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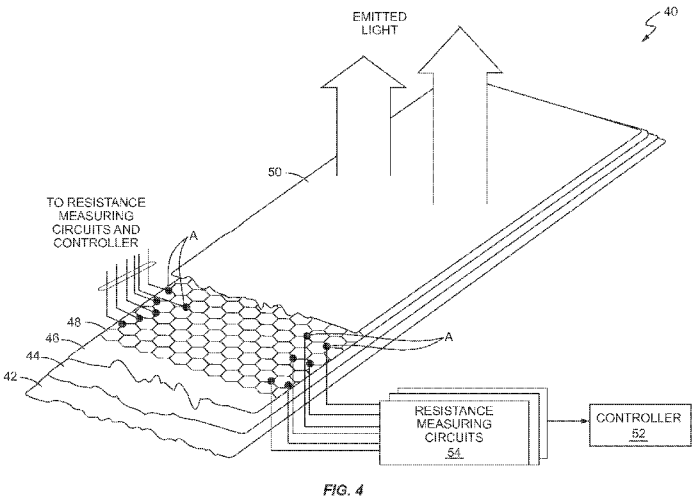

FIG. 4

(57) Abstract: A system and method for determining a current shape of a flexible display of an electronics device is provided. A flexible display has multiple functional layers. At least one of the layers is a flexible material having known piezoresistive properties. When a user bends, folds, twists, or rolls the flexible display, it causes a change in the electrical resistance of the flexible material. The device measures this change in resistance and, based on the measured change, determines a current shape of the flexible display.

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SYSTEM AND METHOD FOR IDENTIFYING THE SHAPE OF A DISPLAY DEVICE

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Serial No. 61/568,261, filed December 8, 2011 and entitled "System and Method for Identifying the Shape of a Display Device." The entire contents of the '261 application are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to display devices, and more particularly to flexible displays devices.

BACKGROUND

Many electronic devices, such as cellular communication devices, for example, have displays. One such type of display is an Organic Light Emitting Diode (OLED) display. It comprises one or more layers of glass that sandwich a transparent electrode layer, an Organic Light Emitting Diode (OLED) luminescent layer, and a silicon-based thin film transistor (TFT) layer. As is known in the art, the TFT layer in such conventional OLED displays include luminescent elements that correspond to red, green, and blue pixels. These elements may be controlled to directly emit light through the other layers.

Although useful, the glass used in the construction of these conventional OLED displays makes them rigid. As such, they tend to break when dropped and are expensive to fix. Therefore, several emerging technologies have produced a flexible display that is able to change its physical shape without breaking. More specifically, display manufacturers have removed the glass layers from some of their displays and now produce the display to include a flexible substrate. Because of the resultant flexibility, a user can bend, roll, or twist the flexible display without cracking or breaking the display.

SUMMARY

The present invention provides a system and method for determining the physical shape of a flexible display. In one embodiment, the method for determining a physical shape of a flexible display comprises measuring a change in electrical resistance of a flexible display that changes shape and determining the shape of the flexible display based on the measured change in resistance.

In one embodiment, measuring a change in electrical resistance comprises measuring the change in electrical resistance of a piezoresistive layer that is associated with the flexible display. The piezoresistive layer may comprise a layer of the flexible display, or it may comprise a part of a layer of the flexible display. In some embodiments, however, the piezoresistive layer comprises an additional layer that is added to the other layers of the flexible display.

In one embodiment, measuring a change in electrical resistance comprises detecting the change in resistance using resistance measuring circuits in communicative contact with the piezoresistive layer at predetermined positions.

In one embodiment, determining the shape of the flexible display comprises determining the shape of the flexible display based on signals received from a resistance measuring circuit in communicative contact with the piezoresistive layer at a selected position.

In one embodiment, determining the shape of the flexible display comprises receiving output signals from a plurality of resistance measuring circuits in communicative contact with the piezoresistive layer when the flexible display changes from a first shape to a second shape, and determining whether the measured change in electrical resistance is proportional to a predetermined diameter of the flexible display when the flexible display is in the second shape.

In one embodiment, the flexible display comprises a touch-sensitive display that may change shape due to a user touch. In such embodiments, the method may further comprise determining whether the change in shape of the flexible display is caused by a user touch on the touch-sensitive display.

In one embodiment, measuring a change in electrical resistance comprises measuring the electrical resistance when the flexible display is rolled or unrolled.

In one embodiment, measuring a change in electrical resistance comprises measuring the electrical resistance when the flexible display is folded or unfolded.

In one embodiment, measuring a change in electrical resistance comprises measuring the electrical resistance when the flexible display is twisted or untwisted.

The present invention also provides a consumer electronics device configured to perform the method of the present invention. In one embodiment, the consumer electronics device comprises a flexible display and a programmable controller. The flexible display is configured to change its shape and has a plurality of functional layers. The programmable controller is configured to measure a change in electrical resistance of the flexible display when the flexible display changes shape, and determine the shape of the flexible display based on the measured change in resistance.

In one embodiment, the programmable controller is further configured to measure the change in electrical resistance of a piezoresistive layer associated with the flexible display. The piezoresistive layer may comprise a layer of the flexible display, or it may comprise a part of a layer of the flexible display. In some embodiments, however, the piezoresistive layer comprises an additional layer that is added to the other layers of the flexible display.

In one embodiment, the device further comprises one or more resistance measuring circuits in communicative contact with the piezoresistive layer. In such embodiments, the programmable controller is further configured to detect the change in resistance based on signals received from the one or more resistance measuring circuits.

In one embodiment, the programmable controller is further configured to determine the shape of the flexible display based on signals received from a selected resistance measuring circuit that communicatively connects to the piezoresistive layer at a predetermined position.

In one embodiment, the programmable controller is further configured to determine the shape of the flexible display by receiving output signals from a plurality of the resistance measuring circuits in communicative contact with the piezoresistive layer when the flexible display changes from a first shape to a second shape, and determining whether the measured

change in electrical resistance is proportional to a predetermined diameter of the flexible display when the flexible display is in the second shape.

In one embodiment, the flexible display comprises a touch-sensitive display. In such embodiments, the programmable controller is further configured to determine whether the change in shape of the flexible display is caused by a user touch on the touch-sensitive display based on signals output by the one or more resistance measuring circuits.

In one embodiment, the programmable controller is further configured to measure the electrical resistance when the flexible display is rolled or unrolled.

In one embodiment, the programmable controller is further configured to measure the electrical resistance when the flexible display is folded or unfolded.

In one embodiment, the programmable controller is further configured to measure the electrical resistance when the flexible display is twisted or untwisted.

Of course, those skilled in the art will appreciate that the present invention is not limited to the above contexts or examples, and will recognize additional features and advantages upon reading the following detailed description and upon viewing the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A-1 B are perspective views of a cellular communications device having a flexible display configured according to one embodiment of the present invention.

Figures 2A-2B are perspective views of a flexible display configured according to one embodiment of the present invention. In this embodiment, the flexible display may be rolled into and out of a cylindrical housing , such as that of a pen.

Figure 3 is a perspective view of a flexible display configured according to one embodiment of the present invention. In this embodiment, the display is a touch sensitive display that displays a keypad and may be rolled and unrolled by a user.

Figure 4 is a block diagram illustrating some exemplary layers of a flexible display configured according to one embodiment of the present invention.

Figure 5 is a flow diagram illustrating a method for determining a current shape of a flexible display according to one embodiment of the present invention.

DETAILED DESCRIPTION

The present invention provides a system and method for determining the current shape of a flexible display. Particularly, the flexible display is constructed to include a flexible material having known piezoresistive properties. When the shape of the flexible display changes, such as when a user bends, folds, twists, or rolls the display, it causes a change in the electrical resistance of the flexible material. The present invention measures this change in resistance and, based on the measured change, determines a current shape of the flexible display. So known, a controller in a device having a flexible display may perform some desired function for the user responsive to a detected shape of the display.

Turning now to the drawings, Figures 1-3 illustrate some types of flexible displays that are suitable for use with various embodiments of the present invention. Particularly, Figures 1A-1B are perspective views illustrating a consumer electronic device having a flexible display configured according to one embodiment of the present invention. As seen in these figures, the consumer electronic device comprises a cellular telephone 10, but as those of ordinary skill in the art will readily appreciate, can be any electronic device having a flexible display known in the art.

Figure 1A illustrates the cellular telephone 10 in an extended state. In this state, the cellular telephone 10 is generally planar, and a user is able to perform functions that include, but are not limited to, placing and receiving voice and/or data calls, sending and receiving text messages, and executing user multimedia applications to render video and audio and play games. Figure 1B illustrates the cellular telephone 10 in a folded state. In this state, the user can perform most if not all of the functions that can be performed on the cellular telephone 10 in the extended state.

As seen in Figures 1A and 1B, the cellular telephone includes a flexible display 12. In one embodiment, the flexible display 12 comprises a touch-sensitive display. The touch-

sensitive display functions as a user input/output (I/O) interface that enables a user to exchange information with the cellular telephone 10. Thus, the flexible display 12 includes software-based controls that facilitate such interaction. In operation, the software controls, which generally include a keypad or other controls that allows the user to enter digits and other alpha-numeric input, allow the user to enter and view information such as dialed digits, images, call status, menu options, and other service information.

The flexible display 12 illustrated in Figures 1A-1 B is a type of phone referred to herein as a "single-foldable" display. With single-foldable displays, a user can bend or fold the cellular telephone 10 along a predetermined part of the flexible display 12. In this embodiment, the predetermined part is indicated in Figures 1A and 1B as a dashed line 14 that traverses the width of the flexible display 12 and bisects the length of the flexible display 12. However, the present invention is not limited with respect to the placement of predetermined parts and/or the direction along which a user may bend or fold the cellular telephone 10. Those skilled in the art will understand that the cellular telephone 10 may be bent or folded along any desired horizontal and/or vertical line traversing the flexible display 12.

In addition, the present invention is not limited as to the number of predetermined parts along which the user can bend or fold flexible display 12. For example, some flexible displays 12 are foldable along more than one predetermined part of the display, each of which may traverse the flexible display 12 along any desired horizontal and/or vertical line. For clarity, such displays are referred to herein as "multiple-foldable" displays. However, regardless of whether any given flexible display 12 is single-foldable or multiple-foldable, those skilled in the art should appreciate that both are suitable for use in one or more embodiments of the present invention. More particularly, both single-foldable and multiple foldable displays may be configured to allow a controller, such as a programmable microprocessor in the cellular telephone 10, to determine a current shape of the flexible display 12 based on a change in the electrical resistance of a material that comprises one or more layers of the flexible display 12.

Figures 2A-2B illustrate another type of a device that utilizes a flexible display. In this embodiment, a pen 20 includes a cylindrical housing 24. The flexible display 22 may be in a

rolled up state within the housing 24 or in an extended state out of the housing 24. When extended, the user can view output such as graphs and other documents, for example, and provide input via a touch-sensitive keypad 28.

Generally, the pen housing 24 includes the needed power and other resources needed by the flexible display 22 to function properly. Therefore, the flexible display 22 is generally not configured to separate completely from the pen housing 24, although it is possible. Additionally, the pen housing 24 also includes a roll mechanism by which the flexible display 22 may be rolled into and out of the pen housing 24. Such mechanisms, as well as the configuration and construction of the pen housing 24 to include the resources needed to drive the flexible display 22, however, are well-known in the art, and therefore, not described in detail here.

The flexible display 22 is bendable or foldable, as previously described. In addition, however, the flexible display 22 is also twistable (Figure 2B). As seen in more detail later, the flexible display 22 is a layered construction having different layers. At least one of the layers comprises a piezoresistive material. According to the present invention, whenever a user bends, folds, rolls, unrolls, twists, or untwists, the flexible display 22, or otherwise changes its shape, a measuring circuit within the pen housing 24 measures the change in resistance of the piezoresistive layer. Based on these measurements, a controller within the pen housing 34 can determine the current shape of the flexible display 22 (e.g., folded, unfolded, rolled up, twisted, rolled out partially, rolled out fully, etc.). So known, the controller can be configured by the manufacturer or the user to perform a predetermined function.

Figure 3 illustrates another type of device that may be configured according to one or more embodiments of the present invention. In this embodiment, the device comprises a keyboard 30 comprised of a flexible display 32. As seen in Figure 3, a user may roll the keyboard 30 into a rolled state for storage and/or transport, or unroll the keyboard 30 into an extended state for use. In some embodiments, the flexible display 32 may be electrically connected to a power source (not shown), and may be operatively connected to a computing device via a wired or wireless connection as is known in the art.

The flexible display 32 comprises a touch-sensitive display that functions as both a user input device and an output device. More specifically, the flexible display 32 may be configured to display the keys 34 of a full QWERTY keyboard to the user. As in the previous embodiments, the flexible display 32 comprises multiple layers. At least one of these layers may be constructed of a material that has a known piezoresistive property. When a user rolls and unrolls the keyboard 30, the electrical resistance of this piezoresistive layer changes as well. This change in the electrical resistance can be measured and utilized by a controller associated with the keypad 30 to determine the current state of the keypad 30 and/or to control the execution of one or more functions.

Figure 4 illustrates a block diagram illustrating an exemplary structure for a flexible display 40 configured according to one embodiment of the present invention. As seen in Figure 4, the flexible display 40 comprises multiple layers 42, 44, 46, 48, and 50. As is known in the art, such structures are bonded or otherwise fixedly attached to each other, and emit light for the user. Although Figure 4 illustrates particular layers 42-50, those of ordinary skill in the art should understand that this is merely illustrative and for clarity only. Other layer structures for flexible display 40 exist; however, so long as a flexible display structure includes a flexible piezoresistive layer that is measured for a change in resistance when it changes shape, such structures are suitable to be configured according to the present invention.

As previously stated, the flexible display 40 comprises multiple layers. Each layer is flexible and may be bent, rolled, and twisted, for example. The layers comprise a substrate layer 42, a thin-film-transistor (TFT) layer 44, a luminescent layer 46, a transparent electrode layer 48, and a cover film 50. The flexible display 40 is typically utilized in an electronics device, such as those illustrated in Figures 1-3 that also includes a programmable controller 52 operatively connected to one or more resistance measuring circuits 54. In operation, the one or more resistance measuring circuits 54 are electrically coupled to corresponding connection points on the flexible transparent electrode layer 48. As described in more detail later, the resistance measuring circuits 54 detect a change in electrical resistance through the transparent electrode layer 48 and report that change to the programmable controller 52. Responsive to

receiving the signals from the resistance measuring circuits 54, the programmable controller 52 is able to determine the physical shape of the flexible display 40, and thus, the shape of the particular device that utilizes flexible display 40.

The substrate layer 42 comprises a flexible, transparent, planar support layer. As is known in the art, the substrate layer 42 functions as the foundation upon which the electronics of the other layers are deposited. In this embodiment, the TFT layer 44, the luminescent layer 46, the transparent electrode layer 48, and the cover film 50 are deposited on the substrate layer 42. The substrate layer 42 is usually manufactured from a plastic material such as Polyethylene Terephthalate (PET or PETE), and may be conductive or non-conductive as needed or desired.

The TFT layer 44 comprises a thin transparent film that carries a plurality of transistors used in the flexible display 40. Each transistor corresponds to a single pixel on the display and is controlled to emit light using signals that are generated, for example, by controller 52. Particularly, the signals drive an electrical current to flow through the transistors. The transistors, in turn, cause light emitting diodes (LEDs) contained in the luminescent layer 46 to emit light. Conventionally, the transistors on the TFT layer 44 are constructed from a wide variety of materials; however, in one embodiment, the transistors carried by TFT layer 44 comprise organic thin-film transistors (OTFT) constructed from organic materials having semiconducting properties.

The luminescent layer 46 also comprises a thin, flexible, transparent layer. In one embodiment, the luminescent layer 46 comprises a plurality of organic light emitting diodes (OLEDs) that emit light in response to receiving an electrical current. Those of ordinary skill in the art will readily understand that OLEDs do not require a backlight to emit light. However, in one embodiment, the OLEDs require the TFT layer 44 as a backplane to switch individual pixels on and off. Particularly, an electrical current flows through selected transistors on the TFT layer 44. This current, in turn, either enables or disables the OLEDs from emitting light.

The transparent electrode layer 48 comprises a layer of material through which light is emitted out of the flexible display 40. In conventional displays, the transparent electrode layers

comprise a thin layer of Indium-Tin oxide (ITO). Traditionally, ITO is used because it is both optically transparent and electrically conductive. Further, ITO can be easily deposited on a substrate as a thin film. However, ITO is not without its problems. Particularly, ITO lacks a great deal of flexibility, and thus, is brittle and has a tendency to crack. Such properties are not desirable for use in a display that a user may repeatedly roll, unroll, bend, and twist. Further, Indium is becoming increasingly scarce, and as such, is also becoming increasingly expensive.

Therefore, in one embodiment of the present invention, the transparent electrode layer 48 comprises a thin planar layer of graphene. As is known in the art, graphene is an allotrope of carbon. Essentially, graphene is transparent, electrically conductive, and extremely durable. Graphene has strong heat transfer properties and can conduct electricity better than copper. Further, graphene is fairly inexpensive because it does not use any exotic materials in its construction. Additionally, graphene is more dense and elastic than other materials, such as ITO, and is therefore, more flexible. Moreover, graphene has an extremely low resistivity of 10^{-6} Ω-cm. This is less than the resistivity of silver, which has the lowest resistivity known for a substance at room temperature. However, one particularly interesting property of graphene is its ability to absorb white light. Specifically, graphene absorbs a mere 2.3% of white light, which is far better than the absorption rate of ITO.

These unique properties of graphene make it an ideal material for use as a flexible transparent electrode layer 48. However, graphene also has piezoresistive properties that are particularly useful to the present invention. Specifically, piezoresistivity describes a changing electrical resistance of a material in response to a mechanical stress applied to the material. The "piezoresistive effect" of a material such as graphene differs from the "piezoelectric effect" of the material because it does not produce a change in electrical potential. Rather, it produces only a change in resistance that is driven by contraction of the material rather than the length and area of a material. Thus, as a user bends, rolls, or twists a device having the flexible display 40, the resistivity of the graphene transparent electrode layer 48 also changes.

According to one or more embodiments of the present invention, this piezoresistive property of the graphene transparent electrode layer 48 is utilized to determine a physical shape

for the flexible display 40. More specifically, the present invention provides a system and method for measuring a change in resistivity of a piezoresistive layer 48, and then using that measured change to determine the current physical shape of the flexible display 40.

As seen in Figure 4, the one or more resistance measuring circuits 54 are electrically connected to the transparent electrode layer 48 at predetermined positions. Generally, the resistance measuring circuits 54 measure the change in electrical resistance of the piezoresistive transparent electrode layer 48, and report that change using appropriate signals to the programmable controller 52. Those of ordinary skill in the art will appreciate that the resistance measuring circuit 54 may comprise any components known to detect and measure a change in resistance. However, in one embodiment, the resistance measuring circuit 54 comprises a Whetstone Bridge connected to a differential amplifier. In operation, the Whetstone Bridge connects to the transparent electrode layer 48 and detects the changes in resistance whenever the shape of the display changes. In response, the Whetstone bridge generates corresponding signals to the differential amplifier. The amplifier, in turn, sends the received signals to the controller 52.

The resistance measuring circuits 54 may be connected to the layer 48 using any method known in the art. However, in one embodiment, the resistance measuring circuits 54 connect to the transparent electrode layer 48 at predetermined positions. These positions, indicated using the letter 'A' in Figure 4, may be disposed along the part where the flexible display 40 bends. When the user folds or bends the device having the flexible display 40, the resistance measuring circuits 54 detect the bend at position(s) A and generate signals to the controller 52, as previously described. Upon receipt of the signals, the controller 52 can determine that the flexible display 40, and thus the electronic device, is being folded or unfolded.

In another embodiment, the resistance measuring circuits 54 are disposed over the surface of the transparent electrode layer 48. These cases are particularly useful for determining whether a user has rolled or unrolled the device having the flexible display 40. Specifically, as a user rolls and unrolls the flexible display 40, multiple resistance measuring

circuits 54 disposed over the surface of layer 48 will detect a change in resistivity and send signals to the controller 52 accordingly. Further, the change in the resistance of the transparent electrode layer 48 is proportional to the diameter of the rolled display. Therefore, the controller 52, upon receipt of the signals, can determine that the user is rolling or unrolling the flexible display 40, as well as the diameter of the rolled display. The controller 52 may also determine whether the user is twisting the display.

In some embodiments, the flexible display 40 comprises a touch-sensitive display. As is known in the art, the shape of a touch-sensitive display may be changed when a user contacts the display to select a control or perform some other function, for example. However, the controller 52 is configured to differentiate between a change in shape caused by rolling, twisting, or bending, and those changes in shape caused by the contact of a user's finger with the touch-sensitive display.

In one embodiment, for example, the touch-sensitive display comprises a pair of thin, electrically conductive layers separated by a narrow gap. As is known in the art, pressure on the display caused by a user's finger or a stylus will force the two layers touch each other at the point of contact. Such contact causes a change in the electrical current, which the controller 52 interprets as a touch event.

The components used to send the touch signals to the controller are different than the resistance measuring circuits 54 that are used to send the signals indicating a change in resistance of the transparent electrode layer 48. Therefore, the controller 52, upon receiving the signals, can simply determine whether the user is folding, rolling, or twisting the display 40 based on whether the signals are received from the components of the touch-sensitive display, or from the resistance measuring circuits 54.

In another embodiment, the controller 52 utilizes the signals received from the one or more resistance measuring circuits 54. Specifically, if the dedicated resistance measuring circuits 54 send the signals, the controller can determine that a user is folding the flexible display. Additionally, determining the diameter of a rolled display 40, as stated above, will

enable the controller 52 to determine that the user has rolled or unrolled the flexible display 40 rather than simply depressed a portion of the display 40 to select a displayed control.

Figure 5 is a flow diagram illustrating a method 60 in which a controller 52 determines a shape of a device having flexible display 40 based on a measured change in the resistance of a piezoresistive layer (e.g., the transparent electrode layer 48) that comprises the flexible display 40. As described above, one or more resistance measuring circuits 54 are electrically connected to the piezoresistive layer using any method known in the art, and communicate output signals to controller 52.

Method 60 begins with the controller 52 receiving signals from the one or more resistance measuring circuits 54 connected to the piezoresistive layer of flexible display 40 as the user is folding, twisting, or rolling the flexible display 40 (box 62). The controller 52 is configured to make a determination, if necessary, as to whether the signals are received from one or more dedicated resistance measuring circuit(s) or a plurality of distributed resistance measuring circuits 54 (box 64).

For dedicated resistance measuring circuits, the controller 52 would use the received signals to measure the amount of resistance at the predetermined connection points (e.g., the positions labeled "A" in Figure 4) as the user folds or unfolds the flexible display 40 (box 66). Based on this measured change in resistance of the piezoresistive layer, the controller 52 would be able to determine whether the flexible display 40, and thus, the electronic device (e.g., cellular telephone 10), is being folded into a folded state (e.g., Figure 1B), or unfolded into an extended state (Figure 1A) (box 68). Having identified the current shape of flexible display 40, the controller 52 can then generate the appropriate signals to cause some function to occur responsive to the shape change.

In embodiments where the resistance measuring circuits 54 are connected to layer 48 in a distributed manner (box 64), the controller 52 uses the received signals to measure the change in resistance across a larger surface of the piezoresistive layer (box 70). Based on these received signals, the controller 52 is configured to determine the physical shape of the piezoresistive layer (box 72). By way of example only, the controller 52 may determine that a

plurality of the resistance measuring circuits 54 have generated the signals in a pattern that matches a predetermined pattern. Such a pattern may be caused, for example, when the user rolls the device (e.g., keyboard 30) from one end. Additionally, the signals output by the resistance measuring circuits 54 in this embodiment may indicate a change in resistance that is proportional to the diameter of the rolled portion of the keyboard 30. Thus, the controller 52 could use this information to determine whether the user is rolling or unrolling the keyboard 30, or whether the keyboard is being twisted or untwisted (e.g., Figures 2A-2B). Once known, the controller 52 can then generate the appropriate signals to cause some function to occur responsive to the shape change.

The present invention may, of course, be carried out in other ways than those specifically set forth herein without departing from essential characteristics of the invention. For example, the previous embodiments illustrate the piezoresistive layer in flexible display 40 as being a layer sandwiched between the luminescent layer 46 and the cover film 50. In this case, the piezoresistive layer comprises an extra layer that is added to the flexible display 40 specifically for determining the current shape of the flexible display 40. However, those of ordinary skill in the art will readily appreciate that this is for illustrative purposes only. Any of the layers 42, 44, 46, 48, and 50 may comprise a graphene layer having the piezoresistive properties used to determine a shape of the flexible display 40.

Further, it is not required for a flexible display 40 to include a dedicated graphene layer dedicated to determining the current shape of the flexible display 40. Any of the layers 42, 44, 46, 48, 50 may perform a dual function. For example, in one embodiment, one of the layers 42, 44, 46, 48, and 50 comprises a piezoresistive layer. In operation, this layer performs its intended function (e.g., functions related to receiving user input or emitting light). In addition to this intended function, however, the layer is also configured to provide the structure for determining the current shape of the flexible display 40.

It is also possible, according to one embodiment, for any of the layers 42, 44, 46, 48, 50 of the flexible display 40 to itself comprise multiple layers. In such embodiments, one or more parts of the layer may perform some intended function, while a part of the layer that comprises

graphene is configured, as described previously, to determine the current shape of the display 40.

Additionally, the graphene layer need not be an active layer that actively contributes to the function of the display 40, but instead, may be an inactive flexible layer that does not directly contribute to the functions of the display 40.

Alternatively, the present invention need not utilize a layer of a piezoresistive material such as graphene, but instead, may utilize other structures such as carbon nano-tubes (CNT). Carbon Nano-Tubes are similar to graphene and also enjoy piezoresistive properties that may be used in the present invention in one or more embodiments. Carbon Nano-Tubes are generally utilized to connect components in a display, such as display 40, but may be electrically coupled to one or more resistance measuring circuits 54, as is known in the art, and used to measure a change in resistivity as previously described.

Therefore, the present embodiments are to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein

CLAIMS

What is claimed is:

1. A method for determining a physical shape of a flexible display, the method comprising:

measuring a change in electrical resistance of a flexible display that changes shape; and

determining the shape of the flexible display based on the measured change in resistance.

2. The method of claim 1 wherein measuring a change in electrical resistance comprises measuring the change in electrical resistance of a piezoresistive layer associated with the flexible display.

3. The method of claim 2 wherein measuring a change in electrical resistance comprises detecting the change in resistance using resistance measuring circuits in communicative contact with the piezoresistive layer at predetermined positions.

4. The method of claim 3 wherein determining the shape of the flexible display comprises determining the shape of the flexible display based on signals received from a resistance measuring circuit in communicative contact with the piezoresistive layer at a selected position.

5. The method of 3 wherein determining the shape of the flexible display comprises:

receiving output signals from a plurality of the resistance measuring circuits in communicative contact with the piezoresistive layer when the flexible display changes from a first shape to a second shape;

determining whether the measured change in electrical resistance is proportional to a predetermined diameter of the flexible display when the flexible display is in the second shape.

6. The method of claim 3 wherein the flexible display comprises a touch-sensitive display, and further comprising determining whether the change in shape of the flexible display is caused by a user touch on the touch-sensitive display.

7. The method of claim 1 wherein measuring a change in electrical resistance comprises measuring the electrical resistance when the flexible display is rolled or unrolled.

8. The method of claim 1 wherein measuring a change in electrical resistance comprises measuring the electrical resistance when the flexible display is folded or unfolded.

9. The method of claim 1 wherein measuring a change in electrical resistance comprises measuring the electrical resistance when the flexible display is twisted or untwisted.

10. A consumer electronics device comprising:

a flexible display configured to change shape and having a plurality of layers; and

a programmable controller configured to:

measure a change in electrical resistance of the flexible display when the flexible display changes shape; and

determine the shape of the flexible display based on the measured change in resistance.

11. The device of claim 10 wherein the programmable controller is further configured to measure the change in electrical resistance of a piezoresistive layer associated with the flexible display.

12. The device of claim 11 wherein the piezoresistive layer comprises one of the plurality of layers of the flexible display.

13. The device of claim 11 wherein the piezoresistive layer comprises an additional layer that is separate from the plurality of layers of the flexible display.

14. The device of claim 11 wherein the piezoresistive layer comprises at least a part of one of the plurality of layers of the flexible display.

15. The device of claim 11 further comprising one or more resistance measuring circuits in communicative contact with the piezoresistive layer, and wherein the programmable controller is further configured to detect the change in resistance based on signals received from the one or more resistance measuring circuits.

16. The device of claim 15 wherein the programmable controller is further configured to determine the shape of the flexible display based on signals received from a selected resistance measuring circuit that communicatively connects to the piezoresistive layer at a predetermined position.

17. The device of 15 wherein the programmable controller is further configured to determine the shape of the flexible display by:

receiving output signals from a plurality of the resistance measuring circuits in communicative contact with the piezoresistive layer when the flexible display changes from a first shape to a second shape; and

determining whether the measured change in electrical resistance is proportional to a predetermined diameter of the flexible display when the flexible display is in the second shape.

18. The device of claim 15 wherein the flexible display comprises a touch-sensitive display, and wherein the programmable controller is further configured to determine whether the change

in shape of the flexible display is caused by a user touch on the touch-sensitive display based on signals output by the one or more resistance measuring circuits.

19. The device of claim 10 wherein the programmable controller is further configured to measure the electrical resistance when the flexible display is rolled or unrolled.

20. The device of claim 10 wherein the programmable controller is further configured to measure the electrical resistance when the flexible display is folded or unfolded.

21. The device of claim 10 wherein the programmable controller is further configured to measure the electrical resistance when the flexible display is twisted or untwisted.

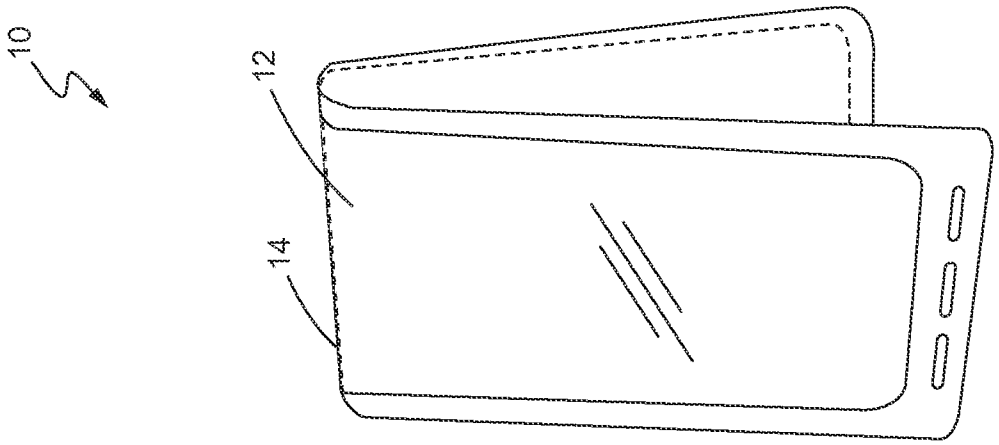

FIG. 1B

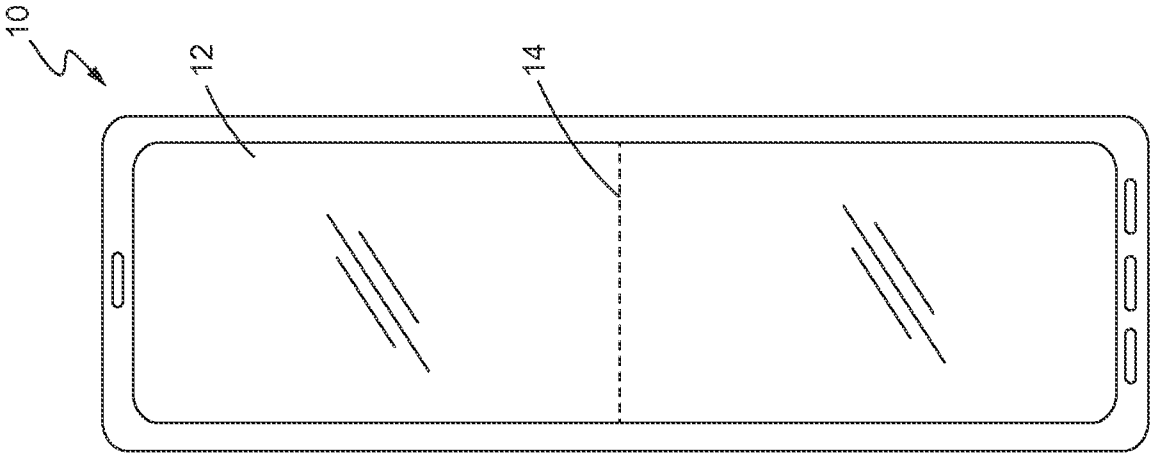

FIG. 1A

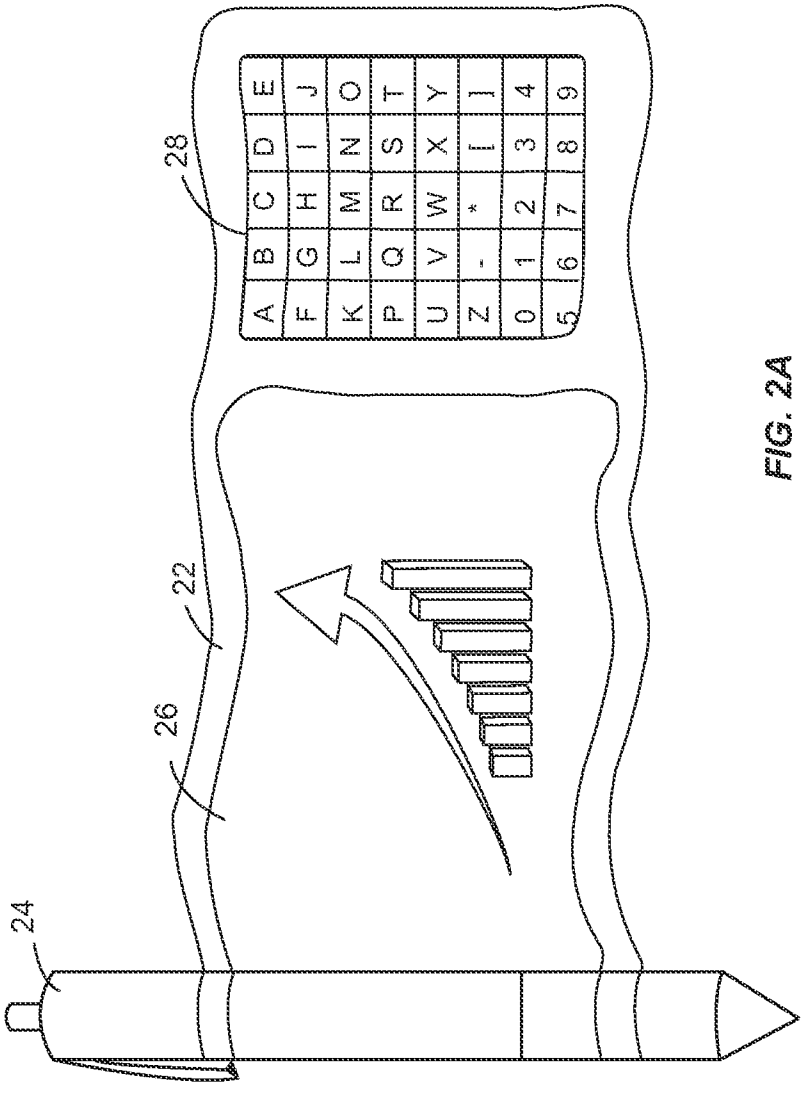

FIG. 2A

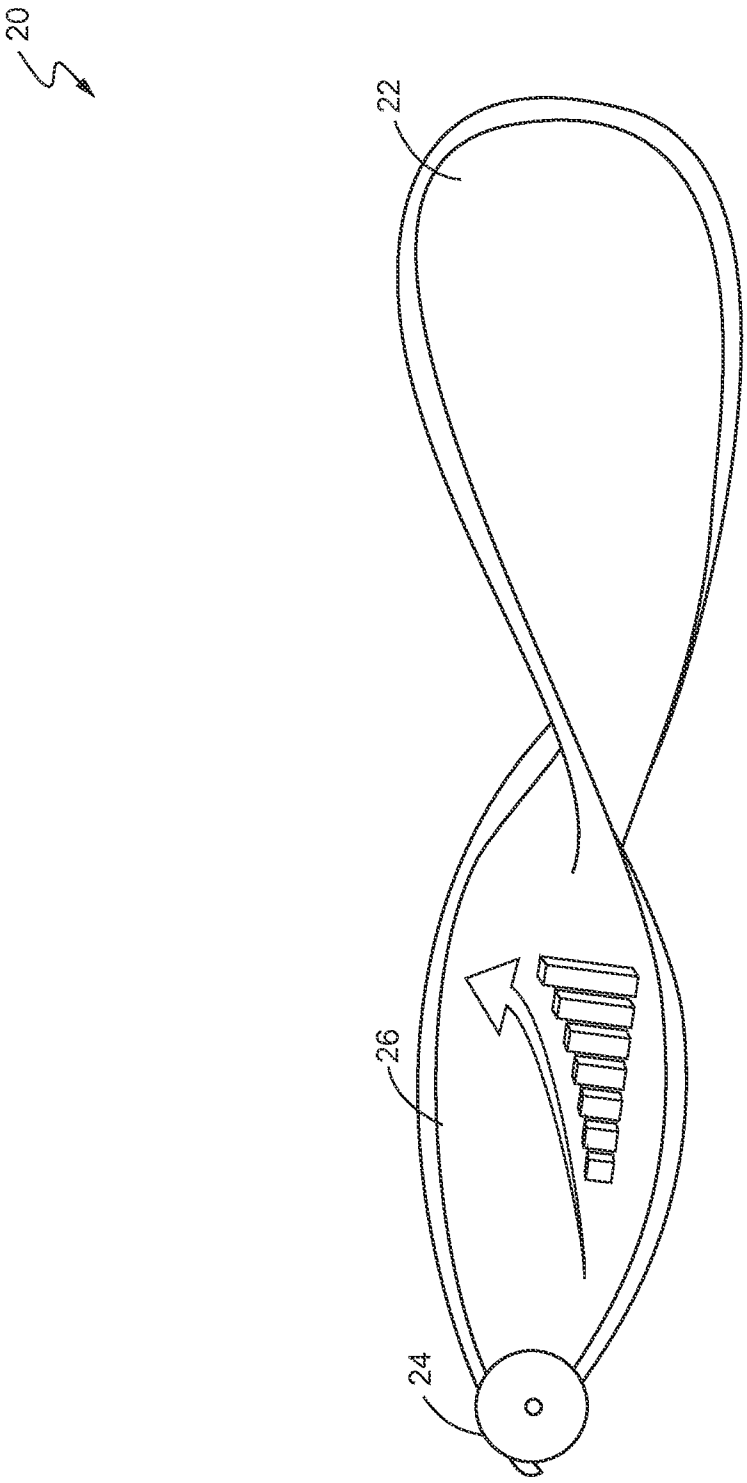

FIG. 2B

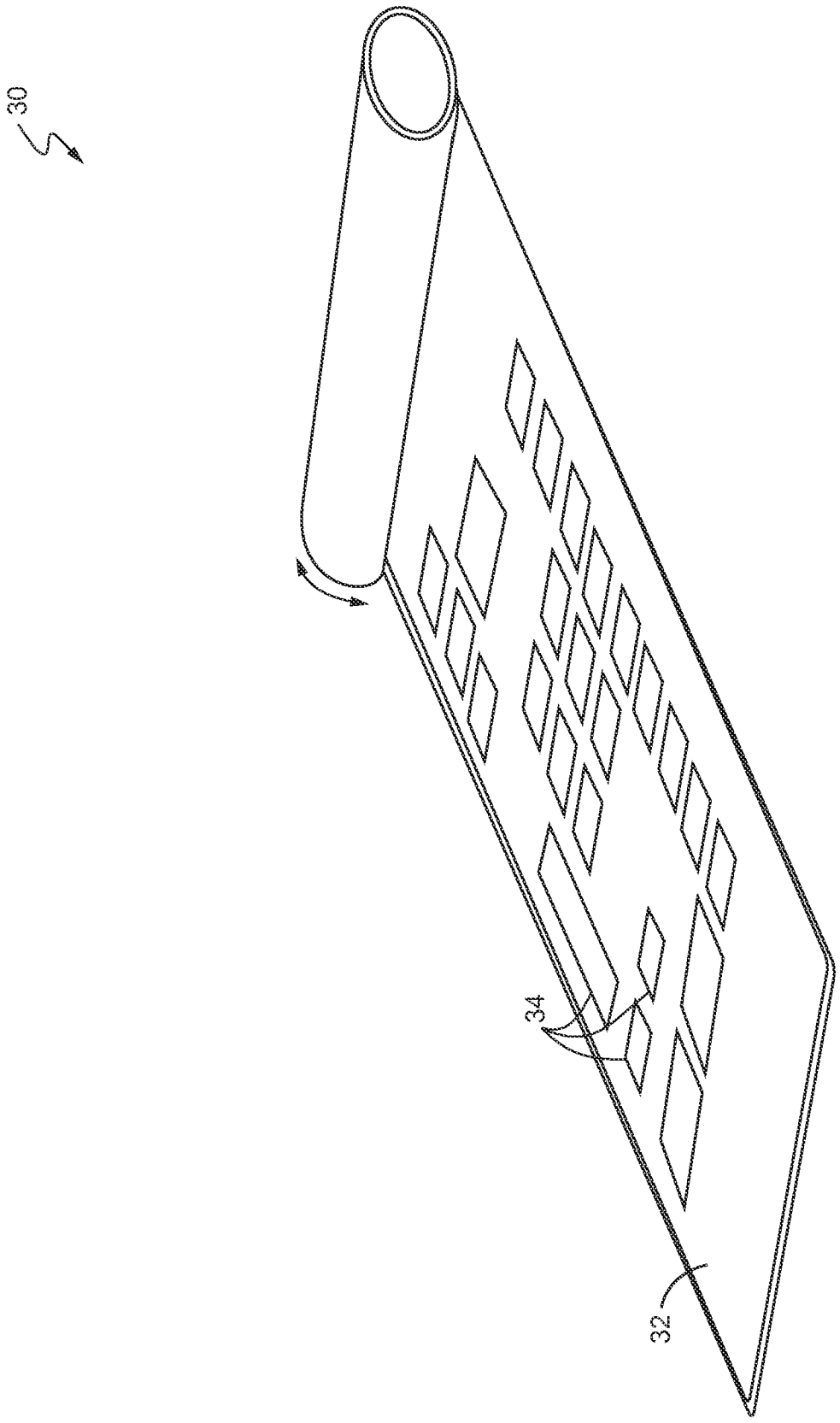

FIG. 3

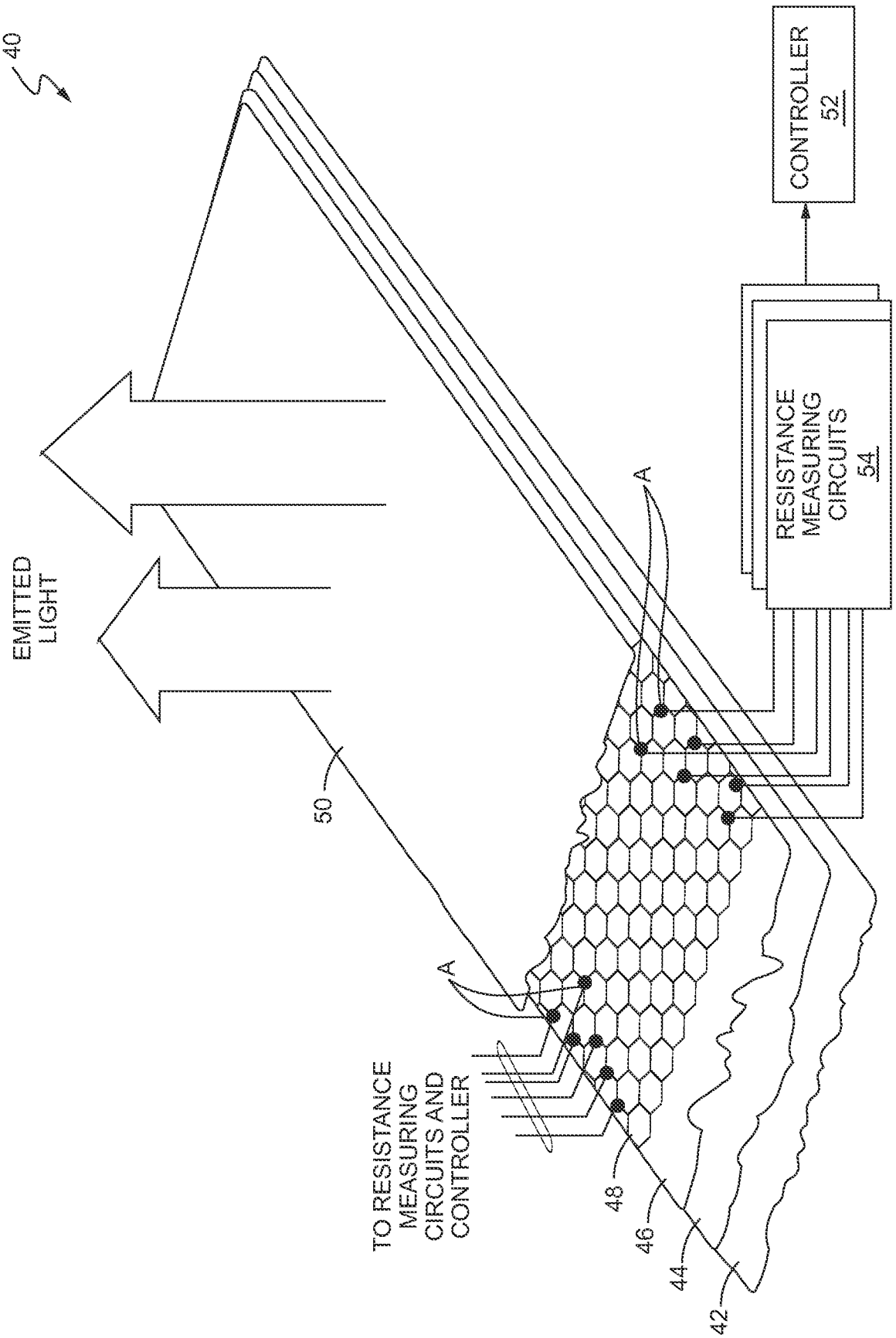
40
EMITTED LIGHT
50
A
A
TO RESISTANCE MEASURING CIRCUITS AND CONTROLLER
48
46
44
42
RESISTANCE MEASURING CIRCUITS 54
CONTROLLER 52

FIG. 4

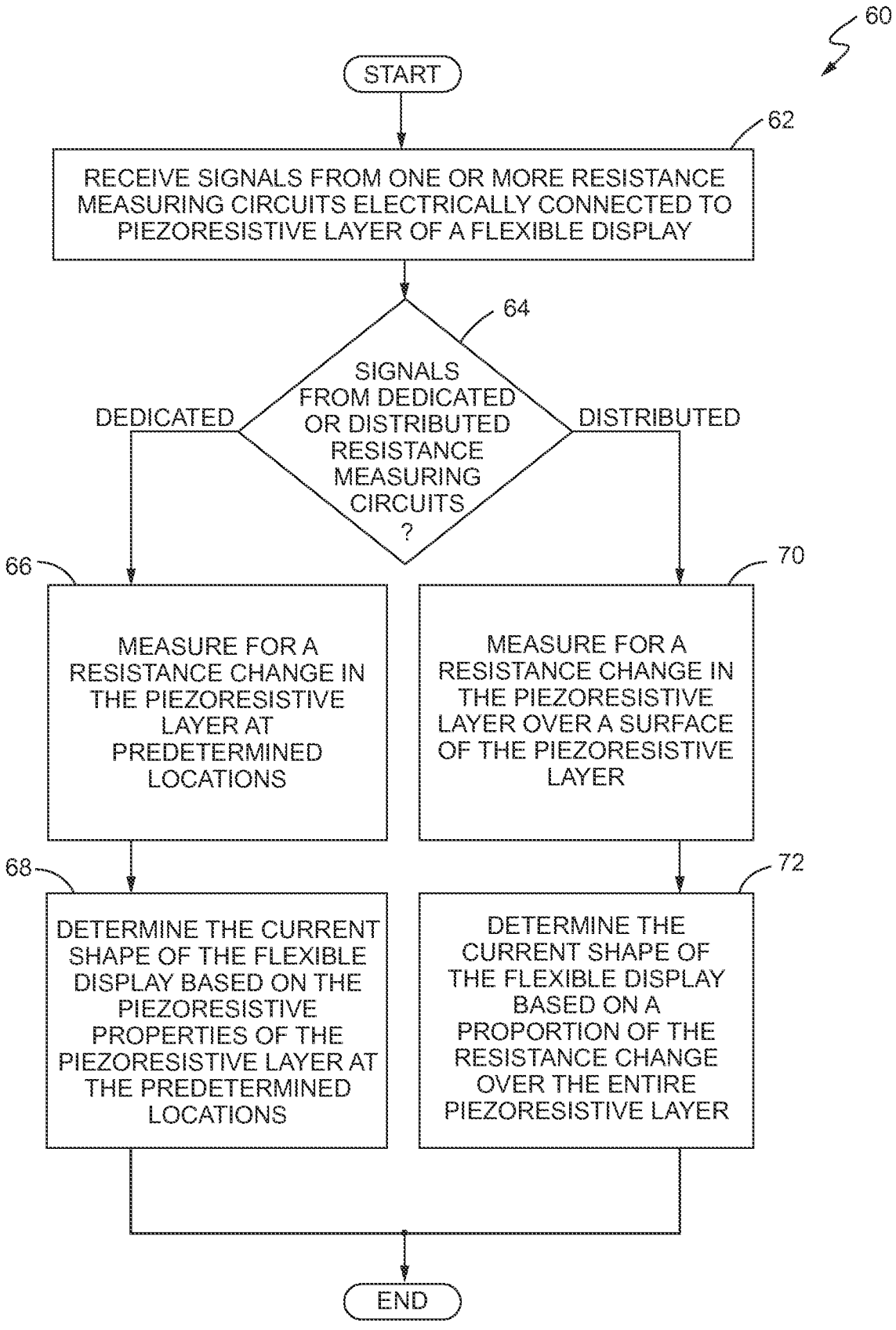
60
START
62
RECEIVE SIGNALS FROM ONE OR MORE RESISTANCE MEASURING CIRCUITS ELECTRICALLY CONNECTED TO PIEZORESISTIVE LAYER OF A FLEXIBLE DISPLAY
64
SIGNALS FROM DEDICATED OR DISTRIBUTED RESISTANCE MEASURING CIRCUITS ?
DEDICATED
DISTRIBUTED
66
MEASURE FOR A RESISTANCE CHANGE IN THE PIEZORESISTIVE LAYER AT PREDETERMINED LOCATIONS
70
MEASURE FOR A RESISTANCE CHANGE IN THE PIEZORESISTIVE LAYER OVER A SURFACE OF THE PIEZORESISTIVE LAYER
68
DETERMINE THE CURRENT SHAPE OF THE FLEXIBLE DISPLAY BASED ON THE PIEZORESISTIVE PROPERTIES OF THE PIEZORESISTIVE LAYER AT THE PREDETERMINED LOCATIONS
72
DETERMINE THE CURRENT SHAPE OF THE FLEXIBLE DISPLAY BASED ON A PROPORTION OF THE RESISTANCE CHANGE OVER THE ENTIRE PIEZORESISTIVE LAYER
END

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/055930

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F1/16 H04M1/02
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 H04M

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	US 2003/227441 A1 (HIOKI TSUYOSHI [JP] ET AL) 11 December 2003 (2003-12-11) abstract paragraphs [0082] - [0133], [0145] - [0152]; figures 1-13,20-22 paragraphs [0219] - [0235] figures 30-32	1-21
X	US 2010/315399 A1 (JAC0BS0N JOSEPH M [US] ET AL) 16 December 2010 (2010-12-16) paragraphs [0031] - [0055], [0069] - [0070], [0099]; figures 1-4	1-21
X	US 2009/219247 A1 (WATANABE JUNICHIRO [JP] ET AL) 3 September 2009 (2009-09-03) abstract paragraphs [0050] - [0054]; figures 3-6	1,10

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

☒ See patent family annex.

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"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

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"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
28 March 2013	08/04/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/055930

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003227441 Al	11-12-2003	US 2003227441 Al	11-12-2003
		US 2006274036 Al	07-12-2006
US 2010315399 Al	16-12-2010	US 2010315399 Al	16-12-2010
		Wo 2010144366 Al	16-12-2010
US 2009219247 Al	03-09-2009	JP 4909922 B2	04-04-2012
		JP 2009205565 A	10-09-2009
		US 2009219247 Al	03-09-2009