Experiment 12: Hall Effect

Scope:
The Hall voltage in a semiconductor will be measured in the magnetic field of a large electromagnet. The Hall coefficient obtained may be used to determine the density of the charge carriers, and may be combined with the measured resistivity to determine the mobility of these carriers. Also, the algebraic sign of the majority carriers may be determined from the directions of the magnetic field and the conventional current, and the polarity of the Hall voltage.

Introduction:
See Brown 5.3, 7.5

The theory of the Hall effect is discussed in Omar, Sections 4.10, 5.19, 6.8, Hutchison and Baird, the Physics of Engineering Solids, Section 11.6, and Kittel, Elementary Solid State Physics, pp. 166-167.

Better references for the purpose of our experiment are Azároff and Brophy, Electronic Processes in Materials, pp. 210-212, and Van der Ziel, Solid State Physical Electronics, Sections 5.5a and 5.5b. Additional references are Wert and Thomson, The Physics of Solids, Section 11.8, Hemenway, Henry, and Caulton, Physical Electronics, Section 12.9, and Martin, The Physical Basis for Electrical Engineering, Sections 5.11 and 6.7.

The Hall voltages will be measured with a sensitive microvoltmeter. See the folder with circuit diagram and specimen dimensions at the lab station. Be sure things are connected correctly and that you understand the function of each of the meters.

Procedure:

Be sure the water is on! Carefully follow the instructions for using the magnet.

Make measurements with the electrometer of the Hall voltage at a fixed field (5000 G = 0.5 T) for several different sample currents. See schematic on the next page.

CAUTION: DO NOT EXCEED 12 mA in the Ge specimen or 300 mA in the InAs specimen.

Be sure to take one measurement at each current with zero magnetic field. Because the Hall voltage connections are not exactly across from each other, the voltage measured without the field results from the "IR drop" along the specimen. This zero-field voltage must be subtracted from the with-field Hall probe voltage to obtain the true Hall voltage, $V_{H}^{\text{true}} = V_{H}^{B=0} - V_{H}^{B=0}$.

Also be sure to measure the voltage drop along the sample, $V_L$, between the current terminals of the specimen to permit the calculation of its resistivity and therefore the conductivity.
Report:

- Plot \( V_H^{\text{true}} \) vs. \( I \) for constant magnetic field and determine \( R_H \) using the slope.
- Using \( R_H \) from above calculate the charge carrier density from this value of \( R_H \).
- From a plot of \( V_L \) vs \( I \) determine the conductivity.
- Now using the carrier density and the conductivity determine the effective mobility. Of course there isn’t just “a mobility”. It is a combination of both types of carriers, as such your value will be low.
- Are the charge carriers electrons or holes? (Use a diagram of magnetic field direction, current direction, and Hall voltage polarity to determine this.)
- Discuss the experimental uncertainties in your measurements and results, and compare your mobility results with published values.

Schematic for Hall effect measurements. A constant current source provides current that is measured with the \( A=\text{ammeter} \). The two relevant voltages, \( V_L=\text{longitudinal voltage} \), \( V_H=\text{Hall voltage} \), are also measured.

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