UNIVERSITY OF BERNE
INSTITUTE FOR APPLIED PHYSICS

Advanced Labcourse

Hall effect

Instructions

Contents

1 Goal of the experiment

The aim of this Lab course is to familiarize with the Hall effects and it's most important applications. We have 2 different semiconductor Hall probes which we examine and compare with each other. With a calibrated Hall probe one can measure unknown magnetic fields where as with a known magnetic field one can measure properties of a conductive solid. Properties that we want to measure include the Hall coefficient, Hall mobility and the charge carrier density. In addition we want to use the Hall effect to directly measure the mean velocity of the electrons in copper (since copper is a typical highly conductive metal).

2 Theory

2.1 General Theory of the Hall effect

For the general understanding of the Hall effect one should consider the literature noted at the end of the instructions. Especially the basics of the Hall effect, the Drude Modell, the band theory for semiconductors as well as electron or hole conductivity should be studied.

2.2 Measuring magnetic fields with the Hall effect

If an electric current I_S (drive current) flows in longitudinal direction through a conductive solid probe with thickness d and the probe is passed through a magnetic field of flux density B the resulting Lorentz Force acts on the electrons perpendicular to the current and the magnetic field direction leading to a voltage U_H

$$U_H = \frac{R_H I_S B}{d} \tag{2.1}$$

with R_H being the Hall coefficient. A derivation of this formula can be found in common physics lecture books. The Hall effect allows us now to measure the magnetic field by measuring a voltage. The proportionality factor is practically derived by calibrating a Hall probe. To obtain a high linearity one needs to use a suitable resistance which depends on the used probe. Since the Hall electrodes are not at the same equipotential line, even when the magnetic field vanishes we still have a purely resistive voltage component. This resistive component can be eliminated by switching the current or magnetic field direction.

3 Devices

3.1 Coil for calibration

The Probes are calibrated in the magnetic field of a coil with different drive currents. The onelayered coil has following characteristic data:

Length: $L = 38.32$ cm
Radius: $r = 40.5$ mm
Winding number: $n = 179$
Current: max 15 A

In the middle of the coil is a section where one can enter the probe to the middle axis of the coil. The power source is the 20V power supply.

3.2 Magnetic Coil with Iron core

Length: $L = 2 \cdot 99$ mm
Radius: $r = 22$ mm
Winding number: $n = 2 \cdot 271$
Gap size: $d = 4.4$ mm
Current: max 5 A

The power source is the 20V power supply. Be careful: Don't let the coil get to hot!

3.3 Hall probes and copper plates

Please check the Data sheets of the 2 Hall probes KSY14 and SBV604. The Hall probe power supply allows various resistance settings (form 10 Ω to ∞). Use the special cable and note the respective color on the plugs. Note the maximum control current of the Hall probes:

KSY 14 (GaAs): max 5 mA

SBV 604 (InAs): max 50 mA

The copper plates are connected to the Powertronic power supply. Although the operation allows up to 50 A it's harmless to humans due to the low voltage. Nevertheless it shouldn't be abused as a toy for welding experiments of any kind. Since the producible Hall voltages are too low for the available instruments the 1000-fold amplifier shall be used (amplifies IN (H) - IN(L)). Using the Digital Multimeter the amplified voltage can be read.

4 Tasks

4.1 Theoretical Preparations

1. Study the theory of the Hall effect and the workings of a Hall probe with the literature
2. Calculate the magnetic field in the middle of a long cylindrical single layered coil.
3. Derive the relationships between magnetic field, Hall voltage, probe current, thickness, resistivity, conductivity of the probe as well as the density, velocity and mobility of the charge carriers. Which variables are specific to the material and which depend on the circumstances of the experiment? Which variables are sensitive to the Probe temperature? Are there characteristic differences between metals and semiconductors?

4.2 Experiments

1. Calibrate and compare the linearity of the 2 Hall probes with different resistances. To make the following measurements as precise as possible use the appropriate resistance setting (Reason?)
2. Measure the specific conductivity and Hall coefficient of the Hall probes as well as the copper plates.
3. Obtain the density and Hall mobility of the charge carriers in the probes and copper.
4. Measure a Hysteresis curve of the Coil with the Iron Core with one of the Hall probes. What is the remanence and coercivity?
5. Directly measure the velocity of the charge carriers in copper (various possibilities). What velocity does one expect from the previous measurements with the Hall probes and copper plates?

Compare the measurements with literature values if possible. Discuss possible sources of error and estimate their influence on the results. Hint: Calculate the theoretical values before starting the experiment. This way it's clear what parameters and values are needed for the evaluation and one can avoid repeating measurements.

5 Report

The report should focus on the experimental part, thus the theoretical part can be kept short. Nevertheless the important relationships and formulas should be clear and the sources should be referenced properly. There is emphasis on clear presentation of the procedures and clear formulations. To give a direct insight in the experimental activities carried out a copy of a Labjournal should be included. A preliminary version of the report can be handed in for corrections while a final version should be bound or stapled.

A Literature

The listed books can be found in the library of the ExWi. The Signatures are in parentheses.

- Kittel: Festkörperphysik (VAZ 161)
- Ibach/Lüth: Festkörperphysik (VAZ 180, 196)
- Ibach/Lüth: Solid State Physics (VAZ 206)
- Bergmann/Schäfer: Experimentalphysik - Aufbau der Materie, Band IV.1. (ODA 114 v4.1)
- Grimsehl: Struktur der Materie (ODA 204)
- Spenke: Elektronische Halbleiter (VNA 119,123)
- Seiler: Physik und Technik der Halbleiter (VNA 123)
- Hannay: Semiconductors (VNA 117)
- Weissmantel/Hamann: Grundlagen der Festkörperphysik (VAZ 126)

B Material

- Power Supply (36V, 50A) Kepco Power Supply
- Power Supply (16V, 50A) Powertronic Power Supply LAB1650D (AP70022.0)
- Power Supply for Hall probes with integrator and connection cable. (AP 2098 E 205)
- Coil (AP 842 ED)
- Coil with Iron Core (AP 201 ED)
- GaAs Hall probe KSY14
- InAs Hall probe SBV604
- 2 Copper plates with connectors
- Multimeter MX515
- Triple power supply HM 8040 / Digital Multimeter JHM 8011-3 (AP70027.0)
- Various cables