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Investigation of Hall Effect with a Germanium Crystal of P- Type

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Abstract: A study on Hall effect has been done to determine the polarity of the charge carriers, hall voltage, V_H, Hall resistance, R_H, with other parameters. Measurement with this method reveals the effectiveness and the simplicity of this method.
Key words: Hall effect, Hall voltage, Hall coefficient, concentration of charge carriers, conductivity of electrons and holes.

I. INTRODUCTION

The Hall effect is basic to solid-state physics and an important diagnostic tool for the characterization of materials– particularly semi-conductors. 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. When a magnetic field is applied perpendicular to a current carrying specimen (metal or semiconductor), a voltage is developed in the specimen in a direction perpendicular to both the current and the magnetic field. This phenomenon is called Hall Effect. The voltage so generated is called Hall Voltage.[1]

We know that 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. Consequently, electrons and holes get separated by opposite forces and produce an electric field E_H, thereby setting up a potential difference between the ends of specimen. This is called Hall Potential V_H.

A. Theory

Considering a semiconductor in the form of a flat strip. Let a current I flows through the strip along X-axis. P and P´ are two points on the opposite faces of abcd and a´b´c´d´ respectively. If a mille voltmeter is connected between point's p and p´, it does not show any reading, indicating that there is no potential difference setup between these points. But, when magnetic field is applied along Y-axis, i.e. perpendicular to the direction of current, a deflection is produced in the mille voltmeter indicating that a potential difference is set up between p and p´. This potential difference is known as hall voltage or Hall Potential V_H.

As shown in fig. 1, if a current is passed along X-axis. The force on electron due to the applied magnetic field B is given by,[2]

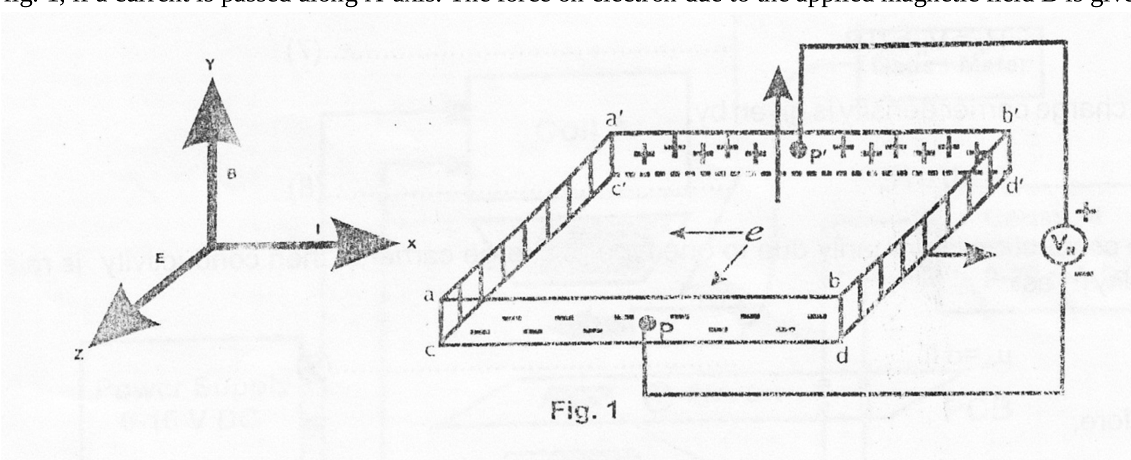

Fig. 1

$$\vec{F} = e(\vec{v} \times \vec{B})$$

$$F = e\,v\,B \sin 90°$$

$$F = e\,v\,B \qquad (1)$$

Where, v is the drift velocity of electron and e is the charge of electron.

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Using Fleming's left hand rule it is seen that force on the electrons will be directed towards the face abcd, i.e. along positive Z-axis, thereby making the face abcd negative and a´b´c´d´ positive.

If the current is carried by positively charged carriers i.e. holes, the carriers move in the same direction as that of the current. The magnetic force causes the positive charge carriers to move towards the face abcd, thereby making the face abcd positive and a´b´c´d´ negative.[3]

At thermal equilibrium, when the Lorentz force exactly matches the force due to the electric field E_H (the Hall Voltage) we have:

$e\,v\,B = e\,E_H$ (2)

If b is the width and t is the thickness of the specimen (crystal), its cross sectional area A is given by:

$A = b\,t$ (3)

The current density $J = I/A$ (4)

or, $I = n\,e\,v\,A$ (5)

Where, n is the number of charge carriers per unit volume.

Using above equations we get

$1/ne = V_H\,b\,/B\,I$ (6)

The Hall coefficient is given by:

$R_H = V_H\,b/I\,B$ (7)

And charge carrier density is given by:

$n = 1/e\,R_H$ (8)

If the conduction is primarily due to one type of charge carriers, then conductivity is related to mobility μ_m as:

$\mu_m = \sigma\,R_H$ (9)

Therefore,

$\mu_m = R_H/\rho$ (10)

Where, ρ is the resistivity.

There is another interesting quantity called the Hall angle (Θ_H) defined by equation

$\tan\Theta_H = E_H/E_X$ (11)

But $E_H = v_X\,B$ (12)

Hence $\tan\Theta_H = v_H\,B/E_X = \mu_m\,B$ (13)

B. *Experimental Details*

An Indosaw SK006 Hall effect apparatus was used with power supply for electromagnet at 0-16 V, 5Amps. The power supply of constant current source was at 0-20 mA. A Gauss meter with Hall probe was used. Semiconductor (Ge single crystal) mounted on a PCB of P-type Ge crystal of thickness 0.5 mm, width 4 mm and length 6 mm.

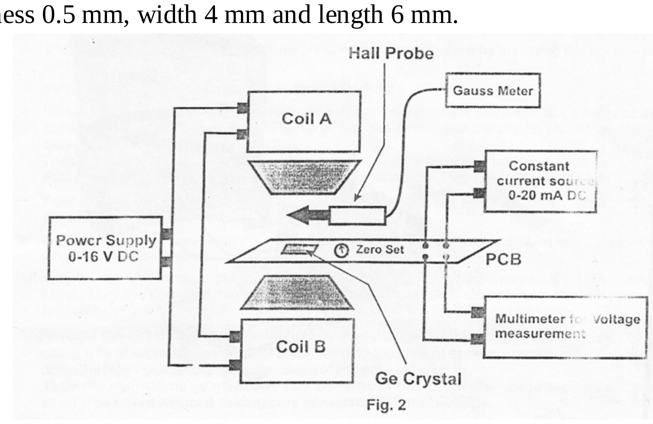

Fig.2: shows the block diagram for experimental set up with connections.

A p-type Ge crystal is mounted on PCB. PCB is provided with four sockets and a pot to make the Hall voltage zero, when there is no current flowing through the crystal and also when there is no magnetic field. The upper two sockets are connected to a constant current dc source and the lower two to a multimeter/ millivolt meter.

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II. RESULTS AND DISCUSSION

Hall coefficient $R_H = V_H b/BI$ m^3C^{-1}
Where, V_H is the Hall voltage in volts.
B is the width of the sample in meter.
Concentration of charge carriers per unit volume
$N = 1/e\, R_H$ carriers m^{-3}
where, $e = 1.6\times10^{-19} C$
Resistivity of the material of the sample
$\rho = V\, b\, t/m$
Where, *V*= voltage between two points situated 1 cm apart on one face of sample
b = width of the sample in m.
t= thickness of the specimen in m.
Mobility $\mu_m = R_H/\rho$ $m^2\, V^{-1}\, s^{-1}$
Hall angle $\Theta_H = tan^{-1}(\mu B)$
Observations:
Width of the specimen, *b*=4 mm
Length of the specimen, *l*= 6mm
Thickness of the specimen, *t*=0.5 mm
Magnetic flux density, *B*=3110 Gauss

A. Table for I and V

Observation No.	Current I In mA	Reading of volt meter		Mean of V_H (mV)	V_H/I In Ohms
		B and I in one direction	B and I in another dire.		
1	0.23	0.3	0.1	0.2	0.87
2	0.82	1.0	0.7	0.85	1.037
3	2.53	3.2	2.1	2.65	1.047
4	3.08	3.8	2.5	3.15	1.023
5	4.58	5.8	3.8	4.8	1.048
6	5.74	7.4	4.6	6.00	1.045
7	6.23	8.1	5.0	6.55	1.0514
8	7.45	9.8	5.8	7.8	1.047
9	8.19	10.8	6.3	8.55	1.044
10	9.50	13.0	9.9	11.45	1.2052
11	10.59	15.0	10.6	12.8	1.2156
12	11.78	17.4	11.5	14.45	1.2267

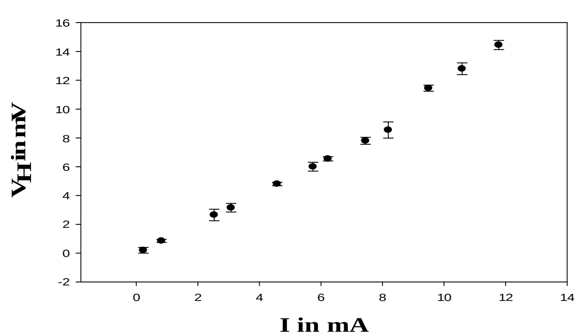

Fig. 3.The variation of hall voltage with current I

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B. Table for Resistivity

Observation no.	Current I in mA	Distance between two points between which potential difference is measured l in m	V_l in mV	$\rho = V_l\, b\, t / I\, l$ in Ωm
1	0.23	0.206×10^{-2}	0.2	2.89×10^{-4}
2	3.08	0.206×10^{-2}	3.15	3.409×10^{-4}
3	7.45	0.206×10^{-2}	7.8	3.489×10^{-4}
4	11.78	0.206×10^{-2}	14.45	4.088×10^{-4}

C. Calculations

1) Mean value of V_H/I=1.072 ohm
2) R_H=1.072×b×B
   $=1.072\times0.004\times10^4/3110$
   $=0.01378\ m^3C^{-1}$
3) Sign of Hall coefficient is positive, thus the semiconductor crystal is of p-type. (to check whether a crystal is of p-type or n-type we have first used a crystal of known type) for this the direction of magnetic field is very important so coils should be put in the standard configuration and direction of current through the coil should be as per standard configuration.
4) $N=1/(1.6\times10^{-19}\times R_H)$
   $=45.36\times10^{19}$ carrier's m^{-3}
5) $\rho=6.938\times10^{-4}\ \Omega\ m$
6) $\mu_H=R_H/\rho = 0.00198\times10^4\ m^2\ V^{-1}\ s^{-1}$
7) the Hall angle $\Theta_H = tan^{-1}(\mu_m B)$
   $=80.775^\circ$

III. CONCLUSION

Before starting the experiment, we need to check that the gauss meter is showing zero value. For this the probe was kept away from electromagnet and switched on the Gauss meter and its zero adjustment knob was adjusted. The specimen is needed to be located at the center between the pole pieces and exactly perpendicular to the magnetic field. To measure the magnetic flux the Hall probe was placed at the center between the centers between the pole pieces, parallel to semiconductor sample. For carrying out the experiment, the magnetic flux density was of its maximum.

IV. ACKNOWLEDGEMENT

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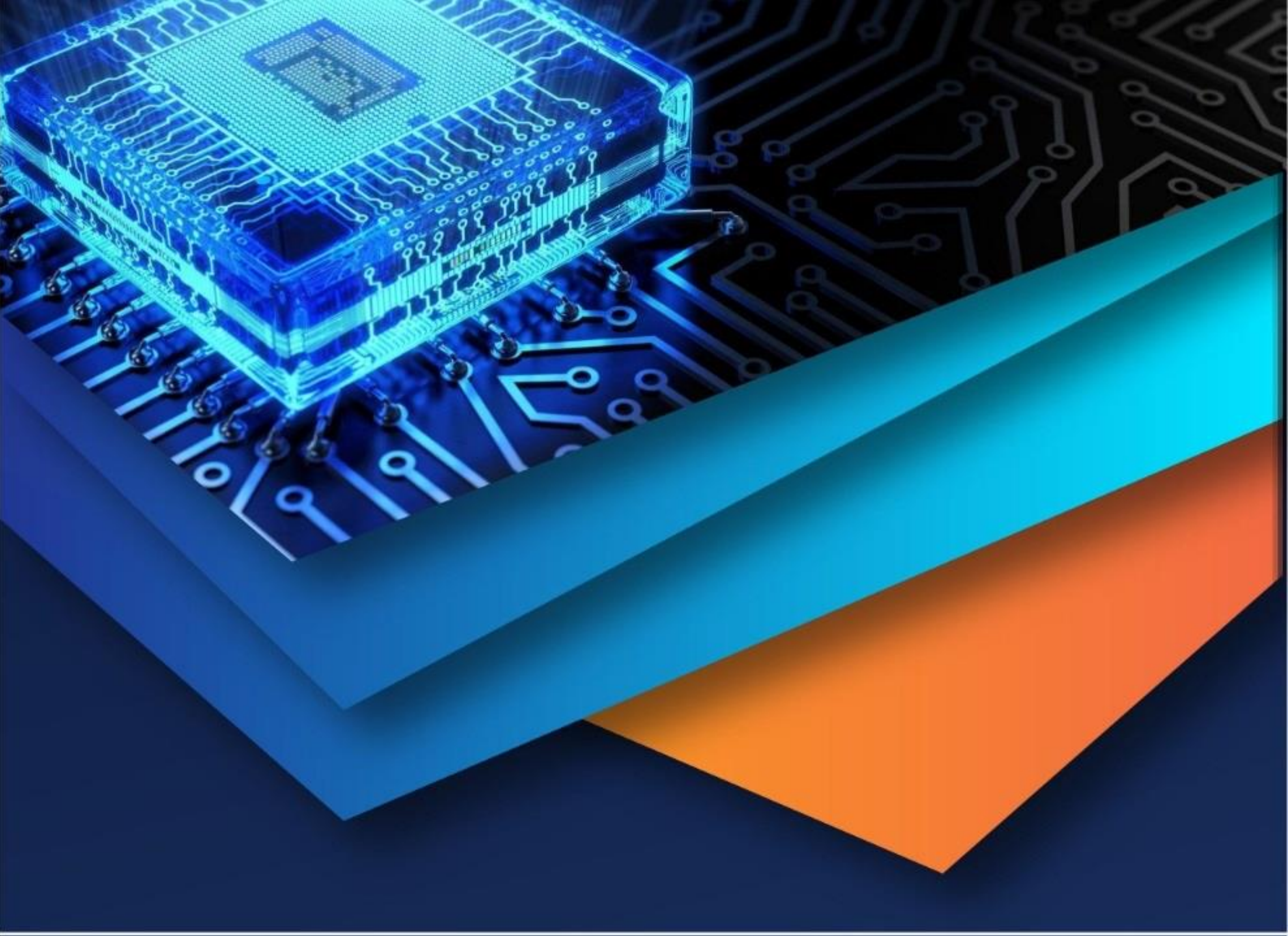
REFERENCES

[1] Sudarshan Nelatury, Hall effect, Research Gate, march 2018
[2] Ludwig Grabner, Longitudinal Hall Effect, Physical review **117**, 1960
[3] H. Stafford Hatfield, A method of investigating the Hall effect, Proc. Phys. Soc. 48 267, 1936



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