Determination of Hall Coefficeint

Experiment No:

Date:

1 Aim

To measure the Hall voltage of the given semiconducter sample and to estimate the Hall coefficient, carrier charge density and carrier mobility.

2 Motivation

The Hall effect is basic to solid-state physics and an important diagnostic tool for the characterization of materials - particularly semionductors. It provides a direct determination of both the sign of the charge carriers, e.g. electron or holes, and their density in a given sample. The objectives of this experiment are to demonstrate the the effects of a magnetic field (B) on a current carrying conductor (semiconductor/metal). If a current carrying conductor is placed in a magnetic field oriented perpendicular to the direction of the current, a voltage is developed across the conductor in a direction perpendicular to both the magnetic field and the direction of the current. This effect is known as the Hall Effect.

3 Basics

A static magnetic field has no effect on charges unless they are in motion. When the charges flow, a magnetic field directed perpendicular to the direction of flow produces a mutually perpendicular force on the charges. When this happens, electrons and holes will be separated by opposite forces. They will in turn produce an electric field ($\vec{E_h}$) which depends on the cross product of the magnetic intensity, $\vec{H}$, and the current density, $\vec{J}$. The situation is demonstrated in Figure 1.

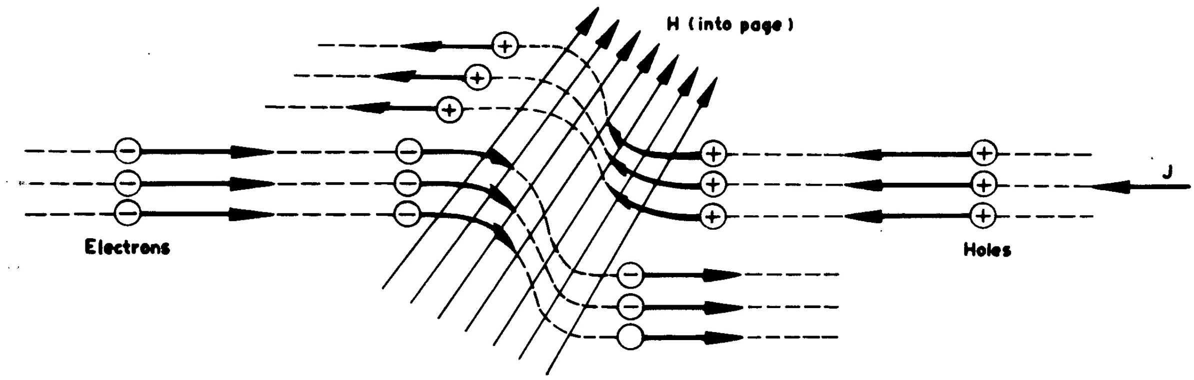

FIGURE 1

Carrier separation due to a magnetic field

In mathematical terms,

$$\vec{E_h} = R.\vec{J} \times \vec{H} \tag{1}$$

where R is called the Hall coefficient.

Now, let us consider a bar of semiconductor, having dimension, x, y and z. Let $\vec{J}$ is directed along X and $\vec{H}$ along Z then $\vec{E_h}$ will be along Y, as in Figure 2.

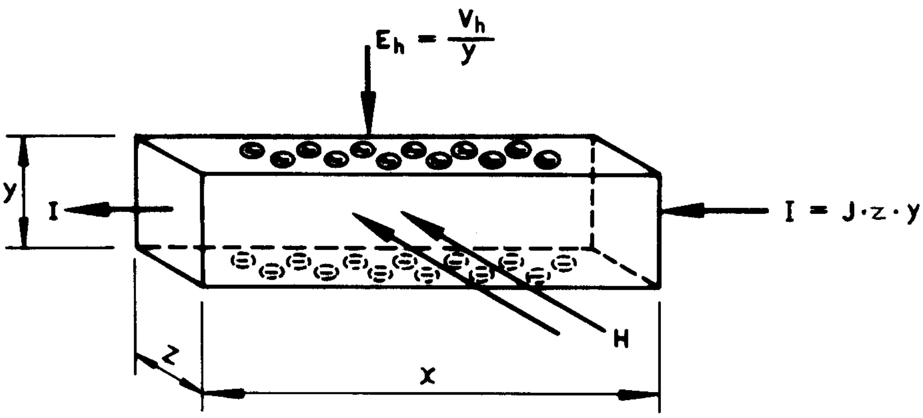

FIGURE 2

Sample for studying Hall effect

Then we could write

$$R = \frac{V_h/y}{J.H} = \frac{V_h.z}{I.H} \tag{2}$$

Where V_h is the Hall voltage appearing between the two surfaces perpendicular to y and $I = \vec{J}yz$.

In general, the Hall voltage is not a linear function of magnetic field applied, i.e. the Hall coefficient is not generally a constant, but a function of the applied magnetic field. In our case, here, we are assuming that carriers of only one type are present and use the following theory.

The magnetic force on the carriers is $\vec{E_m} = e(\vec{v} \times \vec{H})$ and is compensated by the Hall field $\vec{F_h} = e\vec{E_h}$, where v is the drift velocity of the carriers. Assuming the direction of various vectors as before,

$$\vec{v} \times \vec{H} = \vec{E_h} \tag{3}$$

From simple reasoning, the current density $\vec{J}$ is the charge q multiplied by the number of carriers traversing unit area in unit time, which is equivalent to the carrier density multiplied by the drift velocity i.e. $\vec{J} = qn\vec{v}$. By putting these values in Eqn. 3,

$$R = \frac{E_h}{J.H} = \frac{v.H}{qnvH} = \frac{1}{n.q} \tag{4}$$

From this equation, it is clear that the sign of Hall coefficient depend upon the sign of the q. This means, in a p-type specimen the R would be positive, while in n-type it would be negative. Also for a fixed magnetic field and input current, the Hall voltage is proportional to $1/n$ or its resistivity. When one carrier dominates, the conductivity of the material is $\sigma = n.q\ \mu$, where μ is the mobility of the charge carriers. Thus,

$$\mu = R.\sigma \tag{5}$$

Equation 5 provides an experimental measurement of mobility; R is expressed in $\mathrm{cm}^3\ \mathrm{coulomb}^{-1}$ thus μ is expressed in units of $\mathrm{cm}^2.\mathrm{volt}^{-1}\ \mathrm{sec}^{-1}$.

4 Apparatus

1. Hall Probe (Ge Crystal)
2. Hall Effect Set-up
3. Electromagnet
4. Constant Current Power Supply
5. Digital Gaussmeter

5 Procedure

1. Connect the red coloured contacts of the Hall Probe to the terminals marked 'Voltage' and green coloured contacts to terminals marked 'Current'.

2. Switch 'ON' the Hall Effect set-up and check that the adjustment currentis in zero.

3. Switch over the display to voltage side. There may be some voltage reading even outside the magnetic field. This is due to imperfect alignment of the four contacts of the Hall Probe and is generally known as the 'Zero field Potential'. In case its value is comparable to the Hall Voltage it should be adjusted to a minimum possible (for Hall Probe (Ge) only). In all cases, this error should be subtracted from the Hall Voltage reading.

4. Now place the probe in the magnetic field and switch on the electromagnet power supply and adjust the current to the desired value. Rotate the Hall probe till it become perpendicular to magnetic field. Hall voltage will be maximum in this adjustment.

5. Measure Hall voltage for both the directions of the current and magnetic field (i.e. four observations for a particular value of current and magnetic field).

6. Measure the Hall voltage as a function of current keeping the magnetic field constant. Plot a graph.

7. Measure the Hall voltage as a function of magnetic field keeping a suitable value of current as constant. Plot graph.

6 Observations

6.1 Current Vs. Hall Voltage

d=1.5 mm, Constant magnetic field at 0.5 A of coil current is H_z=_______________ Gauss

Current (mA) Sample	Hall Voltage (mV)				Mean H (volts) ($\times 10^{-3}$)
	Current		Magnetic Field		
	First Direction (H1)	Second Direction (H1)	First Direction (H3)	Second Direction (H4)	
1.5					
3.0					
4.5					
6.0					

7 Observations

7.1 Magentic field Vs. Hall Voltage

d=1.5 mm, Constant current = 1.0 mA

Coil Current (A)	Magnetic Field (Gauss)	Hall Voltage (mV)				Mean H (volts) ($\times 10^{-3}$)
		Current		Magnetic Field		
		First Direction (H1)	Second Direction (H2)	First Direction (H3)	Second Direction (H4)	
0.5						
1.0						
1.5						

8 Calculations

1. Hall coefficient can be calculated using (from Eq. 3),

$$R = \frac{V_h.d}{I.H}$$

where, V_h is the Hall voltage (V), d is the sample thickness (m), I is the current (A) and H is the magnetic field (G).

2. Calculate charge carrier density from the relation

$$R = \frac{1}{nq} \Rightarrow n = \frac{1}{Rq}$$

where q is the electronic charge ($q = 1.6 \times 10^{-19}$)

3. Calculate carrier mobility, using the formula

$$\mu_n \text{ (or } \mu_p) = R\sigma$$

The conductivity of Ge samples is about 0.1 coulomb volt^{-1} sec^{-1} cm^{-1} at room temperature.

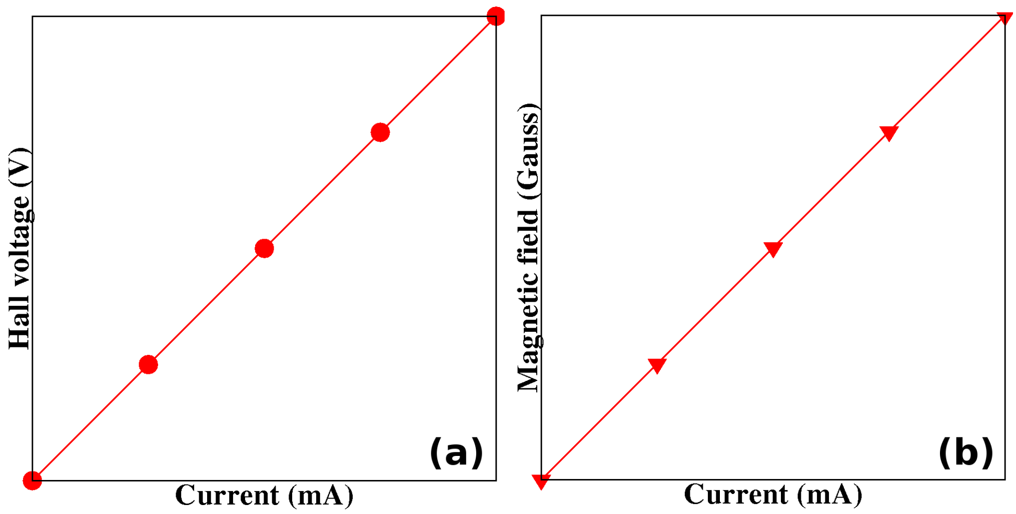

FIGURE 3

Sample graph showing the (a) Current in Hall voltage and (b) Current in the magnetic field

9 Results

Hall coeffecient for given sample is measured and its

1. Hall coeffecient (R) is ______________________________
2. Carrier density (n) is _______________________________
3. Carrier mobilty is ___________________________________

Instructor comments:

Signature

10 Assignments

1. From the experiment, can you say why the Hall potential developed?
2. How does mobility depend on electrical conductivity?
3. What happens to the hall coefficient when number of charge carriers is decreased?
4. Name one practical use.

11 References

11.1 Basics

1. https://www.melexis.com/en/articles/hall-effect
2. https://www.electrical4u.com/hall-effect/
3. http://courses.washington.edu/phys431/hall_effect/hall_effect.pdf

11.2 Experiment

1. https://www.youtube.com/watch?v=lUugrqMOY7E
2. https://www.youtube.com/watch?v=_AwjbHzwWLo
3. https://www.youtube.com/watch?v=mTPjsihEJlw