High Sensitive Magnetic Field Sensor Using Amorphous Wire and Micro-fabricated Fine Pitch Coil

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There were various types of magnetic field sensors available at present to measure the magnetic fields from electromagnet, motor, earth field, and bio-magnetic field. Among these sensors, only a SQUID magnetic field sensor is used to detect quite small magnetic field from biological activity, e.g., human brain and heart fields. However, low temperature facilities are required to operate SQUID sensors, and thus high sensitive magnetic field sensors operated at room temperature are desirable to detect the small bio-magnetic signals without large medical facilities. One of the candidates is a magneto-impedance sensor[1)] which is comprised of an amorphous ferromagnetic wire and winding coils; we refer to this sensor as an amorphous wire sensor.

The amorphous wire for the magnetic field sensor is known to have a special domain structure due to its induced magnetic anisotropy and shape anisotropy, i.e., magnetization in the wire surface layer points in the circumferential direction and one in the wire center points along the wire axis. When the wire is placed in the magnetic field, the surface magnetization canted slightly along the field direction. The pulse current flowing along the wire tends to rotate back the surface magnetization in the circumferential direction, which induce the induction voltage to the coil winding the wire. The ultimate sensitivity of the amorphous wire sensor will be the thermal stability of the domain structure. For the detection of the bio-magnetic field of around 1 pT, the thermal stability factor K_uV should be larger than M_s × 1 pT, where K_u, V, and M_s are the uniaxial anisotropy, volume, and magnetization of the wire, respectively. If we assume the K_u = 1 kerg/cc and M_s = 1000 emu/cc, which corresponds to saturation field of 2 Oe, the necessary dimension to have sufficient K_uV for the detection of 1 pT is estimated to be 4 μmϕ x 500 μm, which is smaller than the present amorphous wire sensor.

The present amorphous wire sensor utilizes the wire of 15 μmϕ × 500 μm and winding coil with a turn number N of 16 (coil pitch of 30 μm), and it is reported to detect the magnetic field of 10 nT[2)]. Since the sensitivity of the wire is roughly proportional to NL^2 / D^2, where L and D are the wire length and diameter, respectively, the wire dimension of 5 μmϕ × 900 μm and winding coil with a coil pitch of 2 μm, corresponding to turn number of ~400, are estimated to be required. In this talk, we describe the micro-fabrication of the amorphous wire sensor with a coil pitch of 5.5 μm, and report the output of the sensor by flowing the pulse current in the wire under an external magnetic field. Figure 1 shows the optical micrograph of the micro-fabricated amorphous wire sensor with a wire dimension of 15 μmϕ × 420 μm and coil turn number of 42. The output signal of this sensor was confirmed to have 3 times larger amplitude than that of commercially available magneto-impedance sensor which has a coil turn number of 16.

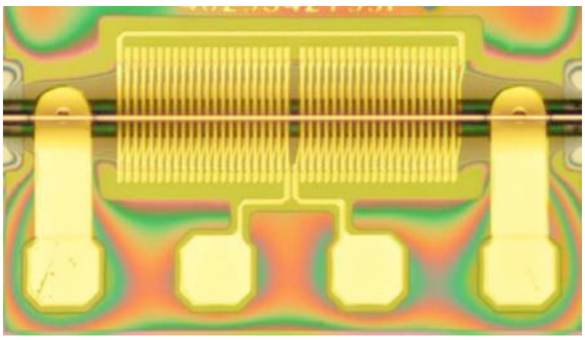

Fig. 1 Optical micrograph of the micro-fabricated amorphous wire sensor with a wire of 15 μmϕ × 420 μm and winding coil with a pitch of 5.5 μm.

Reference
1) L. V. Panina *et al.*, Appl. Phys. Lett., **65**, 1189 (1994).
2) N. Hamada *et al.*, PIERS Proc. 860 (2014).