attenuated at time tm (FIG. 7).

Meanwhile, in the rising pulse detection, tm is close to ti, and the induced voltage is significantly high at the time tm. Thus, the variation due to the magnetic field cannot be ignored (FIG. 8). The present invention aims at removing the induced voltage from the output voltage of the GSR element and achieving a GSR sensor with a rising pulse detection system.

Solution to Problem

[0007] As a result of intensive study of the above-described technical problems, the inventors found that the polarity of an induced voltage becomes opposite relative to the direction of the current flowing in a magnetic wire. Then, they arrived at the technical idea of the present invention that if one coil includes therein two magnetic wires in which currents of opposite polarities flow, an induced voltage is cancelled, allowing for the detection of only a voltage in proportion to a magnetic field.

[0008] Regarding the typical size of a coil in a GSR sensor element with one magnetic wire, the groove width is 20 μm, and the coil width is 40 μm. In the GSR sensor element with two magnetic wires, the groove width is 40 μm, in which two magnetic wires are arranged with a separation wall (or an insulating wall) in the center, and the coil width is 50 μm. The size of the GSR sensor element is almost the same for one magnetic wire and for two magnetic wires.

[0009] Three kinds of structures exist for the element.

The first structure is a type in which two magnetic wires are arranged in a groove deeper than a magnetic wire, with the lower coil having a recessed shape and the upper coil having a plane surface shape. The second structure is

includes, on an electrode wiring board 10, a Co alloy magnetic wire 2 (21 and 22) coated with an insulating film, a coil 3 (31 and 32) wound around the magnetic wire 2, and four terminals (23 and 25, 34 and 36), as illustrated in FIG. 1, FIG. 2A, FIG. 2B, and FIG. 2C.

[0018] As the magnetic wire 2, there are arranged two magnetic wires 21 and 22, which are separated by an insulating wall 41, in a groove 11 on a center part of a board.

The upper part of the magnetic wire 21 on the wire input electrode 26(+) side, illustrated on the right side of FIG. 1, is connected to a wire input electrode 26(+) through the wire terminal 23 and a wire connection portion 21A (right part of FIG. 2B).

The lower part of the magnetic wire 21 is connected to the lower part of the magnetic wire 22 on the wire output electrode 27(-) side through a wire joint part 22B illustrated on the left side through a wire joint part 21B and a wire connection portion 24 (FIG. 2C).

The upper portion of the magnetic wire 22 is connected to a wire output electrode 27(-) through the wire terminal 25 (left part of FIG. 2B).

[0019] Next, the coil 3 includes a lower coil 31, an upper coil 32, and a joint part 33 jointing both coils.

The lower coil 31 is formed in a recessed shape in the groove 11 and on the board 10, while the upper coil 32 is formed from the upper part of a pair of magnetic wires 21 and 22 to the side through an insulating material 4 and then onto the board 10.

The end part of the lower coil 31 and the end part of the upper coil 32 form the joint part 33 on the board 10 to be connected to each other.

structure is of the type in which a chevron-shaped guide is formed on a plane surface and each of the two magnetic wires (21 and 22) is arranged in it, and the lower coil 31 has a plane surface shape, and the upper coil 32 has a convex shape, as illustrated in FIG. 4.

[0025] In any kind of structure, the insulating wall 41 is provided between the two magnetic wires (21 and 22). The joint part 33 connecting the end part of the lower coil 31 and the end part of the upper coil 32 is provided to form the coil 3.

[0026] The following will describe a method of manufacturing the GSR sensor element.

For the electrode wiring board 10, there is used a Si substrate coated with SiN. For the magnetic wire 2, there is used an amorphous wire having a diameter of 1 to 20 μm and a length of 0.07 to 1.0 mm coated with a glass insulating film.

First, in the element 1 having a width of 0.25 mm, the groove 11 with a width of 20 to 60 μm and a depth of 2 to 20 μm is formed in the center part thereof.

[0027] Next, electrode wiring is performed in the lower coil 31 and on the board surface along the groove 11. Then, the insulating wall 41 is formed in the center part of the groove 11 to have a two-groove form, and each one of the two magnetic wires 21 and 22 is arranged therein. Thereafter, an insulating resist is applied onto the entire surface of the board. The insulating resist is applied thinly in the upper part of the two magnetic wires (21 and 22). At that part, the upper coil 32 is formed by photolithographic technology.

The joint part 33 is formed to diagonally join the end parts of the lower coil 31 and the upper coil 32 on the board surface, so as to form the coil 3 with a coil pitch of 2 to 10 μm. A coil terminal 34 is connected to a coil

output electrode 35(+), and a coil terminal 36 is connected to a coil ground electrode 37(-).

[0028] At the four ends of the two magnetic wires, the glass as an insulating film is removed. The wire terminal 23 and the wire connection portion 21A are formed at one of the two ends by metal vapor deposition to enable electrical connection to a wire input electrode 26(+), while the wire terminal 25 and a wire connection portion 22A are formed at the other end by metal vapor deposition to enable electrical connection to a wire output electrode 27(-).

Then, the other two end parts are subjected to metal vapor deposition (21B and 22B), and a connection portion 23 connecting the two end parts is formed by metal vapor deposition.

In this manner, the wiring for the power supply of a pulse current is performed from the wire input electrode 26(+) to the wire output electrode 27(-).

[0029] In the present embodiment, the output voltage exhibits sine wave output characteristics relative to a magnetic field H, and the linearity is 0.3% or lower in a measurement range of ±3 to 90G, which is excellent.

The sensitivity is 50 to 2000 mV/G and is about five times higher than that of the GSR sensor element having the same length of magnetic wire.

The pulse power consumption is 0.3 mW (0.15 mA).

[Example]

[0030] The following will describe the GSR sensor element according to an example of the present invention with reference to FIG. 1, FIG. 5, and FIG. 6.

CLAIMS

1. A GSR sensor element, comprising:

an electrode wiring board;

a magnetic wire that is a magnetosensitive body formed on the electrode wiring board;

a coil wound around the magnetic wire;

and four terminals formed on end parts of the coil for connection to an external integrated circuit, wherein

the magnetic wire of the coil includes a pair of magnetic wires having currents flowing in opposite directions through an insulating material,

the coil includes a coil lower part, a coil upper part, and a joint part connecting both, and

the pair of the magnetic wires are separated by an insulating wall in the coil.

2. The GSR sensor element according to claim 1, wherein the pair of magnetic wires included a plurality of pairs of magnetic wires.

3. The GSR sensor element according to claim 1, wherein an outer periphery of the magnetic wire is coated with an insulating material.

4. The GSR sensor element according to claim 1, wherein

the coil includes a recessed coil lower part, a convex coil upper part, and the joint part connecting both,

the pair of the magnetic wires are embedded in a groove on the board coated with an insulating material and are subjected to wiring at the coil lower part and fixed by insulating resin having an adhesion function and a resist function,

an upper part of the pair of the magnetic wires is covered thinly by surface tension of the insulating resin and subjected to wiring at the coil upper part, and

the joint part electrically joints an end part of the coil lower part and an end part of the coil upper part to form a coil.

5. The GSR sensor element according to claim 1, wherein

the coil includes a recessed coil lower part, a plane coil upper part, and the joint part connecting both,

the pair of the magnetic wires are inserted in a groove on the board having an embedded insulating material and are subjected to wiring at the coil lower part,

an upper surface of the groove is subjected to wiring at the coil upper part, and

the joint part electrically joints an end part of the coil lower part and an end part of the coil upper part to form a coil.

6. The GSR sensor element according to claim 1, wherein

the coil includes a plane coil lower part, a convex coil upper part, and the joint part connecting both,

the pair of the magnetic wires are fixed by insulating resin on an upper surface of wiring at the coil lower part performed on a flat surface of the board,

a side part and an upper part of the pair of the magnetic wires are covered thinly by insulating resin and are subjected to wiring at the coil upper part, and

the joint part electrically joints an end part of the coil lower part and an end part of the coil upper part to form a coil.