Mode for the Invention

[44] Certain exemplary embodiments will now be described in greater detail with reference to the accompanying drawings.

[45] In the following description, same drawing reference numerals are used for the same elements even in different drawings. The matters defined in the description, such as detailed construction and elements, are provided to assist in a comprehensive understanding of the present inventive concept. Accordingly, it is apparent that the exemplary embodiments may be carried out without those specifically defined matters. Also, well-known functions or constructions are not described in detail because they would obscure the invention with unnecessary detail.

[46] FIG. 1 is a view provided to explain a constitution of a flexible device according to an exemplary embodiment. Referring to FIG. 1, the flexible device 1000 includes a body 100 and a plurality of piezoelectric substances 110-1 ~ 110-n.

[47] Respective components of the flexible device 1000 are mounted to the body, which is flexible and may be deformed.

[48] The body may be made from plastic material (e.g., polymer film) that can deform in response to an external pressure. To be specific, the body 100 may be configured as a base film coated on both surfaces with barrier coating. The base film may be formed from various resin such as, for example, polyimide (PI), polycarbonate (PC), polyethyleneterephtalate (PET), polyethersulfone (PES), polythylenenaphthalaten (PEN), or fiber reinforced plastic (FRP). The barrier coating may be applied on both surfaces of the base film, respectively. Organic or inorganic film may be used as the barrier coating to maintain flexibility. Additionally, the body 100 may be formed from various other materials exhibiting flexibility, such as, for example, a metal foil, etc.

[49] The plurality of piezoelectric materials 110-1 ~ 110-n may be mounted to surface or interior of the body 100. To be specific, the plurality of piezoelectric materials 110-1 ~ 110-n may be arranged at different positions of the body 100. FIG. 1 illustrates an example in which the plurality of piezoelectric materials 110-1 ~ 110-n are formed at predetermined intervals on one surface of the body 100 in horizontal and vertical rows, thus forming a matrix pattern. Although the piezoelectric materials 110-1 ~ 110-n in the exemplary embodiment illustrated in FIG. 1 are depicted at uniform intervals from each other, the number, locations, and pattern of arrangement of the piezoelectric materials 110-1 ~ 110-n are not restricted to any specific example, and may be variously modifiable depending on application.

[50] The plurality of piezoelectric materials 110-1 ~ 110-n may be disposed in which two different piezoelectric layers are arranged. For convenience of explanation, the piezoelectric layer on the upper portion is referred to as the 'upper piezoelectric layer', while

[63] FIG. 4 shows a cross-section of bimorph type piezoelectric material. Referring to FIG. 4, the bimorph type piezoelectric material 110 includes an upper piezoelectric layer 111 and a lower piezoelectric layer 113. The upper and lower piezoelectric layers 111, 113 are extended upon application of a first polarity drive signal, while these constrict upon application of a second polarity drive signal. The first polarity may be positive (+), and the second polarity may be negative (-). The piezoelectric material 110 bends to the direction of the second piezoelectric layer 113, when the first piezoelectric layer 111 is extended and the second piezoelectric layer 113 is constricted. On the contrary, the piezoelectric material 110 bends to the direction of the first piezoelectric layer 111 when the first piezoelectric layer 111 is constricted and the second piezoelectric layer 113 is extended.

[64] FIG. 5 illustrates another example of constitution of a bimorph type piezoelectric material. Referring to FIG. 5, an intermediate layer 114 may be provided between the upper and lower piezoelectric layers 111, 113 within the piezoelectric material 110.

[65] The intermediate layer 1124 may be formed from a flexible elastic material. The intermediate layer 1124 may have a shape of a rectangular parallelepiped with thin thickness. The upper piezoelectric layer 111 is stacked on the upper surface of the intermediate layer 1124, and the lower piezoelectric layer 113 is stacked on the lower surface of the intermediate layer 1124. As explained above, the upper and lower piezoelectric layers 111, 113 may be formed from various piezoelectric materials. Referring to FIG. 5, the upper and lower piezoelectric layers 111, 113 may be configured to partially cover the intermediate layer 114. That is, the intermediate layer 113 may be formed to have a longer length. The lengths of the respective piezoelectric layers 111, 113 and the intermediate layer 114 may be determined based on the data measured through experiments.

[66] For example, the frequency and displacement according to the length of the intermediate layer 114 may be measured as follows by the experiment.

[67] Table 1

[Table 1]

Int. Layer(mm)	**80**	**90**	**100**	**110**	**120**
Piezo. Layer (mm)	**30**	**30**	**30**	**30**	**30**
Frequency (Hz)	**40.621**	**32.389**	**24.845**	**20.045**	**19.875**
Displacement (mm)	**8.64**	**12.92**	**13.78**	**6.44**	**6.545**

[68]

[69] Table 1 lists displacements measured by varying the length of the intermediate layer 114 to 80, 90, 100, 110, 120 mm under the condition that each end of the piezoelectric layers 111, 113 and intermediate layer 114 is aligned to each other, and the lengths of the piezoelectric layers 111, 113 are fixed at 30 mm. According to Table 1, the maximum displacement is measured when the length of the intermediate layer 114 is 100 mm, which is shorter than the maximum length (i.e., 120 mm). The 'displacement' refers to a width δ of the other end of the intermediate layer 114 deformed in upward and downward direction.

[70] The displacement may be expressed by the following mathematical formula.

[71] <Mathematical Formula 1>

[72] $\delta = k \cdot d_{31} \cdot V \cdot l^2 \cdot /t^2$

[73]

[74] where, δ denotes displacement, k is integer, d31 is piezoelectric constant, V is applied voltage, l is length of piezoelectric layer, and t is thickness. According to Mathematical Formula 1, the displacement δ increases in proportion to applied voltage, i.e., to drive signal.

[75] Although FIG. 5 illustrates that the intermediate layer 114 to be longer than the piezoelectric layers 111, 113, in another exemplary embodiment, the lengths of the intermediate layer 114 and the piezoelectric layers 111, 113 may be equal. Further, the direction of the piezoelectric material 110 bending may be determined according to a voltage difference between the first drive signal applied to the upper piezoelectric layer 111 and the second drive signal applied to the lower piezoelectric layer 114.

[76] A method for adjusting a direction of deformation of the piezoelectric material 110 inclusive of the upper piezoelectric layer 111, the intermediate layer 114, and the lower piezoelectric layer 113 in equal length will be explained below with reference to FIGS. 6 and 7.

[77] Referring first to FIG. 6, the first drive signal V1 is applied to the upper piezoelectric layer 111, and the second drive signal V2 is applied to the lower piezoelectric layer 113. The upper piezoelectric layer 111 extends and the lower piezoelectric layer 113 contracts when the first drive signal V1 is positive (+), and the second drive signal V2 is negative (-). As a result, the piezoelectric material 110 bends in the first direction. The piezoelectric material 110 may bend in the first direction even when V1 and V2 have same polarity, if V1 is larger than V2.

[78] FIG. 7 illustrates a situation where V1 and V2 are applied in opposite direction to that illustrated in FIG. 6. According to FIG. 7, the piezoelectric material 110 bends to the second direction which is opposite to the first direction.

[79] When the piezoelectric material 110 bends as illustrated in FIGS. 6 and 7, the body 1400 of the flexible device 1000 to which the piezoelectric material 110 is attached also

110-n will not be additionally explained, but referenced to the above corresponding description.

[98] The display 120 is formed from flexible material and performs various display operations under control of the controller 130.

[99] The driver 150 is configured to apply a drive signal to a plurality of piezoelectric materials 110-1 ~ 110-n. The driver 150 may generate drive signals of different sizes and polarities, using the power provided from a battery (not illustrated). The drive signal may be generated in the form of pulse signal.

[100] The storage 140 stores an operating system (O/S) that controls the operation of the flexible device 1000 applications, and other data. The controller 130 is driven by the O/S stored at the storage 140 to execute various applications.

[101] The bus 160 is configured to transmit and receive data, or control signal among the respective components of the flexible device 1000. The bus 160 may include an address bus, a data bus, or a control bus. The address bus is used to transmit and receive address-related information, such as memory address, and the data bus is a bus system which connects the controller 130, the storage 140, and the other input/output for data exchange. The control bus is a bus system used by the controller 130, the storage 140, or the other components to transmit or receive various control signal. The control signal may include a memory sync signal, input/output sync signal, driving control signal, CPU status signal, interrupt request and permission signal, or clock signal.

[102] The controller 130 controls the overall operation of the flexible device 1000 according to user manipulation. To be specific, upon receiving a turn-on command, the controller 130 may execute initialization program to boot up the flexible device 1000 and displays a background screen through the display 120. The background screen may include icons for various functions, applications, or folders. When a user selects one among the icons, the controller 130 performs a corresponding operation according to the selected icon.

[103] When a preset event occurs, the controller 130 may control the driver 150 to apply a drive signal to at least one among the plurality of piezoelectric materials 110-1 ~ 110-n. To be specific, the controller 130 may provide the driver 150 with address signal to designate piezoelectric material to be driven among the respective piezoelectric materials 110-1 ~ 110-n via the address bus, and also provides the driver 150 with direction signal to designate the order of driving via the control bus.

[104] The driver 150 sequentially applies drive signal to the piezoelectric material as designated by the address signal, in accordance with the direction signal. The driver 150 may determine a point of driving the respective piezoelectric materials based on the clock signals.

170, the flexible device 1000 may be rolled when the entire or more than certain number of biosensors 170 sense the OB's touch.

[129] When the flexible device 1000 is rolled, the controller 130 may display various types of UI screens, such as watch UI, content playback screen, playback progress indicator screen, or exercise counter screen, on at least one area of the display 120.

[130] Meanwhile, although the exemplary embodiments explained above include the piezoelectric materials 110-1 ~ 110-n in the same size and shape, and particularly, arranged in the same direction, the direction of arranging the piezoelectric materials may vary depending on embodiments.

[131] FIG. 23 illustrates a piezoelectric material arrangement pattern of the flexible device according to another exemplary embodiment. Referring to FIG. 23, the body 100 includes a plurality of first piezoelectric materials 110-H11, 110-H12, 110-H13, 110-H14, 110-H21, 110-H22, 110-H23, 110-H24, 110-H31, 110-H32, 110-H33, and 110-H34 arranged in column-wise direction (H1, H2, H3), and a plurality of second piezoelectric materials 110-V11, 110-V12, 110-V21, 110-V22, 110-V31, 110-V32 arranged in row-wise directions (V1, V2, V3). The longer axis of the first piezoelectric material is orthogonal to the longer axis of the second piezoelectric material. Accordingly, the operation is not hindered by the second piezoelectric material when the first piezoelectric material is driven and the deformation in horizontal direction occurs, or vice versa.

[132] The plurality of first and second piezoelectric materials may be arranged on the same layer. Referring to FIG. 23, the rows (V1, V2, V3) on which the second piezoelectric materials are arranged may be arranged between the first piezoelectric materials to allow proper connection between the piezoelectric materials and the electrode patterns.

[133] When the different types of piezoelectric materials with different directions of longer axes are provided together, the flexible device 1000 is able to deform not only horizontally, but also vertically.

[134] Although FIG. 23 illustrates an example in which the first and second piezoelectric materials are arranged on the same layer, the piezoelectric materials may be arranged on different layers from each other.

[135] FIG. 24 is a cross-section of a flexible device including a plurality of piezoelectric materials distributed to different layers. Referring to FIG. 24, a plurality of layers 126-1, 126-2 are sequentially stacked on one surface of the display 120. The plurality of piezoelectric materials are distributed over the plurality of layers 126-1, 126-2.

[136] FIG. 24 is a cross section cut along a column-wise direction of the flexible device 1000. Referring to FIG. 24, the first piezoelectric materials 110-H11, 110-H12, 110-H13, 110-H14 aligned in column-wise direction are successively arranged on the upper layer 126-1, while the second piezoelectric materials 110-V11, 110-V21,

CLAIMS:

1. A flexible device comprising:
a flexible body;
~~a lower piezoelectric layer of~~ a first plurality of piezoelectric materials disposed on the flexible body;
~~an intermediate layer disposed on the lower piezoelectric layer;~~
~~an upper piezoelectric layer of~~ a second plurality of piezoelectric materials disposed the flexible body in a direction orthogonal to the first plurality of piezoelectric materials~~on the intermediate layer~~; and
~~a flexible display panel supported by the flexible body.~~
a controller configured to apply a drive signal selectively to the first plurality of piezoelectric materials or the second plurality of piezoelectric materials in response to detecting an event, causing one of the first plurality of piezoelectric materials and second plurality of piezoelectric materials to deform.

~~2. The flexible device of claim 1, further comprising a controller configured to apply a drive signal to at least one of the first plurality of piezoelectric materials of the lower layer and the second plurality of piezoelectric materials of the upper layer, the drive signal causing the at least one of the first plurality of piezoelectric materials and second plurality of piezoelectric materials to deform, in response to detecting an event.~~

3~~2~~. The flexible device of claim 2~~1~~, wherein the drive signal comprises a first drive signal and a second drive signal,
~~wherein the at least one of the first plurality of piezoelectric materials and the second plurality of piezoelectric materials comprises the first plurality of piezoelectric materials and the second plurality of piezoelectric materials,~~
wherein the first plurality of piezoelectric materials deform in a first direction, in response to application of the first drive signal to the first plurality of piezoelectric materials of the lower piezoelectric layer and the second plurality of piezoelectric materials deform in a second direction, in response to application of the second drive signal to the second plurality of piezoelectric materials of the upper piezoelectric layer, and
wherein the first plurality of piezoelectric materials and the second plurality of piezoelectric materials ~~maintain a balanced state~~creates a compressive effect that reinforces the flexible body, in response to application of the first drive signal or the second drive signal to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials.

4~~3~~. The flexible device of claim 2~~1~~, wherein the controller divides the first plurality of piezoelectric materials and the second plurality of piezoelectric materials into a plurality of groups based on locations at which the first plurality of piezoelectric materials and the second plurality of piezoelectric materials are disposed, and applies different ones of the first drive signal and the second drive signal to the respective groups to cause the grouped first plurality of piezoelectric materials and the second plurality of piezoelectric materials to locally deform.

5~~4~~. The flexible device of claim 2~~1~~, further comprising a multi-layered display supported by the flexible body,
wherein the first plurality of piezoelectric materials and the second plurality of piezoelectric materials are disposed ~~on a lower portion~~ in a layer of the display adjacent the flexible body,
wherein the controller selectively applies the first drive signal and the second drive signal to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials based on a type of the event, and
wherein the controller controls the display to display a user interface (UI) corresponding to a deformation state of the flexible body corresponding to the deformation of the first plurality of piezoelectric materials and the second plurality of piezoelectric materials on the display.

6~~5~~. The flexible device of claim 2~~1~~, further comprising
a multi-layered display supported by the flexible body; and
~~at least one biosensor configured to detect a touch of a user arranged on lower side of the display,~~
wherein the first plurality of piezoelectric materials and the second plurality of piezoelectric materials are disposed between the display and at least one biosensor configured to detect a touch of a user~~the at least one biosensor~~, and

the controller selectively applies the first drive signal and the second drive signal to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials and controls the display to display a user interface on the display, in response to the at least one biosensor detecting the touch of the user.

~~7~~6. The flexible device of claim 1, wherein the first plurality of piezoelectric materials are disposed in a column-wise direction and the second plurality of piezoelectric materials are disposed in a row-wise direction.

~~8~~7. The flexible device of claim 1 wherein the lower piezoelectric layer, the intermediate layer, and the upper piezoelectric layer are stacked sequentially on one side of the flexible body.

~~9~~8. The flexible device of claim ~~1~~2, wherein the magnitude of the drive signal corresponds to a degree of deformation of the at least one of the first plurality of piezoelectric materials and the second plurality of piezoelectric materials.

~~10~~9. The flexible device of claim 1, further comprising a detector configured to detect an electric signal generated from one or more piezoelectric materials of the first plurality of piezoelectric materials and the second plurality of piezoelectric materials in response to a deformation of the flexible body,

wherein the controller determines a deformation state of the flexible body based on a change in the electric signal and performs a control operation corresponding to the determined deformation state.

~~11~~10. A method for operating a flexible device, comprising:

detecting, by a controller of the flexible device, occurrence of an event; and

selectively applying drive signals to a first plurality of piezoelectric materials ~~of a lower piezoelectric layer~~ disposed on a flexible body of the flexible device and a second plurality of piezoelectric materials ~~of an upper piezoelectric layer~~ disposed the flexible body in a direction orthogonal to the first plurality of piezoelectric materials~~on the first plurality of piezoelectric materials~~, based on the event,

wherein the drive signals cause deformation of the first plurality of piezoelectric materials and the second plurality of piezoelectric materials.

~~12~~11. The method of claim ~~11~~10, wherein the selectively applying drive signals comprises:

determining drive signals to apply to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials based on the type of the event; and

applying the determined drive signals to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials,

wherein the first plurality of piezoelectric materials deform in a first direction in response to application of a first drive signal to the first plurality of piezoelectric materials of the lower piezoelectric layer and the second plurality of piezoelectric materials deform in a second direction, in response to application of the second drive signal to the second plurality of piezoelectric materials of the upper piezoelectric layer, and

wherein the first plurality of piezoelectric materials and the second plurality of piezoelectric materials creates a compressive effect that reinforces the flexible body~~maintain a balanced state~~, in response to application of the first drive signal or the second drive signal to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials.

~~13~~12. The method of claim ~~11~~10, wherein the selectively applying comprises:

dividing the first plurality of piezoelectric materials and the second plurality of piezoelectric materials into a plurality of groups based on locations at which the first plurality of piezoelectric materials and the second plurality of piezoelectric materials are disposed; and

applying different ones of the drive signals to the respective groups to cause the grouped first plurality of piezoelectric materials and the second plurality of piezoelectric materials to locally deform.

~~14~~13. The method of any of claims ~~11~~10, further comprising displaying a user interface (UI) corresponding to a deformation state of the flexible device corresponding to deformation of the first plurality of piezoelectric materials and the second plurality of piezoelectric materials on a display of the flexible device.

~~15~~14. The method of claim ~~11~~10, further comprising

detecting a touch of a user through a biosensor provided on the flexible device;

selectively applying the drive signals to the first plurality of piezoelectric materials and the second plurality of piezoelectric materials and displaying a user interface on a display of the flexible device, in response to the detecting.