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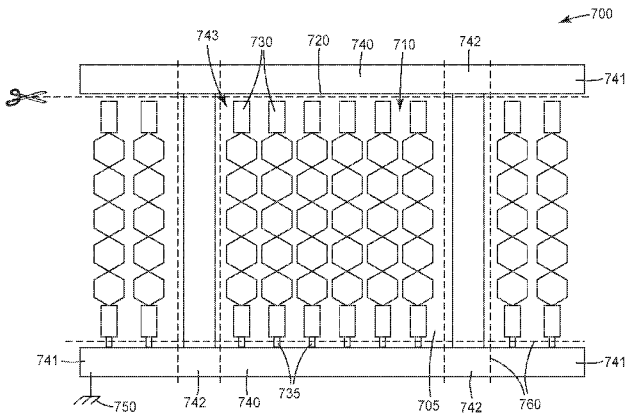

FIG. 7

(57) Abstract: Electrically conductive films are provided. An electrically conductive film includes a dielectric substrate having a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor. The electrically conductive film further includes electrically conductive spaced apart electrodes disposed on the substrate in the first region and adapted to form drive or receive electrodes in the touch sensor, and an electrically conductive pattern disposed on the substrate in the second region. Each electrode extends into the second region and is electrically and physically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes. Also, assemblies and methods for removing static electric charge from electrically conductive patterns are provided.

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ELECTRICALLY CONDUCTIVE FILMS, ASSEMBLIES, AND METHODS OF REMOVING STATIC ELECTRIC CHARGE FROM ELECTRICALLY CONDUCTIVE PATTERNS

Field

This application relates generally to electrically conductive films and assemblies, with particular application to removing static electric charge from electrically conductive patterns of the films and assemblies.

Background

Touch sensitive devices allow a user to conveniently interface with electronic systems and displays by reducing or eliminating the need for mechanical buttons, keypads, keyboards, and pointing devices. For example, a user can carry out a complicated sequence of instructions by simply touching an on-display touch screen at a location identified by an icon.

There are several types of technologies for implementing a touch sensitive device including, for example, resistive, infrared, capacitive, surface acoustic wave, electromagnetic, near field imaging, etc. Capacitive touch sensing devices have been found to work well in a number of applications. In many touch sensitive devices, the input is sensed when a conductive object in the sensor is capacitively coupled to a conductive touch implement such as a user's finger. Generally, whenever two electrically conductive members come into proximity with one another without actually touching, a capacitance is formed therebetween. In the case of a capacitive touch sensitive device, as an object such as a finger approaches the touch sensing surface, a tiny capacitance forms between the object and the sensing points in close proximity to the object. By detecting changes in capacitance at each of the sensing points and noting the position of the sensing points, the sensing circuit can recognize multiple objects and determine the characteristics of the object as it is moved across the touch surface.

Flexible printed circuits employed in touch sensitive devices typically include a single layer film or multilayer film, which contains electrical conductive circuitry that may be easily burned or otherwise damaged due to electrostatic discharge (ESD) generated, for instance, during the manufacturing process.

Summary

The present disclosure provides electrically conductive films, assemblies including the electrically conductive films, and methods of removing static electric charge from electrically conductive patterns of films and assemblies. The electrically conductive films may be used in touch sensors.

In a first aspect, an electrically conductive film for use in a touch sensor is provided. The electrically conductive film includes a dielectric substrate having a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor. The electrically conductive film further includes a plurality of substantially parallel electrically

conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in the touch sensor, and an electrically conductive first pattern disposed on the substrate in the second region. Each first electrode extends into the second region and is electrically and physically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes.

In a second aspect, another electrically conductive film is provided. The electrically conductive film includes a web of dielectric material, a plurality of electrically and physically intersecting electrically conductive rows and columns disposed on the web and defining a plurality of closed cells, and a plurality of substantially parallel electrically conductive spaced apart electrodes disposed on the web in each closed cell and adapted to form a plurality of drive or receive electrodes in a touch sensor. Each electrode in a closed cell terminates at at least one of the rows and columns in the plurality of the rows and columns defining the closed cell.

In a third aspect, yet another electrically conductive film for use in a touch sensor is provided. The electrically conductive film includes a dielectric substrate having a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor. The electrically conductive film further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in a viewing region of the touch sensor, an electrically conductive first pattern disposed on the substrate in the second region, and a plurality of electrically conductive spaced apart first traces disposed on the substrate. A first end of each trace is electrically and physically connected to a corresponding first electrode in the first region, an opposite second end of the trace extends into the second region and is electrically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes, and at least portions of the first traces are adapted to be used in a non-viewing border region of the touch sensor.

In a fourth aspect, an assembly is provided. The assembly includes a web of dielectric material having a length direction along a longer length dimension of the web and a width direction, perpendicular to the length direction, along a shorter width dimension of the web, and an electrically conductive elongated first pattern disposed on the web and extending along the length direction. The assembly further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the web and oriented along the width direction and adapted to form a plurality of drive or receive electrodes in a touch sensor, the first electrodes being physically and electrically isolated from the first pattern, and a drum positioned adjacent the web and comprising an electrically conductive second pattern disposed on an external surface of the drum. As the web moves along the length direction, the drum rotates in synchronism with the web, such that when the second pattern physically and electrically contacts a first electrode at a first location on the second pattern, the second pattern does not electrically contact the first pattern, and when the second pattern physically and electrically contacts the first electrode at a different second location on the second pattern, the second pattern physically contacts the first pattern.

In a fifth aspect, a method of removing static electric charge from an electrically conductive pattern disposed on a web of dielectric material is provided. The method includes providing a web of dielectric material having first and second electrically conductive patterns disposed thereon, the second pattern electrically isolated from the first pattern and connected to a ground, the first pattern having a static electric charge thereon, and bringing an electrically conductive discharge path in electrical and physical contact with the first, but not the second, pattern so that at least a portion of the static electric charge transfers from the first pattern to the discharge path. The method further includes bringing the electrically conductive discharge path in electrical and physical contact with the second pattern while maintaining contact with the first pattern so that at least a portion of the static charge transfers from the discharge path to the ground second pattern.

These and other aspects of the present application will be apparent from the detailed description below. In no event, however, should the above summaries be construed as limitations on the claimed subject matter, which subject matter is defined solely by the attached claims, as may be amended during prosecution.

Brief Description of the Drawings

The invention is further explained with reference to the drawing wherein:

FIG. 1 is a schematic view of a touch device;

FIG. 2 is a schematic side view of a portion of a touch panel used in a touch device;

FIG. 3 is a schematic side view of an electrically conductive film construction during manufacture;

FIG. 4 is a schematic side view of the electrically conductive film construction of FIG. 3 being peeled apart;

FIG. 5 is a schematic side view of the peeled electrically conductive film of FIG. 4 being contacted with a conductive grounding roller;

FIG. 6 is a schematic side view of the electrically conductive film of FIG. 3 being peeled apart and experiencing electrostatic discharge damage;

FIG. 7 is a schematic top view of an exemplary electrically conductive film;

FIG. 8a is a schematic top view of portions of a further exemplary electrically conductive film;

FIG. 8b is a schematic top view of portions of a still further exemplary electrically conductive film;

FIG. 9 is a schematic top view of another exemplary electrically conductive film;

FIG. 10a is a schematic view of an exemplary assembly;

FIG. 10b is a schematic view of the exemplary assembly of 10a in operation;

FIG. 11 is a schematic view of an exemplary roller and a portion of an exemplary electrically conductive film;

FIG. 12a is a schematic view of the assembly of Comparative Example 1 in operation;

FIG. 12b is a schematic view of the assembly of Example 1 in operation; and

FIG. 13 is a schematic top view of a portion of an exemplary silver nanowire pattern on a substrate.

These figures are not to scale and are intended to be merely illustrative and not limiting. In the figures, like reference numerals designate like elements.

Detailed Description

Unless otherwise indicated, all numbers expressing quantities, measurement of properties, and so forth used in the specification and claims are to be understood as being modified by the term “about”. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that can vary depending on the desired properties sought to be obtained by those skilled in the art utilizing the teachings of the present application. Not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, to the extent any numerical values are set forth in specific examples described herein, they are reported as precisely as reasonably possible. Any numerical value, however, may well contain errors associated with testing or measurement limitations.

The recitation of numerical ranges by endpoints includes all numbers subsumed within that range (e.g., 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5). As used in this specification and the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the content clearly dictates otherwise. Thus, for example, reference to a composition containing “a compound” includes a mixture of two or more compounds. As used in this specification and the appended claims, the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

Touch screens are typically covered by a multilayer film, which comprises the electrical conductive circuitry of the touch screen; however the circuit is susceptible to damage due to electrostatic discharge (ESD) during manufacturing process, transportation and final assembly. Such static voltage mostly builds up when peeling the top layer of the multilayer film, plus touching the structure with other charged objects may also affect the static voltage, for example during unreeling, rubbing, separating, covering, and other process steps. During peeling, for instance, the film can be charged up to a couple of kilovolts, thus creating a high risk of undesirable electrostatic discharge (ESD) during manufacturing, testing, transportation, and customer usage. Aspects according to the present disclosure address the problem of high static build up on the electrically conductive film so that ESD events can be minimized or eliminated. For instance, novel patterns are formed on the electrically conductive film, which are connected to the existing circuit patterns, providing methods to keep potential level of the whole film close to zero.

In FIG. 1, an exemplary touch device **110** is shown. The device **110** includes a touch panel **112** connected to electronic circuitry, which for simplicity is grouped together into a single schematic box labeled **114** and referred to collectively as a controller.

The touch panel **112** is shown as having a 5x5 matrix of column electrodes **116a-e** and row electrodes **118a-e**, but other numbers of electrodes and other matrix sizes can also be used. The panel **112** is typically substantially transparent so that the user is able to view an object, such as the pixilated display of a computer, hand-held device, mobile phone, or other peripheral device, through the panel **112**. The boundary **120** represents the viewing area of the panel **112** and also preferably the viewing area of such a display, if used. The electrodes **116a-e**, **118a-e** are spatially distributed, from a plan view perspective, over the viewing area **120**. For ease of illustration the electrodes are shown to be wide and obtrusive, but in practice they may be relatively narrow and inconspicuous to the user. Further, they may be designed to have variable widths, e.g., an increased width in the form of a diamond- or other-shaped pad in the vicinity of the nodes of the matrix in order to increase the inter-electrode fringe field and thereby increase the effect of a touch on the electrode-to-electrode capacitive coupling. In exemplary embodiments the electrodes may be composed of indium tin oxide (ITO) or other suitable electrically conductive materials. From a depth perspective, the column electrodes may lie in a different plane than the row electrodes (from the perspective of FIG. 1, the column electrodes **116a-e** lie underneath the row electrodes **118a-e**) such that no significant ohmic contact is made between column and row electrodes, and so that the only significant electrical coupling between a given column electrode and a given row electrode is capacitive coupling. The matrix of electrodes typically lies beneath a cover glass, plastic film, or the like, so that the electrodes are protected from direct physical contact with a user's finger or other touch-related implement. An exposed surface of such a cover glass, film, or the like may be referred to as a touch surface.

The capacitive coupling between a given row and column electrode is primarily a function of the geometry of the electrodes in the region where the electrodes are closest together. Such regions correspond to the "nodes" of the electrode matrix, some of which are labeled in FIG. 1. For example, capacitive coupling between column electrode **116a** and row electrode **118d** occurs primarily at node **122**, and capacitive coupling between column electrode **116b** and row electrode **118e** occurs primarily at node **124**. The 5x5 matrix of FIG. 1 has 25 such nodes, any one of which can be addressed by controller **114** via appropriate selection of one of the control lines **126**, which individually couple the respective column electrodes **116a-e** to the controller, and appropriate selection of one of the control lines **128**, which individually couple the respective row electrodes **118a-e** to the controller.

When a finger **130** of a user or other touch implement comes into contact or near-contact with the touch surface of the device **110**, as shown at touch location **131**, the finger capacitively couples to the electrode matrix. The finger draws charge from the matrix, particularly from those electrodes lying closest to the touch location, and in doing so it changes the coupling capacitance between the electrodes corresponding to the nearest node(s). For example, the touch at touch location **131** lies nearest the node corresponding to electrodes **116c/118b**. As described further below, this change in coupling capacitance can be detected by controller **114** and interpreted as a touch at or near the **116a/118b** node. Preferably, the controller is configured to rapidly detect the change in capacitance, if any, of all of the nodes of the matrix, and is capable of analyzing the magnitudes of capacitance changes for neighboring nodes so as to accurately determine a touch location lying between nodes by interpolation. Furthermore, the controller **114** advantageously is designed to detect multiple distinct touches applied to different portions of the touch device at the same time, or at overlapping times. Thus, for example, if another finger **132** touches the touch surface of the device **110** at touch location **133** simultaneously with the touch of finger **130**, or if the respective touches at least temporally overlap, the controller is preferably capable of detecting the positions **131**, **133** of both such touches and providing such locations on a touch output **114a**. The number of distinct simultaneous or temporally overlapping touches capable of being detected by controller **114** is preferably not limited to 2, e.g., it may be 3, 4, or more, depending on the size of the electrode matrix.

The controller **114** preferably employs a variety of circuit modules and components that enable it to rapidly determine the coupling capacitance at some or all of the nodes of the electrode matrix. For example, the controller preferably includes at least one signal generator or drive unit. The drive unit delivers a drive signal to one set of electrodes, referred to as drive electrodes. In the embodiment of FIG. 1, the column electrodes **116a-e** may be used as drive electrodes, or the row electrodes **118a-e** may be so used. The drive signal is preferably delivered to one drive electrode at a time, e.g., in a scanned sequence from a first to a last drive electrode. As each such electrode is driven, the controller monitors the other set of electrodes, referred to as receive electrodes. The controller **114** may include one or more sense units coupled to all of the receive electrodes. For each drive signal that is delivered to each drive electrode, the sense unit(s) generate response signals for the plurality of receive electrodes. Preferably, the sense unit(s) are designed such that each response signal comprises a differentiated representation of the drive signal. For example, if the drive signal is represented by a function f(t), which may represent voltage as a function of time, then the response signal may be or comprise, at least approximately, a function g(t), where $g(t) = d\,f(t)/dt$. In other words, g(t) is the derivative with respect to time of the drive signal f(t). Depending on the design details of the circuitry used in the controller **114**, the response signal may include: (1) g(t) alone; or (2) g(t) with a constant offset $(g(t) + a)$; or (3)g(t) with a multiplicative scaling factor $(b * g(t))$, the scaling factor capable of being positive or negative, and capable of having a magnitude greater than 1, or less than 1 but greater than 0; or (4) combinations thereof, for example. In any case, an amplitude of the response signal is advantageously related to the coupling capacitance between the drive electrode being driven and the particular receive electrode being monitored. Of course, the amplitude of g(t) is also proportional to the amplitude of the original function f(t). Note that the amplitude of g(t) can be determined for a given node using only a single pulse of a drive signal, if desired.

The controller may also include circuitry to identify and isolate the amplitude of the response signal. Exemplary circuit devices for this purpose may include one or more peak detectors, sample/hold buffer, and/or low-pass filter, the selection of which may depend on the nature of the drive signal and the corresponding response signal. The controller may also include one or more analog-to-digital converters (ADCs) to convert an analog amplitude to a digital format. One or more multiplexers may also be used to avoid unnecessary duplication of circuit elements. Of course, the controller also preferably includes one or more memory devices in which to store the measured amplitudes and associated parameters, and a microprocessor to perform the necessary calculations and control functions.

By measuring an amplitude of the response signal for each of the nodes in the electrode matrix, the controller can generate a matrix of measured values related to the coupling capacitances for each of the nodes of the electrode matrix. These measured values can be compared to a similar matrix of previously obtained reference values in order to determine which nodes, if any, have experienced a change in coupling capacitance due to the presence of a touch.

Turning now to FIG. 2, we see there a schematic side view of a portion of a touch panel **210** for use in a touch device. The panel **210** includes a front layer **212**, a first electrode layer **214** comprising a first set of electrodes, an insulating layer **216**, a second electrode layer **218** comprising a second set of electrodes **218a-e** preferably orthogonal to the first set of electrodes, and a rear layer **220**. The exposed surface **212a** of the layer **212**, or the exposed surface **220a** of the layer **220**, may be or comprise the touch surface of the touch panel **210**.

Referring to FIG. 3, a schematic side view is provided of a multilayer electrically conductive film construction **300**. More particularly, the electrically conductive film construction **300** comprises a substrate **310** having a conductive layer **320** disposed on a major surface of the substrate **310**. A conductive pattern is provided by selectively depositing a resist material **325** comprising an insulating material in a pattern on the conductive layer **320**. Above the resist material **325**, a polymeric layer **330** is laminated to the construction. Last, a liner **340** is affixed on the polymeric layer **330**.

Turning to FIG. 4, a schematic side view of the electrically conductive film construction 300 of FIG. 3 being peeled apart is shown. As the construction **300** is peeled apart, an electrically conductive film **350** is provided, including the substrate **310**, resist material **325**, and portions of the conductive layer **320** located underneath the resist material **325**. From the construction **300** a disposable film **360** is generated, including the polymeric layer **330**, portions of the conductive layer **320** not located underneath the resist material **325**, and the liner **340**. The process of peeling apart an electrically conductive film construction **300** generates charge localization in different materials throughout the construction. As shown in FIG. 4, the plus symbols (+) indicate positive charges and the minus symbols (-) indicate negative charges, and in this illustrative embodiment the electrically conductive film **350** has an overall positive charge and the disposable film **360** has an overall negative charge. Hence, the substrate may be considered an insulated substrate having charged conductive material on it. Each portion of the conductive layer **320** can carry its own charge and a surface electrical potential gradient may exist on the electrically conductive film **350** after the delamination (e.g., peeling) process. This potential gradient creates a condition for ESD discharge between separate portions of the conductive layer **320**, which can cause structural damage or melting/burning of one or more portions of the conductive layer **320**.

Referring now to FIG. 5, the electrically conductive film **350** of FIG. 4 is shown passing through a drive module following delamination. When each individually charged portion of the conductive layer **320** approaches or touches the conductive grounded roller **410**, electrostatic discharge **420** may occur, causing ESD damage **430** to the electrically conductive film **350** at one or more portions of the conductive layer **320**. Turning to FIG. 6, even in a case where each portion of the conductive layer **320** is individually grounded, such as via traces **370**, it is possible to generate ESD damage **430** because the disposable film **360** can still accrue some charge and a potential difference between the disposable film **360** and the electrically conductive film **350** may increase as the distance between the layers increases.

In a first aspect of the present disclosure, an electrically conductive film for use in a touch sensor is provided. The electrically conductive film includes a dielectric substrate having a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor. The electrically conductive film further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in the touch sensor, and an electrically conductive first pattern disposed on the substrate in the second region. Each first electrode extends into the second region and is electrically and physically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes.

For instance, referring to FIG. 7, a schematic top view is provided of an exemplary electrically conductive film **700**. The electrically conductive film **700** includes a dielectric substrate **705** having a first region **710** adapted to be used in a touch sensor and a second region **720**, adjacent to the first region **710**, not adapted to be used in the touch sensor. The electrically conductive film **700** further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes **730** disposed on the substrate in the first region **710** and adapted to form a plurality of drive or receive electrodes in the touch sensor, and an electrically conductive first pattern **740** disposed on the substrate in the second region. Each first electrode **730** extends into the second region **720** and is electrically and physically connected **735** to the conductive first pattern **740**, the conductive first pattern **740** electrically connecting the plurality of the first electrodes **730**. The electrically conductive first pattern **740** is disposed on the substrate in the second region **720** and is electrically connected to ground **750**. In many embodiments, the second region **720** completely encloses the first region **710** and the electrically conductive first pattern **740** completely encloses the plurality of the first electrodes **730**. FIG. 7 further illustrates dashed lines **760** along which one could cut the electrically conductive film **700** to separate the first region **710** from the second region **720**.

Referring to FIG. 8a, in certain embodiments of an electrically conductive film **800a**, an electrically conductive second pattern **845** is disposed on the substrate **805** in the first region **810** and at least partially overlays and contacts the first electrodes **830**. The first electrodes **830** are adapted to be used in a viewing region of a touch sensor and the second pattern **845** is adapted to be used in a non-viewing border region of the touch sensor. The second pattern **845** preferably extends into the second region **820** and electrically and physically connects to the conductive first pattern **840**.

Referring to FIG. 8b, however, in various embodiments of an electrically conductive film **800b**, the first region **810** comprises an electrode region **815** comprising the plurality of the first electrodes **830** and adapted to be used primarily in a viewing region of a touch sensor, and a trace region **860** is adapted to support a plurality of electrically conductive traces and be used primarily in a non-viewing border region of the touch sensor, the trace region **860** not comprising any electrically conductive pattern thereon. Rather, the plurality of the first electrodes **830** are electrically and physically connected to the conductive first pattern **840** by a conductive jumper **855**. The terms "conductive jumper" and "shunt" are used interchangeably herein. The conductive jumper **855** can subsequently be cut (e.g., by a laser) at a number of cut points **870** to separate the plurality of first electrodes **830** from each other prior to use in a touch sensor.

In certain embodiments of electrically conductive films according to the present disclosure, the film further comprises an electrically conductive third pattern disposed on the substrate on a surface opposite of the electrically conductive first pattern. Moreover, certain embodiments of electrically conductive films can be prepared by forming electrically conductive patterns on separate dielectric substrates followed by lamination of the substrates together to form a multilayer electrically conductive film.

The dielectric substrate comprises any suitable polarizable electrically insulating substrate material, for instance and without limitation, a printable polymer (e.g., polyethylene terephthalate (PET)), a sol-gel metal oxide, or an anodic oxide. Additional suitable printable polymers include but are not limited to polyester, polyimide, polyamide-imide, polytetrafluoroethylene, polypropylene, polyethylene, polyphenylene sulfide, polyethylene naphthalate, polycarbonate, silicone rubber, ethylene propylene diene rubber, polyurethane, acrylates, silicones, natural rubber, epoxies, and synthetic rubber adhesive. Examples of useful dielectric thicknesses include thicknesses between 0.05 microns and 20 microns, preferably between 0.1 and 10 microns, most preferably between 0.25 and 5 microns. In many embodiments, the dielectric substrate comprises a multilayer polymeric film.

Suitable materials for each electrically conductive pattern (first pattern, second, pattern, etc.) include for example and without limitation, copper, silver, aluminum, gold, alloys thereof, carbon nanotubes, and combinations thereof. Typically, the plurality of electrodes are present in the electrically conductive film in the form of wires, micro-wires (e.g., metal mesh), nano-wires, a conductive layer, or a combination thereof, preferably in the form of nano-wires.

Similar to the electrically conductive pattern, suitable materials for each of the plurality of electrodes (first electrodes, second electrodes, etc.) include for example and without limitation, copper, silver, gold, alloys thereof, indium tin oxide (ITO), and combinations thereof.

When employed in a touch sensor application, the electrically conductive film typically lies beneath a cover glass, plastic film, durable coating, or the like, so that the electrodes, conductive patterns, etc., are protected from direct physical contact with a user's finger or other touch object (such as a stylus). An exposed surface of such a cover glass, film, or the like is referred to as the touch surface of touch panel.

The above details regarding materials, substrate thicknesses, etc., also apply to the electrically conductive films and assemblies referred to in the second through fifth aspects below.

In a second aspect of the disclosure, another electrically conductive film is provided. The electrically conductive film includes a web of dielectric material, a plurality of electrically and physically intersecting electrically conductive rows and columns disposed on the web and defining a plurality of closed cells, and a plurality of substantially parallel electrically conductive spaced apart electrodes disposed on the web in each closed cell and adapted to form a plurality of drive or receive electrodes in a touch sensor. Each electrode in a closed cell terminates at at least one of the rows and columns in the plurality of the rows and columns defining the closed cell.

For example, turning back to FIG. 7, the electrically conductive film **700** includes a web of dielectric material **710**, a plurality of electrically and physically intersecting electrically conductive rows **741** and columns **742** disposed on the web **710** and defining a plurality of closed cells **743**, and a plurality of substantially parallel electrically conductive spaced apart electrodes **730** disposed on the web **710** in each closed cell **743** and adapted to form a plurality of drive or receive electrodes in a touch sensor. Each electrode **730** in a closed cell **743** terminates at at least one of the rows **741** and columns **742** in the plurality of the rows **741** and columns **742** defining the closed cell **743**.

In a third aspect of the disclosure, yet another electrically conductive film for use in a touch sensor is provided. The electrically conductive film includes a dielectric substrate having a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor. The electrically conductive film further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in a viewing region of the touch sensor, an electrically conductive first pattern disposed on the substrate in the second region, and a plurality of electrically conductive spaced apart first traces disposed on the substrate. A first end of each trace is electrically and physically connected to a corresponding first electrode in the first region, an opposite second end of the trace extends into the second region and is electrically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes, and at least portions of the first traces are adapted to be used in a non-viewing border region of the touch sensor.

For example, referring to FIG. 9, the electrically conductive film **900** includes a dielectric substrate **905** having a first region **910** adapted to be used in a touch sensor and a second region **920**, adjacent to the first region, not adapted to be used in the touch sensor. The electrically conductive film **900** further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes **930** disposed on the substrate **905** in the first region **910** and adapted to form a plurality of drive or receive electrodes in a viewing region of the touch sensor, an electrically conductive first pattern **940** disposed on the substrate **905** in the second region **920**, and a plurality of electrically conductive spaced apart first traces **945** disposed on the substrate **905**. A first end of each trace **946** is electrically and physically connected to a corresponding first electrode **930** in the first region **910**, an opposite second end of the trace **947** extends into the second region **920** and is electrically connected to the conductive first pattern **940**, the conductive first pattern **940** electrically connecting the plurality of the first electrodes **930**, and at least portions of the first traces **945** are adapted to be used in a non-viewing border region of the touch sensor.

In contrast to the embodiments illustrated in FIGS. 7, 8a, and 8b, the electrically conductive film embodiment shown in FIG. 9 eliminates the need for conductive jumpers and/or an additional cutting step. Rather, the conductive patterns shown in FIG. 9 connect all conductive materials together and provides the possibility for grounding the whole structure.

In certain embodiments, the plurality of electrically conductive spaced apart first traces comprise silver pads printed on top of electrically conductive patterns, and may provide the necessary contact with any external circuits. The connections between these silver pads is still implemented from the electrically conductive patterns. This may be useful to resolve potential alignment issues on closely spaced horizontal electrically conductive patterns due to insufficient silver ink printer resolution. The top interconnect may have a typical silver material and shape.

In a fourth aspect, an assembly is provided. The assembly includes a web of dielectric material having a length direction along a longer length dimension of the web and a width direction, perpendicular to the length direction, along a shorter width dimension of the web, and an electrically conductive elongated first pattern disposed on the web and extending along the length direction. The assembly further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the web and oriented along the width direction and adapted to form a plurality of drive or receive electrodes in a touch sensor, the first electrodes being physically and electrically isolated from the first pattern, and a drum positioned adjacent the web and comprising an electrically conductive second pattern disposed on an external surface of the drum. As the web moves along the length direction, the drum rotates in synchronism with the web, such that when the second pattern physically and electrically contacts a first electrode at a first location on the second pattern, the second pattern does not electrically contact the first pattern, and when the second pattern physically and electrically contacts the first electrode at a different second location on the second pattern, the second pattern physically contacts the first pattern.

For example, referring to FIG. 10a, the assembly **1000** includes a web of dielectric material **1005** having a length direction along a longer length dimension of the web $\mathbf{D_L}$ and a width direction, perpendicular to the length direction, along a shorter width dimension of the web $\mathbf{D_W}$, and an electrically conductive elongated first pattern **1040** disposed on the web and extending along the length direction $\mathbf{D_L}$.

The assembly **1000** further includes a plurality of substantially parallel electrically conductive spaced apart first electrodes **1030** disposed on the web **1005** and oriented along the width direction $\mathbf{D_W}$ and adapted to form a plurality of drive or receive electrodes in a touch sensor, the first electrodes **1030** being physically and electrically isolated from the first pattern **1040**, and a drum **1080** positioned adjacent the web and comprising an electrically conductive second pattern **1085** disposed on an external surface of the drum. Referring to FIG. 10b, as the web **1005** moves along the length direction $\mathbf{D_L}$, the drum **1080** rotates in synchronism with the web **1005**, such that when the second pattern **1085** physically and electrically contacts a first electrode **1031** at a first location on the second pattern **1086**, the second pattern does not electrically contact the first pattern **1040**, and when the second pattern **1085** physically and electrically contacts the first electrode **1031** at a different second location on the second pattern **1085**, the second pattern **1085** physically contacts the first pattern **1040**.

In many embodiments, as the web **1005** moves along the length direction $\mathbf{D_L}$ and the drum **1080** rotates in synchronism with the web **1005**, when the second pattern **1085** first comes in contact with a first electrode **1031**, the second pattern **1085** does not electrically contact the first pattern **1040**, but when the drum **1080** rotates further while maintaining contact with the first electrode **1031**, the second pattern **1085** contacts the first pattern **1040**.

In the assembly illustrated in FIG. 10a, the second pattern **1085** comprises an elongated connecting section **1088** extending along a rotation axis of the drum and opposing first **1086** and second end section **1087** extending from respective first **1086** and second ends **1087** of the connecting section in opposite directions along a circumference of the drum **1080**.

Referring now to FIG. 11, in certain embodiments the drum **1180** comprises a plurality of electrically conductive substantially parallel spaced apart second patterns **1185** disposed on the external surface **1181** of the drum **1180** and electrically isolated from each other, such that as the web **1105** moves along the length direction $\mathbf{D_L}$, the drum **1180** rotates in synchronism with the web **1105** such that each second pattern **1185** contacts a corresponding first electrode **1131** at substantially a same first location **1187** on the second pattern **1185** so that the second pattern **1185** does not electrically contact the first pattern **1140**, and each second pattern **1185** contacts the corresponding first electrode **1131** at substantially a same second location **1189** on the second pattern **1185** so that the second pattern **1185** electrically contacts the first pattern **1140**.

Referring to both FIGS. 10a and 11, in certain embodiments, each of the plurality of the first electrodes **1030**, **1130** is oriented along the shorter width dimension $\mathbf{D_W}$ of the web **1005**, **1105**.

In a fifth aspect, a method of removing static electric charge from an electrically conductive pattern disposed on a web of dielectric material is provided. The method includes providing a web of dielectric material having first and second electrically conductive patterns disposed thereon, the second pattern electrically isolated from the first pattern and connected to a ground, the first pattern having a static electric charge thereon, and bringing an electrically conductive discharge path in electrical and physical contact with the first, but not the second, pattern so that at least a portion of the static electric charge transfers from the first pattern to the discharge path. The method further includes bringing the electrically conductive discharge path in electrical and physical contact with the second pattern while maintaining contact with the first pattern so that at least a portion of the static charge transfers from the discharge path to the ground second pattern.

For example, referring to FIGS. 10a and 10b, the method includes providing a web of dielectric material **1005** having first **1030** and second electrically conductive patterns **1040** disposed thereon, the second pattern **1040** electrically isolated from the first pattern **1030** and connected to a ground **1050**, the first pattern **1030** having a static electric charge thereon, and bringing an electrically conductive discharge path **1080** in electrical and physical contact with the first pattern **1030**, but not the second pattern **1040** so that at least a portion of the static electric charge transfers from the first pattern **1030** to the discharge path **1080**. The method further includes bringing the electrically conductive discharge path **1080** in electrical and physical contact with the second pattern **1040** while maintaining contact with the first pattern **1030** so that at least a portion of the static charge transfers from the discharge path **1080** to the ground second pattern **1040**.

Advantageously, the assembly is configured to relocate a potential discharge point from a functional area of an electrically conductive film to a nonfunctional zone of the electrically conductive film to minimize the possibility of creating ESD damage in portions of the electrically conductive film that are to be used in a product such as a touch sensor. Suitable exemplary shapes of an electrically conductive elongated pattern **1085**, **1185** on a drum **1080**, **1180** are illustrated in FIGS. 10a and 11, and variations of the shapes are contemplated that are configured to contact a charged electrically conductive area followed by contacting an electrically conductive grounded area, wherein the electrically conductive elongated pattern on the drum does not initially touch both the charged electrically conductive area and the electrically conductive grounded area at the same time.

Stated another way, during the movement of an electrically conductive film through an apparatus, contact of the electrically conductive elongated pattern on the drum to the charged electrically conductive area occurs without the electrically conductive elongated pattern touching the electrically conductive grounded area in the non-functional region of the electrically conductive film. Thus, during the first contact of the drum's electrically conductive elongated pattern with charged electrically conductive area, an ESD event does not happen, but rather the static charge from the charged electrically conductive area is redistributed between the charged electrically conductive area and the electrically conductive elongated pattern of the drum. As a result, the electric potential of the charged electrically conductive area and the electrically conductive elongated pattern on the drum is equalized, as shown in FIG. 10a. Since the electrically conductive film continues to move and the drum rotates in synchronicity, the electrically conductive elongated pattern will touch the electrically conductive grounded area and ESD discharge of the whole system may take place. It is hence necessary to design the shape and size of the electrically conductive elongated pattern as well as the diameter of the drum to provide the proper alignment of the electrically conductive elongated pattern to the charged electrically conductive area and to the electrically conductive grounded area.

Optionally, the drum is rotated using mechanical gear that synchronizes the drum with the movement of the web. Other electronic control solutions including position determining sensors, control circuits, and step motor drivers may also be used.

Typically, a drum for use in the assembly is made from dielectric material, for example and without limitation, polystyrene, polyester, polypropylene, polyethylene, polyvinyl chloride, polytetrafluoroethylene, polyacrylonitrile, silicone rubber, ethylene propylene diene rubber, natural rubber, and synthetic rubber adhesive. The electrically conductive elongated pattern on the drum is formed from any suitable conductive material, for example and without limitation, copper, nickel, silver, brass, gold, platinum, or alloys thereof. Preferably, the materials for the drum and for the electrically conductive elongated pattern on the drum are selected to have similar triboelectric charges.

Various modifications and alterations of this invention will be apparent to those skilled in the art without departing from the spirit and scope of this invention, and it should be understood that this invention is not limited to the illustrative embodiments set forth herein. For example, the reader should assume that features of one disclosed embodiment can also be applied to all other disclosed embodiments unless otherwise indicated. It should also be understood that all U.S. patents, patent application publications, and other patent and non-patent documents referred to herein are incorporated by reference, to the extent they do not contradict the foregoing disclosure.

The following items are exemplary embodiments according to aspects of the present invention:

Item 1 is an electrically conductive film for use in a touch sensor, comprising:

a dielectric substrate comprising a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor;

a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in the touch sensor; and

an electrically conductive first pattern disposed on the substrate in the second region, each first electrode extending into the second region and electrically and physically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes.

Item 2 is the electrically conductive film of item 1, wherein the second region completely encloses the first region and the electrically conductive first pattern completely encloses the plurality of the first electrodes.

Item 3 is the electrically conductive film of item 1 further comprising an electrically conductive second pattern disposed on the substrate in the first region and at least partially overlaying and contacting the first electrodes, the first electrodes adapted to be used in a viewing region of a touch sensor and the second pattern adapted to be used in a non-viewing border region of the touch sensor.

Item 4 is the electrically conductive film of item 3, wherein the second pattern extends into the second region and electrically and physically connects to the conductive first pattern.

Item 5 is the electrically conductive film of item 1, wherein the first region comprises an electrode region comprising the plurality of the first electrodes and adapted to be used primarily in a viewing region of a touch sensor, and a trace region adapted to support a plurality of electrically conductive traces and be used primarily in a non-viewing border region of the touch sensor, the trace region not comprising any electrically conductive pattern thereon.

Item 6 is the electrically conductive film of any of items 1 to 5, wherein the dielectric substrate comprises a printable polymer, a sol-gel metal oxide, or an anodic oxide.

Item 7 is the electrically conductive film of any of items 1 to 6, wherein the thickness of the dielectric substrate is between 0.1 and 10 microns.

Item 8 is the electrically conductive film of any of items 1 to 7, wherein the electrically conductive first pattern comprises copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Item 9 is the electrically conductive film of any of items 1 to 8, wherein the electrically conductive second pattern comprises copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Item 10 is the electrically conductive film of any of items 1 to 9, wherein the plurality of first electrodes are in the form of wires, micro-wires, nano-wires, or a conductive layer.

Item 11 is the electrically conductive film of any of items 1 to 10, wherein the plurality of first electrodes are in the form of nano-wires.

Item 12 is the electrically conductive film of any of items 1 to 11, wherein the plurality of first electrodes comprise, copper, silver, gold, alloys thereof, indium tin oxide (ITO), or a combination thereof.

Item 13 is the electrically conductive film of any of items 1 to 12, further comprising an electrically conductive third pattern disposed on the substrate on a surface opposite of the electrically conductive first pattern.

Item 14 is the electrically conductive film of any of items 1 to 13, wherein the substrate is a multilayer polymeric film.

Item 15 is an electrically conductive film, comprising:

a web of dielectric material;

a plurality of electrically and physically intersecting electrically conductive rows and columns disposed on the web and defining a plurality of closed cells;

a plurality of substantially parallel electrically conductive spaced apart electrodes disposed on the web in each closed cell and adapted to form a plurality of drive or receive electrodes in a touch sensor, each electrode in a closed cell terminating at at least one of the rows and columns in the plurality of the rows and columns defining the closed cell.

Item 16 is the electrically conductive film of item 15, wherein the dielectric material comprises a printable polymer, a sol-gel metal oxide, or an anodic oxide.

Item 17 is the electrically conductive film of item 15 or item 16, wherein the thickness of the dielectric material is between 0.1 and 10 microns.

Item 18 is the electrically conductive film of any of items 15 to 17, wherein the plurality of electrically and physically intersecting electrically conductive rows and columns comprises copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Item 19 is the electrically conductive film of any of items 15 to 18, wherein the plurality of substantially parallel electrically conductive spaced apart electrodes are in the form of wires, micro-wires, nano-wires, or a conductive layer.

Item 20 is the electrically conductive film of any of items 15 to 19, wherein the plurality of substantially parallel electrically conductive spaced apart electrodes are in the form of nano-wires.

Item 21 is the electrically conductive film of any of items 15 to 20, wherein the plurality of substantially parallel electrically conductive spaced apart electrodes comprise, copper, silver, gold, alloys thereof, indium tin oxide (ITO), or a combination thereof.

Item 22 is the electrically conductive film of any of items 15 to 21, wherein the web of dielectric material is a multilayer polymeric film.

Item 23 is an electrically conductive film for use in a touch sensor, comprising:

a dielectric substrate comprising a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor;

a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in a viewing region of the touch sensor;

an electrically conductive first pattern disposed on the substrate in the second region; and

a plurality of electrically conductive spaced apart first traces disposed on the substrate, a first end of each trace electrically and physically connected to a corresponding first electrode in the first region, an opposite second end of the trace extending into the second region and electrically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes, at least portions of the first traces adapted to be used in a non-viewing border region of the touch sensor.

Item 24 is the electrically conductive film of item 23, wherein the dielectric substrate comprises a printable polymer, a sol-gel metal oxide, or an anodic oxide.

Item 25 is the electrically conductive film of item 23 or item 24, wherein the thickness of the dielectric substrate is between 0.1 and 10 microns.

Item 26 is the electrically conductive film of any of items 23 to 25, wherein the electrically conductive first traces comprise copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Item 27 is the electrically conductive film of any of items 23 to 26, wherein the plurality of substantially parallel electrically conductive spaced apart first electrodes are in the form of wires, micro-wires, nano-wires, or a conductive layer.

Item 28 is the electrically conductive film of any of items 23 to 27, wherein the plurality of substantially parallel electrically conductive spaced apart first electrodes are in the form of nano-wires.

Item 29 is the electrically conductive film of any of items 23 to 28, wherein the plurality of substantially parallel electrically conductive spaced apart first electrodes comprise, copper, silver, gold, alloys thereof, indium tin oxide (ITO), or a combination thereof.

Item 30 is the electrically conductive film of any of items 23 to 29, wherein the dielectric material is a multilayer polymeric film.

Item 31 is an assembly, comprising:

a web of dielectric material having a length direction along a longer length dimension of the web and a width direction, perpendicular to the length direction, along a shorter width dimension of the web;

an electrically conductive elongated first pattern disposed on the web and extending along the length direction;

a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the web and oriented along the width direction and adapted to form a plurality of drive or receive electrodes in a touch sensor, the first electrodes being physically and electrically isolated from the first pattern;

a drum positioned adjacent the web and comprising an electrically conductive second pattern disposed on an external surface of the drum, such that as the web moves along the length direction, the drum rotates in synchronism with the web, such that when the second pattern physically and electrically contacts a first electrode at a first location on the second pattern, the second pattern does not electrically contact the first pattern, and when the second pattern physically and electrically contacts the first electrode at a different second location on the second pattern, the second pattern physically contacts the first pattern.

Item 32 is the assembly of item 31, such that as the web moves along the length direction and the drum rotates in synchronism with the web, when the second pattern first comes in contact with a first electrode, the second pattern does not electrically contact the first pattern, but when the drum rotates further while maintaining contact with the first electrode, the second pattern contacts the first pattern.

Item 33 is the assembly of item 31, wherein the second pattern comprises an elongated connecting section extending along a rotation axis of the drum and opposing first and second end section extending from respective first and second ends of the connecting section in opposite directions along a circumference of the drum.

Item 34 is the assembly of item 31, wherein the drum comprises a plurality of electrically conductive substantially parallel spaced apart second patterns disposed on the external surface of the drum and electrically isolated from each other, such that as the web moves along the length direction, the drum rotates in synchronism with the web such that each second pattern contacts a corresponding first electrode at substantially a same first location on the second pattern so that the second pattern does not electrically contact the first pattern, and each second pattern contacts the corresponding first electrode at substantially a same second location on the second pattern so that the second pattern electrically contacts the first pattern.

Item 35 is the assembly of any of items 31 to 34, wherein each of the plurality of the first electrodes is oriented along the shorter width dimension of the web.

Item 36 is the assembly of any of items 31 to 35, wherein the dielectric material comprises a printable polymer, a sol-gel metal oxide, or an anodic oxide.

Item 37 is the assembly of any of items 31 to 36, wherein the thickness of the dielectric material is between 0.1 and 10 microns.

Item 38 is the assembly of any of items 31 to 37, wherein the plurality of electrically and physically intersecting electrically conductive rows and columns comprises copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Item 39 is the assembly of any of items 31 to 38, wherein the plurality of substantially parallel electrically conductive spaced apart electrodes are in the form of wires, micro-wires, nano-wires, or a conductive layer.

Item 40 is the assembly of any of items 31 to 39, wherein the plurality of substantially parallel electrically conductive spaced apart electrodes are in the form of nano-wires.

Item 41 is the assembly of any of items 31 to 40, wherein the plurality of substantially parallel electrically conductive spaced apart electrodes comprise, copper, silver, gold, alloys thereof, indium tin oxide (ITO), or a combination thereof.

Item 42 is the assembly of any of items 31 to 41, wherein the web of dielectric material is a multilayer polymeric film.

Item 43 is the assembly of any of items 31 to 42, further comprising an electrically conductive third pattern disposed on the web of dielectric material on a surface opposite of the electrically conductive first pattern.

Item 44 is a method of removing static electric charge from an electrically conductive pattern disposed on a web of dielectric material, comprising:

providing a web of dielectric material having first and second electrically conductive patterns disposed thereon, the second pattern electrically isolated from the first pattern and connected to a ground, the first pattern having a static electric charge thereon;

bringing an electrically conductive discharge path in electrical and physical contact with the first, but not the second, pattern so that at least a portion of the static electric charge transfers from the first pattern to the discharge path; and

bringing the electrically conductive discharge path in electrical and physical contact with the second pattern while maintaining contact with the first pattern so that at least a portion of the static charge transfers from the discharge path to the ground second pattern.

Item 45 is the method of item 44, wherein the dielectric material comprises a printable polymer, a sol-gel metal oxide, or an anodic oxide.

Item 46 is the method of item 44 or item 45, wherein the thickness of the dielectric material is between 0.1 and 10 microns.

Item 47 is the method of any of items 44 to 46, wherein the web of dielectric material is a multilayer polymeric film.

Item 48 is the method of any of items 44 to 47, further comprising an electrically conductive third pattern disposed on the web of dielectric material on a surface opposite of the electrically conductive first pattern.

Item 49 is the method of any of items 44 to 48, wherein the electrically conductive first pattern comprises copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Item 50 is the method of any of items 44 to 49, wherein the electrically conductive second pattern comprises copper, silver, aluminum, gold, alloys thereof, or a combination thereof.

Examples

The invention will be further understood with reference to the following illustrative examples. These examples are merely for illustrative purposes only and are not meant to be limiting on the scope of the appended claims.

Comparative Example 1

Comparative Example 1 demonstrates the results of an experiment in which ESD discharge is provided through a typical conductive drum. Referring to FIG. 12a, a substrate of dielectric material **1205** was provided having a length direction along a longer length dimension of the substrate $\mathbf{D_L}$ and a width direction, perpendicular to the length direction, along a shorter width dimension of the substrate $\mathbf{D_W}$. The electrodes were simulated with an electrically conductive diamond shaped pattern **1230** formed of 3M 9713 conductive tape (commercially available from 3M Company, St. Paul, MN), having a diamond shape similar to the one typical for the touch sensor pattern referred to as a “diamond” pattern. The electrically conductive diamond shaped pattern **1230** was disposed on a polyethylene terephthalate (PET) dielectric substrate **1205**, and oriented along the width direction $\mathbf{D_W}$ of the substrate **1205**. The electrically conductive diamond shaped pattern **1230** was placed under a permanent 15 kV DC voltage to provide a charge. The electrically conductive pattern **1240**, physically and electrically isolated from the electrically conductive diamond shaped pattern **1230**, was provided on the substrate of dielectric material **1205** by 3M 1182 copper tape (commercially available from 3M Company, St. Paul, MN). The electrically conductive pattern **1240** was disposed on the substrate **1205** in a region not adapted to be used in a product such as a touch sensor, and extending along the length direction $\mathbf{D_L}$ of the substrate **1205**. A drum **1280** was made of polytetrafluoroethylene (i.e., TEFLON) and included on the surface of the drum **1280** the electrically conductive elongated pattern **1285**, provided by 3M 1182 copper tape.

When the drum **1280** was rotated, an electrical discharge (e.g., arc) **1290** occurred between the electrically conductive elongated pattern **1285** and the electrically conductive pattern **1240**, as well as between the electrically conductive elongated pattern **1285** and the diamond shaped pattern **1230** (e.g., located in a functional area). Hence, electric discharges formed at various locations randomly at the simultaneous touching of the electrically conductive diamond shaped pattern **1230** and the electrically conductive pattern **1240**, by the electrically conductive elongated pattern **1285**. The electrical discharge **1290** in the electrically conductive diamond shaped pattern **1230** can damage the electrically conductive diamond shaped pattern **1230**.

Example 1

Example 1 demonstrates the results of an experiment in which ESD discharge is provided through a drum having an electrically conductive elongated pattern according to an embodiment of the present disclosure. Referring to FIG. 12b, a substrate of dielectric material **1205** was provided having a length direction along a longer length dimension of the substrate $\mathbf{D_L}$ and a width direction, perpendicular to the length direction, along a shorter width dimension of the substrate $\mathbf{D_W}$. The electrodes were simulated with an electrically conductive diamond shaped pattern **1230** formed of 3M 9713 conductive tape (commercially available from 3M Company, St. Paul, MN), having a diamond shape similar to the one typical for the touch sensor pattern referred to as a “diamond” pattern. The electrically conductive diamond shaped pattern **1230** was disposed on a dielectric substrate **1205** formed of PET, and oriented along the width direction $\mathbf{D_W}$ of the substrate **1205**. The electrically conductive diamond shaped pattern **1230** was placed under a permanent 15 kV DC voltage to provide a charge. The electrically conductive pattern **1240**, physically and electrically isolated from the electrically conductive diamond shaped pattern **1230**, was provided by 3M 1182 copper tape (commercially available from 3M Company, St. Paul, MN). The electrically conductive pattern **1240** was disposed on the substrate **1205** in a region not adapted to be used in a product such as a touch sensor, extending along the length direction $\mathbf{D_L}$ of the substrate **1205**. A drum **1280** was made of polytetrafluoroethylene (i.e., TEFLON), and included on the surface of the drum **1280** the electrically conductive elongated pattern **1285**, provided by 3M 1182 copper tape.

First, the charge potentials were equalized between the diamond shaped pattern **1230** and the electrically conductive elongated pattern **1285** by contacting the electrically conductive elongated pattern **1285** with the charged diamond shaped pattern **1230**. Referring to FIG. 12b, when the drum **1280** was then rotated, the electrically conductive elongated pattern **1285** came into contact with the electrically conductive pattern **1240** and an electrical discharge (e.g., arc) **1290** occurred between the electrically conductive elongated pattern **1285** and the electrically conductive pattern **1240**. In contrast, no arcs were observed on the diamond shaped pattern **1230** (e.g., located in a functional area).

Example 2

Example 2 demonstrates the results of an experiment in which ESD discharge is provided through shunts. A transparent and conductive silver nanowire substrate was prepared as described in WO 2014/088950, such that the sheet resistance of the PET-coated substrate was approximately 50 Ohms per square. This substrate was used as the input material of a roll-to-roll process that patterned the nanowire coating via the following process steps (whose basic patterning steps are described in Embodiment 1 of WO 2014/088950):

1. A patterned resist layer was printed on the nanowire-coated PET with a flexographic printing station, utilizing a 1.0 BCM/in^2 anilox roll and a 67 mil (1.7 mm) thick DuPont DPR high resolution flexographic stamp provided by Southern Graphics Systems (SGS, Minneapolis, MN). The flexographic printing plate was designed to incorporate cross-web electrodes (i.e., perpendicular to the direction of web motion) with a 5 mm pitch, along with shunts across the two ends of the electrodes to electrically connect the electrodes together during the patterning process. The printing ink, used as the resist material, was Flint Group UFRO-0061-465U (Flint Group Print Media North America, Batavia, IL), which was subsequently cured (i.e., solidified) with an “H bulb” UV-curing lamp (UV-Ray Lamp head type Maxwell 550 – Lamp type UVH5519-600); UVRay, Italy). The resist was printed at a speed of 20 feet per minute (6.1 meters per minute).

2. A layer of 99.75% MacDermid Print and Peel (MacDermid Inc., Denver, CO) and 0.25% Tergitol 15-s-7 (available from Sigma Aldrich, St. Louis, MO) was gravure coated with a 24 billion cubic microns per square inch (BCM/in^2) (3.72 BCM/cm^2) anilox at 20 feet/minute (6.1 meters per minute) and dried (i.e., solidified by evaporation of solvent) via a combination of IR and air impingement ovens.

3. A 3M 3104C (3M Company, St. Paul, MN) pre-mask liner was laminated to the exposed surface of the MacDermid Print and Peel layer, and a roll of material was removed from the process line.

4. Samples of the printed cross-web electrode artwork were cut from the roll fabricated in step (3). The pre-mask liner and attached MacDermid Print and Peel strippable polymer coating were peeled from the substrate, leaving a pattern of silver nanowire on the PET substrate. The patterned nanowire layer was that as illustrated in FIG. 13. Referring to FIG. 13, the dark portions of the pattern in are the nanowires, whereas the contrasting light portions of the pattern are where the nanowires were removed when the strippable polymer coating was peeled from the substrate. The electrodes are illustrated in FIG. 13 to be provided as columns, while the web was moved in a direction perpendicular to the columns (e.g., in the row direction).

Stated another way, the electrically conductive film of FIG. 13 includes a dielectric substrate having a first region adapted to be used in a touch sensor (i.e., the region including the columns of electrodes) and a second region, adjacent to the first region, not adapted to be used in the touch sensor (i.e., the region including the shunt illustrated connecting the ends of the columns of electrodes). The electrically conductive film includes a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in the touch sensor, and an electrically conductive first pattern disposed on the substrate in the second region (e.g., a solid region of conductive nanowires). Each first electrode extends into the second region and is electrically and physically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes. The second region is electrically connected to ground.

The shunts joining the cross-web electrodes at the two opposing ends of the electrodes in each sample from step (4) were manually removed with scissors, isolating each of 104 cross-web electrodes for every repeat pattern of silver nanowire. The resistance of each of the 104 cross-web electrodes were measured with an ohm meter (for all samples from (4)), and no opens in resistance were detected (i.e., all tested electrodes were conductive and free of electrostatic defects).

In contrast, steps (1) through (4) were repeated for a pattern that was the same as the pattern of FIG. 13 except lacking the shunts at the opposing ends of the electrodes, and all measured samples exhibited opens in resistance due to electrostatic defects.

The complete disclosure of all patents, patent documents, and publications cited herein are incorporated by reference. The foregoing detailed description and examples have been given for clarity of understanding only. No unnecessary limitations are to be understood therefrom. The invention is not limited to the exact details shown and described, for variations obvious to one skilled in the art will be included within the invention defined by the claims.

What is claimed is:

1. An electrically conductive film for use in a touch sensor, comprising:

a dielectric substrate comprising a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor;

a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in the touch sensor; and

an electrically conductive first pattern disposed on the substrate in the second region, each first electrode extending into the second region and electrically and physically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes.

2. The electrically conductive film of claim 1, wherein the second region completely encloses the first region and the electrically conductive first pattern completely encloses the plurality of the first electrodes.

3. The electrically conductive film of claim 1, further comprising an electrically conductive second pattern disposed on the substrate in the first region and at least partially overlaying and contacting the first electrodes, the first electrodes adapted to be used in a viewing region of a touch sensor and the second pattern adapted to be used in a non-viewing border region of the touch sensor.

4. The electrically conductive film of claim 3, wherein the second pattern extends into the second region and electrically and physically connects to the conductive first pattern.

5. The electrically conductive film of claim 1, wherein the first region comprises an electrode region comprising the plurality of the first electrodes and adapted to be used primarily in a viewing region of a touch sensor, and a trace region adapted to support a plurality of electrically conductive traces and be used primarily in a non-viewing border region of the touch sensor, the trace region not comprising any electrically conductive pattern thereon.

6. An electrically conductive film, comprising:

a web of dielectric material;

a plurality of electrically and physically intersecting electrically conductive rows and columns disposed on the web and defining a plurality of closed cells;

a plurality of substantially parallel electrically conductive spaced apart electrodes disposed on the web in each closed cell and adapted to form a plurality of drive or receive electrodes in a touch sensor, each electrode in a closed cell terminating at at least one of the rows and columns in the plurality of the rows and columns defining the closed cell.

7. An electrically conductive film for use in a touch sensor, comprising:

a dielectric substrate comprising a first region adapted to be used in a touch sensor and a second region, adjacent to the first region, not adapted to be used in the touch sensor;

a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the substrate in the first region and adapted to form a plurality of drive or receive electrodes in a viewing region of the touch sensor;

an electrically conductive first pattern disposed on the substrate in the second region; and

a plurality of electrically conductive spaced apart first traces disposed on the substrate, a first end of each trace electrically and physically connected to a corresponding first electrode in the first region, an opposite second end of the trace extending into the second region and electrically connected to the conductive first pattern, the conductive first pattern electrically connecting the plurality of the first electrodes, at least portions of the first traces adapted to be used in a non-viewing border region of the touch sensor.

8. An assembly, comprising:

a web of dielectric material having a length direction along a longer length dimension of the web and a width direction, perpendicular to the length direction, along a shorter width dimension of the web;

an electrically conductive elongated first pattern disposed on the web and extending along the length direction;

a plurality of substantially parallel electrically conductive spaced apart first electrodes disposed on the web and oriented along the width direction and adapted to form a plurality of drive or receive electrodes in a touch sensor, the first electrodes being physically and electrically isolated from the first pattern;

a drum positioned adjacent the web and comprising an electrically conductive second pattern disposed on an external surface of the drum, such that as the web moves along the length direction, the drum rotates in synchronism with the web, such that when the second pattern physically and electrically contacts a first electrode at a first location on the second pattern, the second pattern does not electrically contact the first pattern, and when the second pattern physically and electrically contacts the first electrode at a different second location on the second pattern, the second pattern physically contacts the first pattern.

9. The assembly of claim 8, such that as the web moves along the length direction and the drum rotates in synchronism with the web, when the second pattern first comes in contact with a first electrode, the second pattern does not electrically contact the first pattern, but when the drum rotates further while maintaining contact with the first electrode, the second pattern contacts the first pattern.

10. The assembly of claim 8, wherein the second pattern comprises an elongated connecting section extending along a rotation axis of the drum and opposing first and second end section extending from respective first and second ends of the connecting section in opposite directions along a circumference of the drum.

11. The assembly of claim 8, wherein the drum comprises a plurality of electrically conductive substantially parallel spaced apart second patterns disposed on the external surface of the drum and electrically isolated from each other, such that as the web moves along the length direction, the drum rotates in synchronism with the web such that each second pattern contacts a corresponding first electrode at substantially a same first location on the second pattern so that the second pattern does not electrically contact the first pattern, and each second pattern contacts the corresponding first electrode at substantially a same second location on the second pattern so that the second pattern electrically contacts the first pattern.

12. The assembly of claim 8, wherein each of the plurality of the first electrodes is oriented along the shorter width dimension of the web.

13. A method of removing static electric charge from an electrically conductive pattern disposed on a web of dielectric material, comprising:

providing a web of dielectric material having first and second electrically conductive patterns disposed thereon, the second pattern electrically isolated from the first pattern and connected to a ground, the first pattern having a static electric charge thereon;

bringing an electrically conductive discharge path in electrical and physical contact with the first, but not the second, pattern so that at least a portion of the static electric charge transfers from the first pattern to the discharge path; and

bringing the electrically conductive discharge path in electrical and physical contact with the second pattern while maintaining contact with the first pattern so that at least a portion of the static charge transfers from the discharge path to the ground second pattern.

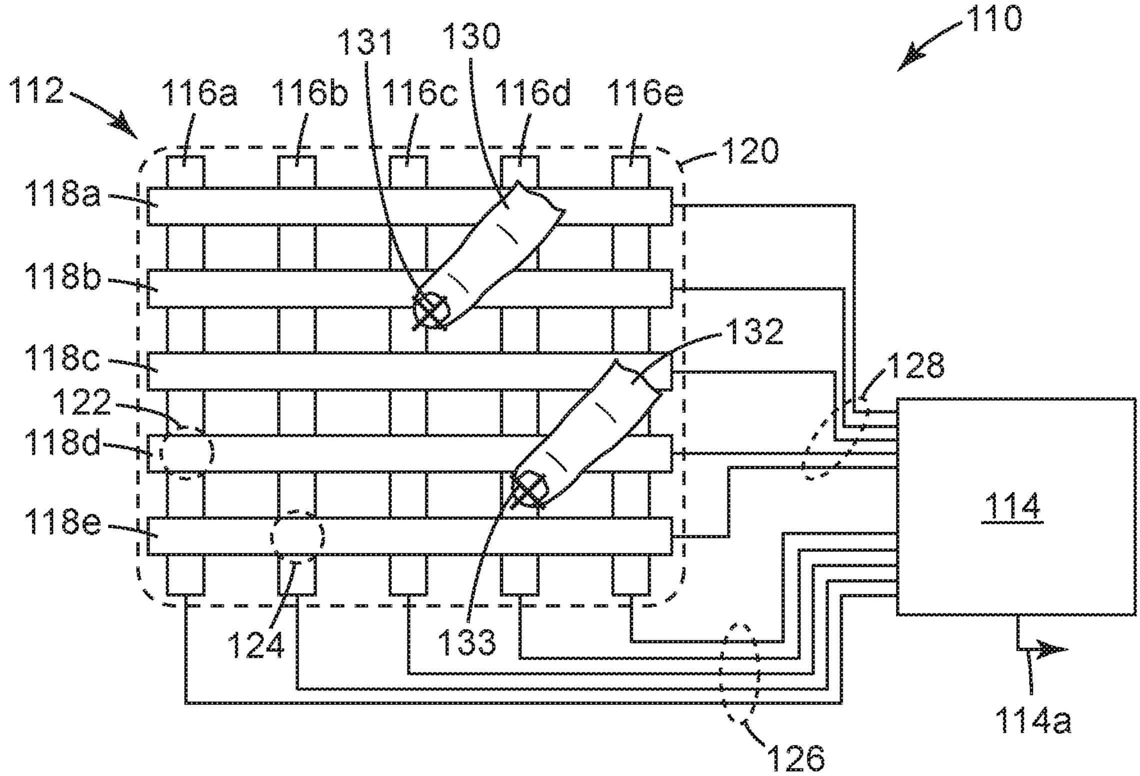

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FIG. 1

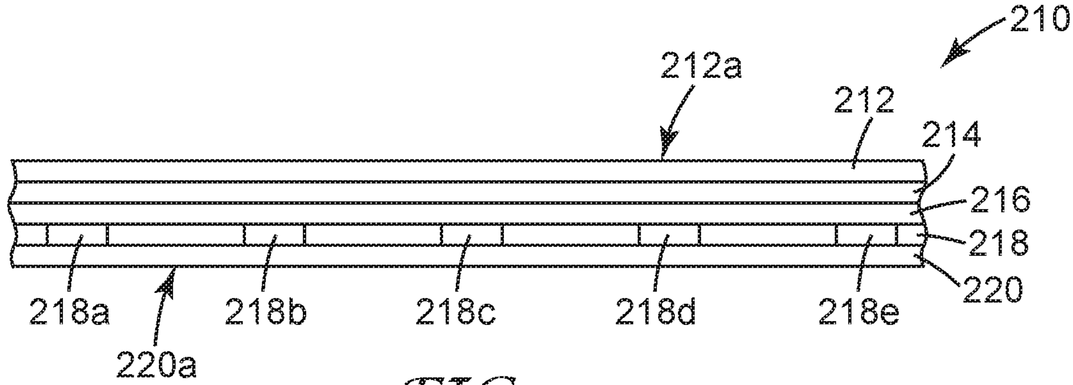

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FIG. 2

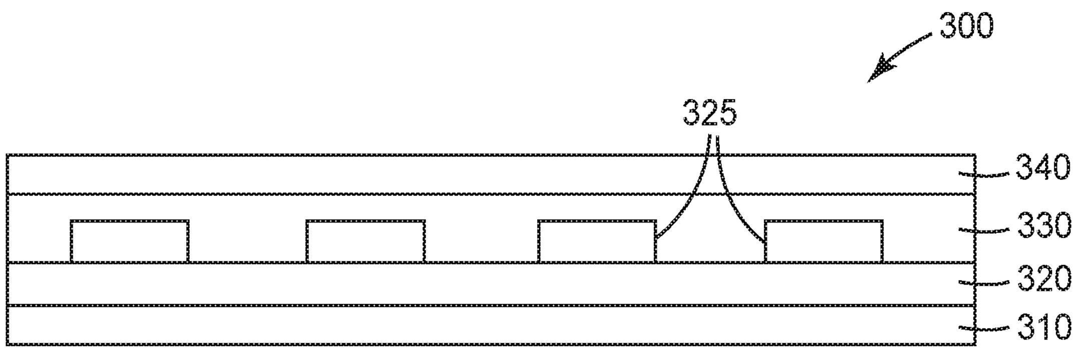

FIG. 3

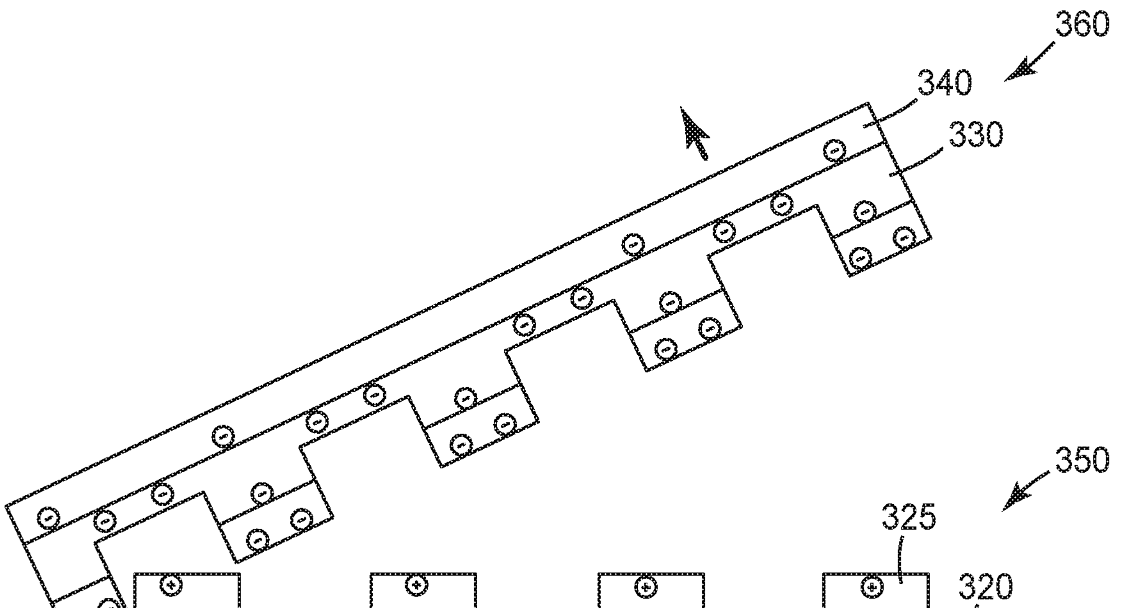

FIG. 4

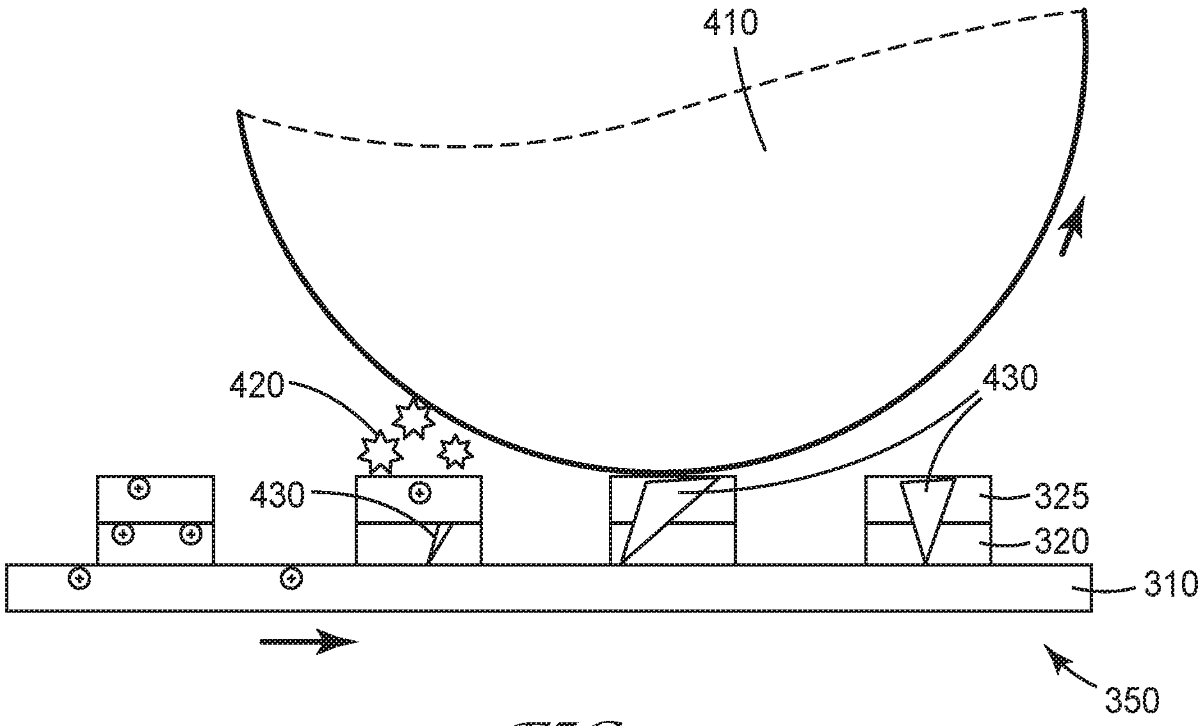
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FIG. 5

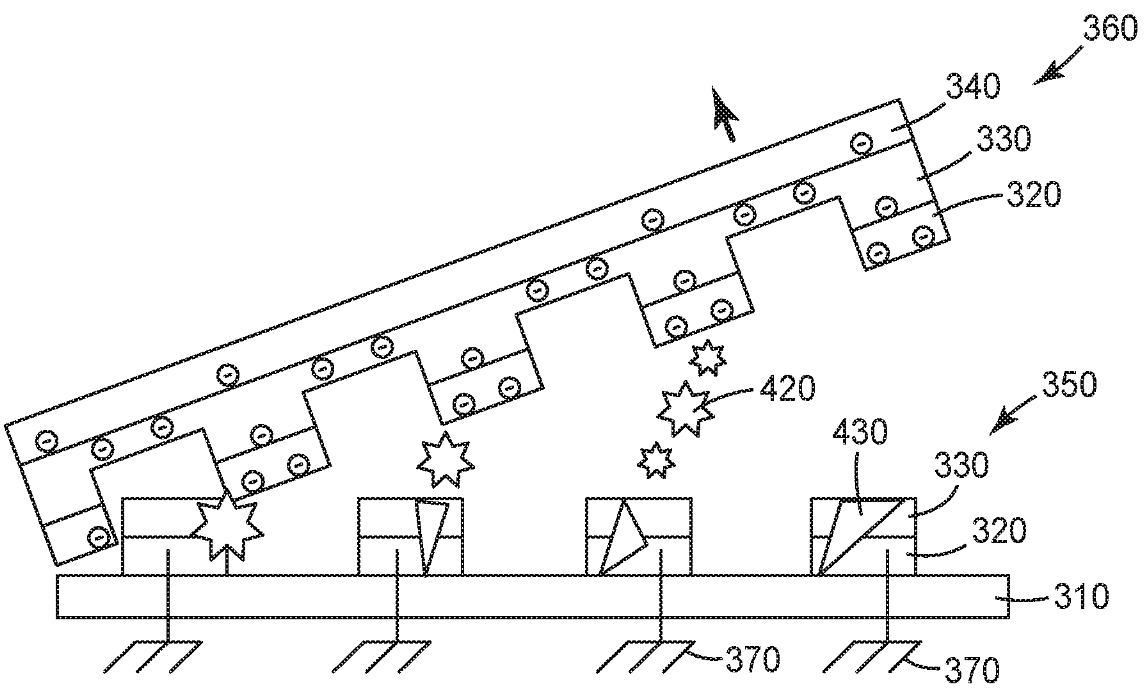
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FIG. 6

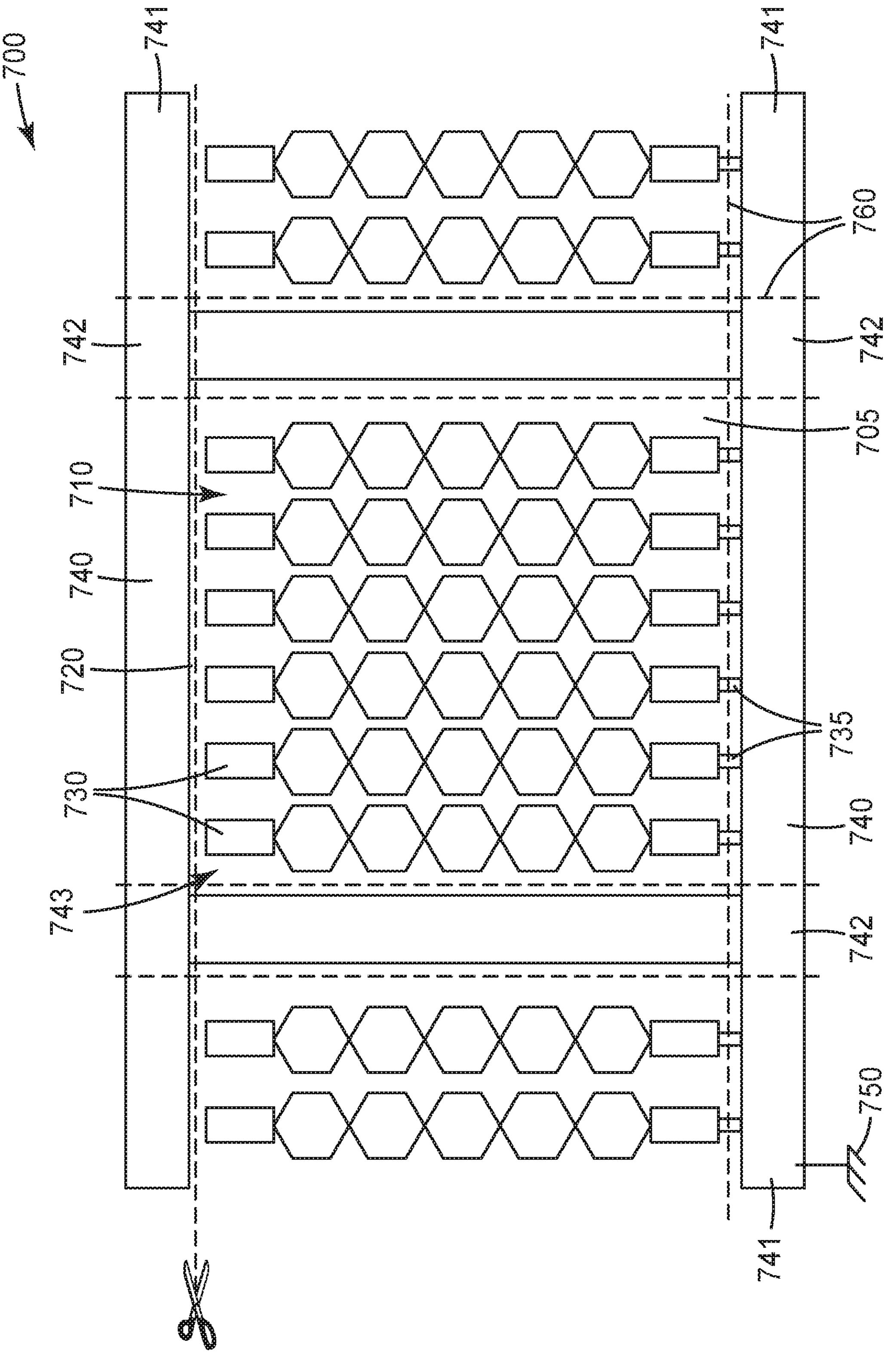
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FIG. 7

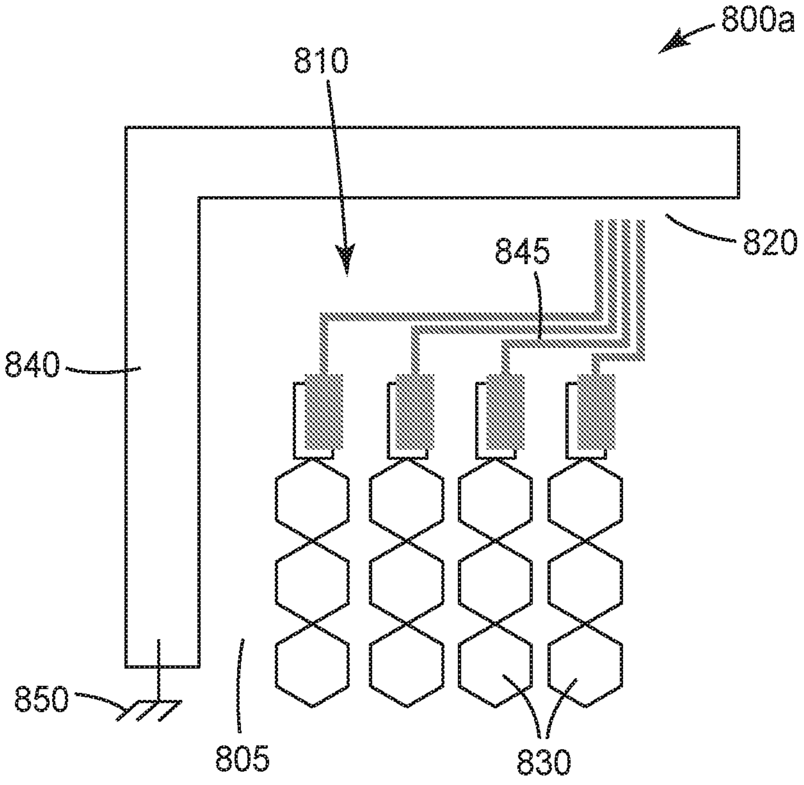
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FIG. 8A

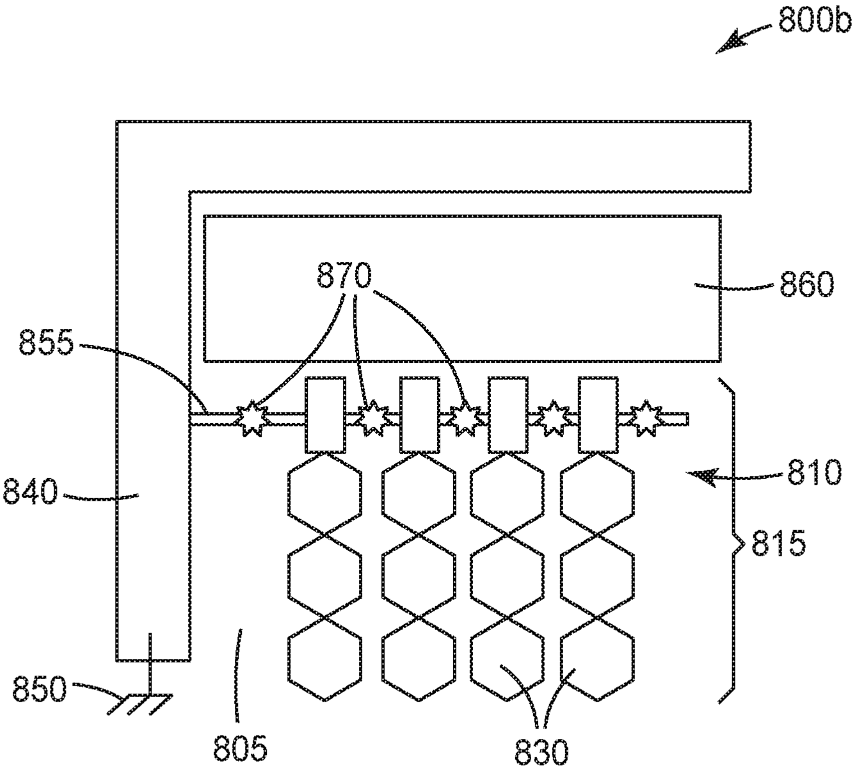
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FIG. 8B

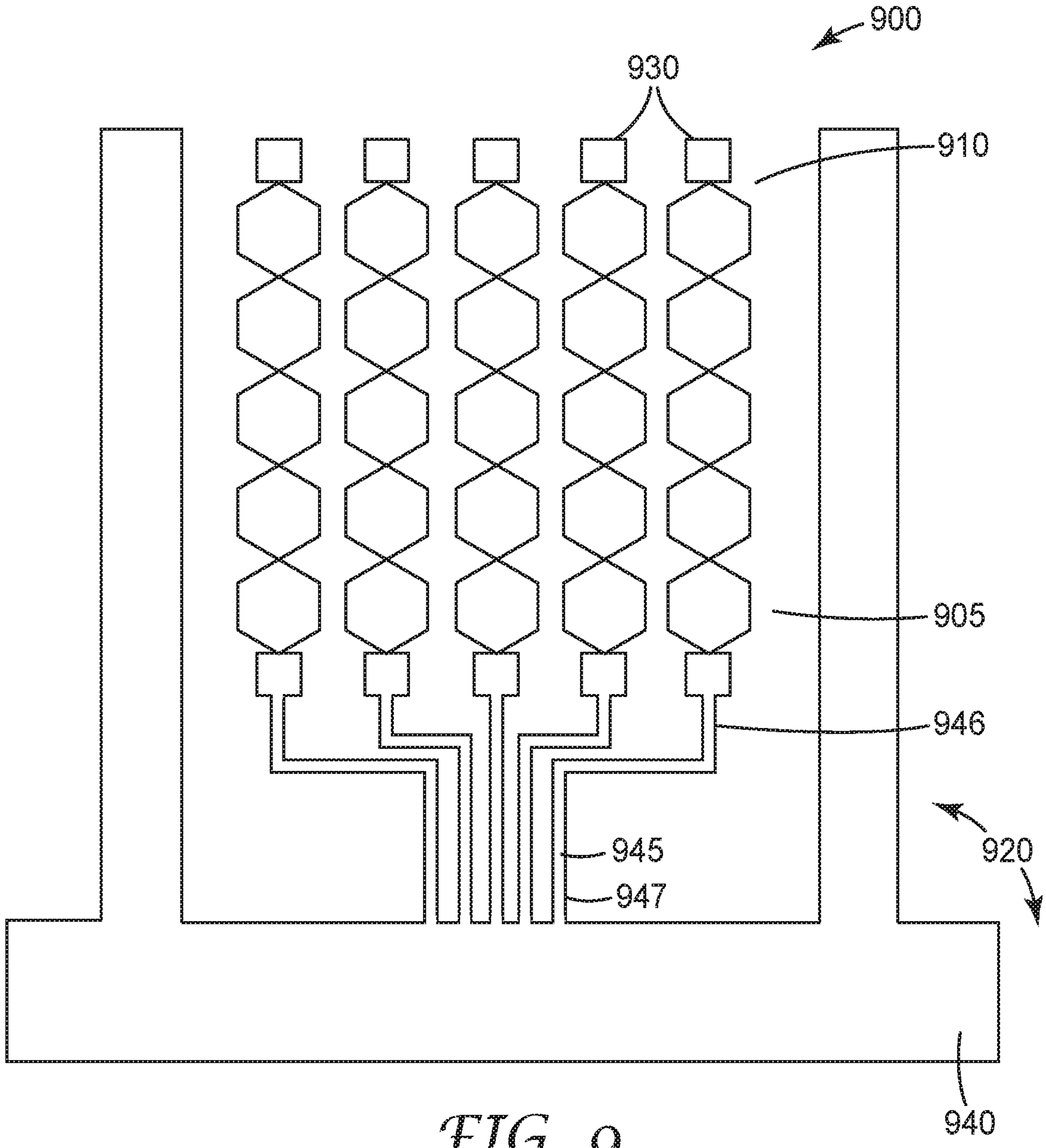


FIG. 9

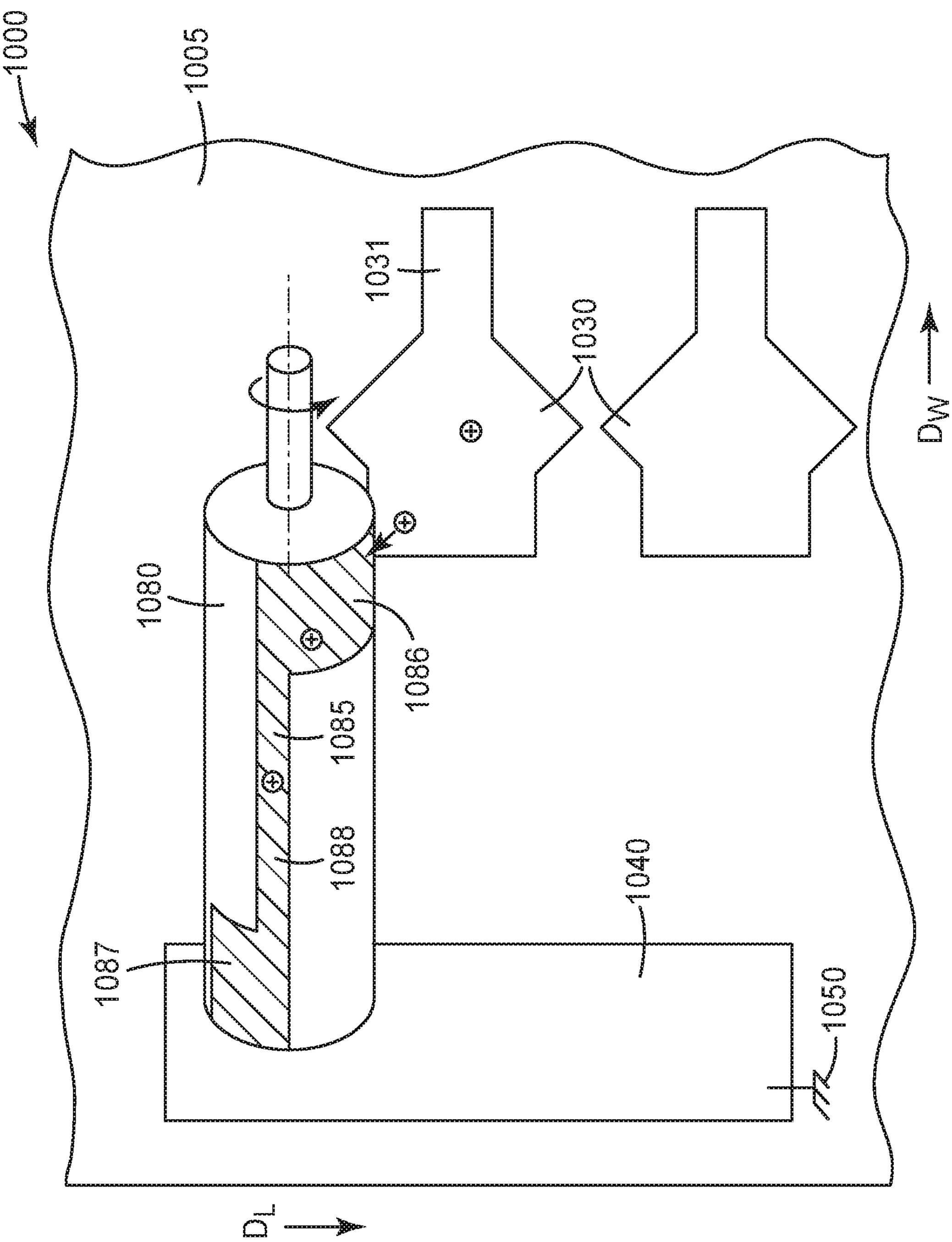


FIG. 10A

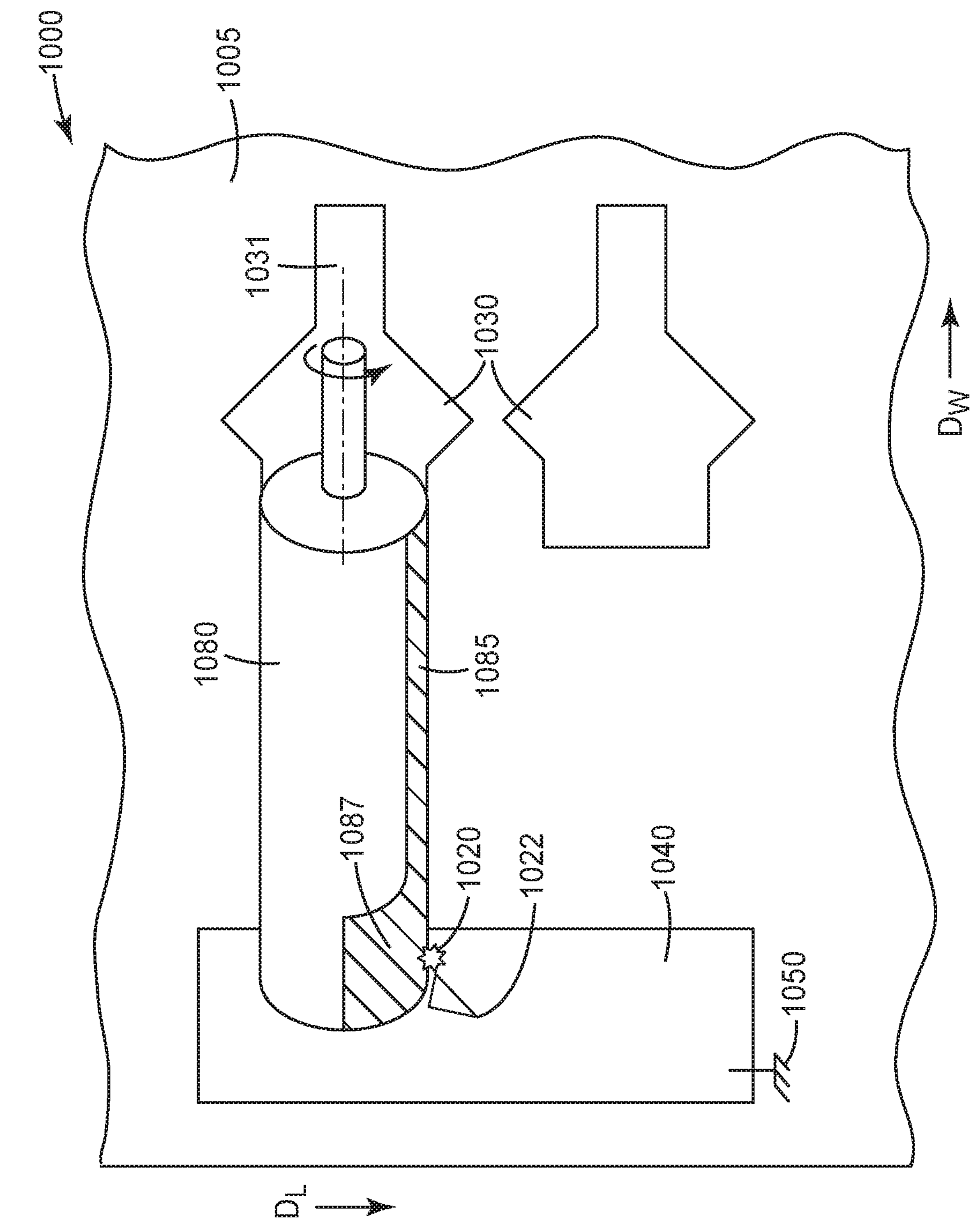
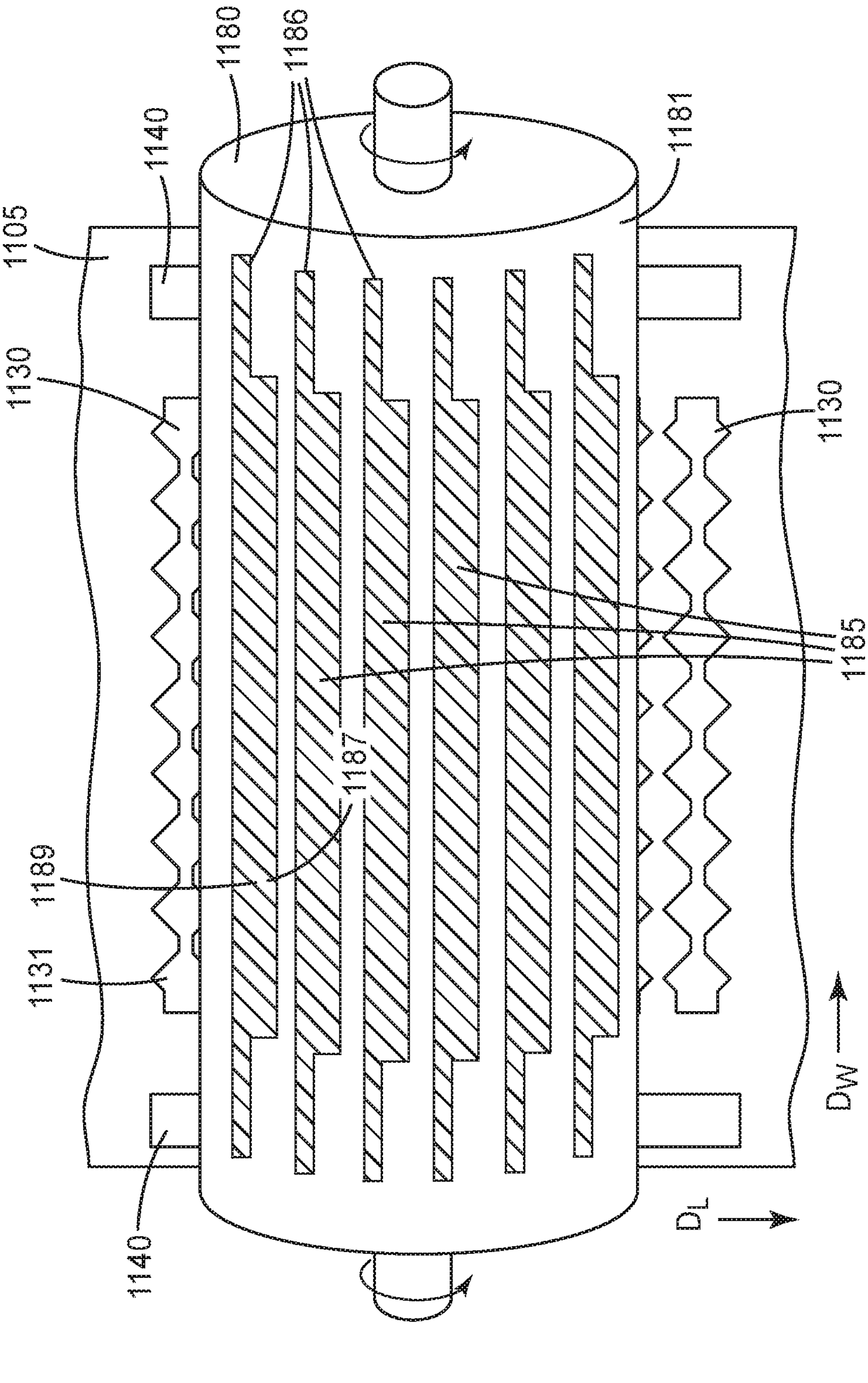


FIG. 10B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D_L

FIG. 11

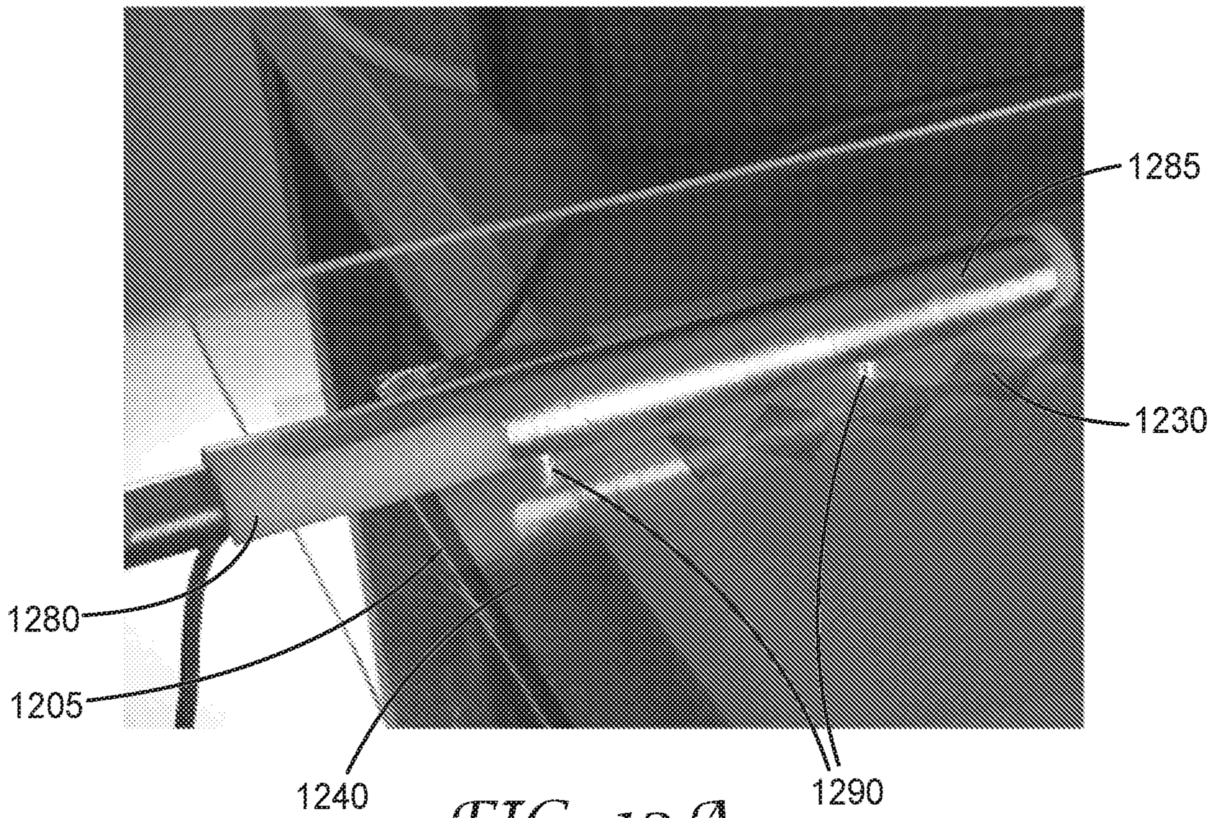

FIG. 12A

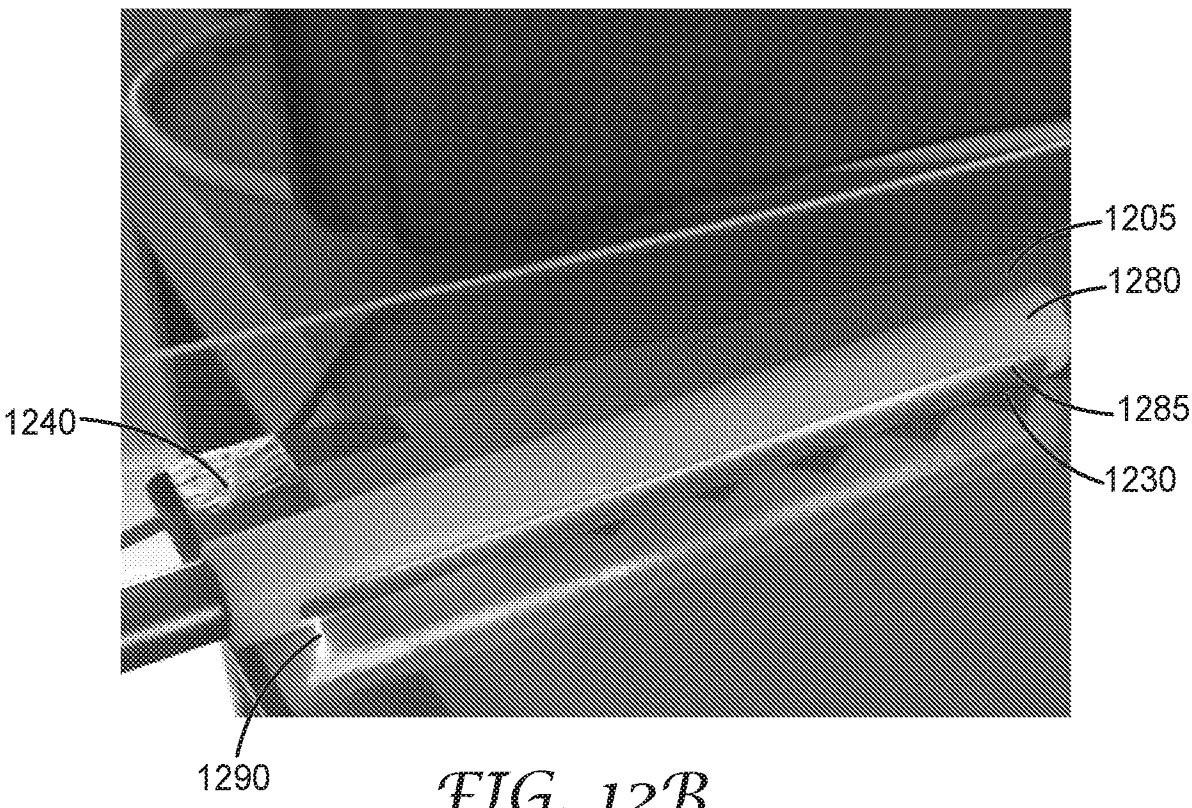

FIG. 12B

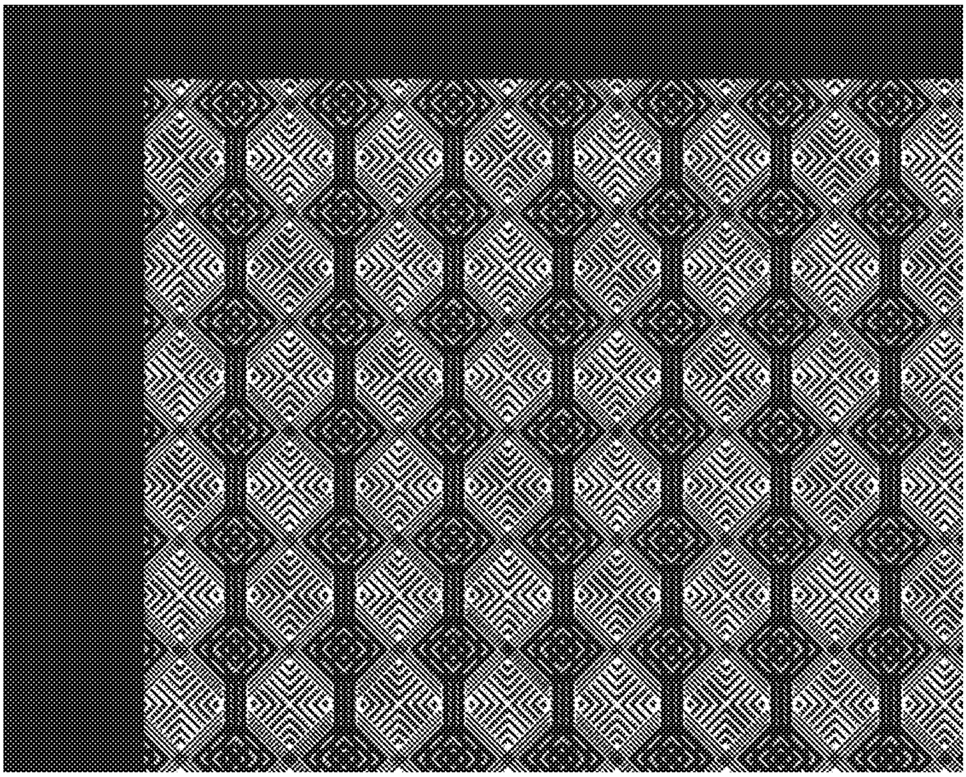

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/041335

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F3/044
ADD.

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)
G06F H01L H05K

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2014/070824 A1 (MOHAPATRA SIDDHARTH [US] ET AL) 13 March 2014 (2014-03-13) abstract; paragraphs [0003] - [0028]; figures 1-4	1-7 8-13
A	US 2011/157071 A1 (HUANG YEN-LIANG [TW] ET AL) 30 June 2011 (2011-06-30) paragraphs [0024], [0029], [0030]; figures 1, 2, 5	2,6
A	WO 2014/099951 A1 (3M INNOVATIVE PROPERTIES CO [US]) 26 June 2014 (2014-06-26) pages 17-22; figures 1-5	8,13

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

☒ See patent family annex.

* Special categories of cited documents :

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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
17 October 2016	25/10/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Nourestani, S

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/041335

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2011157071 A1	30-06-2011	TW 201122637 A	01-07-2011
		US 2011157071 A1	30-06-2011
WO 2014099951 A1	26-06-2014	CA 2895818 A1	26-06-2014
		CN 104870345 A	26-08-2015
		EP 2935061 A1	28-10-2015
		JP 2016504248 A	12-02-2016
		KR 20150096481 A	24-08-2015
		SG 11201504905U A	30-07-2015
		TW 201440578 A	16-10-2014
		US 2016185549 A1	30-06-2016
		WO 2014099951 A1	26-06-2014