열영상 현미경을 이용한 PHE 센서의 인가전류에 따른 온도변화 측정

Measurement of Temperature Variation on PHE sensor with Applied Currents using Infrared Thermal Microscope

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Key words : Infrared Thermal Microscope , PHE sensor, Temperature Variation

1. Introduction

Magnetic sensor can detect magnetic field. Several kinds of magnetic sensors have been fabricated for use in microcompasses, magnetic random access memory and magnetic biosensors, such as anisotropic magnetoresistance (AMR), giant manetoresistance (GMR) magnetic tunnel junctions (MTJ), micro-Hall sensors, and planar Hall effect (PHE) sensors [1].

PHE sensors have prominent merits of high signal-to-noise ratio and very linear response at low field range compared to other magnetoresistive sensors. However its sensitivity was not so high compared to others [1].

The sensitivity of PHE sensors have been improved by applying high sensor current and employing PHE multi-ring geometry and design of thicker ferromagnetic layer or trilayer [2-4]. However, these modifications raise an increase of inherent resistance of PHE sensor.

A direct electrical readout in bioassay can be obtained from magnetic biosensors capturing magnetic beads with biomolecules on its surface. Biomoleucles or organisms are heat-sensitive.

In this study, we have compared the change of temperature of PHE sensors with applied currents. These results will provide the basic information and confidence for its applications.

2. Materials and Methods

We have fabricated different shapes (ring and cross-shaped) of PHE sensor with Ta (3 nm)/NiFe (20 nm)/IrMn (10 nm)/Ta (3 nm) exchange bias material structure. They were prepared by a standard photolithographic technique and lift off process. The junctions were connected with Ta (10 nm)/Au (200 nm) electrodes.

The thermal and sensor properties of PHE sensor were measured at several currents applied to a set of electrodes. The change of the output voltage was measured with electrodes vertical to the current electrodes. The Magnetic field was applied to the sensor by using Helmholtz coil with controlled current. The thermal image of sensor was captured with IR camera and used to measure the change of temperature of current-imposed PHE sensor.

3. Results and Discussion

Several shapes of PHE sensor were designed for application and characterized its performance. There is an increment in sensor sensitivity from cross-shaped to ring-shaped sensors (Fig. 1). Also, the sensor sensitivity further increases with the number of rings. Moreover, sensitivity also increases with the applied sensor current. Different applied current can

be used for various purposes of sensor applications. Infrared thermal imaging was used to observe the applied current-produced temperature change in a PHE sensor with 17 rings (Fig. 2). The applied current induced initially exponential increase of sensor temperature which then was going to slowly steady state. The sensor had the highest inherent resistance and also showed the largest increase of temperature about 5 °C. The change of temperature was correlated with the number of ring and applied current, resulting from Joule heating (Fig. 3).

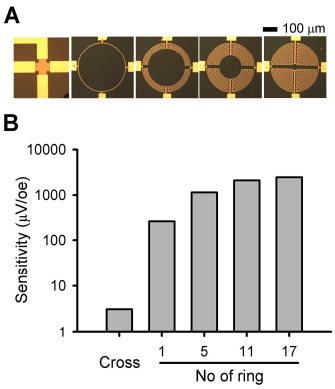

Fig. 1 Design of PHE sensor (A) and its sensitivity to magnetic field (B). The sensitivity was measured with applied sensor current of 2 mA.

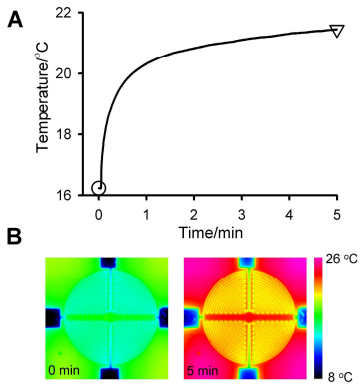

Fig. 2 Change of temperature (A) and infrared thermal image at 0 and 5 min (B) of 17 ring PHE sensor applied with 2 mA.

4. Conclusion

Increase of temperature was observed with various design of PHE sensors. It showed correlation with applied sensor current and inherent sensor resistance. The change of temperature should be considered in PHE sensor applications, especially as biosensor.

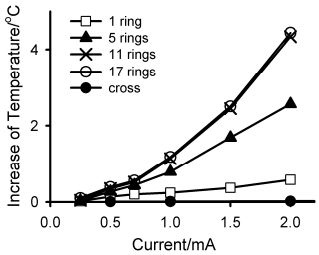

Fig. 3 Increase of temperature by PHE sensors at different applied currents.

Acknowledgements

This research was supported by the World Class University program (R32-20026) and the Korea Basic Science Institute Grant (D32200).

Reference

1. Freitas, P.P., Ferreira, F.A., Graham, D.L., Clarke, L.A., Amaral, M.D., Martins, V., Fonseca, L., and Cabral, L., in: *Magnetoelectronics*, edited by M. Johnson, Elsevier, Amsterdam (2004). Montaigne,
2. Hung, T.Q., Oh, S., Sinha, B., Jeong, J.-R., Kim, D.-Y. and Kim, C.G., "High field-sensitivity planar Hall sensor based on NiFe/Cu/IrMn trilayer structure," J. Appl. Phys. **107**, 09E715-09E717, 2010.
3. Henriksen, A.D, Dalslet, B.T., Skieller, D.H., Lee, K.H., Okkels, F., and Hansen, M.F., "Planar Hall effect bridge magnetic field sensors," Appl. Phys. Lett. **97**, 013507-013509, 2010.
4. Sinha, B., Oh, O., Ramulu, T.S., Lim, J., Kim, D.-Y., and Kim, C.G., "Planar Hall effect ring sensors for high field-sensitivity," Advanced Materials Research , **317-319**, 1136-1140, 2011.