Hall Effect – Instruction Notes

Keywords: intrinsic and doped semiconductors, band gap, Fermi-Dirac statistics, mobility of the electric carrier, conductivity, resistivity, Hall coefficient

I. GOALS OF THE EXPERIMENT

In this experiment, the Hall effect is used to experimentally determine the charge carrier density *n* or *p* of several semiconductor samples as a function of temperature in the range 80 - 300 K. Additionally, the temperature-dependent mobility μ of the carriers is obtained measuring the resistivity *ρ*. Another task of the experiment is to get acquainted with precision measuring techniques.

II. LEARNING CONTENT

- van der Pauw method for measuring the density and mobility of charge carriers in semiconductor samples concentration specific resistances
- the influence of sample orientation on Hall voltage
- low – temperature measurements using a cryostat

III. PROCEDURE

The aim of this experiment is to measure the carrier densities *n* (n-doped sample) or *p* (p-doped sample) as well as the carrier mobilities *μ* of a semiconductor sample as functions of temperature using the method of van der Pauw (vdP).

1) Preparing measurements

1.1 Calibration of the electromagnet (T = 300 K)

- Determine the dependence of the magnetic field strength *B* on the current I_B through the magnetic coils by means of a calibrated Hall sensor (0.01172 T/mV at 100 mA) in the range 0 A ≤ I_B ≤ 15 A in steps of 1 A. Do not forget to align the Hall sensor perpendicular the the magnetic field prior to the measurements!

1.2 Sample contacts (T = 300 K oder 80 K)

- Verify that the sample contacts exhibit ohmic behaviour. For this purpose, measure the current-voltage *U(I)* characteristic between two of the four contacts with current strengths -150 µA ≤ *I* ≤ 150 µA in steps of 10 µA.
- Draw the result in a linear plot

1.3 Orientation of the sample (T = 300 K oder 80 K)

- Measure the transverse voltage U_t (Hall voltage including offset voltage) at various angles α between magnetic field and surface normal of the sample in the range $-90° \leq \alpha \leq 90°$ with $\Delta\alpha = 10°$ ($B \sim 0.5$ T, $I = 100$ µA). What is the appropriate configuration for this measurement?
- Adjust the sample such that the magnetic field B is oriented perpendicular to the surface normal! Derive the offset voltage from a curve - fitting procedure using the function $U_t(\alpha) = U_0 \cos(\alpha + \Phi) + U_{offset}$ with U_0, Φ, and U_{offset} as fitting parameters.

2) Determination of *n* or *p* and *µ* for *T* = 80 - 300 K

- Cool, if not yet done, the sample down to 80 K and determine then ρ and R_H using the method of vdP in the temperature range 80 K ≤ T ≤ 300 K in steps of 5K with $B \sim 0.5$ T.
- Calculate the electron n or hole p density as well as the mobility µ as functions of temperature. Show the results in diagrams with appropriate scales.

Attention: Adjust the heater voltage within the range 8 - 12 V and close the outlet for the cold nitrogen gas. Switch off the heater voltage at T = 300 K!!!

3) Simulation

- Calculate the theoretical temperature dependence of the electron n or hole p density and plot the result together with the measured values in one diagram. Calculate also $n(T)$ or $p(T)$. Add the corresponding curve plots to the same diagram. The sample-specific material parameters are provided by the advisor.
- Plot the two curves with $\mu / T^{3/2}$ and $\mu / T^{-3/2}$ together with the measured values of $\mu(T)$ in one diagram

Some physical parameters of silicon:

$m_t = 0.1905\ m_0$

$m_l = 0.9163\ m_0$

$m_{dh} = 0.689\ m_0$

IV. REFERENCES:

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