



Effects of different ohmic contact widths and distances on the absolute sensitivity of two-dimensional hall sensor

Yongyut Kaewjumras¹⁾, Athirot Mano¹⁾, Amporn Poyai²⁾ and Wisut Titiroongruang^{*1)}

¹⁾Department of Electronic Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.

²⁾Thai Microelectronics Center (TMEC) 51/4 Moo 1, Wang-Takien, Amphur Muang, Chachengsao 24000, Thailand.

Received April 2016
Accepted June 2016

Abstract

This research has investigated the effect of different ohmic contact widths and spacing (distances) on the perpendicular- and parallel-directional absolute sensitivity of silicon-based two-dimensional (2D) Hall sensors. The experimental sensors were of two configurations. The first configuration was of 100 μm and 40 μm in width (W) and spacing (S), while the other configuration was of 300 μm in W and 60 μm in S. The sensors were fabricated on a 20-30 $\Omega\cdot\text{cm}$ -resistivity p-type silicon substrate with five etched aluminum (Al) ohmic contacts. In the experiment, the perpendicular and parallel absolute sensitivity of the sensors were tested by varying the magnetic flux density from -5000 to 5000 Gauss (G). The findings revealed that the proposed sensors were capable of magnetic sensing in both perpendicular and parallel directions. Specifically, the perpendicular absolute sensitivity of the sensor with the 300 μm contact width was 2.08 times higher than that with 100 μm width. Meanwhile, the parallel absolute sensitivity characteristics associated with the two different contact distances (i.e. 40 μm and 60 μm) were similar. Thus, the ohmic contact width plays a more crucial role in the sensitivity enhancement of the Hall sensors.

Keywords: Hall effect, 2D hall, Hall structure, Width space, Sensitivity

1. Introduction

In the magnetic field measurement system, a Hall effect sensor is typically deployed to sense the magnetic flux density. The most common Hall sensor structures include the magnetic field effect transistor (MAGFET), magneto diode, magneto transistor and conventional Hall plate [1]. Of particular interest is the conventional Hall plate which is of straightforward structure and high linear sensitivity. The determinants of the Hall sensor sensitivity encompass its structure, mobility and the carrier concentration [2-3]. Ideally, a Hall sensor should be capable of multi-directional sensing with high magnetic field sensitivity and wider applications.

In [4], a low-cost two-dimensional silicon-based planar Hall effect sensor was proposed and experiments carried out. The author documented that the absolute sensitivity of the Hall device was subject to the width and spacing (i.e. distance) between ohmic contacts.

The aims of this research are to propose two-dimensional (2D) silicon-based Hall sensors capable of perpendicular and parallel magnetic sensing; and to examine the parameters influencing the absolute sensitivity of the sensor. The parameters under investigation consist of the width (W) and spacing (S) between ohmic contacts (C) on the substrate, whereby both parameters were varied and the sensor's

absolute sensitivity measured. The perpendicular- and parallel-directional absolute sensitivity characteristics are respectively correlated to the varying widths and distances between ohmic contacts [1].

2. Devices design and experiment

2.1 Device design

The proposed 2D Hall sensors are of simple structure fabricated using the silicon technology on a p-type silicon wafer with a resistivity range of 20-30 $\Omega\cdot\text{cm}$. In the sensor fabrication, aluminum (Al) was grown on the substrate using RF-sputtering and subsequently etched for five ohmic contacts (i.e. C1, C2, C3, C4, C5). In the experiment, the drive currents were applied to C1 and C2, while the output Hall voltages were measured at C1, C2 and at C3, C4 for the parallel- and perpendicular-directional sensing, respectively. C5 is the ground contact. The entire sensor has an active area of 600x300 μm^2 .

In this research, the experiments were carried out with two different configurations of 2D Hall sensor and the sensor sensitivity determined. In the first configuration, the spacing (S) between C1 and C2 and the width (W) between C3 and C4 were respectively 40 μm and 100 μm . Meanwhile, in the second configuration, the spacing (S) between C1 and C2

*Corresponding author.

Email address: Yongyutkaewjumras@gmail.com, manoathirot@yahoo.com, Amporn.poyai@nectec.or.th, ktwisut@kmitl.ac.th*
doi: 10.14456/kkuenj.2016.60

and the width (W) between C3 and C4 were 60µm and 300µm. The schematics of both configurations are respectively illustrated in Figures 1(a)-(b).

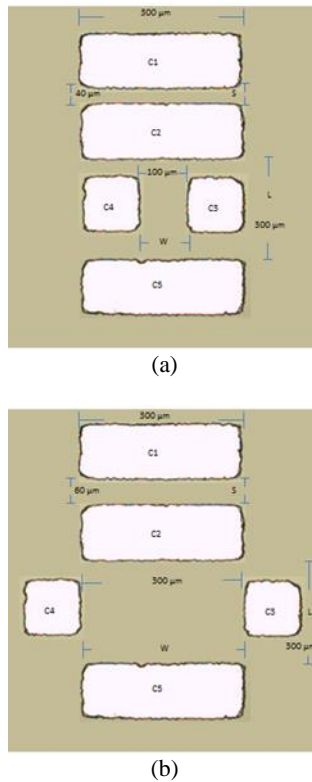


Figure 1 The top view of the proposed 2D Hall sensors: (a) 1st structure, (b) 2nd structure

2.2 Experiment

The perpendicular- and parallel-directional absolute sensitivity characteristics of both configurations of 2D Hall sensors were investigated. In the experiment, a 1mA bias current was applied to C1 and C2 correspondingly through two resistors (R1, R2). In addition, the measurements of the Hall output voltages, using a Fluke 8808A multimeter, in the perpendicular direction were taken at C3 and C4, while those in the parallel direction at C1 and C2. A magnetizer (Ohsumi Electric Manufacture) was deployed to generate the magnetic field for testing the 2D Hall sensors, in which the magnetic flux density was varied between -5000 and 5000 Gauss (G) [5]. Figure 2 illustrates the operating principle of the proposed sensor and the magnetizer.

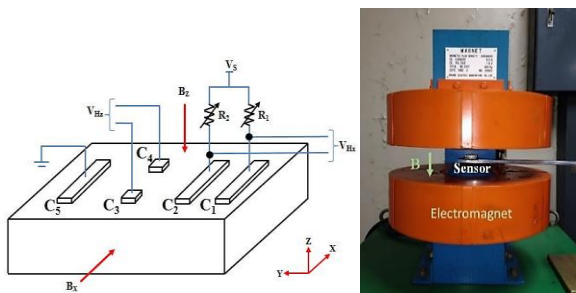


Figure 2 The operating principle of the proposed sensor and the magnetizer

3. Results and discussion

In this research, the perpendicular and parallel-directional absolute sensitivity of the proposed 2D Hall sensors were determined by varying the magnetic flux density between -5000 and 5000 Gauss. In the first configuration (W = 100µm, S = 40µm), the perpendicular-directional absolute sensitivity of C3 and C4 was significantly linear, corresponding to $Y = 0.000074x - 0.000558$, with the perpendicular absolute sensitivity of 0.000074mV/G. On the other hand, the perpendicular-directional absolute sensitivity of C1 and C2 was negligible, as depicted in Figure 3.

In Figure 4, the parallel-directional absolute sensitivity of C1 and C2 was significantly linear, corresponding to $Y = 0.000699x + 0.005385$, with the absolute sensitivity of 0.000699mV/G. Meanwhile, the parallel-directional sensing was inconsequential for C3 and C4.

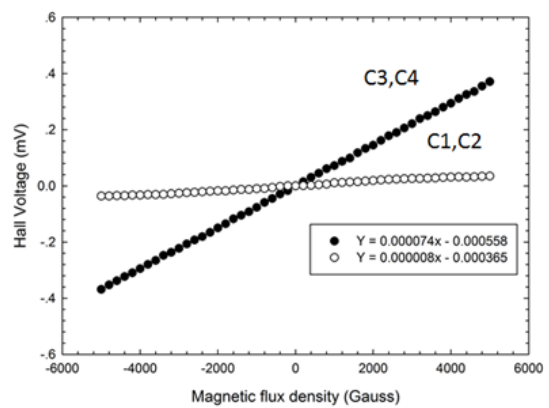


Figure 3 The perpendicular-directional absolute sensitivity of the 2D Hall sensor of the first configuration

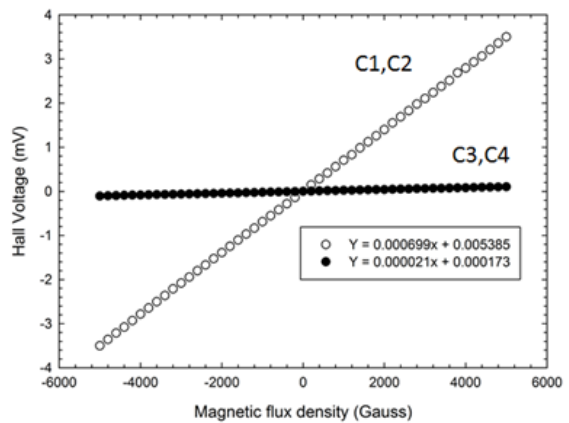


Figure 4 The parallel-directional absolute sensitivity of the 2D Hall sensor of the first configuration

In the second configuration (W = 300µm, S = 60µm), the perpendicular-directional absolute sensitivity of C3 and C4 was significantly linear, corresponding to $Y = 0.000154x + 0.004731$, with the perpendicular absolute sensitivity of 0.000154mV/G. On the other hand, the perpendicular-directional sensing was negligible for C1 and C2, as depicted in Figure 5.

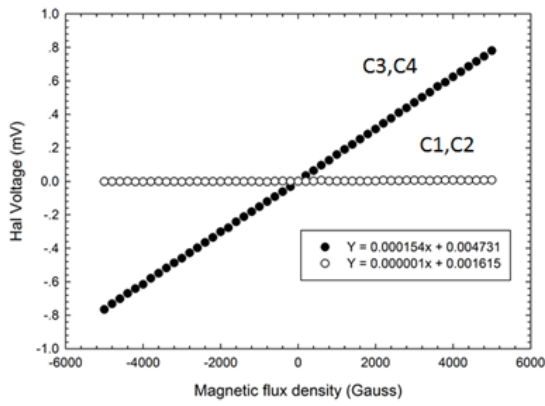


Figure 5 The perpendicular-directional absolute sensitivity of the 2D Hall sensor of the second configuration

In Figure 6, the parallel-directional absolute sensitivity of C1 and C2 was significantly linear, corresponding to $Y = 0.000747x - 0.001423$, with the absolute sensitivity of 0.000747mV/G. Meanwhile, the parallel sensing was minimal for C3 and C4.

The experimental results validate the utility of the proposed silicon-based 2D Hall sensors for the simultaneous perpendicular- and parallel-directional sensing. Table 1 compares the absolute sensitivity values in the perpendicular and parallel directions of both configurations of the 2D Hall sensor.

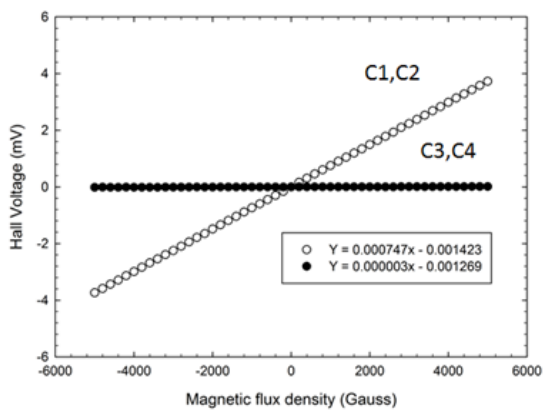


Figure 6 The parallel-directional absolute sensitivity of the 2D Hall sensor of the second configuration

Table 1 The absolute sensitivity in the perpendicular and parallel directions of both configurations of the sensor

Configuration	Condition (μm)	Parallel field (mV/G)	Perpendicular field (mV/G)
1 st	S=40,W=100	0.000699	0.000074
2 nd	S=60,W=300	0.000747	0.000154

By comparison, the perpendicular-directional absolute sensitivity of the second configuration (0.000154 mV/G), in which the width (W) is 300μm, was 2.08 times higher than that of the first configuration (0.000074mV/G) whose width is 100 μm. In addition, the parallel-directional absolute sensitivity of the second configuration (0.000747 mV/G), where the spacing (S) is 60μm, resembles that of the first

structure whose spacing is 40 μm (0.000699 mV/G). The similarity in sensitivity could be attributed to the close proximity between C1 and C2, resulting in the high current density in this particular region.

4. Conclusion

This research has proposed the silicon-based 2D Hall sensors capable of magnetic sensing in both perpendicular and parallel directions. The experimental findings revealed that the perpendicular absolute sensitivity belonging to the configuration with the larger width (W) of 300μm was 2.08 times higher than that of the other configuration with the narrower width of 100μm. Meanwhile, the parallel absolute sensitivity characteristics associated with the two different spacing (40 μm and 60 μm) were similar, indicating that the ohmic contact spacing (S) has minimal effect on the sensor sensitivity. In other words, the ohmic contact width (W) plays a significant role in the sensing enhancement of the Hall sensors.

5. Acknowledgments

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

6. References

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