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Octagonal MOSFET for Simultaneous Sensing of Temperature and Magnetic Field

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Abstract

In this paper, we design, fabricate, and evaluate temperature and magnetic field detectable Octagonal MOSFET sensor. In previous works, one sensor device, such as resistor, capacitor, and etc., can detect only one physical or chemical phenomenon. In order to acquire a lot of information of the outside world, many sensors are necessary. Thus, sensor system may become large. However, multi sensing operation is available for proposed sensor device, octagonal MOSFET type Hall sensor. This sensor can detect both magnetic field and temperature at the same time. As the results, we can realize that sensitivity of magnetic field and temperature are 16.3 mV/T and 0.053 mV/℃, respectively.

1. Introduction

A Hall sensor is a small magnetic sensor currently in use. Normally, compound semiconductors such as GaAs and InSb are used as the material of the Hall sensor. By using these materials, it is possible to detect a magnetic field with high sensitivity, but there are disadvantages of using Si-based semiconductor processes due to high cost integration. Therefore, by making the Hall sensor using Si MOSFET, it is possible to manufacture the sensor by the existing Si process, and it is possible to obtain merit such as low cost and easier circuit incorporation [1].

By making the MOSFET sensor structure an octagonal shape [2], the electrode arrangement becomes line symmetrical and point symmetrical, and an effect of suppressing deviation of terminals at the time of manufacturing can be expected. It has been shown that it can be used as a stress detection element or a temperature detection element as a previous study [2] and it can be expected to be utilized as a multi sensor.

In this paper, we propose and evaluate an octagonal MOSFET sensor that can simultaneously measure temperature and magnetic field using Hall effect.

2. Temperature and Hall sensor for Octagonal MOSFET

Device design

Fig. 1 (a) and fig.1 (b) show the device layout and microphotograph of Octagonal MOSFET. This device is designed and fabricated by 2.0um 1-poly 2-metal CMOS process [2].

In general, MOSFET has only Gate, Drain, Source, and Bulk electrode. But, octagonal MOSFET has additional 6 output electrodes which locate along the side of regular octagon radially. Thus, these electrodes, which are A to H in fig.1, can be defined source, drain, one pair of hall effect detection outputs, which is perpendicular to drain current direction, and the other pair of temperature sensing output, which is parallel to drain current direction, arbitrarily.

Measurements and results

Fig.2 (a)(b) show the definition of source, drain, hall effect output, and temperature output. When octagonal MOSFET is used as Hall sensor, it is assumed that Drain-Source is any one of A-E, B-F, C-G and D-H. The terminal pair orthogonal to them is output terminal for magnetic field detection (output for Hall effect), and the parallel terminal pair is output terminal for temperature detection.

Fig.3 shows the measurement system for both magnetic field and temperature sensing. By arranging the sensor at the center between the two coils, it is possible to obtain a uniform magnetic field at the center part between the coils. This system is covered with permalloy shield to avoid the influence of geomagnetism. Fig.4 shows the electrical measurement method. V_{TEMP} and V_{HALL} is temperature output voltage and magnetic field output voltage, which is hall voltage, respectively. Since two terminals, temperature and hall effect output terminals, are independent from each other, these two parameters can be measured at the same time.

Fig.5 shows the result of the Hall effect at Drain-Source=A-E. From these results, it can be confirmed that ΔV_{HALL} changes almost linearly with the applied magnetic field. Therefore, an octagonal MOSFET can be used as a Hall sensor.

Fig.6 and fig.7 show the results of multi sensing operation (simultaneous measurement for the temperature and magnetic field). In fig.6 and 7, T is the temperature of fig.2 measured using thermocouple gauge, and the other data are from voltages of hall effect and temperature measurement terminals. When the magnetic field is applied, heat is generated. Thus, temperature is increased in this field. From the result of temperature, ΔV_{TEMP} and temperature from thermocouple gauge are almost the same behavior. Thus, both hall effect and temperature detection are available in proposed device. Sensitivity of magnetic field and temperature are 16.3 mV/T and 0.053 mV/℃, respectively.

3. Conclusions

An octagonal MOSFET can be used as a Hall element and can be expected to be utilized as a multi sensor that can simultaneously detect two kinds of physical quantities such as a magnetic field and a temperature by an output terminal pair to be used.

Acknowledgements

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References

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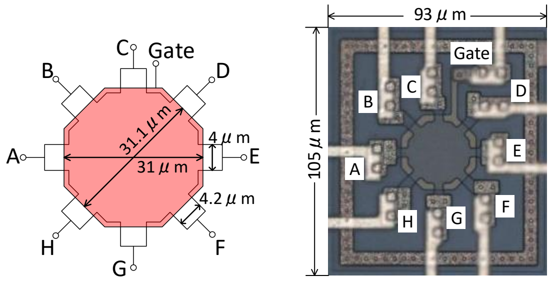
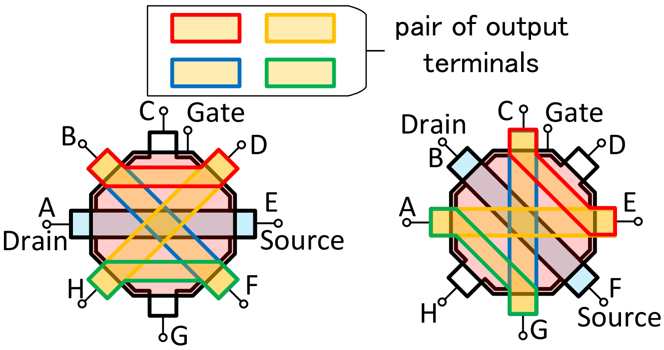
[2] T.Harada, K.Kaiwa and Y.Yamazaki, “No Reattaching and 8 Directions Detectable Octagonal MOSFET Stress Sensor”,2015 International Conference on Solid State Devices and Materials(SSDM), F-6-4,pp848-849, Sep.30, 2015



(a) device layout (b) microphotograph

Fig.1 octagonal MOSFET [2]



(a) Drain=A, Source=E (b) Drain=B, Source=F

Fig.2 definition of temperature outputs and drain-source direction. If the Drain-Source=A-E, a pair of output terminals for Hall effect is C-G. If the Drain-Source=B-F, a pair of output terminals for Hall effect is D-H.

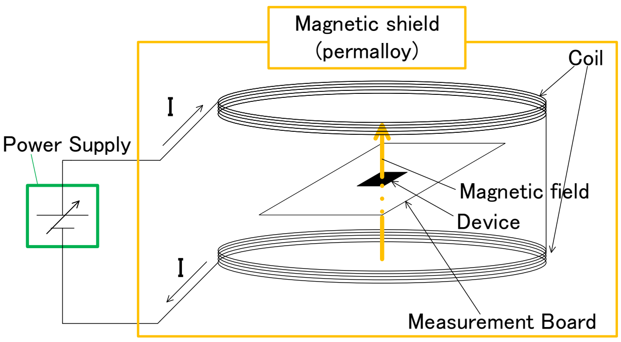


Fig.3 measurement environment

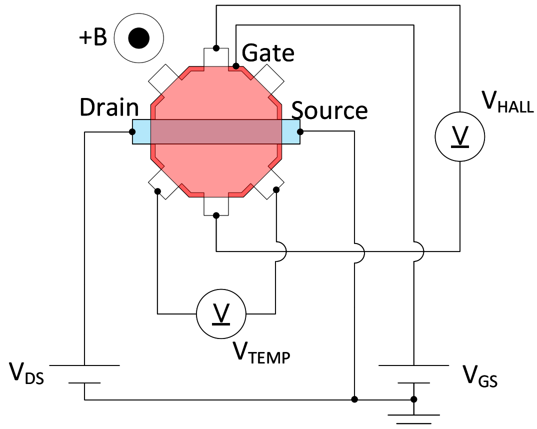


Fig.4 octagonal MOSFET electrical measurement method

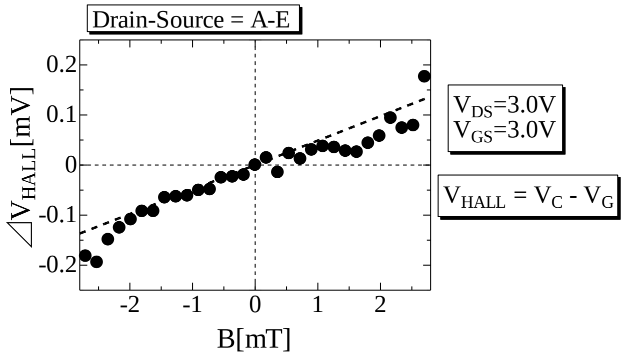


Fig.5 measurement result of hall effect when drain and source are A and E, respectively.

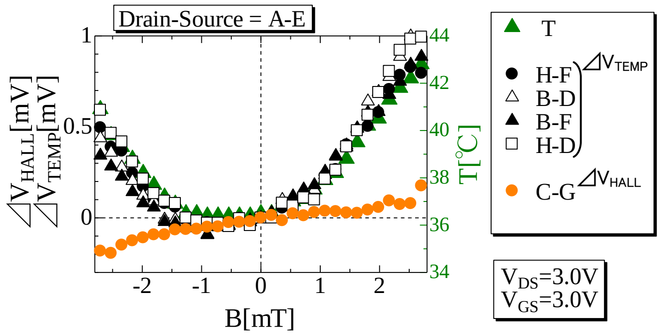


Fig.6 the measurement results of multi sensing operation, both magnetic field and temperature, at Drain-Source=A-E.

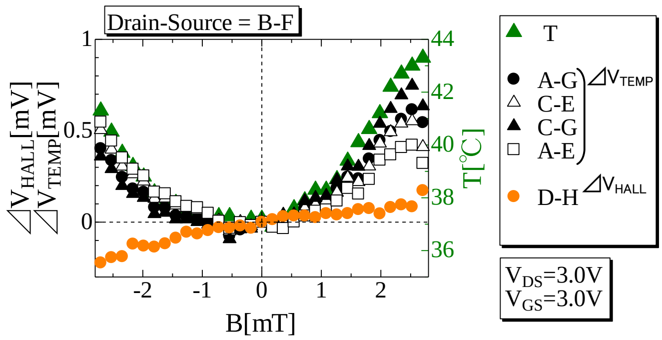


Fig. 7 the measurement results of multi sensing operation, both magnetic field and temperature, at Drain-Source=B-F