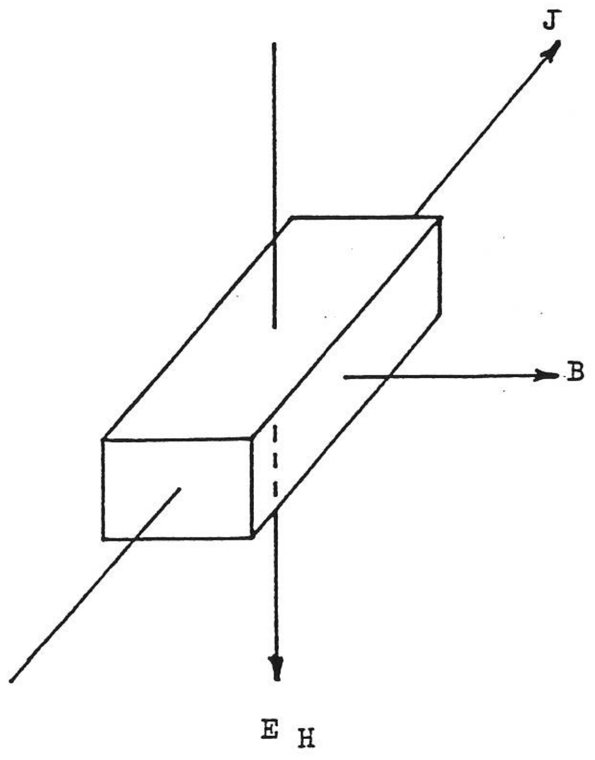
HALL EFFECT IN GERMANIUM

Theory

If a current is passed through a semiconductor and a magnetic field is applied at right angles to the direction of current flow, charge carriers are deflected and an electric field induced in a direction mutually perpendicular to B and to the direction of current flow. This phenomenon is known as the Hall Effect. The Hall Effect experiment illustrates the existence of two independent charge carriers, electrons and holes, in a semiconductor and allows the determination of the sign of the charge of the majority carrier. The density and mobility of majority carriers may also be deducted.



The magnitude of the transverse Hall field can be found by equating the sideways forces acting on the moving charges. The Lorentz force (B.e.v) due to the influence of the magnetic field on the moving charge carriers is exactly compensated by the resulting force due to the existence of the Hall field (eE_H).

$$\text{i.e. } eE_H = Be\bar{v}$$

where E_H is the Hall Field and $\bar{v}$ is the average drift velocity of the moving charge.

If J is the current density

$$J = ne\bar{v}$$

$$\bar{v} = \frac{J}{n.e}$$

$$\therefore E_H = \frac{1}{n.e} J.B$$

where n is the carrier density.

The Hall Coefficient R_H is defined as

$$R_H = \frac{E_H}{JB} = \frac{1}{n.e}$$

By measuring the Hall Coefficient it is possible to obtain a value for the carrier density. The sign of the Hall Coefficient enables one to deduce whether the sample is predominantly n type or predominantly p type.

The above theory applies in a case where the 'free' carriers in the conduction band are entirely free. In the case of a semiconductor this is not so and it is found that for semiconductors

$$R = \frac{1.18}{ne}$$

For an extrinsic semiconductor the conductivity is given by

$$\sigma = ne\mu$$

where n and μ are the concentration and mobility of the majority carrier. One can, therefore, obtain a value for the majority carrier mobility from the Hall coefficient:

$$\mu = \frac{\sigma R}{1.18}$$

EXPERIMENTAL WORK

A. Germanium

Refer to benchnotes for details on connecting equipment.

Plot E_H against J for two values of B (one positive and one negative value of the same magnitude). You will also need to calculate the conductivity of the sample and should therefore note both applied longitudinal voltage and current.

The encapsulated sample for this experiment is a rectangular bar of germanium having the following dimensions: Length 16.5 mm

Height 3.35 mm

Breadth 2.17 mm

Hall voltage probes are positioned at approximately mid point along the length of the sample and are separated by 3.35 mm. There are ohmic contacts at either end.

DO NOT EXCEED 10 mA SAMPLE CURRENT

Calculate the Hall Coefficient R_H, the conductivity σ, the mobility μ, and 'n' the carrier density for the sample and deduce whether it is n or p type.

N.B. A voltage will be recorded by the Hall probes even in the absence of a magnetic field. This is due to the slight misalignment of the probes (i.e. they are not placed exactly opposite each other on the sample). This effect must be taken into account in the analysis of your data.

Question

If the sample were replaced by a similar slice of intrinsic Germanium, would it exhibit a Hall voltage under similar conditions?

B. GOLD

Repeat the experiment for gold using a high value of B for both positive and negative values. (You will need a more sensitive voltmeter scale.) Calculate R_H, σ, μ, and 'n' the carrier density. Compare the values of μ and σ with the tabulated values and comment on the differences. (Think of the thickness of the gold film relative to the mean free path.) Compare your value for 'n' with the theoretical value whereby one assumes that each atom contributes one free electron in the solid.

Dimensions of gold:	Length	30mm
	Height	10mm
	Breadth	60nm

Recommended Reading:

1. Electronic Processes in Materials by L.V. Azaroff and J.J. Brophy.

2. Electronic Engineering Semiconductors and Devices by J. Allison.