintaining a selected material thickness. However, depositing a relatively thin layer of metal oxide to achieve a high sheet resistance may present challenges with regard to maintaining a uniform layer thickness. According the embodiments of the invention, a thicker layer of material may be initially deposited, thus mitigating uniformity problems that may be associated with the deposition of thin layers. The sheet resistance of the relatively thick layer is increased to the desired value by removing selected areas of the conductive layer, which also increases optical transmission through the conductive layer.

[0027] **FIG. 1C** illustrates a conductive layer configured in accordance with an embodiment of the invention. A conductive layer arranged as illustrated in **FIG. 1C** may be used to form the conductive layer **175** of the capacitive touch sensor **101** illustrated in **FIG. 1B**. One or both conductive layers **110**, **120** of the resistive touch sensor **100** illustrated in **FIG. 1A** may be configured as illustrated **FIG. 1C**.

[0028] The conductive layer **190** shown in **FIG. 1C** incorporates a number of voids **195**, **196** arranged randomly over the conductive layer **190**. The voids **195**, **196** may define apertures **195** through the conductive material or they may form craters **196** wherein the conductive material is only partially penetrated by the crater **196**. The voids may optionally penetrate into or through layers adjacent to the conductive layer. The random pattern of voids **195**, **196** creates a stochastic screen, resulting in little or no formation of moiré interference patterns.

[0029] The voids **195**, **196**, which are shown as substantially circular in **FIG. 1C**, may be any shape. In one example, each void **195**, **196** defines an area less than about 10,000 μm^2. The density of the voids **195**, **196** is selected to maintain the physical and electrical continuity of the con-