Proceedings of the International MultiConference of Engineers and Computer Scientists 2017 Vol II,
IMECS 2017, March 15 - 17, 2017, Hong Kong

Application of Multi-Dimensional Hall Sensor for Gauss Measurement

Yongyut Kaewjumras, Athirot Mano, and Wisut Titiroongruang

***Abstract*—This paper reported on a two-dimensional Hall sensor enabling to measure the two spatial components of the magnetic field and applied for gauss measurement application. The device was operated through only five contacts and tested by varying the magnetic flux density from -5000 to 5000 Gauss (G) and using signal conditioning circuitry for amplifying and adjusting the both similar sensitivity. After that, the output signals were converted to digital signals by ADC for transmitting a computer using LAB-VIEW programming and comparison with the standard gauss meter (F.W.Bell5170). The result of gauss measuring application comparison with the standard gauss meter has done with a precision of 0.04-3.80% including a calibration process.**

***Index Terms*—Hall effect, Two-dimensional Hall sensor, Sensitivity, Signal conditioning circuitry.**

I. Introduction

A Hall effect sensor in silicon (Si) are used for applications in current measurement, angular measurement, and gauss measurement etc. Of particular interest is gauss measurement technique which is a contactless position sensing using a magnetic flux density and a Hall effect sensor. Conventional Hall sensor serves to measure the perpendicular-dimensional magnetic field vector (B_z). One-dimensional may not be able to get accurate in measurement that a Hall sensor should be capable of multi-directional sensing with magnetic field sensitivity. With such multi-directional sensing, the contactless detection can be executed with high accuracy. These two-directional (2D) Hall sensor detects simultaneously two in-axis z-x magnetic field components B_z and B_x [1,2].

In [3], an application of 2-D silicon Hall device for independent directional magnetic field measurement technique was proposed and experiments carried out.
The author mentioned that the 2-D silicon hall device was capable of sensing in two-dimensional and independent directional magnetic field.

The present paper aims at making a comparison standard gauss meter and gauss measurement from two-dimensional Hall sensor based on a simple silicon process technology. The advantage of this two-dimensional Hall sensor is that its be capable of sensing a magnetic field one more direction, perpendicular-directional (B_z) and parallel-directional (B_x). Furthermore, signals from the device are coalesced to signal conditioning circuitry for amplifying and adjusting similar sensitivity, and then the output signals were converted to digital signals by ADC for transmitting a computer using LAB-VIEW programming and comparison with the standard gauss meter (F.W.Bell5170). This technique is capable of sensing magnetic flux density with high accurate measurement. Section II briefly the concept and the two-dimensional Hall structure device. The experimental examination of the absolute sensitivity and gauss measurement technique corresponding the two-dimensional Hall sensor are described in Section III. Results and Discussion are presented in Section IV and a conclusion in Section V.

Kaewjumras, A. Mano, and W. Titiroongruang are with Department of Electronic Engineering, Faculty of Engineering, King Mongkut's Institute of technology Ladkrabang, Bangkok 10520, Thailand.(email:Yongyutkaewjumras@gmail.com,manoathirot@yahoo.com, ktwisut@kmitl.ac.th).

II. Concept and Structure of 2D Hall Sensor

In [4,5] it has been concluded that ideal conventional and vertical Hall effect sensor were combined. The two-dimensional Hall sensor was fabricated using silicon technology on a p-type silicon wafer with a resistivity range of 20-30 Ω.cm. The aluminum was grown on the substrate using RF-sputtering and consequently etched for five ohmic contacts (i.e.C1,C2,C3,C4,C5). In the experiment, the bias currents were applied to C1 and C2. Meanwhile, the output Hall voltage was measured at C1,C2 and at C3,C4 for parallel- and perpendicular-directional sensing, respectively. C5 is the ground contact. The entire sensor has an active area of 600x300μm^2 as figure 1. Both the two output signals were coalesced to signal conditioning circuitry for amplifying signals and adjusting the similarly absolute sensitivity and comparison with standard gauss meter (F.W.Bell5170).

III. The Operating Principle

The magnetic field measurement includes two-dimensional Hall sensor, signal conditioning circuitry, analog to digital converter, and computation stage. The diagram of measurement as depicted in Figure 2.

In the first experiment, A bias current 1 mA was applied to C1 and C2 correspondingly through two resistors (R1,R2). C5 is the ground contact. An electromagnet (Ohsumi Electric Manufacture) was deployed to generate the magnetic field for testing, in which the magnetic flux density was varied between -5000 and 5000 Gauss (G). the output signal of both perpendicular- and parallel-field

ISBN: 978-988-14047-7-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

absolute sensitivity were tested on two-dimensional Hall sensor. The Hall output voltages, in the perpendicular direction were taken at C3 and C4, while in the parallel direction at C1 and C2. Figure 3 illustrates the operating principle of the proposed sensor and the electromagnet.

After that, the both output signals were connected to signal conditioning circuitry for amplifying and adjusting similar absolute sensitivity, then output signals were converted to digital signals by ADC for transmitting a computer using LAB-VIEW programming and comparison with standard gauss meter (F.W.Bell5170).

IV. EXPERIMENTAL RESULTS

As the results, the perpendicular- and parallel-directional absolute sensitivity of the two-dimensional Hall sensor were imposed by varying the magnetic flux density between -5000 and 5000 Gauss. The perpendicular-directional absolute sensitivity of C3 and C4 was highly linear, corresponding to Y = 0.000146x + 0.001800, with the perpendicular absolute sensitivity of 0.000146 mV/G. Meanwhile, the perpendicular-directional absolute sensitivity of C1 and C2 was negligible, as illustrated in Figure 4.

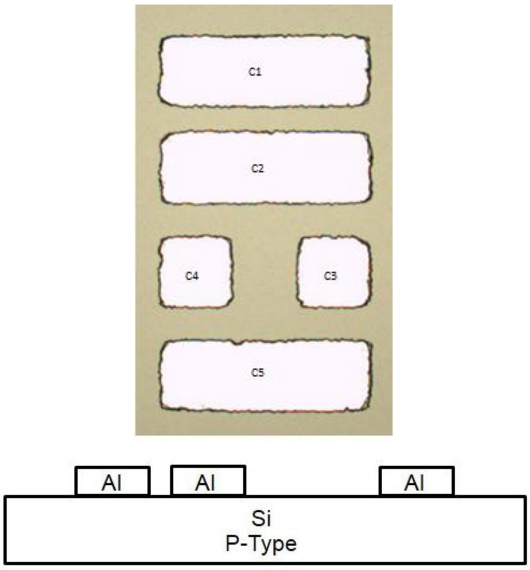

Fig.1 Top-view and cross-section of two-dimensional Hall sensor.

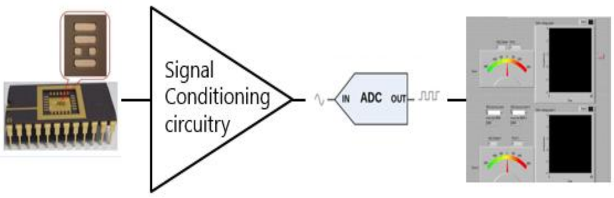

Fig.2 The diagram of gauss measurement.

Fig.3 The operating principle of the proposed sensor and the electromagnet.

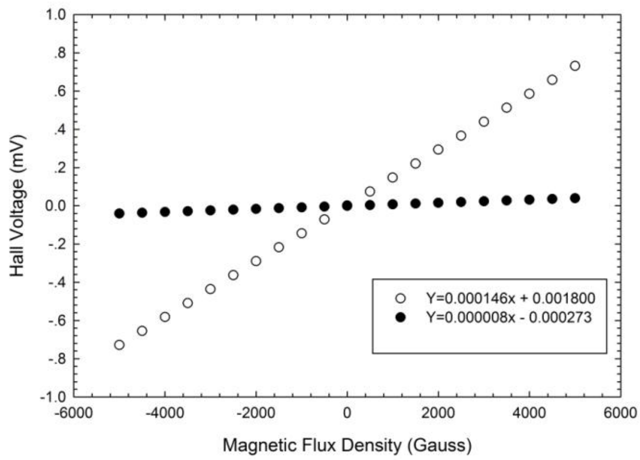

Fig.4 The perpendicular-directional absolute sensitivity of the two-dimensional Hall sensor.

ISBN: 978-988-14047-7-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

In Figure 5, the parallel-directional absolute sensitivity of C1 and C2 was significantly linear, corresponding to Y = 0.000703 – 0.005600, with the absolute sensitivity of 0.000703 mV/G. On the other hand, the parallel-directional sensing was inconsequential for C3 and C4.

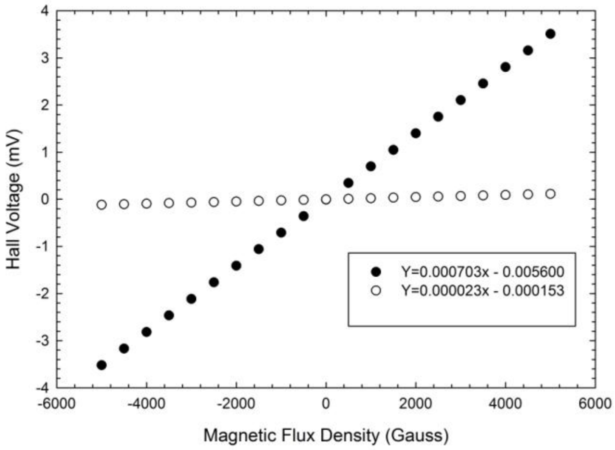

Fig.5 The parallel-directional absolute sensitivity of the two-dimensional Hall sensor.

The output from signal conditioning circuitry was amplified and adjusted the similar absolute sensitivity of both directions. In addition, the perpendicular- and parallel-directional absolute sensitivity of the proposed two-dimensional Hall sensor was determined by varying the magnetic flux density between -5000 and 5000 Gauss and the absolute voltage signal was measured. In Figure 6, the perpendicular- and parallel-directional absolute sensitivity were 0.00102 mV/G and 0.001013 mV/G, respectively. The both of absolute sensitivity was similarly sensing.

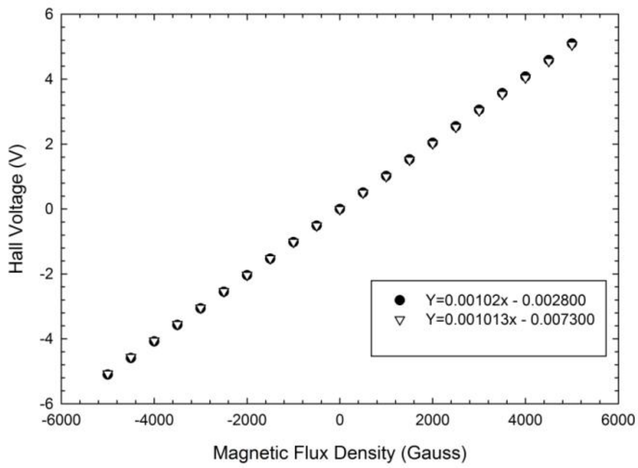

Fig.6 The both of absolute sensitivity of the two-dimensional Hall sensor with signal conditioning circuitry.

The output from signal conditioning circuitry was prepared for the gauss measuring application comparison with standard gauss meter (F.W.Bell5170) by varying the magnetic flux density from 0 to 5000 Gauss. The output result was analyzed and calculated using LAB-VIEW programing. Figure 7 illustrated the gauss measuring application comparison with a standard gauss meter. The achieved total gauss measuring application accuracy of the laboratory setup of the two-dimensional Hall sensor was 0.04 – 3.80% for the comparison standard gauss meter.

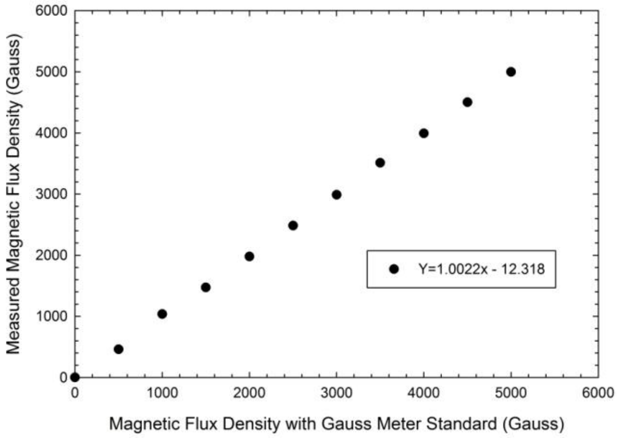

Fig.7 The gauss measuring application comparison with standard gauss meter (F.W.Bell5170).

The experimental results validate the utility of the gauss measuring application comparison with standard gauss meter were listed in Table1.

V. CONCLUSION

This paper has proposed the ideal conventional Hall sensor and vertical Hall sensor by a combination that the two-dimensional Hall sensor was capable of magnetic sensing in both perpendicular and parallel directions. We introduced for this application the two sensitive directions as a first step of amplifying with the signal conditioning circuitry for both similar sensitivities. The result of gauss measuring application comparison with the standard gauss meter has done with a precision of 0.04-3.80% including a calibration process.

TABLE I
TECHNICAL DATA OF GAUSS MEASURING APPLICATION COMPARISON WITH STANDARD GAUSS METER

Setting magnetic flux density with standard gauss meter (Gauss)	Measured magnetic flux density (Gauss)	Error (%)
0	0	0
500	481	3.80
1000	1036	3.60
1500	1472	1.86
2000	1978	1.10
2500	2483	0.68
3000	2989	0.36
3500	3512	0.34
4000	3994	0.15
4500	4503	0.06
5000	4998	0.04

ACKNOWLEDGMENT

The authors would like to extend sincere appreciation to the Thai Microelectronics Center (TMEC) for the technical contributions to this research.

REFERENCES

[1] R S Popovic, Hall Effect Devices. 2nd ED. IOP Publishing Ltd, 2004.

[2] Dieter K.Schroder, Semiconductor material and device characterization. John Wiley&Sons, New York, 1990.

[3] Athirot Mano and Wisut Titiroongruang, "An application of 2-D Silicon Hall Device for Independent Directional Magnetic Field Measurement Technique" International Journal of Industrial Electronics and Electrical Engineering, Vol. 3, June 2015.

[4] Yongyut Kaewjumras, Athirot Mano, Amporn Poyai and Wisut Titiroongruang "Effect of different ohmic contact widths and distances on the absolute sensitivity of the two-dimensional Hall sensor" The 6th KKU International Engineering Conference.

[5] Mano A, Titiroongruang W. A Fabrication of low cost two dimensions Hall effect sensor base on silicon technology. 8th Conference of Electrical Engineering Network of Rajamangala University of Technology 2016 (EENET 2016); 2016 May 25-27; Phuket, Thailand. Nakhon Pathom: Rajamangala University of Technology Rattanakosin; 2016.

BIOGRAPHIES

Yongyut Kaewjumras was born on 1989, Thailand. He received his B.Sc. degree in Applied physics (2010) and M.Eng. degree in Microelectronics (2013) at the King Mongkut's Institute of Technology Ladkrabang. His scientific focus is on Silicon sensor, Semiconductor materials and characterization, Magnetic material and its application. He is currently studying in Electrical Engineering at the Faculty of Engineering at the King Mongkut's Institute of Technology Ladkrabang.

Athirot Mano was born on 1986, Thailand. He received the bachelor's degree major in Applied Physics, Faculty of Science and received the Master's degree major in Microelectronics Engineering at Electronics Engineering Department from King Mongkut's Institute of technology Ladkrabang (KMITL). His current research interests include Silicon sensor and signal conditioning, Semiconductor materials and characterization, Magnetic material and its applications. He was served as a teaching assistant at Department of Applied Physics, Faculty of Science (KMITL). For subjects that were served as a teaching assistant are Semiconductor Device Laboratory, Atomic Structures Laboratory and Basic Electronics Laboratory.

Wisut Titiroongruang was born on 1957,Thailand. He obtained the B.E and M.E degree in Electronics Engineering from King Mongkut's Institute of Technology Ladkrabang(KMITL) and Ph.D. degree from Tokai University in Japan. His current research interests include Superconductor materials, Diamond thin film synthetic, Semiconductor device and its application. He teaches in Electronics at the department of electronics of the King Mongkut's Institute of Technology Ladkrabang.

ISBN: 978-988-14047-7-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)