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# High Sensitive Hall Element by Vacuum Deposition

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New type of high sensitive Hall Element of InSb thin film and InAs thin film by vacuum deposition are developed. These Hall Element show the small temperature dependence near at the room temperature under the constant voltage driving.

## § 1. Introduction

InSb Hall Element is the first application of the Hall effect for electrical devices and is discussed in the textbook of H.Weiss[1], S.Kataoka[2], and Y.Sakai[3]. The Hall Elements appeared in these text are the first generation device in the history of the Hall Element. These Hall Elements are used to measure or sensing the magnetic field but rather expensive devices.

Our target is the second generation Hall Element. This is the Hall Element with small size device, low cost, good mass productivity, high output voltage, high reliability, and small temperature dependence of the Hall output voltage. This type of Hall Element is required to magnetic field sensor for small size fine controlled DC brushless motors used in Audio, Video and other application.

Under the needs of such situation it is developed the Hall Element of the High sensitivity and High output Hall voltage with small temperature dependence by using the InSb thin film by vacuum deposition and also for InAs thin film by ultra high vacuum deposition method such as MBE.

In the next section § 2 the driving methods and the structure of the Hall Element having high output voltage are shown. The fabrication process of the thin film Hall Element and the method of vacuum deposition are mentioned. The properties of the Hall Element will be discussed In § 4. § 5 is conclusions.

## § 2. Two types of driving methods and the structure of the Hall Element

There are the two type of driving method for the Hall Element. One of this is the famous constant current driving shown in Table 1(b), and the second one is the constant voltage driving shown in Table 1(a). The difference between these two driving methods is the temperature dependence of the Hall output voltage. Hall coefficient of the InSb thin film has large temperature dependence at near room temperature shown in Fig.1.

(a) Constant voltage drive ($V_{in}$=constant)

$$V_H=\mu_H \cdot V_{in} \cdot B \cdot W/L$$

$V_H$ = Hall output voltage
$\mu_H$ = Electron mobility
$V_{in}$ = Input voltage
$B$ = Magnetic flux density

(b) Constant current drive ($I_c$=constant)

$$V_H=R_H \cdot I_c \cdot B/d$$

$R_H$ = Hall cofficient
$I_c$ = Input current

Table 1 Driving methods for the Hall Element

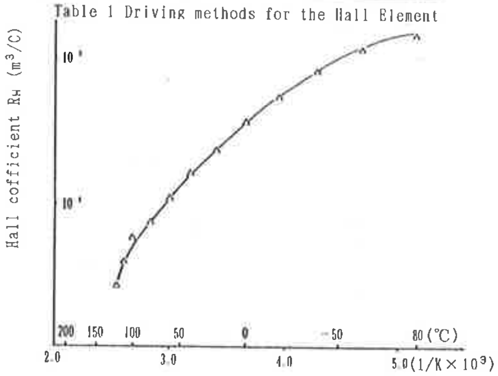


Fig. 1 Temperature dependence of the InSb thin film. (d=1.0 μm)

Temperature dependence of Hall output voltage at constant current driving is therefor large by Table 1(b).

The electron mobility dose not vary so much as shown in Fig.2 for InSb thin film at near room temperature. Therefor, the Hall output voltage at constant voltage driving has small temperature dependence by Table 1(a). To realize this for the Hall Element, it should be designed the Hall Element with large input resistance. By reducing the thickness of InSb thin film and keeping high mobility by vacuum deposition, the constant voltage driving of the Hall Element is realized.

Then, we discuss the structure of the high sensitive Hall Element. Thus, a thin film of InSb (or InAs) is sandwiched between ferrite substrate with about 1.0 $mm^2$ and 0.3 mm thickness and cubic ferrite chip with about 0.30 mm shown in Fig.3.

The external magnetic field at the position of the thin film is amplified by this structure. The value of amplification is approximately 1/L ;where L is the demagnetizing factor of the magnetic structure of the Hall Element and usually 1/L = 3~ 5.

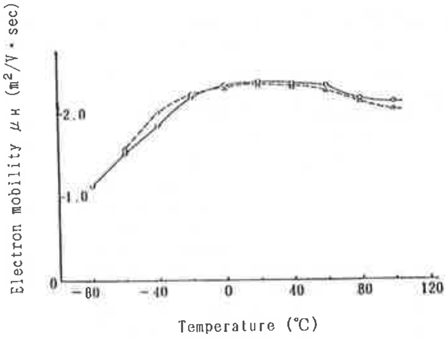


Fig. 2 Temperature dependence of the InSb thin film.
(d=1.0 $\mu$m)

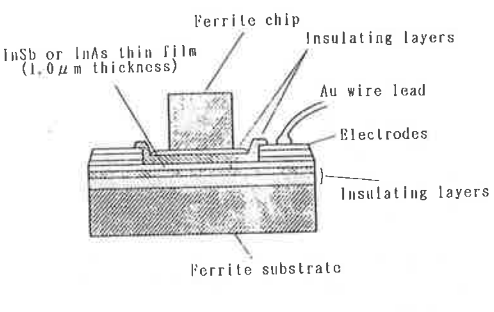


Fig. 3 Structure of the high sensitive Hall Element.
(Cross sectional view)

Therefore, the magnetic flux density at the thin film position is 3~ 5 times of the magnetic flux density of the applied external magnetic field. Therefore, Hall output voltage is amplified by the magnetization of both the ferrite substrate and cubic chip.

## § 3. Fabrication process of the Hall Element

The Fabrication process of the Hall Element by vacuum deposition and following process is shown in Fig.4[4-9].

To obtain InSb thin film with high electron mobility, and large sheet resistance (~ 150 Ω /□ ), following conditions are used i.e. source material is InSb single crystal, thin mica with smooth surface as substrate, vacuum chamber with multi-evaporators heated by electrical power controlling, and the substrate of mica is heated by programmed process under ~ $10^{-6}$Torr.

In case of InAs, it is necessary to use that the vacuum chamber with large deposition area and, molecular beam sources for As and In, and thin mica substrate and the substrate is heated by the programmed process in order to obtain high electron mobility and large sheet resistance in ultra-high vacuum chamber. Properties of InSb and InAs thin films by these processes are shown in Table 2.

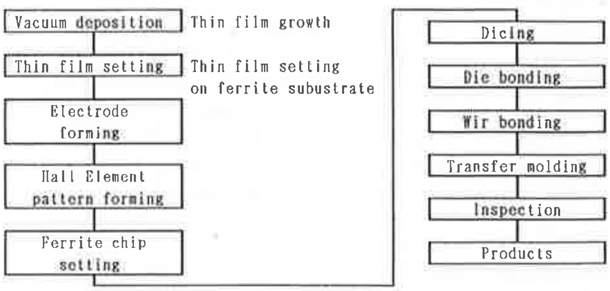


Fig. 4 High sensitive Hall Element process.

| | InSb | InAs | unit |
|---|---|---|---|
| Electron mobility | 20,000~30,000 | 6,000~8,000 | $cm^2$/V · sec |
| Sheet resistance | ~ 150 | ~ 150 | Ω |

Table 2 Typical thin film properties by vacuum deposition

Thin film of vacuum deposited InSb (or InAs) is peeled from the mica substrate and placed on the ferrite substrate using the thin resin adhesive layer.

Following this process , plating of the electrode metals, etching, passivation process, dicing, bonding and assembling process, are taken place as shown in Fig.4. Thus, we obtain high sensitive Hall Element.

## § 4. Characteristic properties of the Hall Elements

In Table 3, the characteristic properties of InSb thin film Hall Element HW-300A as a example of high sensitive Hall Element by vacuum deposition is shown[10].

Fig.5 and Fig.6 shows magnetic field properties of HW-300A. The temperature dependence of the Hall output voltage at constant voltage driving is shown in Fig.7 and is also shown in Fig.8 for constant current driving.

Temperature dependence of the input resistance of the HW-300A is shown in Fig.9.

As reading these data , thin film InSb Hall Element has nice electric and magnetic properties.

In the case of InAs Hall Element HY-300B, the magnetic field properties is shown in Table 4 and Fig.10, and the temperature dependence of the Hall output voltage for the constant voltage driving is shown in Fig.11. Then, temperature dependence of the input resistance is shown in Fig.12.

| | | min max | unit |
|---|---|---|---|
| Hall output voltage ($V_{in}$=1V, B=500G) | $V_H$ | 122 ~ 274 | mV |
| Input resistance | $R_{in}$ | 240 ~ 550 | Ω |
| Output voltage | $R_{out}$ | 240 ~ 550 | Ω |
| Unvalanced voltage ($V_{in}$=1V, B=0G) | $V_u$ | -7 ~ 7 | mV |

Table 3 Specification of the InSb Hall Element (HW-300A)

| | | min max | unit |
|---|---|---|---|
| Hall output voltage ($V_{in}$=3V, B=500G) | $V_H$ | 122 ~ 236 | mV |
| Input resistance | $R_{in}$ | 240 ~ 550 | Ω |
| Output voltage | $R_{out}$ | 240 ~ 550 | Ω |
| Unvalanced voltage ($V_{in}$=3V, B=0G) | $V_u$ | -10 ~ 10 | mV |

Table 4 Specification of the InAs Hall Element (HY-300B)

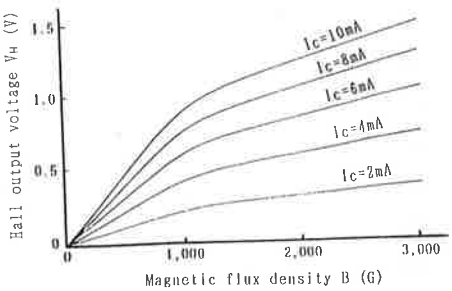


Fig. 5 $V_H$-B characteristics of the InSb Hall Element at constant current driving (HW-300A).

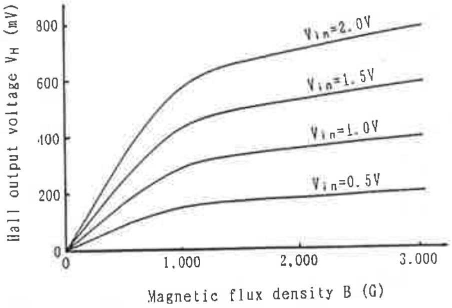


Fig. 6 $V_H$-B characteristics of the InSb Hall Element at constant voltage driving (HW-300A).

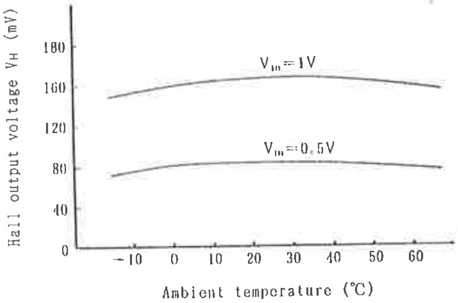


Fig. 7 Temperature dependence of the Hall output voltage at constant voltage driving (HW-300A, B=500G).

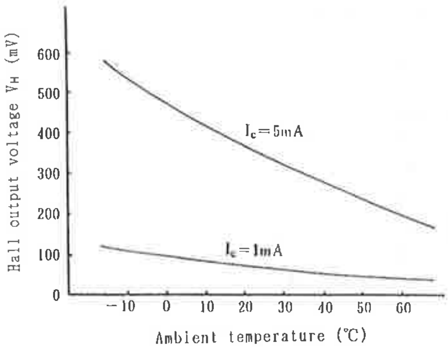


Fig. 8 Temperature dependence of the Hall output voltage at constant current driving (HW-300A).

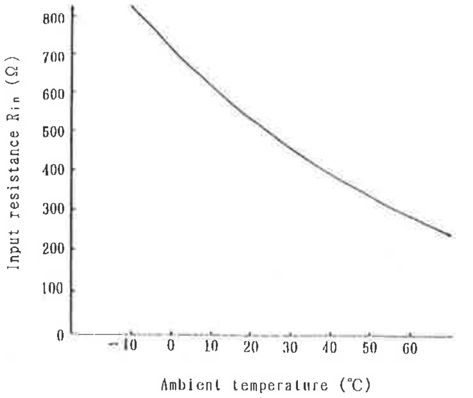


Fig. 9 Temperature dependence of the input resistance of the InSb Hall Element (HW-300A).

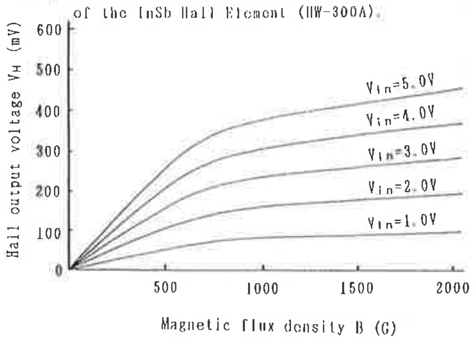


Fig. 10 $V_H$-B chracteristics of the InAs Hall Element at constant current driving (HY-300B).

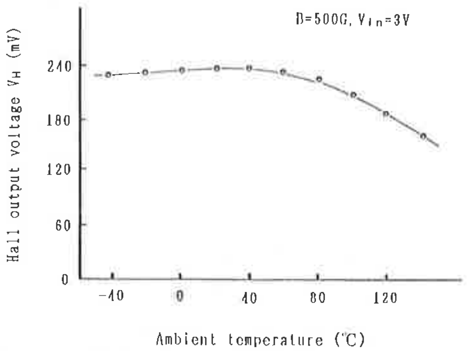


Fig. 11 Temperature dependence of the Hall output voltage of the InAs Hall Element at constant voltage driving (HY-300B).

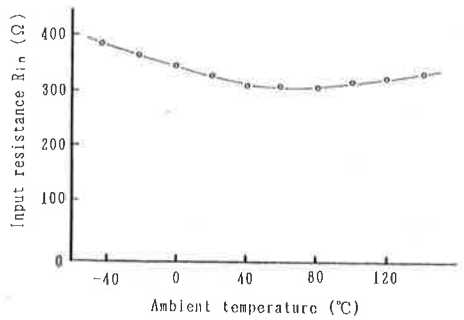


Fig. 12 Temperature dependence of the input resistance of the InAs Hall Element (HY-300B).

## § 5. Conclusions

New type of thin film Hall Elements are developed using the vacuum deposition and they have the high sensitivity for magnetic field with good temperature dependence around room temperature.

These Hall Elements are low cost, highly reliable and small size.

These Hall Elements are used for magnetic field sensing and produce a new stage for small size DC brushless motor technology because of the high magnetic field sensitivity, and (or) high output voltage, new constant voltage driving method for InSb Hall Element, and high reliability.

Hall Element was born in old days and is used much recently, still, has many problems which should be solved in future.

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