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### NON-RIGID DEVICE AND DISPLAY DEVICE

#### Abstract

A device with a flexible region that is manipulable in a second standard direction substantially perpendicular to a rotational axis extending in a first standard direction includes a flexible touch sensing panel. The flexible touch sensing panel includes first touch sensing electrodes and a first bridge. The first bridge is on a layer substantially different from a layer on which the first touch sensing electrodes are located and the first bridge connects two first touch sensing electrodes adjacent to each other. The first bridge includes a first portion extending in a first extension direction, which forms a first angle with the first standard direction. The first angle is not about  $k \times 90^\circ$  (where “k” is a non-zero positive or negative odd integer) and is not about  $m \times 180^\circ$  (where “m” is an integer).

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## **Background/Summary**

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 16/841,691, filed Apr. 7, 2020, which claims priority to and the benefit of Korean Patent Application No. 10-2019-0047837, filed Apr. 24, 2019, and Korean Patent Application No. 10-2019-0072825, filed Jun. 19, 2019, the entire content of all of which is incorporated herein by reference.

### **BACKGROUND**

#### **Field**

[0002] Exemplary embodiments generally relate to devices, and, more particularly, to devices including an input sensing sensor.

#### **Discussion**

[0003] Various display devices may be applied to a multimedia device, such as a television set, a mobile phone, a tablet computer, a navigation unit, a game unit, etc. As an input unit of a display device, a keyboard or a mouse may be used. In addition, the display device may include a touch panel as an input unit.

[0004] The above information disclosed in this section is only for understanding the background of the inventive concepts, and, therefore, may contain information that does not form prior art.

### **SUMMARY**

[0005] Some exemplary embodiments are capable of providing a device with reduced defects.

[0006] Some exemplary embodiments are capable of providing a non-rigid device with reduced defects.

[0007] Some exemplary embodiments are capable of providing a display device including an input sensing sensor with reduced defects.

[0008] Additional aspects will be set forth in the detailed description which follows, and, in part, will be apparent from the disclosure, or may be learned by practice of the inventive concepts.

[0009] According to an exemplary embodiment, a non-rigid device with a flexible region that is foldable, slidable, or rollable in a second standard direction substantially perpendicular to a rotational axis extending in a first standard direction includes a flexible touch sensing panel. The flexible touch sensing panel includes first touch sensing electrodes and a first bridge. The first bridge is on a layer substantially different from a layer on which the first touch sensing electrodes are located. The first bridge connects two first touch sensing electrodes adjacent to each other. The first bridge includes a first portion extending in a first extension direction forming a first angle with the first standard direction. The first angle is not about  $k \times 90^\circ$  (where “k” is a non-zero positive or negative odd integer) and is not about  $m \times 180^\circ$  (where “m” is an integer).

[0010] According to an exemplary embodiment, a non-rigid device with a flexible region that is foldable, slidable, or rollable in a second standard direction substantially perpendicular to a rotational axis extending in a first standard direction includes a flexible display panel and a flexible touch sensing panel on the flexible display panel. The flexible display panel includes an active area including emitting portions spaced apart from each other and a non-emitting area disposed between the emitting portions and a peripheral area surrounding the active area. The flexible touch sensing panel includes a touch sensing electrode and a signal transmission line transmitting a signal sensed

by the touch sensing electrode to the peripheral area. The signal transmission line includes a first portion extending in a first extension direction, which forms a first angle with the first standard direction. The first angle is not about  $q \times 90^\circ$  (where “q” is a non-zero positive or negative odd integer) and is not about  $r \times 180^\circ$  (where “r” is an integer). The touch sensing electrode and the signal transmission line are integrally formed with each other on a same layer as one piece or are disposed on substantially different layers from each other.

[0011] According to an exemplary embodiment, a display device includes a display panel and a touch sensing panel on the display panel. The display panel includes an active area including emitting portions spaced apart from each other and a non-emitting area between the emitting portions and a peripheral area surrounding the active area. The touch sensing panel includes a touch sensing electrode overlapping the active area and a signal transmission line transmitting a signal sensed by the touch sensing electrode to the peripheral area. The touch sensing electrode and the signal transmission line are integrally formed with each other on a same layer as one piece or are disposed on substantially different layers from each other.

[0012] According to various exemplary embodiments, even though a bridge or a signal transmission line may be disposed on a same or a substantially different layer than a touch sensing electrode, a flexible touch sensing panel including the bridge or the signal transmission line may be folded many times from the viewpoint of a folding axis such that it is possible to reduce damage to the bridge and/or the signal transmission line, as well as relieve creases and/or buckling of the flexible touch sensing panel due to the bridge or signal transmission line.

[0013] The foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the claimed subject matter.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The accompanying drawings, which are included to provide a further understanding of the inventive concepts, and are incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the inventive concepts, and, together with the description, serve to explain principles of the inventive concepts. In the drawings:

[0015] FIG. 1 is a perspective view showing a foldable display device according to an exemplary embodiment;

[0016] FIG. 2 is a plan view showing a flexible display panel in an area A1 of the foldable display device shown in FIG. 1 according to an exemplary embodiment;

[0017] FIG. 3 is a cross-sectional view showing an in-folding operation of the foldable display device shown in FIG. 1 according to an exemplary embodiment;

[0018] FIG. 4 is a cross-sectional view showing an out-folding operation of the foldable display device shown in FIG. 1 according to an exemplary embodiment;

[0019] FIG. 5 is a plan view showing a flexible touch sensing panel in an area B1 of FIG. 1 according to an exemplary embodiment;

[0020] FIG. 6 is an enlarged view showing an area CA1 of FIG. 5 according to an exemplary embodiment;

[0021] FIG. 7 is an enlarged view showing an area D1 of FIG. 5 according to an exemplary embodiment;

[0022] FIG. 8 is a cross-sectional view showing the flexible touch sensing panel taken along sectional line I-I' of FIG. 5 according to an exemplary embodiment;

[0023] FIG. 9 is a cross-sectional view showing the flexible touch sensing panel taken along a line I-I' shown in FIG. 5 according to an exemplary embodiment;

[0024] FIG. 10 is a plan view showing a flexible touch sensing panel in an area B1 of FIG. 1

according to an exemplary embodiment;

[0025] FIG. 11 is a plan view showing a flexible touch sensing panel in an area B1 of FIG. 1 according to an exemplary embodiment;

[0026] FIG. 12 is an enlarged view showing an area E1 of FIG. 11 according to an exemplary embodiment;

[0027] FIG. 13 is an enlarged view showing an area E1 of FIG. 11 according to an exemplary embodiment;

[0028] FIG. 14 is a cross-sectional view showing the flexible touch sensing panel taken along sectional line II-IF of FIG. 13 according to an exemplary embodiment;

[0029] FIG. 15 is a cross-sectional view showing the flexible touch sensing panel taken along sectional line II-IF of FIG. 13 according to an exemplary embodiment;

[0030] FIG. 16 is an enlarged view showing an area F1 of FIG. 11 according to an exemplary embodiment;

[0031] FIG. 17 is an enlarged view showing an area G1 of FIG. 11 according to an exemplary embodiment; and

[0032] FIG. 18 is an enlarged view showing an area G1 of FIG. 11 according to an exemplary embodiment.

#### DETAILED DESCRIPTION OF SOME EXEMPLARY EMBODIMENTS

[0033] In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of various exemplary embodiments. As used herein, the terms “embodiments” and “implementations” are used interchangeably and are non-limiting examples employing one or more of the inventive concepts disclosed herein. It is apparent, however, that various exemplary embodiments may be practiced without these specific details or with one or more equivalent arrangements. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring various exemplary embodiments. Further, various exemplary embodiments may be substantially different, but do not have to be exclusive. For example, specific shapes, configurations, and characteristics of an exemplary embodiment may be used or implemented in another exemplary embodiment without departing from the inventive concepts.

[0034] Unless otherwise specified, the illustrated exemplary embodiments are to be understood as providing exemplary features of varying detail of some exemplary embodiments. Therefore, unless otherwise specified, the features, components, modules, layers, films, panels, regions, aspects, etc. (hereinafter individually or collectively referred to as an “element” or “elements”), of the various illustrations may be otherwise combined, separated, interchanged, and/or rearranged without departing from the inventive concepts.

[0035] The use of cross-hatching and/or shading in the accompanying drawings is generally provided to clarify boundaries between adjacent elements. As such, neither the presence nor the absence of cross-hatching or shading conveys or indicates any preference or requirement for particular materials, material properties, dimensions, proportions, commonalities between illustrated elements, and/or any other characteristic, attribute, property, etc., of the elements, unless specified. Further, in the accompanying drawings, the size and relative sizes of elements may be exaggerated for clarity and/or descriptive purposes. As such, the sizes and relative sizes of the respective elements are not necessarily limited to the sizes and relative sizes shown in the drawings. When an exemplary embodiment may be implemented differently, a specific process order may be performed differently from the described order. For example, two consecutively described processes may be performed substantially at the same time or performed in an order opposite to the described order. Also, like reference numerals denote like elements.

[0036] When an element, such as a layer, is referred to as being “on,” “connected to,” or “coupled to” another element, it may be directly on, connected to, or coupled to the other element or intervening elements may be present. When, however, an element is referred to as being “directly

on,” “directly connected to,” or “directly coupled to” another element, there are no intervening elements present. Other terms and/or phrases used to describe a relationship between elements should be interpreted in a like fashion, e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” “on” versus “directly on,” etc. Further, the term “connected” may refer to physical, electrical, and/or fluid connection. In addition, the X-axis, the Y-axis, and the Z-axis are not limited to three axes of a rectangular coordinate system, and may be interpreted in a broader sense. For example, the X-axis, the Y-axis, and the Z-axis may be perpendicular to one another, or may represent different directions that are not perpendicular to one another. For the purposes of this disclosure, “at least one of X, Y, and Z” and “at least one selected from the group of X, Y, and Z” may be construed as X only, Y only, Z only, or any combination of two or more of X, Y, and Z, such as, for instance, XYZ, XYY, YZ, and ZZ. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0037] Although the terms “first,” “second,” etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are used to distinguish one element from another element. Thus, a first element discussed below could be termed a second element without departing from the teachings of the disclosure.

[0038] Spatially relative terms, such as “beneath,” “below,” “under,” “lower,” “above,” “upper,” “over,” “higher,” “side” (e.g., as in “sidewall”), and the like, may be used herein for descriptive purposes, and, thereby, to describe one element's relationship to another element(s) as illustrated in the drawings. Spatially relative terms are intended to encompass different orientations of an apparatus in use, operation, and/or manufacture in addition to the orientation depicted in the drawings. For example, if the apparatus in the drawings is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. Furthermore, the apparatus may be otherwise oriented (e.g., rotated 90 degrees or at other orientations), and, as such, the spatially relative descriptors used herein interpreted accordingly.

[0039] The terminology used herein is for the purpose of describing particular embodiments and is not intended to be limiting. As used herein, the singular forms, “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Moreover, the terms “comprises,” “comprising,” “includes,” and/or “including,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, components, and/or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It is also noted that, as used herein, the terms “substantially,” “about,” and other similar terms, are used as terms of approximation and not as terms of degree, and, as such, are utilized to account for inherent deviations in measured, calculated, and/or provided values that would be recognized by one of ordinary skill in the art.

[0040] Various exemplary embodiments are described herein with reference to sectional views, isometric views, perspective views, plan views, and/or exploded illustrations that are schematic illustrations of idealized exemplary embodiments and/or intermediate structures. As such, variations from the shapes of the illustrations as a result of, for example, manufacturing techniques and/or tolerances, are to be expected. Thus, exemplary embodiments disclosed herein should not be construed as limited to the particular illustrated shapes of regions, but are to include deviations in shapes that result from, for instance, manufacturing. To this end, regions illustrated in the drawings may be schematic in nature and shapes of these regions may not reflect the actual shapes of regions of a device, and, as such, are not intended to be limiting.

[0041] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure is a part. Terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense, unless expressly so defined

herein.

[0042] Hereinafter, various exemplary embodiments will be explained in detail with reference to the accompanying drawings.

[0043] FIG. 1 is a perspective view showing a foldable display device according to an exemplary embodiment.

[0044] Referring to FIG. 1, a foldable display device **100** includes a support structure **10**, a flexible display panel **20**, and a flexible touch sensing panel **30**.

[0045] The support structure **10** includes a first section **10a**, a second section **10b**, and a third section **10c**. The first section **10a** and the second section **10b** are rigid. The first section **10a** and the second section **10b** are spaced apart from each other. The third section **10c** is flexible. For the purposes of this disclosure, the concept of “flexibility” also includes a case that a plurality of rigid portions is connected to each other to have overall flexibility. For example, the third section **10c** may be, but is not limited to, a multi joint structure that includes joints **1c**. The third section **10c** may not be used depending on occasions (or implementations), and, as such, the third section **10c** between the first section **10a** and the second section **10b** may be an empty space, such as a patterned portion of support structure **10**.

[0046] The flexible display panel **20** is disposed on the support structure **10**. The flexible display panel **20** includes a first section **20a**, a second section **20b**, and a third section **20c**. The first section **20a**, the second section **20b**, and the third section **20c** of the flexible display panel **20** are disposed on the first section **10a**, the second section **10b**, and the third section **10c** of the support structure **10**, respectively.

[0047] The flexible display panel **20** may be a flexible organic light emitting display panel, but exemplary embodiments are not limited thereto. The flexible display panel **20** includes an active area AA through which an image is displayed and a peripheral area PA outside (e.g., surrounding) the active area AA.

[0048] The flexible touch sensing panel **30** is disposed on the flexible display panel **20**. The flexible touch sensing panel **30** includes a first section **30a**, a second section **30b**, and a third section **30c**. The first section **30a**, the second section **30b**, and the third section **30c** of the flexible touch sensing panel **30** are disposed on the first section **20a**, the second section **20b**, and the third section **20c** of the flexible display panel **20**, respectively. In this manner, the flexible display panel **20** may be disposed between the flexible touch sensing panel **30** and the support structure **10**.

[0049] The third section **10c** of the support structure **10**, the third section **20c** of the flexible display panel **20**, and the third section **30c** of the flexible touch sensing panel **30** correspond to a folding region FR of the foldable display device **100**. The folding region FR is a flexible region having flexibility, e.g., configured to be intentionally bended, folded, rolled, twisted, and/or the like.

[0050] The first section **10a** and the second section **10b** of the support structure **10**, the first section **20a** and the second section **20b** of the flexible display panel **20**, and the first section **30a** and the second section **30b** of the flexible touch sensing panel **30** correspond to a non-folding region NFR of the foldable display device **100**. The non-folding region NFR is a non-flexible region that does not have the flexibility, e.g., not configured to be intentionally bended, folded, rolled, twisted, and/or the like.

[0051] FIG. 2 is a plan view showing the flexible display panel in an area A1 of the foldable display device shown in FIG. 1 according to an exemplary embodiment.

[0052] Referring to FIG. 2, the flexible display panel **20** includes a plurality of pixel circuit portions PCP. The pixel circuit portion PCP is an area occupied by a driving circuit. The flexible display panel **20** includes a plurality of emitting portions EP. The emitting portion EP emits a light. The lights from the emitting portions EP make an image displayed on the foldable display device **100**. The pixel circuit portions PCP may correspond to the emitting portions EP, respectively. In FIG. 2, the emitting portions EP completely overlap the pixel circuit portions PCP, however, according to some exemplary embodiments, the pixel circuit portions PCP and the emitting

portions EP may partially overlap each other or may not overlap each other.

[0053] In the case where the flexible display panel **20** is an organic light emitting display panel, the emitting portions EP are respective areas in which an anode, an intermediate layer disposed on the anode and including a light emitting layer, and a cathode disposed on the intermediate layer completely overlap each other without an insulating layer interposed therebetween. The emitting portions EP form an emitting area EA. An area except for the emitting area EA corresponds to a non-emitting area NEA of the active area AA.

[0054] FIG. **3** is a cross-sectional view showing an in-folding operation of the foldable display device shown in FIG. **1** according to an exemplary embodiment.

[0055] Referring to FIGS. **1** and **3**, the folding region FR of the foldable display device **100** may be inwardly folded at an in-folding radius R1 with respect to an in-folding axis IFA crossing an in-folding center C1. In this case, the first section **30a** and the second section **30b** of the flexible touch sensing panel **30** face each other, and the first section **10a** and the second section **10b** of the support structure **10** are disposed opposite to each other. In some exemplary embodiments, the third section **10c**, which includes the joints **1c**, of the support structure **10** may be omitted. The in-folding axis IFA corresponds to a rotational axis.

[0056] FIG. **4** is a cross-sectional view showing an out-folding operation of the foldable display device **100** shown in FIG. **1**.

[0057] Referring to FIGS. **1** and **4**, the folding region FR of the foldable display device **100** may be outwardly folded at an out-folding radius R2 with respect to an out-folding axis OFA crossing an out-folding center C2. In this case, the first section **10a** and the second section **10b** of the support structure **10** face each other, and the first section **30a** and the second section **30b** of the flexible touch sensing panel **30** are disposed opposite to each other. In this case, the out-folding axis OFA corresponds to a rotational axis.

[0058] FIG. **5** is a plan view showing the flexible touch sensing panel in an area B1 of FIG. **1** according to an exemplary embodiment.

[0059] Referring to FIG. **5**, touch sensing electrodes **32** include first touch sensing electrodes **32a** and second touch sensing electrodes **32b**.

[0060] The first touch sensing electrodes **32a** are arranged in a first standard direction SD1 to be electrically connected to each other. The first standard direction SD1 is (or is substantially) parallel to the in-folding axis IFA or the out-folding axis OFA. The first touch sensing electrodes **32a** include at least one light transmission hole h1. The light transmission hole h1 corresponds to the emitting portion EP of the flexible display panel **20** such that the first touch sensing electrodes **32a** do not interfere with a light emission from the emitting portion EP.

[0061] A first bridge **34a** connects two first touch sensing electrodes **32a** adjacent to each other.

[0062] The first bridge **34a** may include at least one light transmission hole h2. The light transmission hole h2 corresponds to the emitting portion EP of the flexible display panel **20** such that the first bridge **34a** does not interfere with the light emission from the emitting portion EP. However, the first bridge **34a** may not include a light transmission hole. In this case, the first bridge **34a** is disposed not to overlap the emitting area EA and to overlap only the non-emitting area NEA such that the first bridge **34a** does not interfere with the light emission from the emitting area EA. The first bridge **34a** has a relatively small width and a relatively small area. Thus, it is possible to minimize (or at least reduce) interference with the light emission from the emitting portion EP by the first bridge **34a** even if the emitting portion EP overlaps with the first bridge **34a** due to an error in arrangement.

[0063] The first bridge **34a** includes a first portion **341a** and a second portion **341b**.

[0064] The first portion **341a** extends in a first extension direction ED1 that forms a first angle  $\theta 1$  with the first standard direction SD1. In a case where the first angle  $\theta 1$  is about " $k \times 90^\circ$ " (where k is a non-zero positive or negative odd integer), the first portion **341a** is easily damaged when the folding region FR is folded, and in a case where the first angle  $\theta 1$  is about " $m \times 180^\circ$ " (where m is

an integer), a crease or a buckling may easily occur in the folding region FR when the folding region FR is folded several times. Accordingly, it is advantageous that the first angle  $\theta 1$  is not about " $k \times 90^\circ$ " and not about " $m \times 180^\circ$ ."

[0065] The second portion **341b** extends in a second extension direction ED2 that forms a second angle  $\theta 2$  with the first standard direction SD1. The second extension direction ED2 is not substantially in line with the first extension direction ED1 and is not substantially parallel to the first extension direction ED1. An angle between the first extension direction ED1 and the second extension direction ED2 may be about " $u \times 90^\circ$ " (where  $u$  is a non-zero positive or negative odd integer).

[0066] In a case where the second angle  $\theta 2$  is about " $n \times 90^\circ$ " (where  $n$  is a non-zero positive or negative odd integer), the second portion **341b** is easily damaged when the folding region FR is folded, and in a case where the second angle  $\theta 2$  is about " $p \times 180^\circ$ " (where  $p$  is an integer), a crease or a buckling may easily occur in the folding region FR when the folding region FR is folded several times. Accordingly, it is advantageous that the second angle  $\theta 2$  is not about " $n \times 90^\circ$ " and not about " $p \times 180^\circ$ ."

[0067] A second bridge **34b** may be further included in the flexible touch sensing panel **30**. The second bridge **34b** is substantially symmetrical with the first bridge **34a** with respect to a direction in which the first touch sensing electrodes **32a** are electrically connected to each other. The second bridge **34b** may have substantially the same structure as that of the first bridge **34a**. The second bridge **34b** may be formed through the same process as the first bridge **34a** when the first bridge **34a** is formed. As the flexible touch sensing panel **30** further employs the second bridge **34b**, the first touch sensing electrodes **32a** are more securely electrically connected to each other.

[0068] The second touch sensing electrodes **32b** are arranged in a second standard direction SD2 to be electrically connected to each other. Each of the second touch sensing electrodes **32b** has a smaller area than each of the first touch sensing electrodes **32a**. The second touch sensing electrodes **32b** include at least one light transmission hole **h3**, and the light transmission hole **h3** corresponds to the emitting portion EP of the emitting area EA of the flexible display panel **20** such that the second touch sensing electrodes **32b** do not interfere with the light emission from the emitting portion EP.

[0069] A third bridge **34c** connects two second touch sensing electrodes **32b** adjacent to each other. The third bridge **34c** may be formed in the same layer as the second touch sensing electrodes **32b** and integrally formed with the second touch sensing electrodes **32b** as one piece. Although not shown, in some exemplary embodiments, the number of the third bridges **34c** connected between two second touch sensing electrodes **32b** adjacent to each other may be at least two.

[0070] The third bridge **34c** may include at least one light transmission hole **h4**. The light transmission hole **h4** corresponds to the emitting portion EP of the flexible display panel **20** such that the third bridge **34c** does not interfere with the light emission from the emitting portion EP. Differently, the third bridge **34c** may not include a light transmission hole. In this case, the third bridge **34c** may be disposed not to overlap the emitting area EA and to overlap the non-emitting area NEA such that the third bridge **34c** does not interfere with the light emission from the emitting area EA. The third bridge **34c** has a relatively small width and a relatively small area. Thus, it is possible to minimize (or at least reduce) the interference with the light emission from the emitting portion EP by the third bridge **34c** even if the emitting area EA overlaps with the third bridge **34c** due to an error in arrangement.

[0071] It is advantageous that at least one selected from the group of the first touch sensing electrodes **32a**, the second touch sensing electrodes **32b**, the first bridge **34a**, the second bridge **34b**, and the third bridge **34c** includes a metal material with flexibility by taking into account a stress applied to the folding region FR when the folding region FR is folded. For example, at least one selected from the group of the first touch sensing electrodes **32a**, the second touch sensing electrodes **32b**, the first bridge **34a**, the second bridge **34b**, and the third bridge **34c** may have a



metal single-layered structure or a metal multi-layered structure.

[0072] FIG. 6 is an enlarged view showing an area CA1 of FIG. 5 according to an exemplary embodiment.

[0073] Referring to FIG. 6, the first portion 341a of the first bridge 34a includes at least one overlap area 1a. The overlap area 1a overlaps with a plane-occupied area occupied by the first touch sensing electrodes 32a, the second touch sensing electrodes 32b, and the third bridges 34c in a plan view. As seen in FIG. 6, the overlap area 1a is defined inside an outer line of the plane-occupied area. In this case, the overlap area 1a of the first portion 341a and a portion of at least one selected from the group of the first touch sensing electrodes 32a, the second touch sensing electrodes 32b, and the third bridge 34c, the portion vertically corresponding to the overlap area 1a of the first portion 341a, vertically form a double-layered structure.

[0074] The overlap area 1a of the first portion 341a may extend in the first extension direction ED1 that forms the first angle  $\theta 1$  with the first standard direction SD1. For example, a length L of the overlap area 1a, which is measured in the first extension direction ED1, may be substantially greater than an average width AW of the overlap area 1a, which is measured in a direction substantially perpendicular to the first extension direction ED1, such as in the second extension direction ED2. As seen in FIG. 6, the average width AW has a value obtained by dividing an area of the overlap area 1a by the length L. It is advantageous that the first angle  $\theta 1$  is set to have a value that is not about " $k \times 90^\circ$ " (where k is a non-zero positive or negative odd integer) and about " $m \times 180^\circ$ " (where m is an integer) to prevent the folding operation of the folding region FR from being interfered by the double-layered structure having a relatively small flexibility.

[0075] FIG. 7 is an enlarged view showing an area D1 of FIG. 5 according to an exemplary embodiment.

[0076] Referring to FIG. 7, the second portion 341b of the first bridge 34a includes at least one overlap area 2b. The overlap area 2b overlaps with a plane-occupied area occupied by the first touch sensing electrodes 32a, the second touch sensing electrodes 32b, and the third bridge 34c in a plan view. That is, the overlap area 2b is defined inside an outer line of the plane-occupied area. In this case, the overlap area 2b of the second portion 341b and a portion of at least one selected from the group of the first touch sensing electrodes 32a, the second touch sensing electrodes 32b, and the third bridge 34c, the portion vertically corresponding to the overlap area 2b of the second portion 341b, vertically form a double-layered structure.

[0077] The overlap area 2b of the second portion 341b may extend in the second extension direction ED2 that forms the second angle  $\theta 2$  with the first standard direction SD1. For example, a length L of the overlap area 2b, which is measured in the second extension direction ED2, may be substantially greater than an average width AW of the overlap area 2b, which is measured in a direction substantially perpendicular to the second extension direction ED2. The average width AW has a value obtained by dividing the area of the overlap area 2b by the length L. It is advantageous that the second angle  $\theta 2$  is set to have a value that is not about " $n \times 90^\circ$ " (where n is a non-zero positive or negative odd integer) and about " $p \times 180^\circ$ " (where p is an integer) to prevent the folding operation of the folding region FR from being interfered by the double-layered structure having a relatively small flexibility.

[0078] FIG. 8 is a cross-sectional view showing the flexible touch sensing panel taken along sectional line I-I' shown in FIG. 5 according to an exemplary embodiment.

[0079] Referring to FIG. 8, the first bridge 34a is disposed on a first flexible insulating layer 31. The first flexible insulating layer 31 may include an inorganic material or an organic material. According to an exemplary embodiment, a multi-layered encapsulation structure included in the flexible display panel 20 may be employed as the first flexible insulating layer 31.

[0080] A second flexible insulating layer 33 is disposed on the first flexible insulating layer 31 to cover the first bridge 34a. The second flexible insulating layer 33 includes a contact hole 33a defined therethrough to expose the first bridge 34a. The second flexible insulating layer 33 may

include an inorganic material or an organic material.

[0081] The first touch sensing electrodes **32a**, the second touch sensing electrodes **32b**, and the third bridge **34c** are disposed on the second flexible insulating layer **33**. The first touch sensing electrodes **32a** may include a contact CNT formed integrally therewith as one piece and electrically connected to the first bridge **34a** via the contact hole **33a**. As seen in FIG. **8**, the contact CNT has a shape extending substantially vertically downward.

[0082] A third flexible insulating layer **35** is disposed on the second flexible insulating layer **33** to cover the first touch sensing electrodes **32a**, the second touch sensing electrodes **32b**, and the third bridge **34c**. The third flexible insulating layer **35** may include an inorganic material or an organic material.

[0083] FIG. **9** is a cross-sectional view showing a flexible touch sensing panel taken along sectional line I-I' shown in FIG. **5** according to an exemplary embodiment.

[0084] The exemplary embodiment described with reference to FIG. **9** is substantially the same as the exemplary embodiment described in association with FIG. **8**, except that the first touch sensing electrodes **32a**, the second touch sensing electrodes **32b**, and the third bridge **34c** are disposed between the first flexible insulating layer **31** and the second flexible insulating layer **33**, the first bridge **34a** is disposed between the third flexible insulating layer **35** and the second flexible insulating layer **33**, and the contact CNT that extends downward is a portion of the first bridge **34a**, and, thus, the same descriptions will be omitted.

[0085] Referring to FIG. **5** again, the folding operation may occur in a relatively small folding region **FR1** shown in FIG. **5** instead of the relatively large folding region **FR** shown in FIG. **5**. The first bridge **34a** including the first portion **341a** and the second portion **341b** is not disposed in the folding region **FR1**, and the first bridge **34a** is disposed in the non-folding region **NFR** except the folding region **FR1**. Therefore, when the folding region **FR1** is folded, the first bridge **34a** may be prevented from being damaged, and the crease and the buckling that would otherwise be formed in the folding region **FR1** may be improved. Employing the relatively small folding region **FR1** is generally advantageous for the in-folding with a relatively small folding radius and also may be advantageous for the out-folding when the folding radius is sufficiently small.

[0086] FIG. **10** is a plan view showing a flexible touch sensing panel in an area **B1** of FIG. **1** according to an exemplary embodiment.

[0087] Referring to FIG. **10**, the exemplary embodiment is substantially the same as the exemplary embodiment described in association with FIG. **5**, except that the first standard direction **SD1** in which the first touch sensing electrodes **32a** are arranged to be electrically connected to each other is substantially perpendicular to the in-folding axis **IFA** or the out-folding axis **OFA**, and, thus, the same descriptions will be omitted.

[0088] FIG. **11** is a plan view showing a flexible touch sensing panel in an area **B1** of FIG. **1** according to an exemplary embodiment.

[0089] Referring to FIG. **11**, a plurality of touch sensing electrodes **36** spaced apart from each other and a plurality of signal transmission lines **37** are disposed. The signal transmission line **37** transmits a signal information sensed by the touch sensing electrode **36** to the peripheral area **PA**. The signal transmission line **37** may overlap the pixel circuit portion **PCP** (refer to FIG. **2**) and may have a relatively constant width. The signal transmission line **37** includes a first portion **37a** and a second portion **37b**.

[0090] It is advantageous that at least one selected from the group of the touch sensing electrode **36** and the signal transmission line **37** includes a metal material with flexibility by taking into account a stress applied to the folding region **FR** when the folding region **FR** is folded. For example, at least one selected from the group of the touch sensing electrode **36** and the signal transmission line **37** may have a metal single-layered structure or a metal multi-layered structure.

[0091] The touch sensing electrode **36** may include at least one light transmission hole **h5**. The light transmission hole **h5** corresponds to the emitting portion **EP** of the flexible display panel **20**

such that the touch sensing electrode **36** does not interfere with the light emission from the emitting portion EP.

[0092] The first portion **37a** extends in a third extension direction ED3 that forms a first angle  $\theta 1$  with the in-folding axis IFA or the out-folding axis OFA. In a case where the first angle  $\theta 1$  is about " $q \times 90^\circ$ " (where  $q$  is a non-zero positive or negative odd integer), the first portion **37a** is easily damaged when the folding region FR is folded, and in a case where the first angle  $\theta 1$  is about " $r \times 180^\circ$ " (where  $r$  is an integer), the crease or the buckling may easily occur in the folding region FR when the folding region FR is folded several times. Accordingly, it is advantageous that the first angle  $\theta 1$  is not about " $q \times 90^\circ$ " and is not about " $r \times 180^\circ$ ."

[0093] The second portion **37b** extends in a fourth extension direction ED4 that forms a second angle  $\theta 2$  with the in-folding axis IFA or the out-folding axis OFA. The fourth extension direction ED4 is not substantially in line with the third extension direction ED3 and is not substantially parallel to the third extension direction ED3. The angle between the third extension direction ED3 and the fourth extension direction ED4 may be about " $v \times 90^\circ$ " (where  $v$  is a non-zero positive or negative odd integer).

[0094] In a case where the second angle  $\theta 2$  is about " $s \times 90^\circ$ " (where  $s$  is a non-zero positive or negative odd integer), the second portion **37b** is easily damaged when the folding region FR is folded, and in a case where the second angle  $\theta 2$  is about " $t \times 180^\circ$ " (where  $t$  is an integer), the crease or the buckling may easily occur in the folding region FR when the folding region FR is folded several times. Accordingly, it is advantageous that the second angle  $\theta 2$  is not about " $s \times 90^\circ$ " and not about " $t \times 180^\circ$ ."

[0095] FIG. 12 is an enlarged view showing an area E1 of FIG. 11 according to an exemplary embodiment.

[0096] Referring to FIG. 12, the touch sensing electrode **36** may be formed in the same layer as the signal transmission line **37** and the touch sensing electrode **36** and the signal transmission line **37** may be integrally formed as one piece.

[0097] FIG. 13 is an enlarged view showing an area E1 of FIG. 11 according to an exemplary embodiment.

[0098] Referring to FIG. 13, the touch sensing electrode **36** and the signal transmission line **37** may be disposed on substantially different layers from each other. The touch sensing electrode **36** and the signal transmission line **37** may be electrically connected to each other by a contact CNT1 filled in a contact hole **42a**.

[0099] FIG. 14 is a cross-sectional view showing the flexible touch sensing panel taken along sectional line II-IF of FIG. 13 according to an exemplary embodiment.

[0100] Referring to FIG. 14, the signal transmission line **37** is disposed on a first flexible insulating layer **41**. The first flexible insulating layer **41** may include an inorganic material or an organic material. According to an exemplary embodiment, a multi-layered encapsulation structure included in the flexible display panel **20** may be employed as the first flexible insulating layer **41**.

[0101] A second flexible insulating layer **42** is disposed on the first flexible insulating layer **41** to cover the signal transmission line **37**. The second flexible insulating layer **42** includes the contact hole **42a** defined therethrough to expose the signal transmission line **37**. The second flexible insulating layer **42** may include an inorganic material or an organic material.

[0102] The touch sensing electrodes **36** are disposed on the second flexible insulating layer **42**. The touch sensing electrodes **36** may include the contact CNT1 formed integrally therewith as one piece and electrically connected to the signal transmission line **37** via the contact hole **42a**. In the present exemplary embodiment, the contact CNT1 has a shape extending downward.

[0103] A third flexible insulating layer **43** is disposed on the second flexible insulating layer **42** to cover the touch sensing electrodes **36**. The third flexible insulating layer **43** may include an inorganic material or an organic material.

[0104] FIG. 15 is a cross-sectional view showing the flexible touch sensing panel taken along

sectional line II-IF of FIG. 13 according to an exemplary embodiment.

[0105] The exemplary embodiment described with reference to FIG. 15 is substantially the same as the exemplary embodiment described in association with FIG. 14, except that the touch sensing electrodes 36 are disposed between the second flexible insulating layer 42 and the first flexible insulating layer 41, the signal transmission line 37 is disposed between the third flexible insulating layer 43 and the second flexible insulating layer 42, and the contact CNT1 that extends downward is a portion of the signal transmission line 37, and, thus, the same descriptions will be omitted.

[0106] FIG. 16 is an enlarged view showing an area F1 of FIG. 11 according to an exemplary embodiment.

[0107] Referring to FIG. 16, the signal transmission line 37, e.g., the second portion 37b of the signal transmission line 37, may include at least one light transmission hole h6. The light transmission hole h6 corresponds to the emitting portion EP of the flexible display panel 20 such that the signal transmission line 37 does not interfere with the light emission from the emitting area EA.

[0108] FIG. 17 is an enlarged view showing an area G1 of FIG. 11 according to an exemplary embodiment.

[0109] Referring to FIG. 17, the signal transmission line 37 may not include the light transmission hole h6. The signal transmission line 37 may overlap the non-emitting area NEA and may not overlap the emitting portion EP. Accordingly, the signal transmission line 37 may not interfere with the light emission from the emitting portion EP.

[0110] FIG. 18 is an enlarged view showing an area G1 of FIG. 11 according to an exemplary embodiment.

[0111] Referring to FIG. 18, the number of the signal transmission lines 37 that do not include the light transmission hole h6 may be plural. A width and an area of the signal transmission lines 37 that do not include the light transmission hole h6 are relatively small. As such, it is advantageous that the number of the signal transmission lines 37 that do not include the light transmission hole h6 is plural to prevent a signal transmission failure, which may occur when the number of the signal transmission lines 37 that do not include the light transmission hole h6 is one, during breakage or disconnection of the signal transmission line 37 that does not include the light transmission hole h6.

[0112] According to various exemplary embodiments, a foldable display device folded in a direction substantially perpendicular to a rotational axis is described as a representative example of a non-rigid device. However, the inventive concepts are not to be limited thereto or thereby. That is, the inventive concepts may be applied to a non-rigid or otherwise manipulable device, such as a rollable display device that is rolled in the direction substantially perpendicular to the rotational axis, a slidable display device that is slid in the direction substantially perpendicular to the rotational axis, and/or the like. In addition, exemplary embodiments may be applied to rigid devices or hybrid devices including at least one rigid area and at least one non-rigid area.

[0113] Although certain exemplary embodiments and implementations have been described herein, other embodiments and modifications will be apparent from this description. Accordingly, the inventive concepts are not limited to such embodiments, but rather to the broader scope of the accompanying claims and various obvious modifications and equivalent arrangements as would be apparent to one of ordinary skill in the art.

## Claims

1. A non-rigid device with a flexible region that is foldable, slidable, or rollable in a second standard direction perpendicular to a rotational axis extending in a first standard direction, the non-rigid device comprising: a flexible touch sensing panel comprising: first touch sensing electrodes arranged in the first standard direction; a first bridge on a layer different from a layer on which the

first touch sensing electrodes are located, the first bridge connecting two first touch sensing electrodes adjacent to each other in the first standard direction from among the first touch sensing electrodes; a second bridge in a same layer as the first bridge and connecting the two first touch sensing electrodes adjacent to each other in the first standard direction; second touch sensing electrodes in a same layer as the first touch sensing electrodes, and arranged in the second standard direction; and a third bridge in a same layer as the first touch sensing electrodes, connecting the second touch sensing electrodes and integrally formed with the second touch sensing electrodes as one piece, and overlapping with the first bridge and the second bridge, wherein each of the first bridge and the second bridge has a shape inclined with respect to the first standard direction, and wherein the first bridge and the second bridge do not overlap the second touch sensing electrodes.

**2.** The non-rigid device of claim 1, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein each of the first bridge and the second bridge comprises at least one light transmission hole, and the at least one light transmission hole overlaps with at least one of the emitting portions.

**3.** The non-rigid device of claim 1, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein each of the first bridge and the second bridge does not comprise a light transmission hole, and the first bridge overlaps with the non-emitting area and does not overlap the emitting portions.

**4.** The non-rigid device of claim 1, wherein: the first bridge comprises a first portion extending a first extension direction inclined with respect to the first standard direction the first portion comprises an overlap area overlapping at least one selected from the group of the first touch sensing electrodes, the second touch sensing electrodes, and the third bridge; and a length of the overlap area, which is measured in the first extension direction, is greater than an average width of the overlap area, which is measured in a direction perpendicular to the first extension direction.

**5.** The non-rigid device of claim 4, wherein: the first bridge further comprises a second portion extending in a second extension direction inclined with respect to the first standard direction, and the second extension direction is not in line with the first extension direction and is not parallel to the first extension direction.

**6.** The non-rigid device of claim 5, wherein: the second portion comprises an overlap area overlapping at least one selected from the group of the first touch sensing electrode, the second touch sensing electrode, and the third bridge, and a length of the overlap area, which is measured in the second extension direction is greater than an average width of the overlap area, which is measured in a direction perpendicular to the second extension direction.

**7.** The non-rigid device of claim 1, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein the second touch sensing electrodes comprises at least one light transmission hole, and the at least one light transmission hole overlaps with at least one of the emitting portions.

**8.** The non-rigid device of claim 1, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein the third bridge comprises at least one light transmission hole, and the at least one light transmission hole overlaps with at least one of the emitting portions.

**9.** The non-rigid device of claim 1, wherein the first bridge, the second bridge, and the third bridge are in a non-flexible region and not in the flexible region.

**10.** The non-rigid device of claim 1, further comprising: a non-flexible region adjacent to the flexible region, wherein the first bridge and the second bridge are in the non-flexible region and not in the flexible region.

**11.** A non-rigid device with a flexible region that is foldable, slidable, or rollable in a second standard direction perpendicular to a rotational axis extending in a first standard direction, the non-rigid device comprising: a flexible touch sensing panel comprising: first touch sensing electrodes arranged in the first standard direction; a first bridge on a layer different from a layer on which the first touch sensing electrodes are located, the first bridge connecting two first touch sensing electrodes adjacent to each other in the first standard direction from among the first touch sensing electrodes; a second bridge in a same layer as the first bridge, symmetrical with the first bridge with respect to the first standard direction, and connecting the two first touch sensing electrodes adjacent to each other in the first standard direction; second touch sensing electrodes in a same layer as the first touch sensing electrodes, and arranged in the second standard direction; and a third bridge in a same layer as the first touch sensing electrodes, connecting the second touch sensing electrodes and integrally formed with the second touch sensing electrodes as one piece, and overlapping with the first bridge and the second bridge, wherein the first bridge comprises a first portion extending a first extension direction inclined with respect to the first standard direction and a second portion extending a second extension direction inclined with respect to the first standard direction, and wherein the first bridge and the second bridge do not overlap the second touch sensing electrodes.

**12.** The non-rigid device of claim 11, wherein: the second extension direction is not in line with the first extension direction and is not parallel to the first extension direction.

**13.** The non-rigid device of claim 11, wherein: the first portion is symmetrical with the second portion with respect to the second standard direction.

**14.** The non-rigid device of claim 11, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein each of the first bridge and the second bridge comprises at least one light transmission hole, and the at least one light transmission hole overlaps with at least one of the emitting portions.

**15.** The non-rigid device of claim 11, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein each of the first bridge and the second bridge does not comprise a light transmission hole, and the first bridge overlaps with the non-emitting area and does not overlap the emitting portions.

**16.** The non-rigid device of claim 11, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein the second touch sensing electrodes comprises at least one light transmission hole, and the at least one light transmission hole overlaps with at least one of the emitting portions.

**17.** The non-rigid device of claim 11, further comprising: a flexible display panel under the flexible touch sensing panel, wherein the flexible display panel comprises: emitting portions spaced apart from each other; and a non-emitting area between the emitting portions, and wherein the third bridge comprises at least one light transmission hole, and the at least one light transmission hole overlaps with at least one of the emitting portions.

**18.** The non-rigid device of claim 11, wherein the first bridge, the second bridge, and the third bridge are in a non-flexible region and not in the flexible region.

**19.** The non-rigid device of claim 11, further comprising: a non-flexible region adjacent to the flexible region, wherein the first bridge and the second bridge are in the non-flexible region and not in the flexible region.

**20.** A foldable device that is foldable in a second standard direction perpendicular to a rotational axis extending in a first standard direction, the foldable device comprising: a display panel; and a touch sensing panel disposed on the display panel, the touch sensing panel comprising: first touch sensing electrodes arranged in the first standard direction; a first bridge on a layer different from a

layer on which the first touch sensing electrodes are located, the first bridge connecting two first touch sensing electrodes adjacent to each other in the first standard direction from among the first touch sensing electrodes; a second bridge in a same layer as the first bridge and connecting the two first touch sensing electrodes adjacent to each other in the first standard direction; second touch sensing electrodes in a same layer as the first touch sensing electrodes, and arranged in the second standard direction; and a third bridge in a same layer as the first touch sensing electrodes, connecting the second touch sensing electrodes and integrally formed with the second touch sensing electrodes as one piece, and overlapping with the first bridge and the second bridge, wherein each of the first bridge and the second bridge has a shape inclined with respect to the first standard direction, and wherein the first bridge and the second bridge do not overlap the second touch sensing electrodes.

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