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(54) PRESSURE SENSOR, PRESSURE SENSOR SYSTEM, MICROPHONE, BLOOD PRESSURE SENSOR AND TOUCH PANEL

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(57) **ABSTRACT**

According to one embodiment, a pressure sensor includes a film portion, a sensor unit, and a structure body. The film portion has a front surface and is deformable. The sensor unit includes a plurality of sensing elements arranged along the front surface. One of the plurality of sensing elements includes a magnetic layer, a opposing magnetic layer, and a nonmagnetic intermediate layer. The structure body is arranged with the first sensor unit along the arrangement direction of the plurality of sensing elements. The structure body includes a structure body layer, a opposing structure body layer, and a intermediate structure body layer. The structure body layer has at least one of a floating potential with respect to the opposing structure body layer or same potential as a potential of the opposing structure body layer.

FIG. 1A

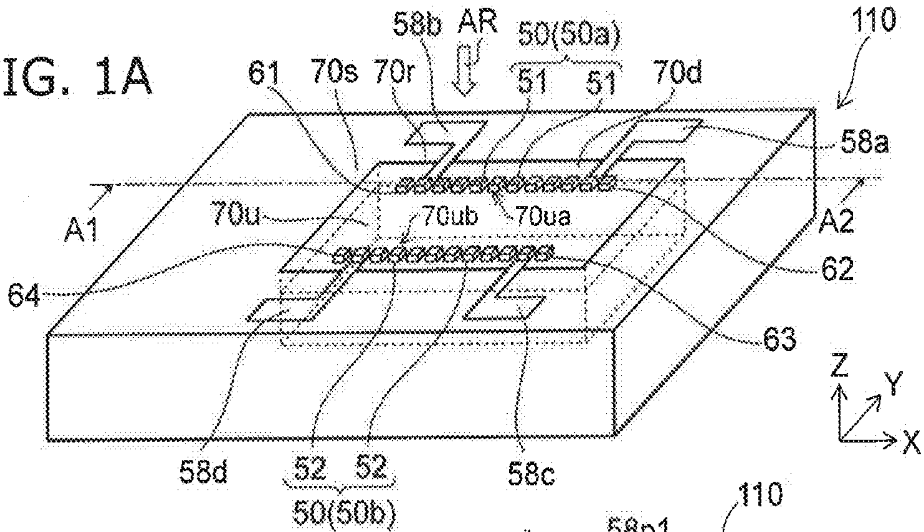


FIG. 1B

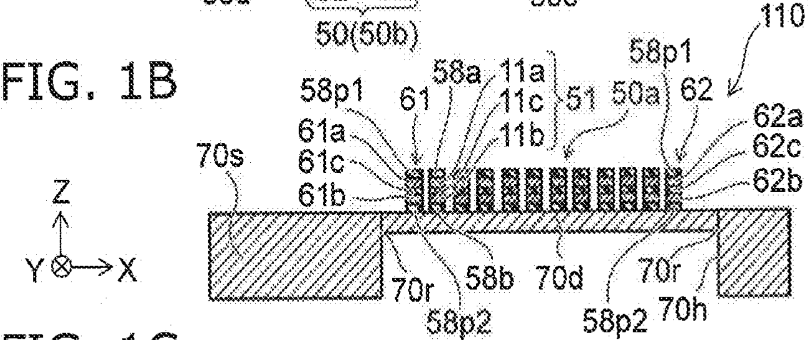


FIG. 1C

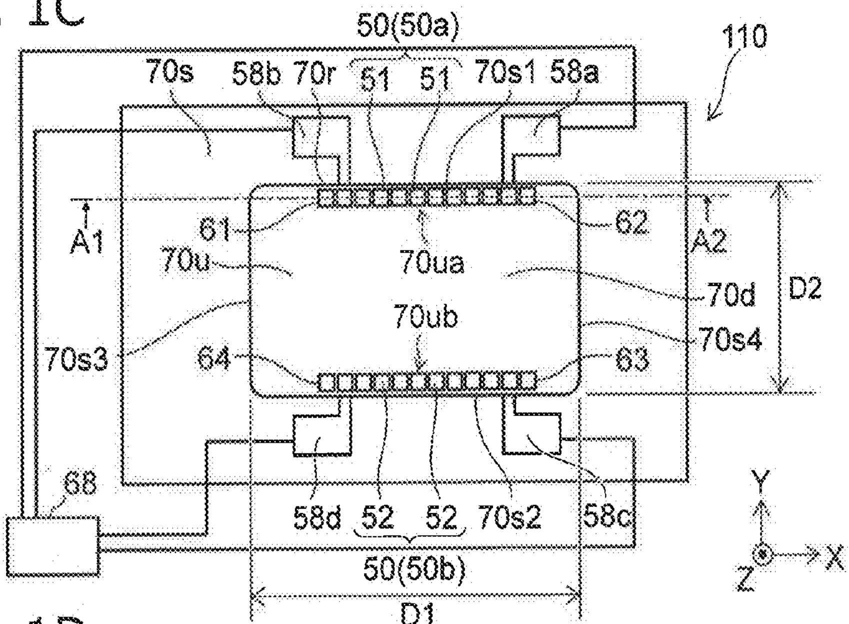
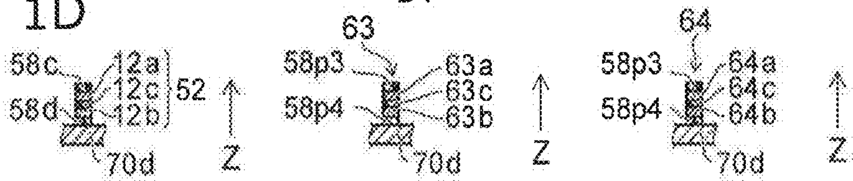


FIG. 1D



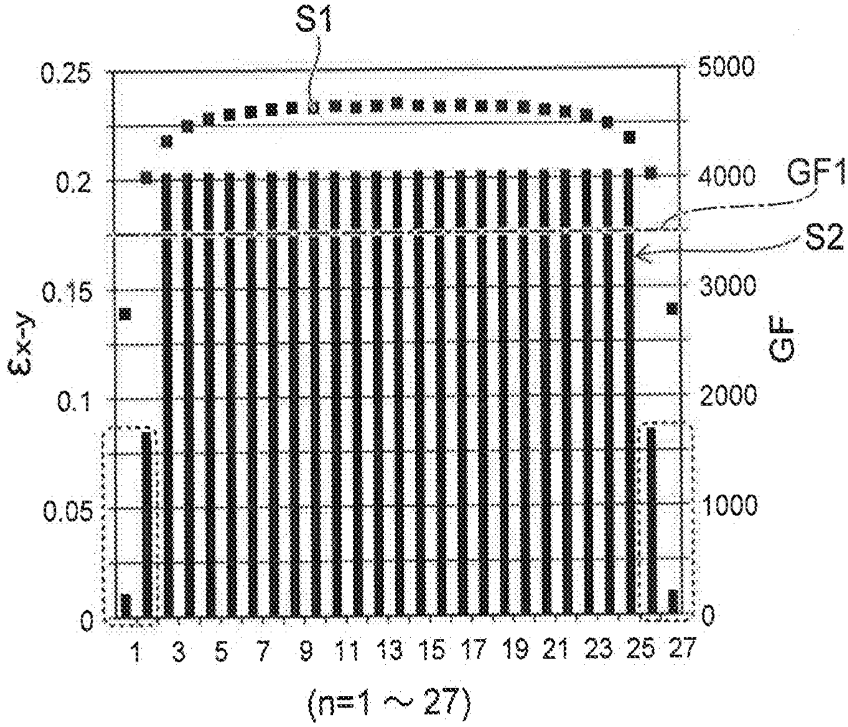

S1
0.25
0.2
0.15
0.1
0.05
0
εx-y
5000
4000
3000
2000
1000
0
GF
GF1
S2
1 3 5 7 9 11 13 15 17 19 21 23 25 27
(n=1 ~ 27)

FIG. 2A

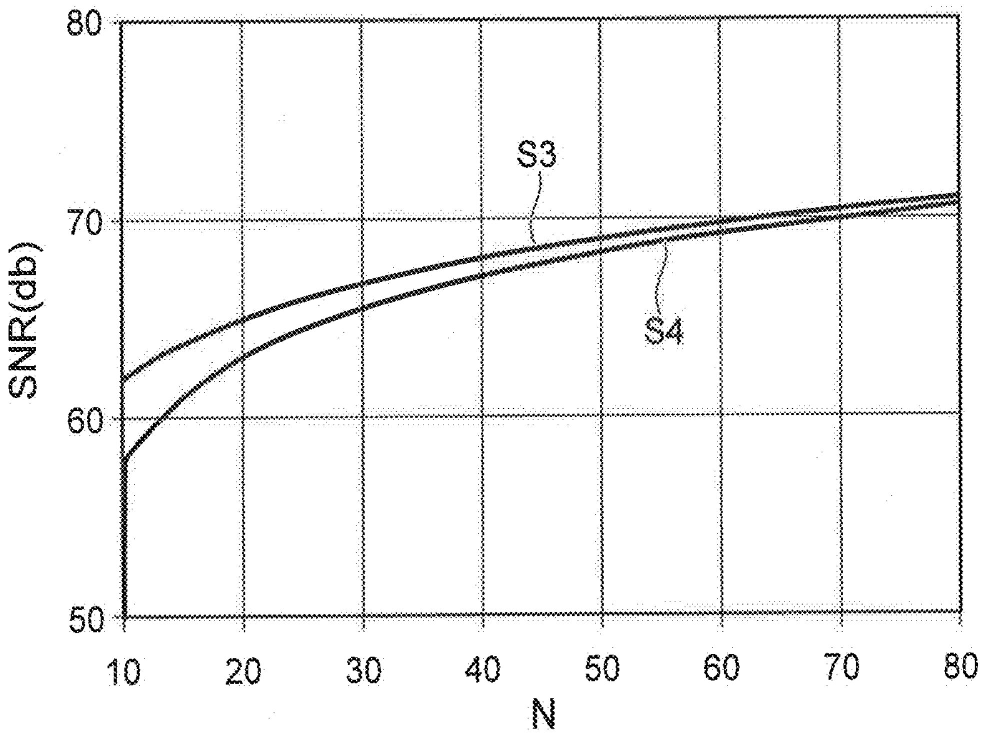
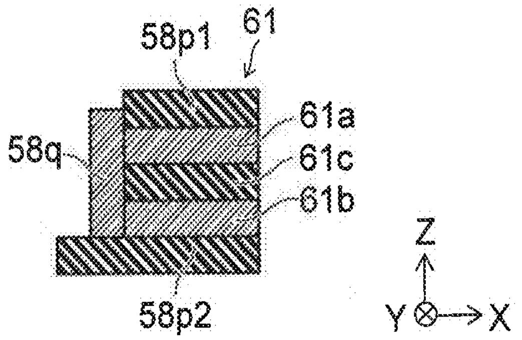

80
70
60
50
SNR(db)
S3
S4
10 20 30 40 50 60 70 80
N

FIG. 2B

FIG. 3



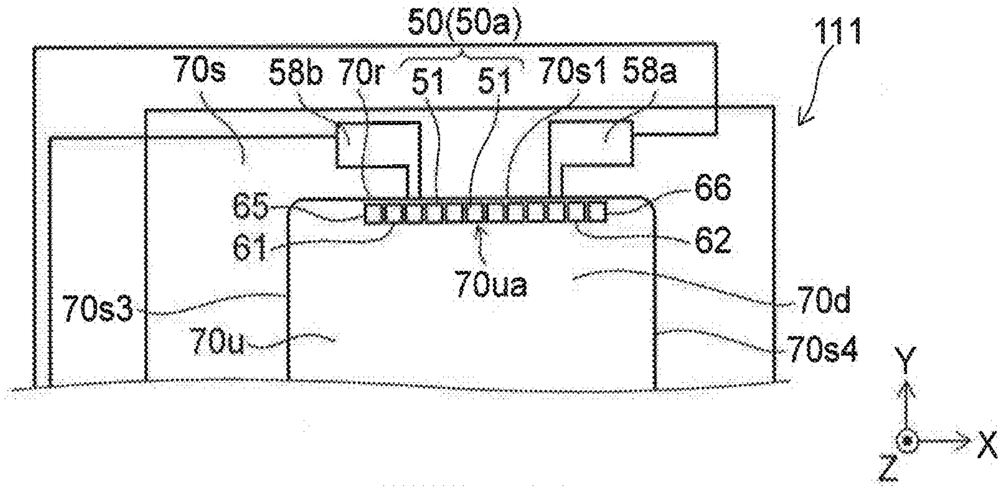


FIG. 4A

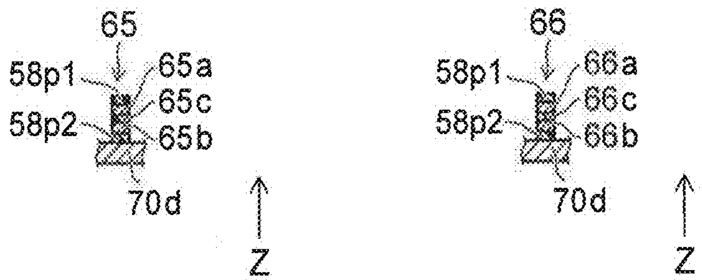


FIG. 4B

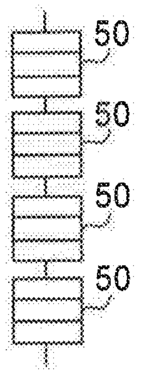


FIG. 5A

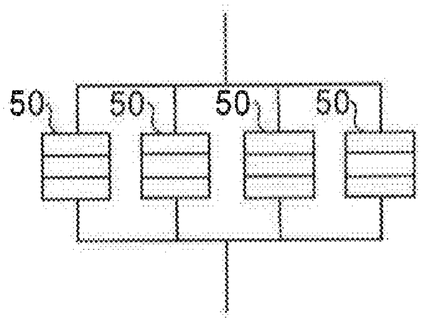


FIG. 5B

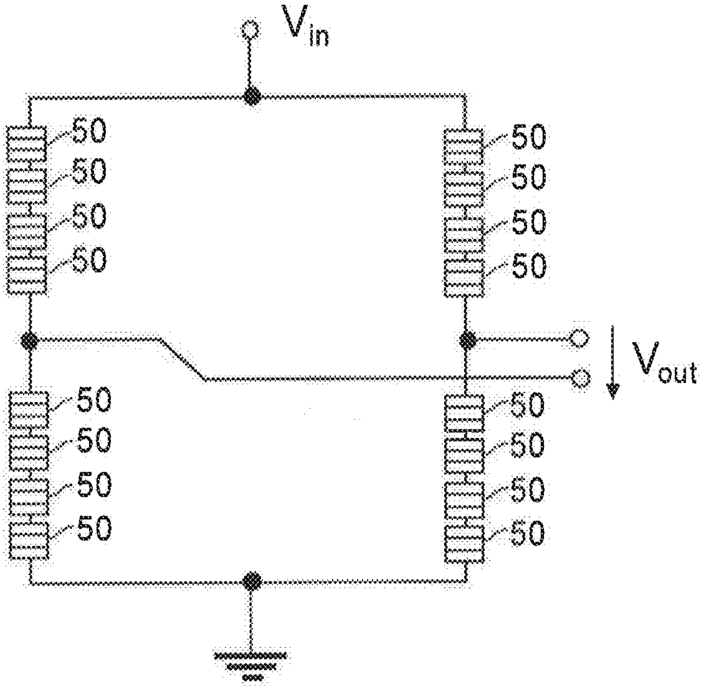


FIG. 5C

FIG. 6A

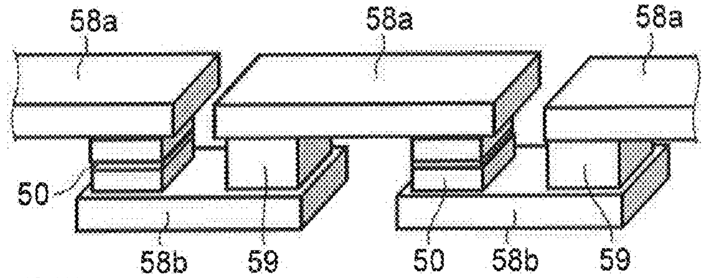


FIG. 6B

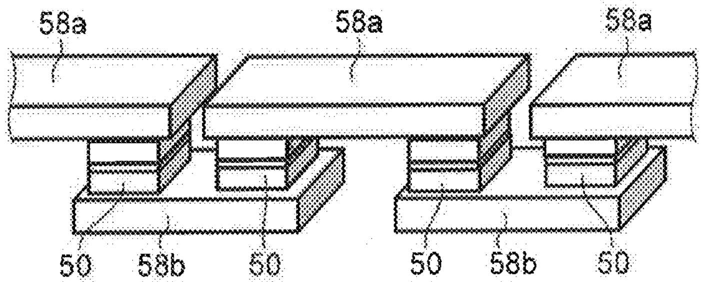


FIG. 6C

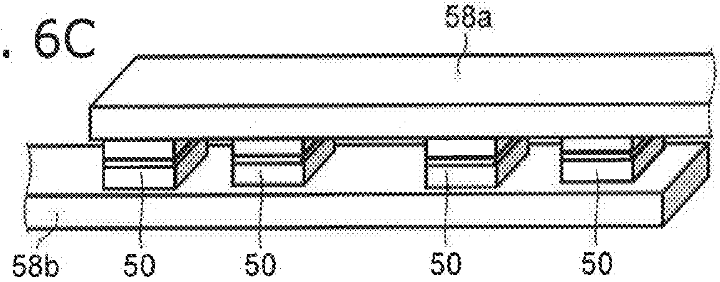


FIG. 7

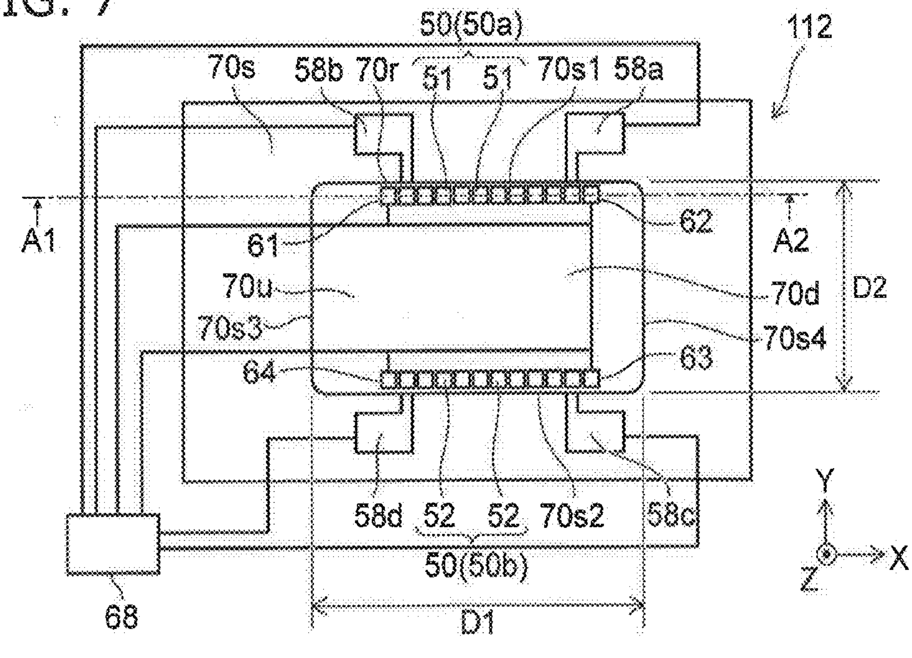


FIG. 8A

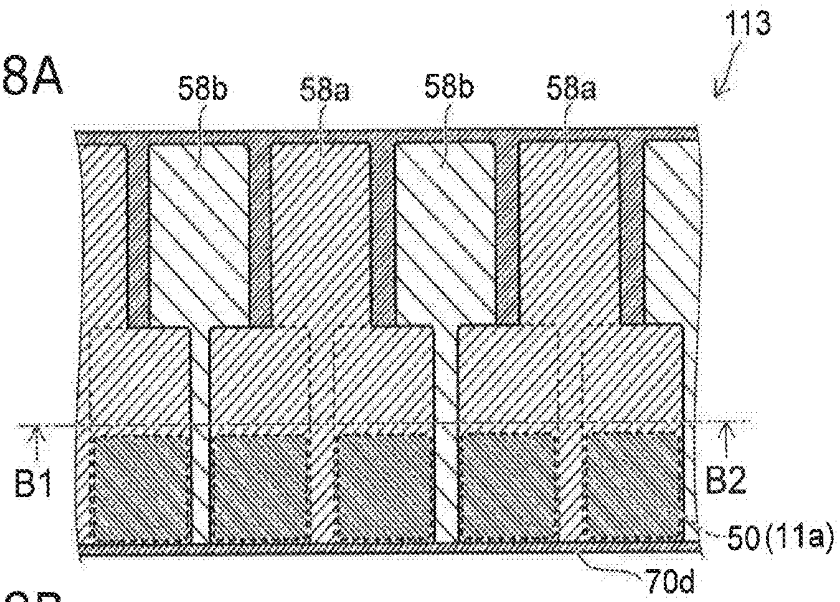


FIG. 8B

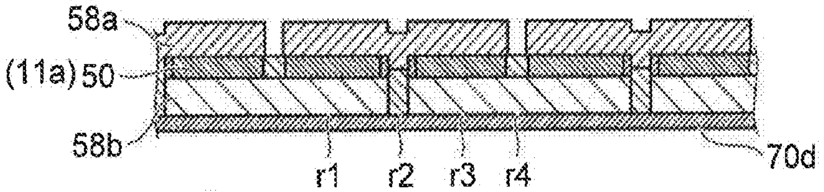


FIG. 9A

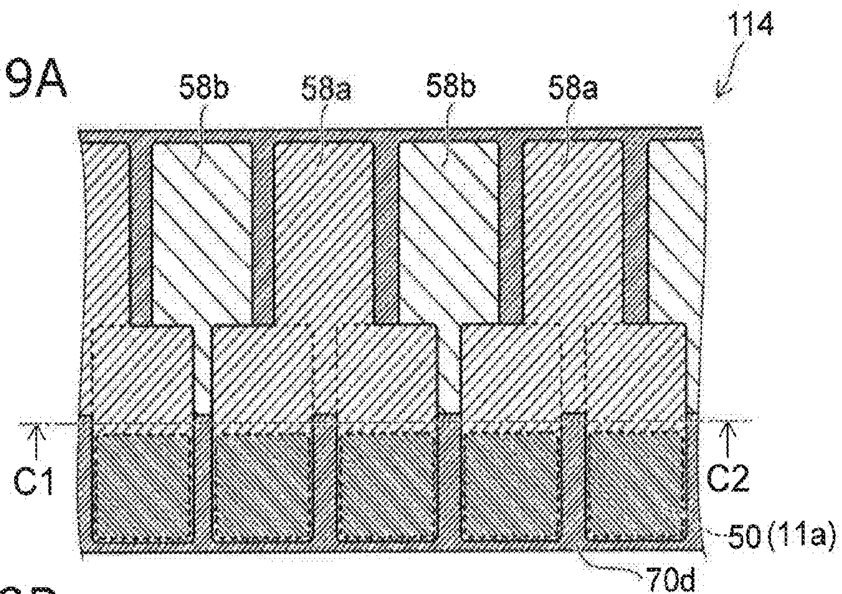
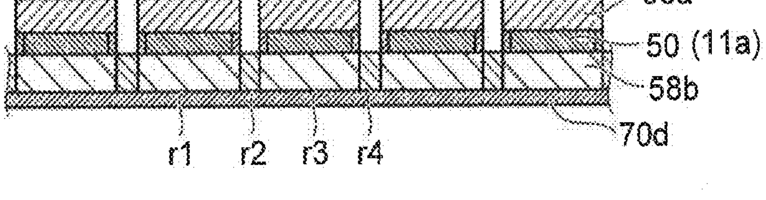


FIG.9B



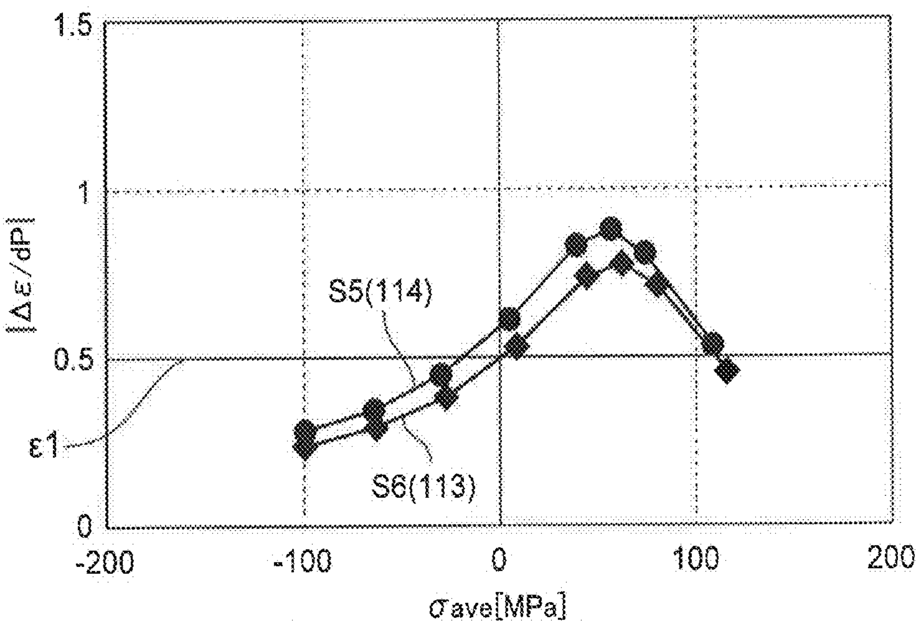


FIG. 10

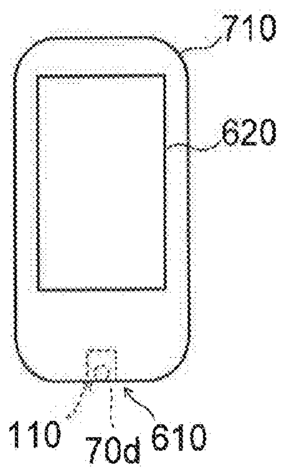


FIG. 11

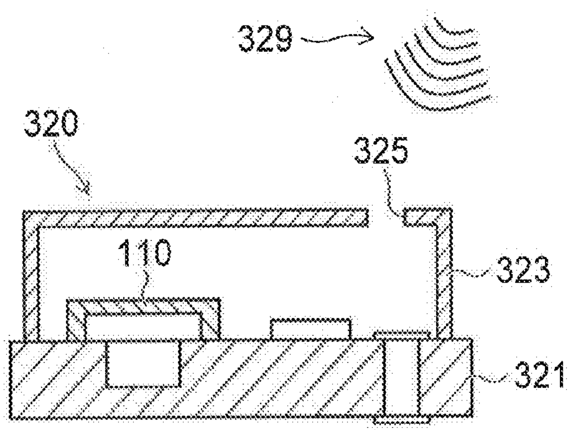


FIG. 12

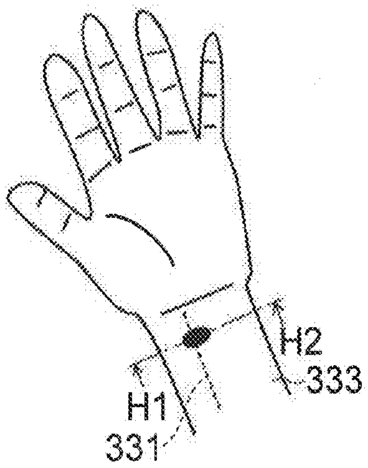


FIG. 13A

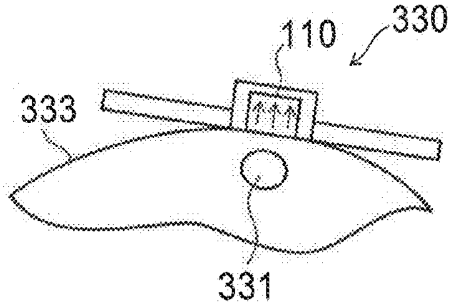


FIG. 13B

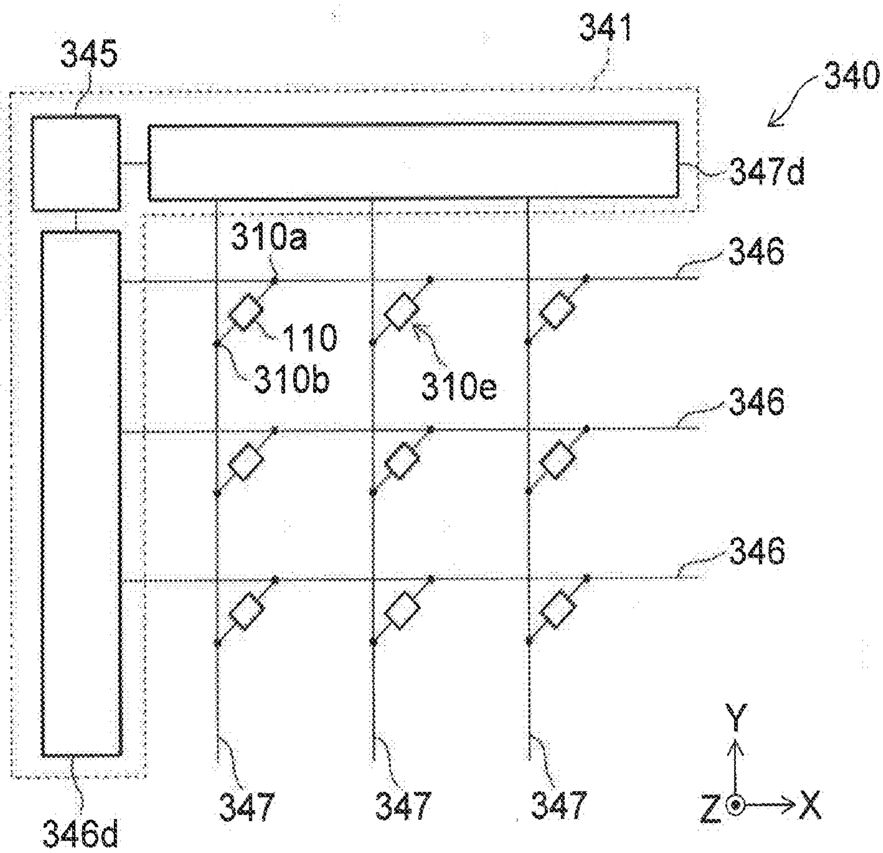


FIG. 14

PRESSURE SENSOR, PRESSURE SENSOR SYSTEM, MICROPHONE, BLOOD PRESSURE SENSOR AND TOUCH PANEL

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2016-029093, filed on Feb. 18, 2016; the entire contents of which are incorporated herein by reference.

FIELD

[0002] Embodiments of the invention relate generally to a pressure sensor, a pressure sensor system, a microphone, a blood pressure sensor, and a touch panel.

BACKGROUND

[0003] A pressure sensor that uses a magnetic layer has been proposed. For example, the pressure sensor is applied to a microphone, a blood pressure sensor, a touch panel, etc. It is desirable to increase the sensitivity of the pressure sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1**A to FIG. **1**D are schematic views illustrating a pressure sensor according to a first embodiment;

[0005] FIG. **2**A and FIG. **2**B are graphs illustrating characteristics of the pressure sensor;

[0006] FIG. **3** is a schematic cross-sectional view illustrating one portion of the pressure sensor according to the first embodiment;

[0007] FIG. **4**A and FIG. **4**B are schematic views illustrating one portion of a pressure sensor according to a second embodiment;

[0008] FIG. **5**A to FIG. **5**C are schematic views illustrating the pressure sensor according to the embodiment;

[0009] FIG. **6**A to FIG. **6**C are schematic perspective views illustrating the pressure sensor according to the embodiment;

[0010] FIG. **7** is a schematic cross-sectional view illustrating a pressure sensor system according to a third embodiment;

[0011] FIG. **8**A and FIG. **8**B are schematic views illustrating electrode portions of the pressure sensor according to the embodiment;

[0012] FIG. **9**A and FIG. **9**B are schematic views illustrating the electrode portions of the pressure sensor according to the embodiment;

[0013] FIG. **10** is a graph illustrating characteristics of the pressure sensors;

[0014] FIG. **11** is a schematic view illustrating a microphone according to a fourth embodiment;

[0015] FIG. **12** is a schematic cross-sectional view illustrating another microphone according to the fourth embodiment;

[0016] FIG. **13**A and FIG. **13**B are schematic views illustrating a blood pressure sensor according to a fifth embodiment; and

[0017] FIG. **14** is a schematic view illustrating a touch panel according to a sixth embodiment.

DETAILED DESCRIPTION

[0018] According to one embodiment, a pressure sensor includes a film portion, a first sensor unit, and a first structure body. The film portion has a front surface. The film portion is deformable. The first sensor unit is separated from a first portion of an outer edge of the front surface and fixed to one portion of the front surface. The first sensor unit includes a plurality of first sensing elements arranged along the front surface. One of the plurality of first sensing elements includes a first magnetic layer, a first opposing magnetic layer, and a first nonmagnetic intermediate layer provided between the first magnetic layer and the first opposing magnetic layer. The first structure body is arranged with the first sensor unit along the arrangement direction of the plurality of first sensing elements. The first structure body includes a first structure body layer, a first opposing structure body layer, and a first intermediate structure body layer provided between the first structure body layer and the first opposing structure body layer. The first structure body layer has at least one of a floating potential with respect to the first opposing structure body layer or same potential as a potential of the first opposing structure body layer.

[0019] According to one embodiment, a pressure sensor includes a film portion, a first sensor unit, and a first structure body. The film portion has a front surface. The film portion is deformable. The first sensor unit is separated from a first portion of an outer edge of the front surface and fixed to one portion of the front surface. The first sensor unit includes a plurality of first sensing elements arranged along the front surface. One of the plurality of first sensing elements includes a first magnetic layer, a first opposing magnetic layer, and a first nonmagnetic intermediate layer provided between the first magnetic layer and the first opposing magnetic layer. The first structure body is arranged with the first sensor unit along the arrangement direction of the plurality of first sensing elements. The first structure body includes a first structure body layer, a first opposing structure body layer, and a first intermediate structure body layer provided between the first structure body layer and the first opposing structure body layer. The first structure body layer has at least one of a floating potential with respect to the first opposing structure body layer or same potential as a potential of the first opposing structure body layer. The first sensor unit includes: a first electrode electrically connected to the first magnetic layer; and a second electrode electrically connected to the first opposing magnetic layer. The first magnetic layer is provided between the first electrode and the second electrode. The first opposing magnetic layer is provided between the first magnetic layer and the second electrode. the film portion including: a first region overlapping the first electrode, the first magnetic layer and the second electrode; a second region not overlapping the first electrode, the first magnetic layer and the second electrode; a third region overlapping the first electrode, the first magnetic layer and the second electrode; and a fourth region not overlapping the first electrode, the first magnetic layer and the second electrode. The second region is located between the first region and the third region. The third region is located between the second region and the fourth region.

[0020] According to one embodiment, a pressure sensor system includes a film portion, a first sensor unit, a first structure body and a controller. The film portion has a front surface. The film portion is deformable. The first sensor unit is separated from a first portion of an outer edge of the front surface and fixed to one portion of the front surface. The first sensor unit includes a plurality of first sensing elements arranged along the front surface. One of the plurality of first sensing elements includes a first magnetic layer, a first opposing magnetic layer, and a first nonmagnetic intermediate layer provided between the first magnetic layer and the first opposing magnetic layer. The first structure body is arranged with the first sensor unit along the arrangement direction of the plurality of first sensing elements. The first structure body includes a first structure body layer, a first opposing structure body layer, and a first intermediate structure body layer provided between the first structure body layer and the first opposing structure body layer. The controller is connected with the first sensor unit and the first structure body. The controller is configured to supply a current to the first sensor unit. The controller is configured to electrically connect the first structure body layer with the first opposing structure body layer, or to make an electrical potential of the first structure body layer floating with respect to an electrical potential of the first opposing structure body.

[0021] According to one embodiment, a microphone includes the pressure sensor described above.

[0022] According to one embodiment, a blood pressure sensor includes the pressure sensor described above.

[0023] According to one embodiment, a touch panel includes the pressure sensor described above.

[0024] Various embodiments will be described hereinafter with reference to the accompanying drawings.

[0025] The drawings are schematic and conceptual; and the relationships between the thickness and width of portions, the proportions of sizes among portions, etc., are not necessarily the same as the actual values thereof. Further, the dimensions and proportions may be illustrated differently among drawings, even for identical portions.

[0026] In the specification and drawings, components similar to those described or illustrated in a drawing thereinabove are marked with like reference numerals, and a detailed description is omitted as appropriate.

First Embodiment

[0027] FIG. **1**A to FIG. **1**D are schematic views illustrating a pressure sensor according to a first embodiment.

[0028] FIG. **1**A is a perspective view. FIG. **1**B is a line A1-A2 cross-sectional view of FIG. **1**A. FIG. **1**C is a plan view as viewed along arrow AR of FIG. **1**A. FIG. **1**D is a cross-sectional view illustrating one portion of the pressure sensor.

[0029] As shown in FIG. **1**A, the pressure sensor **110** according to the embodiment includes a film portion **70***d*, a first sensor unit **50***a*, a second sensor unit **50***b*, and first to fourth structure bodies **61** to **64**.

[0030] The film portion **70***d* is deformable. The film portion **70***d* has a front surface **70***u*. The first sensor unit **50***a* is fixed to one portion **70***ua* of the front surface **70***u*. The first sensor unit **50***a* is not provided on the entire surface of the front surface **70***u*. One portion **70***ua* of the front surface **70***u* is separated from a first portion of an outer edge **70***r* of the front surface **70***u*. The first portion is, for example, one of first to fourth sides **70***s***1** to **70***s***4** described below. The first sensor unit **50***a* includes multiple first sensing elements **51**. The second sensor unit **50***b* is fixed to another one portion **70***ub* of the front surface **70***u*. The second sensor unit **50***b* includes multiple second sensing elements **52**. Thus, the multiple sensing elements **50** are provided. The multiple first sensing elements **51** are one portion of the multiple sensing elements **50**. The multiple second sensing elements **52** are one portion of the multiple sensing elements **50**.

[0031] The direction from the film portion **70***d* toward the first sensing elements **51** is taken as a Z-axis direction. One direction perpendicular to the Z-axis direction is taken as an X-axis direction. A direction perpendicular to the Z-axis direction and the X-axis direction is taken as a Y-axis direction.

[0032] In the example, the multiple first sensing elements **51** are arranged along the X-axis direction. The multiple second sensing elements **52** are arranged along the X-axis direction. For example, the second sensing elements **52** are arranged in the Y-axis direction with the first sensing elements. For example, at least one portion of the multiple first sensing elements **51** is connected in series to each other. For example, at least one portion of the multiple second sensing elements **52** is connected in series to each other. In the embodiment, the number of the first sensing elements **51** is arbitrary. The number of the second sensing elements **52** is arbitrary.

[0033] The film portion **70***d* is held by a holder **70***s*. The holder **70***s* holds the outer edge **70***r*. For example, a substrate that is used to form the film portion **70***d* and the holder **70***s* is provided. The substrate is, for example, a silicon substrate. A hollow **70***h* is provided in the substrate by removing one portion of the substrate. The thin portion of the substrate is used to form the film portion **70***d*. The thick portion of the substrate is used to form the holder **70***s*.

[0034] As shown in FIG. **1**B, the first sensing element **51** includes a first magnetic layer **11***a*, a first opposing magnetic layer **11***b*, and a first nonmagnetic intermediate layer **11***c*. The first nonmagnetic intermediate layer **11***c* is provided between the first magnetic layer **11***a* and the first opposing magnetic layer **11***b*. The first opposing magnetic layer **11***b* is separated from the first magnetic layer **11***a* substantially along the Z-axis direction. In the example, the first opposing magnetic layer **11***b* is provided between the first magnetic layer **11***a* and the film portion **70***d*. In the embodiment, the first magnetic layer **11***a* may be disposed between the first opposing magnetic layer **11***b* and the film portion **70***d*.

[0035] As shown in FIG. **1**D, the second sensing element **52** includes a second magnetic layer **12***a*, a second opposing magnetic layer **12***b*, and a second nonmagnetic intermediate layer **12***c*. The second nonmagnetic intermediate layer **12***c* is provided between the second magnetic layer **12***a* and the second opposing magnetic layer **12***b*. The second opposing magnetic layer **12***b* is separated from the second magnetic layer **12***a* substantially along the Z-axis direction. In the example, the second opposing magnetic layer **12***b* is provided between the second magnetic layer **12***a* and the film portion **70***d*. In the embodiment, the second magnetic layer **12***a* may be disposed between the second opposing magnetic layer **12***b* and the film portion **70***d*.

[0036] A first structure body **61** is arranged with the first sensor unit **50***a* in the X-axis direction. The first structure body **61** is provided between a third side **70***s***3** (described below) and one end of the first sensor unit **50***a*. The first structure body **61** is not electrically connected to the first sensor unit **50***a*.

[0037] The first structure body **61** includes a first structure body layer **61***a*, a first opposing structure body layer **61***b*, and a first intermediate structure body layer **61***c*. The first intermediate structure body layer **61***c* is provided between the first structure body layer **61***a* and the first opposing structure body layer **61***b*. The first opposing structure body layer **61***b* is separated from the first structure body layer **61***a* substantially along the Z-axis direction. In the example, the first opposing structure body layer **61***b* is provided between the first structure body layer **61***a* and the film portion **70***d*. In the embodiment, the first structure body layer **61***a* may be disposed between the first opposing structure body layer **61***b* and the film portion **70***d*.

[0038] The first structure body layer **61***a* has at least one of a floating potential with respect to the first opposing structure body layer **61***b* or the same potential as the potential of the first opposing structure body layer **61***b*.

[0039] The first structure body layer **61***a* includes, for example, the same material as a material included in the first magnetic layer **11***a*. The first opposing structure body layer **61***b* includes, for example, the same material as a material included in the first opposing magnetic layer **11***b*. The first intermediate structure body layer **61***c* includes, for example, the same material as a material included in the first non-magnetic intermediate layer **11***c*. For example, although the structure of the first structure body **61** is substantially the same as the structure of the first sensing element **51**, the first structure body **61** does not function as the sensing element **50**.

[0040] For example, the first structure body layer **61***a* is formed from a magnetic film that is used to form the first magnetic layer **11***a*. For example, the first opposing structure body layer **61***b* is formed from a magnetic film that is used to form the first opposing magnetic layer **11***b*. For example, the first intermediate structure body layer **61***c* is formed from a nonmagnetic film that is used to form the first nonmagnetic intermediate layer **11***c*.

[0041] The sensitivity of the pressure sensor can be increased by increasing the number of the sensing elements **50** of the sensor unit. For example, in the case where the multiple sensing elements **50** are connected in series, the signal voltage is N times and the noise is $N^{1/2}$ times according to the number N of the sensing elements **50**. The SN ratio SNR is improved by increasing the number.

[0042] On the other hand, it was found that the amount of strain of the sensing element **50** positioned at the end of the sensor unit is small compared to the amount of strain of the sensing element **50** positioned at the center of the sensor unit. For example, it was found that the SN ratio SNR decreases when the sensing element **50** positioned at the end of the sensor unit is electrically connected to the other sensing elements **50** of the sensor unit.

[0043] FIG. **2**A and FIG. **2**B are graphs illustrating characteristics of the pressure sensor.

[0044] In FIG. **2**A, the horizontal axis shows the position of each of the sensing elements **50**. The vertical axis shows an anisotropic strain ϵ_{x-y} or a gauge factor GF. The gauge factor GF is the change amount (dR/R) of the electrical resistance per unit strain ($d\epsilon$). For example, the sensitivity is high when the gauge factor GF is high.

[0045] In the example, the multiple sensing elements **50** are arranged in series. The number of the multiple sensing elements **50** is 27. In the example, the anisotropic strain ϵ_{x-y} and the gauge factor GF are shown for the sensing element **50** at each of first to twenty-seventh positions. A characteristic S1 shows the anisotropic strain ϵ_{x-y}. The anisotropic strain ϵ_{x-y} is small for the sensing elements **50** at the two ends compared to the sensing elements **50** at the center. A characteristic S2 shows the gauge factor GF of each of the sensing elements **50**. The gauge factor GF is small for the sensing elements **50** at the two ends compared to the sensing elements **50** at the center. For example, the gauge factors GF of the sensing elements **50** at the first, second, twenty-sixth, and twenty-seventh positions are lower than a reference value GF**1**. The desired sensitivity (e.g., 70 dB) is obtained at and above the reference value GF**1**. The SN ratio SNR decreases when the sensing elements **50** at the two ends are connected to the sensing elements **50** at the center.

[0046] In the embodiment, for example, the first structure body **61** is disposed instead of the sensing element **50** of the first position. For example, the second structure body **62** is disposed instead of the sensing element **50** of the twenty-seventh position. The first structure body **61** and the second structure body **62** are not electrically connected to the sensing elements **50** of the second to twenty-sixth positions. In the embodiment, the decrease of the SN ratio SNR can be suppressed. Thereby, the sensitivity can be increased.

[0047] In FIG. **2**B, the horizontal axis shows the number N of the multiple sensing elements **50**. The vertical axis shows the SN ratio SNR (dB). A characteristic S3 shows the SN ratio SNR when the first structure body **61** is disposed at one end of the multiple sensing elements **50**, and the second structure body **62** is disposed at the other end. The first structure body **61** and the second structure body **62** are not included in the number N. A characteristic S4 shows the SN ratio SNR when only the multiple sensing elements **50** are disposed, and the first structure body **61** and the second structure body **62** are not disposed. In the example, the SN ratio SNR of the characteristic S3 is relatively higher than the SN ratio SNR of the characteristic S4 when the number N is not less than 10 and not more than 80. In other words, by disposing the first structure body **61** and the second structure body **62**, the decrease of the SN ratio SNR can be suppressed.

[0048] In the example as shown in FIG. **1**C, the film portion **70***d* has the outer edge **70***r*. The outer edge **70***r* is substantially a polygon (a quadrilateral, and specifically a rectangle). The outer edge **70***r* includes the first side **70***s***1**, the second side **70***s***2**, the third side **70***s***3**, and the fourth side **70***s***4**.

[0049] Various configurations are applicable to the film portion **70***d* (the outer edge **70***r*). The film portion **70***d* (the outer edge **70***r*) may have, for example, a substantially perfect circle configuration, may have a flattened circular configuration (including an elliptical configuration), may have a substantially square configuration, or may have a rectangular configuration. For example, in the case where the film portion **70***d* (the outer edge **70***r*) has a substantially square configuration or a substantially rectangular configuration, the portions at the four corners (the corner portions) may have curved configurations.

[0050] The first side **70***s***1** extends in a first direction (in the example, the X-axis direction). The second side **70***s***2** is separated from the first side **70***s***1** in a second direction. The second direction crosses the first direction. In the example, the second direction is the Y-axis direction. The second side **70***s***2** extends in the first direction (the X-axis direction). The third side **70***s***3** extends in the second direction (the Y-axis direction). The fourth side **70***s***4** extends in the second direction (the Y-axis direction) and is separated from the third side **70***s***3** in the first direction (the X-axis direction).

[0051] In the example, a distance D**1** along the first direction between the first side **70***s***1** and the second side **70***s***2** is longer than a distance D**2** along the second direction between the third side **70***s***3** and the fourth side **70***s***4**. The film portion **70***d* is substantially a rectangle; and the first side **70***s***1** and the second side **70***s***2** are the long sides. The third side **70***s***3** and the fourth side **70***s***4** are the short sides.

[0052] In the embodiment as illustrated in FIG. **1**C, a curved portion may be provided in the outer edge **70***r* between the sides. For example, the corner portions of the film portion **70***d* (the outer edge **70***r*) have curved configurations. Thereby, for example, the strength of the film portion **70***d* is increased.

[0053] A large strain (anisotropic strain) occurs at the vicinity of the outer edge **70***r* of the film portion **70***d* when stress is applied to the film portion **70***d*. By disposing the sensing elements **50** at the vicinity of the outer edge **70***r* of the film portion **70***d*, a large strain is applied to the sensing elements **50**; and a high sensitivity is obtained. In particular, in the case where one length of the film portion **70***d* is longer than the length in the other direction (i.e., in the case where the configuration is anisotropic), a particularly large strain occurs in the portion along the major axis inside the outer edge **70***r*. Therefore, by disposing the sensing elements **50** in the portion along the long side of the outer edge **70***r*, a particularly high sensitivity is obtained.

[0054] In the example, the multiple first sensing elements **51** are arranged along the first side **70***s***1**. The multiple second sensing elements **52** are arranged along the second side **70***s***2**. In the case where one length of the film portion **70***d* is longer than the other length of the film portion **70***d* (in the case where the configuration is anisotropic), the region where the anisotropic strain occurs at the end portion vicinity on the minor axis side of the film portion **70***d* is wide compared to the case where the film portion **70***d* has an isotropic configuration.

[0055] Anisotropic strain having a larger absolute value occurs in a wider region for the end portion on the minor axis side of the film portion **70***d* having the anisotropic configuration than for the end portion of the film portion **70***d* having the isotropic configuration. More sensing elements **50** can be disposed in the film portion **70***d* having the anisotropic configuration than in the film portion **70***d* having the isotropic configuration. The sensing elements **50** that are disposed are sensing elements **50** in which a similar change of the electrical resistance (e.g., having the same polarity) occurs according to the pressure. Thereby, a highly-sensitive pressure sensor can be provided.

[0056] By connecting the multiple sensing elements **50** in series, the SN ratio can be improved. In the embodiment, the multiple sensing elements **50** can be disposed in which electrical signals of the same polarity are obtained when the pressure is applied. Thereby, the SN ratio improves.

[0057] The second structure body **62** may be provided in the embodiment. The second structure body **62** is arranged with the first sensor unit **50***a* in the X-axis direction. The second structure body **62** is provided between the fourth side **70***s***4** and the other end of the first sensor unit **50***a*. The second structure body **62** is not electrically connected to the first sensor unit **50***a*. The second structure body **62** includes a second structure body layer **62***a*, a second opposing structure body layer **62***b*, and a second intermediate structure body layer **62***c*. The second intermediate structure body layer **62***c* is provided between the second structure body layer **62***a* and the second opposing structure body layer **62***b*. The second opposing structure body layer **62***b* is separated from the second structure body layer **62***a* substantially along the Z-axis direction. In the example, the second opposing structure body layer **62***b* is provided between the second structure body layer **62***a* and the film portion **70***d*. In the embodiment, the second structure body layer **62***a* may be disposed between the second opposing structure body layer **62***b* and the film portion **70***d*. The second structure body layer **62***a* has at least one of a floating potential with respect to the second opposing structure body layer **62***b* or the same potential as the potential of the second opposing structure body layer **62***b*.

[0058] The second structure body layer **62***a* includes, for example, the same material as a material included in the first magnetic layer **11***a*. The second opposing structure body layer **62***b* includes, for example, the same material as a material included in the first opposing magnetic layer **11***b*. The second intermediate structure body layer **62***c* includes, for example, the same material as a material included in the second nonmagnetic intermediate layer **12***c*. For example, although the structure of the second structure body **62** is substantially the same as the structure of the first sensing element **51**, the second structure body **62** does not function as the sensing element **50**.

[0059] The third structure body **63** may be provided. The third structure body **63** is arranged with the second sensor unit **50***b* in the X-axis direction. The third structure body **63** is provided between the fourth side **70***s***4** and one end of the second sensor unit **50***b*. The third structure body **63** is not electrically connected to the second sensor unit **50***b*. The third structure body **63** includes a third structure body layer **63***a*, a third opposing structure body layer **63***b*, and a third intermediate structure body layer **63***c*. The third intermediate structure body layer **63***c* is provided between the third structure body layer **63***a* and the third opposing structure body layer **63***b*. The third opposing structure body layer **63***b* is separated from the third structure body layer **63***a* substantially along the Z-axis direction. In the example, the third opposing structure body layer **63***b* is provided between the third structure body layer **63***a* and the film portion **70***d*. In the embodiment, the third structure body layer **63***a* may be disposed between the third opposing structure body layer **63***b* and the film portion **70***d*. The third structure body layer **63***a* has at least one of a floating potential with respect to the third opposing structure body layer **63***b* or the same potential as the potential of the third opposing structure body layer **63***b*.

[0060] The third structure body layer **63***a* includes, for example, the same material as a material included in the second magnetic layer **12***a*. The third opposing structure body layer **63***b* includes, for example, the same material as a material included in the second opposing magnetic layer **12***b*. The third intermediate structure body layer **63***c* includes, for example, the same material as a material included in the second nonmagnetic intermediate layer **12***c*. For example, although the structure of the third structure body **63** is substantially the same as the structure of the second sensing element **52**, the third structure body **63** does not function as the sensing element **50**.

[0061] The fourth structure body **64** may be provided. The fourth structure body **64** is arranged with the second sensor unit **50***b* in the X-axis direction. The fourth structure body **64** is provided between the third side **70***s***3** and the other end of the second sensor unit **50***b*. The fourth structure body **64** is not electrically connected to the second sensor unit **50***b*. The fourth structure body **64** includes a fourth structure body layer **64***a*, a fourth opposing structure body layer **64***b*, and a fourth intermediate structure body layer **64***c*. The fourth intermediate structure body layer **64***c* is provided between the fourth structure body layer **64***a* and the fourth opposing structure body layer **64***b*. The fourth opposing structure body layer **64***b* is separated from the fourth structure body layer **64***a* substantially along the Z-axis direction. In the example, the fourth opposing structure body layer **64***b* is provided between the fourth structure body layer **64***a* and the film portion **70***d*. In the embodiment, the fourth structure body layer **64***a* may be disposed between the fourth opposing structure body layer **64***b* and the film portion **70***d*. The fourth structure body layer **64***a* has at least one of a floating potential with respect to the fourth opposing structure body layer **64***b* or the same potential as the potential of the fourth opposing structure body layer **64***b*.

[0062] The fourth structure body layer **64***a* includes, for example, the same material as a material included in the second magnetic layer **12***a*. The fourth opposing structure body layer **64***b* includes, for example, the same material as a material included in the second opposing magnetic layer **12***b*. The fourth intermediate structure body layer **64***c* includes, for example, the same material as the material included in the second nonmagnetic intermediate layer **12***c*. For example, although the structure of the fourth structure body **64** is substantially the same as the structure of the second sensing element **52**, the fourth structure body **64** does not function as the sensing element **50**.

[0063] The magnetization of the first magnetic layer **11***a* changes according to the deformation of the film portion **70***d*. The magnetization of the second magnetic layer **12***a* changes according to the deformation of the film portion **70***d*. The first magnetic layer **11***a* is, for example, a free magnetic layer. The second magnetic layer **12***a* is, for example, a free magnetic layer.

[0064] For example, the magnetization of the first opposing magnetic layer **11***b* does not change easily compared to the magnetization of the first magnetic layer **11***a*. The first opposing magnetic layer **11***b* is, for example, a fixed magnetic layer. For example, the magnetization of the second opposing magnetic layer **12***b* does not change easily compared to the magnetization of the second magnetic layer **12***a*. The second opposing magnetic layer **12***b* is, for example, a fixed magnetic layer.

[0065] For example, pressure (the pressure to be sensed) is applied to the film portion **70***d*. Thereby, strain occurs in the magnetic layers of the sensing elements **50**. The strain is, for example, anisotropic strain. Due to the strain, the magnetization of the first magnetic layer **11***a* and the magnetization of the second magnetic layer **12***a* each change. For example, the changes are based on the inverse magnetostrictive effect. Thereby, the angle between the direction of the magnetization of the first magnetic layer **11***a* and the direction of the magnetization of the first opposing magnetic layer **11***b* changes. Thereby, the resistance between the first magnetic layer **11***a* and the first opposing magnetic layer **11***b* changes. On the other hand, the angle between the direction of the magnetization of the second magnetic layer **12***a* and the direction of the magnetization of the second opposing magnetic layer **12***b* changes. Thereby, the resistance between the second magnetic layer **12***a* and the second opposing magnetic layer **12***b* changes. For example, the changes of the resistances are based on the magnetoresistance effect (the MR effect).

[0066] In other words, the resistance between the first magnetic layer **11***a* and the first opposing magnetic layer **11***b* changes according to the deformation of the film portion **70***d*. The angle between the direction of the magnetization of the second magnetic layer **12***a* and the direction of the magnetization of the second opposing magnetic layer **12***b* changes. By sensing the changes of the resistances, the pressure that is applied to the film portion **70***d* is sensed. In other words, the pressure that is to be sensed is sensed.

[0067] For example, the change of the resistance is sensed by causing a current to flow in the sensing elements **50**.

[0068] As illustrated in FIG. 1B, the first sensor unit **50***a* further includes, for example, a first electrode **58***a* and a second electrode **58***b*. For example, the first magnetic layer **11***a*, the first opposing magnetic layer **11***b*, and the first nonmagnetic intermediate layer **11***c* are disposed between the first electrode **58***a* and the second electrode **58***b*. The resistance of the first sensing element **51** is sensed by applying a voltage between the first electrode **58***a* and the second electrode **58***b*.

[0069] As illustrated in FIG. 1D, the second sensor unit **50***b* further includes, for example, a third electrode **58***c* and a fourth electrode **58***d*. For example, the second magnetic layer **12***a*, the second opposing magnetic layer **12***b*, and the second nonmagnetic intermediate layer **12***c* are disposed between the third electrode **58***c* and the fourth electrode **58***d*. The resistance of the second sensing element **52** is sensed by applying a voltage between the third electrode **58***c* and the fourth electrode **58***d*.

[0070] In the embodiment, the first structure body **61** further includes a first conductive layer **58***p***1** and a second conductive layer **58***p***2**. The first conductive layer **58***p***1** is electrically connected to the first structure body layer **61***a*. The second conductive layer **58***p***2** is electrically connected to the first opposing structure body layer **61***b*. The first structure body layer **61***a* is provided between the first conductive layer **58***p***1** and the second conductive layer **58***p***2**. The first opposing structure body layer **61***b* is provided between the first structure body layer **61***a* and the second conductive layer **58***p***2**. A voltage is not applied to the first structure body **61** because the first structure body **61** is not electrically connected to the first sensing element **51**.

[0071] The first conductive layer **58***p***1** is further electrically connected to the second structure body layer **62***a*. The second conductive layer **58***p***2** is electrically connected to the second opposing structure body layer **62***b*. The second structure body layer **62***a* is provided between the first conductive layer **58***p***1** and the second conductive layer **58***p***2**. The second opposing structure body layer **62***b* is provided between the second structure body layer **62***a* and the second conductive layer **58***p***2**. A voltage is not applied to the second structure body **62** because the second structure body **62** is not electrically connected to the first sensing element **51**.

[0072] The third structure body **63** further includes a third conductive layer **58***p***3** and a fourth conductive layer **58***p***4**. The third conductive layer **58***p***3** is electrically connected to the third structure body layer **63***a*. The fourth conductive layer **58***p***4** is electrically connected to the third opposing structure body layer **63***b*. The third structure body layer **63***a* is provided between the third conductive layer **58***p***3** and the fourth conductive layer **58***p***4**. The third opposing structure body layer **63***b* is provided between the third structure body layer **63***a* and the fourth conductive layer **58***p***4**. A voltage is not applied to the third structure body **63** because the third structure body **63** is not electrically connected to the second sensing element **52**.

[0073] The third conductive layer **58***p***3** is further electrically connected to the fourth structure body layer **64***a*. The fourth conductive layer **58***p***4** is electrically connected to the fourth opposing structure body layer **64***b*. The fourth structure body layer **64***a* is provided between the third conductive layer **58***p***3** and the fourth conductive layer **58***p***4**. The fourth opposing structure body layer **64***b* is provided between the fourth structure body layer **64***a* and the fourth conductive layer **58***p***4**. A voltage is not applied to the fourth structure body **64** because the fourth structure body **64** is not electrically connected to the second sensing element **52**.

[0074] The magnetic layers (the first magnetic layer **11***a* and the second magnetic layer **12***a*) include, for example, at least one of Fe, Co, or Ni. The opposing magnetic layers (the first opposing magnetic layer **11***b* and the second opposing magnetic layer **12***b*) include, for example, at least one of Fe, Co, or Ni. The nonmagnetic intermediate layers (the first nonmagnetic intermediate layer **11***c* and the second nonmagnetic intermediate layer **12***c*) may include a metal or an insulator. In the case of a metal, for example, Cu, Au, Ag, or the like is used. In the case of an insulator, for example, magnesium oxide, aluminum oxide, titanium oxide, zinc oxide, or the like is used.

[0075] An insulating layer (not illustrated) is provided between the first electrode **58***a* and the film portion **70***d*. For example, the insulating layer is provided also between the first electrode **58***a* and the second electrode **58***b*. For example, the insulating layer is provided also between the third electrode **58***c* and the fourth electrode **58***d*. Electrical insulation between the electrodes is obtained due to the insulating layer.

[0076] As shown in FIG. **1**C, a controller **68** (e.g., a processing circuit) may be further provided. The controller **68** is electrically connected to the first sensing element **51** and the second sensing element **52**. For example, the controller **68** is electrically connected to the first electrode **58***a*, the second electrode **58***b*, the third electrode **58***c*, and the fourth electrode **58***d*. The controller **68** outputs a signal corresponding to the signal obtained from the first sensing element **51** (the signal generated by the first sensing element **51**). The controller **68** outputs a signal corresponding to the signal obtained from the second sensing element **52** (the signal generated by the second sensing element **52**). The controller **68** outputs a signal corresponding to the change of the resistance occurring in the sensing elements **50**. The signals obtained by the controller **68** correspond to the pressure to be sensed.

[0077] FIG. **3** is a schematic cross-sectional view illustrating one portion of the pressure sensor according to the first embodiment.

[0078] As shown in FIG. **3**, the first structure body **61** further includes the first conductive layer **58***p***1**, the second conductive layer **58***p***2**, and an interconnect layer **58***q*. The first structure body layer **61***a* is provided between the first conductive layer **58***p***1** and the second conductive layer **58***p***2**. The length along the X-axis direction of the second conductive layer **58***p***2** on the lower side is longer than the length along the X-axis direction of the first conductive layer **58***p***1** on the upper side. The interconnect layer **58***q* electrically connects the first conductive layer **58***p***1** and the second conductive layer **58***p***2**. The first structure body layer **61***a* has the same potential as the potential of the first opposing structure body layer **61***b*. This is similar for the second to fourth structure bodies **62** to **64** as well.

[0079] According to the embodiment, the structure body that is not electrically connected to the end of the sensor unit is disposed. The structure body does not function as the sensing element **50**. Therefore, the decrease of the SNR can be suppressed. Thereby, the sensitivity can be increased.

Second Embodiment

[0080] FIG. **4**A and FIG. **4**B are schematic views illustrating one portion of a pressure sensor according to a second embodiment.

[0081] FIG. **4**A is a plan view illustrating one portion of the pressure sensor.

[0082] FIG. **4**B is a cross-sectional view illustrating one portion of the pressure sensor.

[0083] The pressure sensor **111** according to the embodiment further includes a fifth structure body **65** and a sixth structure body **66**. The fifth structure body **65** is arranged with the first sensor unit **50***a* in the X-axis direction. The fifth structure body **65** is not electrically connected to the first sensor unit **50***a*. The fifth structure body **65** is provided between the first structure body **61** and the third side **70***s***3**. The sixth structure body **66** is arranged with the first sensor unit **50***a* in the X-axis direction. The sixth structure body **66** is not electrically connected to the first sensor unit **50***a*. The sixth structure body **66** is provided between the second structure body **62** and the fourth side **70***s***4**.

[0084] The fifth structure body **65** includes a fifth structure body layer **65***a*, a fifth opposing structure body layer **65***b*, and a fifth intermediate structure body layer **65***c*. The fifth intermediate structure body layer **65***c* is provided between the fifth structure body layer **65***a* and the fifth opposing structure body layer **65***b*. The fifth opposing structure body layer **65***b* is separated from the fifth structure body layer **65***a* substantially along the Z-axis direction. In the example, the fifth opposing structure body layer **65***b* is provided between the fifth structure body layer **65***a* and the film portion **70***d*. In the embodiment, the fifth structure body layer **65***a* may be disposed between the fifth opposing structure body layer **65***b* and the film portion **70***d*. The fifth structure body layer **65***a* has at least one of a floating potential with respect to the fifth opposing structure body layer **65***b* or the same potential as the potential of the fifth opposing structure body layer **65***b*.

[0085] The fifth structure body layer **65***a* includes, for example, the same material as a material included in the first magnetic layer **11***a*. The fifth opposing structure body layer **65***b* includes, for example, the same material as a material included in the first opposing magnetic layer **11***b*. The fifth intermediate structure body layer **65***c* includes, for example, the same material as a material included in the first nonmagnetic intermediate layer **11***c*. For example, although the structure of the fifth structure body **65** is substantially the same as the structure of the first sensing element **51**, the fifth structure body **65** does not function as the sensing element **50**.

[0086] The sixth structure body **66** includes a sixth structure body layer **66***a*, a sixth opposing structure body layer **66***b*, and a sixth intermediate structure body layer **66***c*. The sixth intermediate structure body layer **66***c* is provided between the sixth structure body layer **66***a* and the sixth opposing structure body layer **66***b*. The sixth opposing structure body layer **66***b* is separated from the sixth structure body layer **66***a* substantially along the Z-axis direction. In the example, the sixth opposing structure body layer **66***b* is provided between the sixth structure body layer **66***a* and the film portion **70***d*. In the embodiment, the sixth structure body layer **66***a* may be disposed between the sixth opposing structure body layer **66***b* and the film portion **70***d*. The sixth structure body layer **66***a* has at least one of a floating potential with respect to the sixth opposing structure body layer **66***b* or the same potential as the potential of the sixth opposing structure body layer **66***b*.

[0087] The sixth structure body layer **66***a* includes, for example, the same material as a material included in the first magnetic layer **11***a*. The sixth opposing structure body layer **66***b* includes, for example, the same material as a material included in the first opposing magnetic layer **11***b*. The sixth intermediate structure body layer **66***c* includes, for example, the same material as a material included in the first non-magnetic intermediate layer **11***c*. For example, although the structure of the sixth structure body **66** is substantially the same as the structure of the first sensing element **51**, the sixth structure body **66** does not function as the sensing element **50**.

[0088] The number of structure bodies disposed at one end of the second sensor unit **50***b* and at the other end of the second sensor unit **50***b* may be 2 each,

[0089] As described in reference to FIG. **2**A, the gauge factors GF are small for the two sensing elements **50** provided at the end on one side of the sensor unit. In the embodiment, these sensing elements **50** (the number being 4) are structure bodies that are not electrically connected. The structure bodies do not function as the sensing elements **50**. For example, the fifth structure body **65** is disposed instead of the sensing element **50** of the first position. The first structure body **61** is disposed instead of the sensing element **50** of the second position. The second structure body **62** is disposed instead of the sensing element **50** of the twenty-sixth position. The sixth structure body **66** is disposed instead of the sensing element **50** of the twenty-seventh position. First, second, fifth, and sixth structure bodies **61**, **62**, **65**, and **66** are not electrically connected to the sensing elements **50** of the third to twenty-fifth positions. Therefore, the decrease of the SNR can be suppressed. Thereby, the sensitivity can be increased.

[0090] FIG. **5**A to FIG. **5**C are schematic views illustrating the pressure sensor according to the embodiment.

[0091] These drawings show examples of the connection states of the multiple sensing elements **50**.

[0092] In FIG. **5**A, the sensing elements **50** correspond to the first sensing element **51**, the second sensing element **52**, etc. The multiple sensing elements **50** are connected in series. The number of the multiple sensing elements **50** connected in series is N. Therefore, the electrical signal that is obtained is N times that of the case where the number of the sensing elements **50** is 1. On the other hand, the thermal noise and the Schottky noise are $N^{1/2}$ times. In other words, SNR is $N^{1/2}$ times. By increasing the number N of the sensing elements **50** connected in series, the SN ratio can be improved without increasing the size of the film portion **70***d*.

[0093] In the embodiment, by using the film portion **70***d* having the anisotropic configuration, the change (e.g., the polarity) of the electrical resistance according to the pressure is similar for each of the multiple sensing elements **50** disposed to be clustered at the center of gravity vicinity of the film portion **70***d*. Therefore, it is possible to add the signals of each of the multiple sensing elements **50**.

[0094] The bias voltage that is applied to one sensing element **50** is, for example, not less than 50 millivolts (mV) and not more than 150 mV. In the case where the N sensing elements **50** are connected in series, the bias voltage is not less than 50 mV×N and not more than 150 mV×N. For example, in the case where the number N of the sensing elements **50** connected in series is 25, the bias voltage is not less than 1 V and not more than 3.75 V.

[0095] When the value of the bias voltage is 1 V or more, the design of the electronic circuit processing the electrical signals obtained from the sensing elements **50** is easy and is practically favorable. In the embodiment, the sensing elements **50** can be multiply disposed in which the electrical signals obtained have the same polarity when the pressure is applied. Therefore, these sensing elements **50** are connected in series; and the SN ratio can be improved as recited above.

[0096] For the electronic circuit that processes the electrical signals obtained from the sensing elements **50**, it is undesirable for the bias voltage (the voltage across the terminals) to exceed 10 V. In the embodiment, the bias voltage and the number N of the sensing elements **50** connected in series are set to provide the appropriate voltage range.

[0097] For example, it is favorable for the voltage when the multiple sensing elements **50** are connected electrically in series to be not less than 1 V and not more than 10 V. For example, the voltage that is applied between the terminals of the multiple sensing elements **50** connected electrically in series (between the terminal of one end and the terminal of the other end) is not less than 1 V and not more than 10 V.

[0098] To generate such a voltage, in the case where the bias voltage that is applied to one sensing element **50** is 50 my, it is favorable for the number N of the sensing elements **50** connected in series to be not less than 20 and not more than 200. In the case where the bias voltage that is applied to one sensing element **50** is 150 mV, it is favorable for the number N of the sensing elements **50** connected in series to be not less than 7 and not more than 66.

[0099] As shown in FIG. **5**B, at least one portion of the multiple sensing elements **50** may be electrically connected in parallel.

[0100] As shown in FIG. **5**C, the multiple sensing elements **50** may be connected so that the multiple sensing elements **50** form a Wheatstone bridge circuit. Thereby, for example, temperature compensation of the sensing characteristics can be performed.

[0101] FIG. **6**A to FIG. **6**C are schematic perspective views illustrating the pressure sensor according to the embodiment.

[0102] These drawings show examples of the connections of the multiple sensing elements **50**.

[0103] As shown in FIG. **6**A, in the case where the multiple sensing elements **50** are connected electrically in series, the sensing element **50** and a via contact **59** are provided between the second electrode **58***b* on the lower portion side and the first electrode **58***a* on the upper portion side. Thereby, the conduction direction is in one direction. The current that is conducted in the multiple sensing elements **50** is downward or upward. By such a connection, the difference between the characteristics of each of the multiple sensing elements **50** can be small.

[0104] As shown in FIG. 6B, the sensing elements **50** are disposed between the second electrode **58***b* and the first electrode **58***a* without providing the via contact **59**. In the example, the directions of the currents conducted in each of two mutually-adjacent sensing elements **50** are mutually reversed. The density of the arrangement of the multiple sensing elements **50** is high for such a connection.

[0105] As shown in FIG. 6C, the multiple sensing elements **50** are provided between one second electrode **58***b* and one first electrode **58***a*. The multiple sensing elements **50** are connected in parallel.

Third Embodiment

[0106] FIG. **7** is a schematic cross-sectional view illustrating a pressure sensor system according to a third embodiment.

[0107] The pressure sensor system **112** according to the embodiment includes the film portion **70***d*, the first sensor unit **50***a*, the second sensor unit **50***b*, the first to fourth structure bodies **61** to **64**, and the controller **68**.

[0108] For example, the controller **68** is electrically connected to the first sensor unit **50***a* and the first structure body **61**. The controller **68** electrically connects the first structure body layer **61***a* (referring to FIG. 1B) and the first opposing structure body layer **61***b* while supplying a current to the first sensor unit **50***a*. The controller **68** causes the potential of the first structure body layer **61***a* to be floating with respect to the first opposing structure body layer **61***b* while supplying the current to the first sensor unit **50***a*.

[0109] As in the embodiment, the controller **68** may control the potential of the first structure body **61**. A similar control is possible for the second to sixth structure bodies **62** to **66** as well.

[0110] FIG. **8**A and FIG. **8**B are schematic views illustrating electrode portions of the pressure sensor according to the embodiment.

[0111] FIG. **8**A is a schematic plan view of the electrode portions. FIG. **8**B is a line B**1**-B**2** cross-sectional view of FIG. **8**A. Line B**1**-B**2** is aligned with the outer edge **70***r* of the film portion **70***d*.

[0112] The pressure sensor **113** according to the embodiment includes the film portion **70***d*, the multiple sensing elements **50**, the first electrode **58***a*, and the second electrode **58***b*. As shown in FIG. **8**B, the film portion **70***d* includes a first region r**1**, a second region r**2**, a third region r**3**, and a fourth region r**4**. The first region r**1** overlaps the first electrode **58***a*, the first magnetic layer **11***a* (the sensing element **50**), and the second electrode **58***b*. The second region r**2** overlaps the first electrode **58***a* but does not overlap the first magnetic layer **11***a* (the sensing element **50**) or the second electrode **58***b*. The third region r**3** overlaps the first electrode **58***a*, the first magnetic layer **11***a* (the sensing element **50**), and the second electrode **58***b*. The fourth region r**4** overlaps the second electrode **58***b* but does not overlap the first magnetic layer **11***a* (the sensing element **50**) or the first electrode **58***a*. The second region r**2** is positioned between the first region r**1** and the third region r**3**. The third region r**3** is positioned between the second region r**2** and the fourth region r**4**. That is, on the film portion **70***d*, the first electrode **58***a* on the upper side and the second electrode **58***b* on the lower side are electrically connected.

[0113] FIG. **9**A and FIG. **9**B are schematic views illustrating the electrode portions of the pressure sensor according to the embodiment.

[0114] FIG. **9**A is a schematic plan view of the electrode portions. FIG. **9**B is a line C**1**-C**2** cross-sectional view of FIG. **9**A. Line C**1**-C**2** is aligned with the outer edge **70***r* of the film portion **70***d*.

[0115] The pressure sensor **114** according to the embodiment includes the film portion **70***d*, the multiple sensing elements **50**, the first electrode **58***a*, and the second electrode **58***b*. As shown in FIG. **9**B, the film portion **70***d* includes the first region r**1**, the second region r**2**, the third region r**3**, and the fourth region r**4**. The first region r**1** overlaps the first electrode **58***a*, the sensing element **50**, and the second electrode **58***b*. The second region r**2** does not overlap the first electrode **58***a*, the sensing element **50**, or the second electrode **58***b*. The third region r**3** overlaps the first electrode **58***a*, the sensing element **50**, and the second electrode **58***b*. The fourth region r**4** does not overlap the first electrode **58***a*, the sensing element **50**, or the second electrode **58***b*. The second region r**2** is positioned between the first region r**1** and the third region r**3**. The third region r**3** is positioned between the second region r**2** and the fourth region r**4**. That is, on the film portion **70***d*, the first electrode **58***a* on the upper side and the second electrode **58***b* on the lower side are not electrically connected. In such a case, the first electrode **58***a* and the second electrode **58***b* are electrically connected inside the holder **70***s*.

[0116] FIG. **10** is a graph illustrating characteristics of the pressure sensors.

[0117] In FIG. **10**, the horizontal axis shows an element unit volumetric average stress σave (MPa). The vertical axis shows an anisotropic strain slope $|\Delta\epsilon/dP|$. The element unit volumetric average stress cave illustrates the average stress per unit volume generated in the element unit when pressure (sound pressure) is not applied. The element unit includes the first electrode **58***a*, the sensing element **50**, and the second electrode **58***b*. The anisotropic strain slope $|\Delta\epsilon/dP|$ illustrates the absolute value of the change amount (de) of the strain per unit stress (dP) generated in the sensing element **50**.

[0118] A characteristic **55** shows the anisotropic strain slope $|\Delta\epsilon/dP|$ of the pressure sensor **114**. A characteristic **56** shows the anisotropic strain slope $|\Delta\epsilon/dP|$ of the pressure sensor **113**. In the example, the anisotropic strain slope $|\Delta\epsilon/dP|$ has a peak when the element unit volumetric average stress cave is in the vicinity of +60 MPa. For example, a reference value ϵ**1** is taken to be 0.5. The desired characteristics are obtained when the anisotropic strain slope $|\Delta\epsilon/dP|$ is not less than the reference value ϵ**1**.

[0119] For example, for the element unit volumetric average stress σave at the vicinity of +60 MPa, the anisotropic strain slope $|\Delta\epsilon/dP|$ (the characteristic S5) of the pressure sensor **114** is larger than the anisotropic strain slope $|\Delta\epsilon/dP|$ (the characteristic **56**) of the pressure sensor **113**. That is, compared to the pressure sensor **113**, a larger amount of strain can be obtained for the pressure sensor **114**. It is considered that this is caused by the difference between the electrode structure of the pressure sensor **114** and the electrode structure of the pressure sensor **113**.

[0120] In the case of the pressure sensor **113**, strain of the reverse orientations occurs due to the first electrode **58***a* and the second electrode **58***b* in the sensing element **50**; and the amount of strain decreases. Conversely, in the case of the pressure sensor **114**, strain of the same orientation occurs due to the first electrode **58***a* and the second electrode **58***b* in the sensing element **50**; and the amount of strain does not decrease. Therefore, it is considered that the amount of strain of the pressure sensor **114** is larger than the amount of strain of the pressure sensor **113**. Therefore, the electrode structure of the pressure sensor **114** is more desirable than the electrode structure of the pressure sensor **113**.

Fourth Embodiment

[0121] FIG. **11** is a schematic view illustrating a microphone according to a fourth embodiment.

[0122] As shown in FIG. **11**, a microphone **610** according to the embodiment includes any pressure sensor according to the embodiments or a pressure sensor according to a modification of the embodiments recited above. In the example, the pressure sensor **110** is used as the pressure sensor.

[0123] For example, the microphone **610** is provided in a personal digital assistant **710**. For example, the film portion **70***d* of the pressure sensor **110** is substantially parallel to the surface in which a display unit **620** of the personal digital assistant **710** is provided. The disposition of the film portion **70***d* is arbitrary. According to the embodiment, a microphone in which the dynamic range can be enlarged can be provided. For example, the microphone **610** according to the embodiment may be provided in an IC recorder, a pin microphone, etc.

[0124] FIG. **12** is a schematic cross-sectional view illustrating another microphone according to the fourth embodiment.

[0125] A microphone **320** (an acoustic microphone) according to the embodiment includes a printed circuit board **321**, a cover **323**, and a pressure sensor. Any pressure sensor according to the embodiments or a modification of the embodiments is used as the pressure sensor. In the example, the pressure sensor **110** is used as the pressure sensor. The printed circuit board **321** includes, for example, a circuit such as an amplifier, etc. An acoustic hole **325** is provided in the cover **323**. Sound **329** passes through the acoustic hole **325** and enters the interior of the cover **323**. The microphone **320** responds to the sound pressure. A highly-sensitive microphone **320** is obtained by using the highly-sensitive pressure sensor **110**. For example, the pressure sensor **110** is mounted on the printed circuit board **321**; and electrical signal lines are provided. The cover **323** is provided on the printed circuit board **321** to cover the pressure sensor **110**. A microphone in which the dynamic range can be enlarged can be provided.

Fifth Embodiment

[0126] FIG. **13**A and FIG. **13**B are schematic views illustrating a blood pressure sensor according to a fifth embodiment.

[0127] FIG. **13**A is a schematic plan view illustrating skin on an arterial vessel of a human. FIG. **13**B is a line H1-H2 cross-sectional view of FIG. **13**A.

[0128] The blood pressure sensor **330** according to the embodiment includes any pressure sensor according to the embodiments or a modification of the embodiments. In the example, the pressure sensor **110** is used as the pressure sensor. The pressure sensor **110** is pressed onto the skin **333** on the arterial vessel **331**. Thereby, the blood pressure sensor **330** can continuously perform blood pressure measurements. According to the embodiment, a blood pressure sensor in which the dynamic range can be enlarged can be provided. The blood pressure can be measured with high sensitivity.

Sixth Embodiment

[0129] FIG. **14** is a schematic view illustrating a touch panel according to a sixth embodiment.

[0130] The touch panel **340** according to the embodiment includes any pressure sensor according to the embodiments or a modification of the embodiments. In the example, the pressure sensor **110** is used as the pressure sensor. In the touch panel **340**, the pressure sensors **110** are mounted to at least one of the interior of the display or the exterior of the display.

[0131] For example, the touch panel **340** includes multiple first interconnects **346**, multiple second interconnects **347**, the multiple pressure sensors **110**, and a controller **341**.

[0132] In the example, the multiple first interconnects **346** are arranged along the Y-axis direction. Each of the multiple first interconnects **346** extends along the X-axis direction. The multiple second interconnects **347** are arranged along the X-axis direction. Each of the multiple second interconnects **347** extends along the Y-axis direction.

[0133] The multiple pressure sensors **110** are provided respectively at the crossing portions between the multiple first interconnects **346** and the multiple second interconnects **347**. One pressure sensor **110** is used as one sensing component **310***e* for sensing. Here, the crossing portion includes the position where the first interconnect **346** and the second interconnect **347** cross and includes the region at the periphery of the position.

[0134] One end **310**.*a* of each of the multiple pressure sensors **110** is connected respectively to the multiple first interconnects **346**. One other end **310***b* of each of the multiple pressure sensors **110** is connected respectively to the multiple second interconnects **347**.

[0135] The controller **341** is connected to the multiple first interconnects **346** and the multiple second interconnects **347**. For example, the controller **341** includes a first interconnect circuit **346***d* that is connected to the multiple first interconnects **346**, a second interconnect circuit **347***d* that is connected to the multiple second interconnects **347**, and a control circuit **345** that is connected to the first interconnect circuit **346***d* and the second interconnect circuit **347***d*. The pressure sensor **110** is compact and can perform highly-sensitive pressure sensing. Therefore, it is possible to realize a high definition touch panel.

[0136] According to the embodiment, a touch panel in which the dynamic range can be enlarged can be provided. A highly-sensitive touch input is possible.

[0137] Other than the applications recited above, the pressure sensors according to the embodiments are applicable to an atmospheric pressure sensor, an air pressure sensor of a tire, etc. The pressure sensors according to the embodiments are applicable to various pressure sensing.

[0138] According to the embodiments, a pressure sensor, a microphone, a blood pressure sensor, and a touch panel in which the dynamic range can be enlarged can be provided.

[0139] According to the embodiments, a pressure sensor, a pressure sensor system, a microphone, a blood pressure sensor, and a touch panel can be provided in which the sensitivity can be increased.

[0140] Hereinabove, exemplary embodiments of the invention are described with reference to specific examples.

However, the embodiments of the invention are not limited to these specific examples. For example, one skilled in the art may similarly practice the invention by appropriately selecting specific configurations of components included in sensors such as film portions, sensor unites, structure bodies, etc., from known art. Such practice is included in the scope of the invention to the extent that similar effects thereto are obtained.

[0141] Further, any two or more components of the specific examples may be combined within the extent of technical feasibility and are included in the scope of the invention to the extent that the purport of the invention is included.

[0142] Moreover, all pressure sensors, all pressure sensor systems, all microphones, all blood pressure sensors, and all touch panels practicable by an appropriate design modification by one skilled in the art based on the pressure sensors, the pressure sensor systems, the microphones, the blood pressure sensors, and the touch panels described above as embodiments of the invention also are within the scope of the invention to the extent that the spirit of the invention is included.

[0143] Various other variations and modifications can be conceived by those skilled in the art within the spirit of the invention, and it is understood that such variations and modifications are also encompassed within the scope of the invention.

[0144] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the invention.

What is claimed is:

1. A pressure sensor, comprising:

a film portion having a front surface, the film portion being deformable;

a first sensor unit separated from a first portion of an outer edge of the front surface and fixed to one portion of the front surface, the first sensor unit including a plurality of first sensing elements arranged along the front surface, one of the plurality of first sensing elements including a first magnetic layer, a first opposing magnetic layer, and a first nonmagnetic intermediate layer provided between the first magnetic layer and the first opposing magnetic layer; and

a first structure body arranged with the first sensor unit along the arrangement direction of the plurality of first sensing elements, the first structure body including a first structure body layer, a first opposing structure body layer, and a first intermediate structure body layer provided between the first structure body layer and the first opposing structure body layer, the first structure body layer having at least one of a floating potential with respect to the first opposing structure body layer or same potential as a potential of the first opposing structure body layer.

2. The sensor according to claim **1**, wherein

the first structure body layer includes same material as a material included in the first magnetic layer,

the first opposing structure body layer includes same material as a material included in the first opposing magnetic layer, and

the first intermediate structure body layer includes same material as a material included in the first nonmagnetic intermediate layer.

3. The sensor according to claim **1**, wherein

the outer edge includes:

a first side extending in a first direction;

a second side extending in the first direction and being separated from the first side in a second direction, the second direction crossing the first direction;

a third side extending in the second direction; and

a fourth side extending in the second direction and being separated from the third side in the first direction,

the plurality of first sensing elements is arranged in the first direction of the first side, and

the first structure body is provided between the third side and one end of the first sensor unit.

4. The sensor according to claim **3**, wherein a distance along the first direction between the first side and the second side is longer than a distance along the second direction between the third side and the fourth side.

5. The sensor according to claim **1**, wherein

the first structure body further includes:

a first conductive layer electrically connected to the first structure body layer; and

a second conductive layer electrically connected to the first opposing structure body layer,

the first structure body layer is provided between the first conductive layer and the second conductive layer, and

the first opposing structure body layer is provided between the first structure body layer and the second conductive layer.

6. The sensor according to claim **5**, wherein the first structure body further includes an interconnect layer electrically connecting the first conductive layer and the second conductive layer.

7. The pressure sensor according to claim **5**, wherein the first sensor unit further includes:

a first electrode electrically connected to the first magnetic layer; and

a second electrode electrically connected to the first opposing magnetic layer,

the first magnetic layer is provided between the first electrode and the second electrode, and

the first opposing magnetic layer is provided between the first magnetic layer and the second electrode.

8. The sensor according to claim **7**, wherein

the first conductive layer includes a material included in the first electrode, and

the second conductive layer includes a material included in the second electrode.

9. The sensor according to claim **3**, further comprising a second structure body arranged with the first sensor unit along the first direction and provided between the fourth side and one other end of the first sensor unit,

the second structure body including a second structure body layer, a second opposing structure body layer, and a second intermediate structure body layer provided between the second structure body layer and the second opposing structure body layer,

the second structure body layer having at least one of a floating potential with respect to the second opposing structure body layer or same potential as a potential of the second opposing structure body layer.

10. The sensor according to claim **3**, further comprising:

a second sensor unit including a plurality of second sensing elements, the plurality of second sensing elements being arranged in the first direction of the second side, one of the plurality of second sensing elements including a second magnetic layer, a second opposing magnetic layer, and a second nonmagnetic intermediate layer provided between the second magnetic layer and the second opposing magnetic layer; and

a third structure body arranged with the second sensor unit along the first direction and provided between the fourth side and one end of the second sensor unit, the third structure body including a third structure body layer, a third opposing structure body layer, and a third intermediate structure body layer provided between the third structure body layer and the third opposing structure body layer, the third structure body layer having at least one of a floating potential with respect to the third opposing structure body layer or same potential as a potential of the third opposing structure body layer.

11. The sensor according to claim **10**, further comprising a fourth structure body arranged with the second sensor unit along the first direction and provided between the third side and one other end of the second sensor unit,

the fourth structure body including a fourth structure body layer, a fourth opposing structure body layer, and a fourth intermediate structure body layer provided between the fourth structure body layer and the fourth opposing structure body layer,

the fourth structure body layer having at least one of a floating potential with respect to the fourth opposing structure body layer or same potential as a potential of the fourth opposing structure body layer.

12. The sensor according to claim **3**, further comprising:

a fifth structure body provided between the first structure body and the third side; and

a sixth structure body provided between the second structure body and the fourth side,

the fifth structure body including a fifth structure body layer, a fifth opposing structure body layer, and a fifth intermediate structure body layer provided between the fifth structure body layer and the fifth opposing structure body layer,

the sixth structure body including a sixth structure body layer, a sixth opposing structure body layer, and a sixth intermediate structure body layer provided between the sixth structure body layer and the sixth opposing structure body layer,

the fifth structure body layer having at least one of a floating potential with respect to the fifth opposing structure body layer or same potential as a potential of the fifth opposing structure body layer,

the sixth structure body layer having at least one of a floating potential with respect to the sixth opposing structure body layer or same potential as a potential of the sixth opposing structure body layer.

13. The pressure sensor according to claim **1**, wherein

the first magnetic layer includes at least one of Fe, Co, or Ni, and

the first opposing magnetic layer includes at least one of Fe, Co, or Ni.

14. The sensor according to claim **1**, wherein the plurality of first sensing elements is connected in series.

15. The sensor according to claim **1**, further comprising a holder holding the film portion.

16. The pressure sensor according to claim **1**, wherein a magnetization of the first magnetic layer changes according to a deformation of the film portion.

17. A pressure sensor, comprising:

a film portion having a front surface, the film portion being deformable;

a first sensor unit separated from a first portion of an outer edge of the front surface and fixed to one portion of the front surface, the first sensor unit including a plurality of first sensing elements arranged along the front surface, one of the plurality of first sensing elements including a first magnetic layer, a first opposing magnetic layer, and a first nonmagnetic intermediate layer provided between the first magnetic layer and the first opposing magnetic layer; and

a first structure body arranged with the first sensor unit along the arrangement direction of the plurality of first sensing elements, the first structure body including a first structure body layer, a first opposing structure body layer, and a first intermediate structure body layer provided between the first structure body layer and the first opposing structure body layer, the first structure body layer having at least one of a floating potential with respect to the first opposing structure body layer or same potential as a potential of the first opposing structure body layer,

the first sensor unit including:

a first electrode electrically connected to the first magnetic layer; and

a second electrode electrically connected to the first opposing magnetic layer,

the first magnetic layer being provided between the first electrode and the second electrode, and

the first opposing magnetic layer being provided between the first magnetic layer and the second electrode,

the film portion including:

a first region overlapping the first electrode, the first magnetic layer and the second electrode,

a second region not overlapping the first electrode, the first magnetic layer and the second electrode,

a third region overlapping the first electrode, the first magnetic layer and the second electrode, and

a fourth region not overlapping the first electrode, the first magnetic layer and the second electrode,

the second region being located between the first region and the third region, and

the third region being located between the second region and the fourth region.

18. A pressure sensor system, comprising:

a film portion having a front surface, the film portion being deformable;

a first sensor unit separated from a first portion of an outer edge of the front surface and fixed to one portion of the front surface, the first sensor unit including a plurality of first sensing elements arranged along the front surface, one of the plurality of first sensing elements including a first magnetic layer, a first opposing magnetic layer, and a first nonmagnetic intermediate layer provided between the first magnetic layer and the first opposing magnetic layer;

a first structure body arranged with the first sensor unit along the arrangement direction of the plurality of first sensing elements, the first structure body including a first structure body layer, a first opposing structure body layer, and a first intermediate structure body layer provided between the first structure body layer and the first opposing structure body layer; and

a controller connected with the first sensor unit and the first structure body,

the controller being configured to supply a current to the first sensor unit,

the controller being configured to electrically connect the first structure body layer with the first opposing structure body layer, or to make an electrical potential of the first structure body layer floating with respect to an electrical potential of the first opposing structure body.

19. A microphone, comprising

the pressure sensor according to claim **1**.

20. A blood pressure sensor, comprising

the pressure sensor according to claim **1**.

* * * * *

专利名称(译)	压力传感器，压力传感器系统，麦克风，血压传感器和触摸屏		
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申请号	US15/262795	申请日	2016-09-12
[标]申请(专利权)人(译)	株式会社东芝		
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摘要(译)

根据一个实施例，压力传感器包括膜部分，传感器单元和结构体。薄膜部分具有前表面并且是可变形的。传感器单元包括沿前表面布置的多个传感元件。多个传感元件中的一个包括磁性层，相对的磁性层和非磁性中间层。结构体沿着多个传感元件的排列方向设置有第一传感器单元。结构体包括结构体层，相对结构体层和中间结构体层。结构体层具有相对于相对的结构体层的浮动电位或与相对的结构体层的电位相同的电位中的至少一个。

FIG. 1A

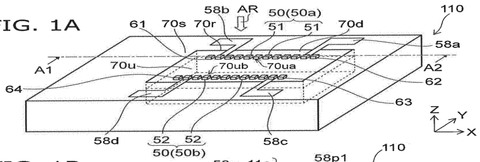

FIG. 1B

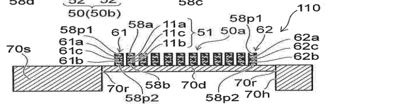

FIG. 1C

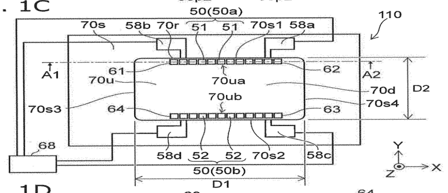

FIG. 1D