DESCRIPTION

ULTRA HIGH-SENSITIVITY MICRO MAGNETIC SENSOR

Field

[0001] The present invention relates to a technology of improving sensitivity characteristics of a GSR sensor by adopting rising pulse detection.

Here, the GSR sensor is an ultra high-sensitivity micro magnetic sensor based on the GHz spin rotation effect.

Background

[0002] The high-sensitivity micro magnetic sensor includes a horizontal FG sensor, a vertical FG sensor, a hole sensor, a GMR sensor, a TMR sensor, a MI sensor, a GSR sensor, a high frequency carrier sensor, and the like. These sensors are currently used widely in smartphones, vehicles, medical treatment, robots, and the like. Among the above-described sensors, the GSR sensor is excellent in sensitivity and size, and draws the most attention.

[0003] To achieve remote control of an in-vivo motion device, an investigation is currently advanced for finding a position and a direction by providing a three-dimensional magnetic sensor utilizing a GSR sensor.

The sensor is preferably smaller to provide it in a motion device. However, the detection sensitivity is deteriorated inversely proportional thereto. Furthermore,

magnetic wire and two magnetic wires,

Fig. 11 is an explanatory diagram of the linearity P in relation between the change of the external magnetic field and the output, and

Fig. 12 is a relational diagram between the magnetic field Hx and a deviation amount in the rising pulse of the GSR sensor.

Description of Embodiments

[0019] An embodiment of the invention is described as follows.

Note that one, or two or more configurations arbitrarily selected from the specification may be added to the configuration of the invention. The most preferable embodiment varies depending on a subject and required characteristics.

[0020] A GSR sensor that is an ultra high-sensitivity micro magnetic sensor according to the invention includes

a magnetic field detection element including two conductive magnetic wires for magnetic field detection arranged adjacent to each other on a substrate, a round coil wound around the two magnetic wires, two electrodes for wire energization, and two electrodes for coil voltage detection, a means for applying a pulse current to the magnetic wires, a circuit for detecting a coil voltage occurred when the pulse current is applied to the magnetic wires in opposite directions, and a means for converting

the coil voltage into an external magnetic field H,

in which the magnetic wire has a magnetic anisotropy field of 20 G or less, with a two-phase magnetic domain structure of a surface magnetic domain with circumferential spin alignment and a center core magnetic domain with longitudinal spin alignment, and

the pulse current applied to the magnetic wire has a pulse frequency of 0.2 GHz to 4 GHz and a strength required to generate over a 1.5 times larger circumferential magnetic field than the anisotropy field on a surface of the wire, and

the coil has a coil pitch of 10 μm or less. The average inner diameter of the coil is preferably 35 μm or smaller.

In the case where a plurality of pairs of wires are arranged, the interval between the coil and the magnetic wire is preferably 1 μm to 5 μm.

[0021] Moreover, in the GSR sensor that is the ultra high-sensitivity micro magnetic sensor according to the invention,

the pulse current is applied to the magnetic wire, and the circumferential spin inclined in an axial direction is subjected to super high speed rotation by a wire axial magnetic field in the surface magnetic domain, to take out only a magnetization change in the wire axial direction due to a super high speed rotation phenomena occurred at the

rotation and perform conversion into a field H using an equation (1):

$$Vs = Vo \cdot 2L \cdot \pi D \cdot p \cdot Nc \cdot f \cdot \sin(\pi H/2Hm) \quad \ldots\ldots \quad (1)$$

where Vs is a coil output voltage and Vo is a constant of proportionality, and as a control factor constant, L is a wire length, D is a wire diameter, p is a skin depth of a pulse current, Nc is the number of winding of a coil, f is a pulse frequency, Hm is an external magnetic strength to obtain a maximum coil output voltage.

[0022] Furthermore, the GSR sensor that is the ultra high-sensitivity micro magnetic sensor according to the invention further includes an electronic circuit including a pulse generating circuit for generating the pulse current, an input circuit for inputting a coil voltage, a pulse compliant buffer circuit, a sample hold circuit with an electronic switch for detecting a peak voltage of an output waveform of the coil voltage and a capacitor with a capacitance of 4 to 100 pF for holding the peak voltage, and an programming amplifier for amplification before AD (analog-digital) conversion.

[0023] The embodiment of the invention will be described in detail with reference to Fig. 1 to Fig. 6.

The GSR sensor element (hereinafter, referred to as an

CLAIMS

1. An ultra high-sensitivity micro magnetic sensor, comprising:

a magnetic field detection element including two conductive magnetic wires for magnetic field detection arranged adjacent to each other on a substrate, a round coil wound around the two magnetic wires, two electrodes for wire energization, and two electrodes for coil voltage detection;

a means for applying a pulse current to the magnetic wires;

a circuit for detecting a coil voltage occurred when the pulse current is applied to the two magnetic wires in opposite directions; and

a means for converting the coil voltage into an external magnetic field H, wherein

the two magnetic wires for magnetic field detection include a first magnetic wire and a second magnetic wire, the first magnetic wire and the second magnetic wire being arranged parallel to each other,

the first magnetic wire has a first end and a second end in order according to a direction of the pulse current,

the second magnetic wire has a first end and a second end in order according to the direction of the pulse current,

the first end of the first magnetic wire and the second end of the second magnetic wire are respectively connected to the two electrodes for wire energization,

the second end of the first magnetic wire and the first end of the second magnetic wire are respectively

connected to each other,

the first magnetic wire and the second magnetic wire are separated by an insulating wall interposed therebetween in the round coil,

the magnetic wire has a magnetic anisotropy field of 20 G or less, with a two-phase magnetic domain structure of a surface magnetic domain with circumferential spin alignment and a center core magnetic domain with longitudinal spin alignment, and

the pulse current applied to the magnetic wire has a pulse frequency of 0.2 GHz to 4.0 GHz and a strength required to generate over a 1.5 times larger circumferential magnetic field than the anisotropy field on a surface of the wire, and

the coil has a coil pitch of 10 μm or less.

2. The ultra high-sensitivity micro magnetic sensor according to claim 1, wherein the pulse current is applied to the magnetic wire, and the circumferential spin inclined in an axial direction is subjected to super high speed rotation by a wire axial magnetic field in the surface magnetic domain, to take out as a coil output only a magnetization change in the wire axial direction due to a super high speed rotation phenomena occurred at the rotation and perform conversion into a field H using an equation (1):

$$Vs = Vo \cdot 2L \cdot \pi D \cdot p \cdot Nc \cdot f \cdot \sin(\pi H/2Hm) \quad \cdots\cdots (1)$$

where Vs is a coil output voltage and Vo is a constant of proportionality, and as a control factor constant, L is a wire length, D is a wire diameter, p is a skin depth of a pulse current, Nc is number of winding of a coil, f is a

pulse frequency, Hm is an external magnetic strength to obtain a maximum coil output voltage.

3. The ultra high-sensitivity micro magnetic sensor according to claim 1, further including an electronic circuit including a pulse generating circuit for generating the pulse current, an input circuit, a pulse compliant buffer circuit for inputting the coil voltage, a sample hold circuit with an electronic switch for detecting a peak voltage of an output waveform of the coil voltage and a capacitor with a capacitance of 4 to 100 pF for holding the peak voltage, and an programming amplifier for amplification before AD conversion.