Studying the Hall Effect of Semiconductors

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I. OBJECTIVE

1. To determine the Hall coefficient of certain semiconductors at room temperature.
2. To study the variation of Hall coefficient with temperature.

II. THEORY

Measurement of Hall effect is an important tool is determining mobilities of electrons and holes in semiconductors where simple measurements of conductivity is insufficient to distinguish the both. To observe Hall effect, consider a crystal, with contacts 1, 2 and 3 perpendicular to the magnetic field H in the z-direction. When a voltage V_x is applied between contacts 1 and 2 to induce current flow through the crystal in x-direction, a voltage will arise across contacts 3 and 4 in the y-direction. Assuming all carriers possess equal drift velocity, it is easy to compute this (Hall) voltage. To do so, we make one of the two assumptions, (a) that there is only one kind of carrier present, and (b) that both types of carriers are present.

A. One type of Carrier

Under the Hall voltage, the magnetic force on the carriers is $\overrightarrow{F}_m = e\overrightarrow{E}_m = e(\overrightarrow{v} \times \overrightarrow{H})$ and is compensated by the force $\overrightarrow{F_h}$ due to the Hall fields $\overrightarrow{E_h}$. The electric field $\overrightarrow{E_m}$ is along the y-axis and is provided by $E_m = vH = \mu E_x H$, where the carrier mobility μ is determined by $v = E_x$, and E_x is the applied electric field along the x-axis. This is because $\overrightarrow{v}$ is along the x-axis, and $\overrightarrow{H}$ is along the z-axis. $E_x = J_x$ describes the relationship between the electric field, current density, and conductivity. The Hall coefficient R_H is given by:

$$|R_H| = \frac{E_m}{J_x H} = \frac{1}{ne} = \frac{V_y t}{I_x H} \tag{1}$$

here t is the thickness of the sample. Thus, for a fixed magnetic field and input current, the Hall voltage is proportional to $1/n$.

B. Two Types of Carriers

We observe that the Hall voltage for p-type carriers (holes) has the opposite sign from that for n-type carriers (electrons) for the same electric field E_x. Consequently, the sign of the Hall coefficient R_H is also different for the two types of carriers. Both types of carriers experience a transverse motion due to the Hall field E_y, which fails to counteract the magnetic force acting on them. However, since no current flows through contacts 3, 4, and 5, the net transverse transfer of charge remains zero.

In the x-direction, we have:

III. EXPERIMENTAL SETUP

Apparatus

1.

IV. OBSERVATION AND CALCULATIONS

V. DISCUSSION

VI. PRECAUTIONS AND SOURCES OF ERROR

1.

VII. CONCLUSION

[1] SPS, NISER (2023).