Exp 6 Hall Effect

The apparatus is used to demonstrate the Hall constant(R_H) and carrier concentration (n) by measuring the Hall voltage U_H on N-type semiconductor or P-type semiconductor bearing a current I in a magnet field B acting at right angles to the direction of current.

When using the Hall effect apparatus, semi-conductor, quantitative investigation of the relationships

$$U_H = f(I) \quad \text{and} \quad U_H = f(B)$$

via the proportionalities

$$U_H \sim f(I) \quad \text{and} \quad U_H \sim f(B)$$

gives $U_H = const.\, IB$

The theoretically derived formula for the Hall voltage of a strip-shaped conductor (of thickness d) made of material with a charge carrier concentration n is thus confirmed:

$$U_H = \frac{1}{n \cdot e} \cdot \frac{1}{d} \cdot I \cdot B \qquad (1)$$

The material-dependent factor $\frac{1}{n \cdot e}$ is designated as the Hall constant R_H .

In equation (1), all quantities except n are accessible to measurement) so that the Hall effect enables the charge carrier concentration to be determined by experiment.

The direction of the Hall voltage in silver indicates negative charge carriers. The result is in agreement with the concepts of the model of the free electron gas. According to this, the most weakly bonded electrons (valency electrons) - for silver e.g. 1 valency electron per atom - are moving freely with in the metal.

The limits of this model are shown by the so-called "abnormal Hall effect" of tungsten. Experiments carried out with the Hall effect apparatus, tungsten under identical conditions give the following result: The Hall voltage in tungsten has the same magnitude but the opposite direction as in silver. This can be explained by the "energy band diagram". So-called hole electrons or holes are assigned to empty positions near the upper edge of an otherwise filled energy band. As can also be shown theoretically, such holes behave relative to electric or magnetic fields in such a way that they would seem to have positive charges.

Equipment:

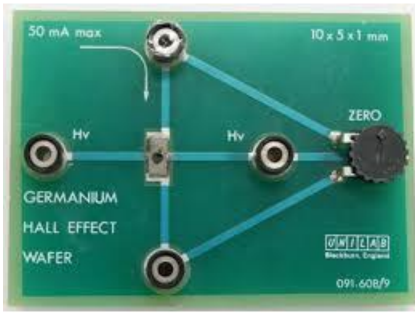

Fig1a semi-conductor wafer

Fig1b Adjustable magnets set

1 Safety notes

For protecting the Hall Effect wafer, the transverse current must be less than 50mA.
No matter N-type or P-type semi-conductor cell is so fragile, avoid dropping or squeezing.

2 Description and technical data

① Strip type conductor of N-ytpe or P-type semiconductor; strip thickness $d = 1 \times 10^{-3}$m

② Sockets for transverse current I, max. admissible intensity of current I: 50m A DC.

③ Pair of sockets for tapping the Hall voltage U_H; with polarity designation (for indicating a positive Hall voltage). Magnitude of Hall voltage $U_H : 10^{-1}$ V.

④ Adjusting knob for built-in 5 Ohm potentiometer for zero point adjustment

⑤ The U-set which the adjustable electromagnet for generation of the homogeneous magnetic field is about 0.5kg. Generating field strength B can be 0.01 T to 0.9 T depending on the distance of two magnets.

3 Operation

3.1 Circuit assembly equipment and measuring instruments

For both Hall apparatus the circuit is assembled according to Fig. 2, using the following equipment and measuring instruments for the transverse current I, the magnetic field and the Hall voltage.

3.1.1 Transverse current I

DC voltage source, 50mA, to tap $U_H = f(\mathrm{B})$, adjustable.

3.1.2 Magnetic field

Electromagnet, assembled from U-set pair of distance adjustable magnets Weight about 0.5kg

Measuring device for magnetic field strength B

Tangential B-probe

Teslameter

3.1.3 Hall voltage U_H

Voltage-sensitive measuring instrument, range $10V$ to $10^{-1}V$ DC voltmeter

4 Steps on experiments

1. Setup the Hall effect apparatus according to Fig. 3a without plugging any wire yet.

> Notice: The semi-conductor cell is just at the middle of two magnets.

2. Adjust both two magnets to close wafer until both the air gaps are about 5mm as Fig 3a.
3. Use two rulers to mark the locations of two magnets as R(r1) and L(l1) as Fig 3a. in table 1.
4. Remove wafer from adjustable magnets set.
5. Insert the measuring probe of Teslameter into the middle of two magnets to measure the magnetic field strength and record as B(1) as Fig 3b. in table 1.
6. Turn both magnets away from each other for 1mm to get R(r1+1) and L(l1+1) and measure those magnetic filed strengths as B(2) in table 1.
7. Repeat step 6. Until all the data in table 1 are full filled.

> Notice: Steps from 1. to 7. are designed to contribute a magnetic field strength diagram.

8. Put semiconductor wafer back into the middle of the adjustable magnets set and adjust both magnets back to R(r1) and L(l1).
9. Set the transverse current into 50mA DC into the electro-magnet whose pole pieces are placed right against the panel so as to keep the air gap where the semiconductor is positioned as narrow as possible. Determine the curve $U_H = f(\mathrm{B})$.

5 Example of measurement using the Hall effect apparatus, silver, (see Fig. 3)

Hall voltage U_H as a function of the magnetic flux density *B* at a transverse current I of 20 *A*; the slope $\frac{\Delta U_H}{\Delta B}$ is given for calculating the Hall constant. $\because \mathrm{U}_H = \frac{1}{n \cdot e} \cdot \frac{1}{d} \cdot I \cdot B$

$$\therefore R_H \equiv \frac{\Delta U_H}{\Delta B} \cdot \frac{d}{I} = \frac{1}{n \cdot e}$$

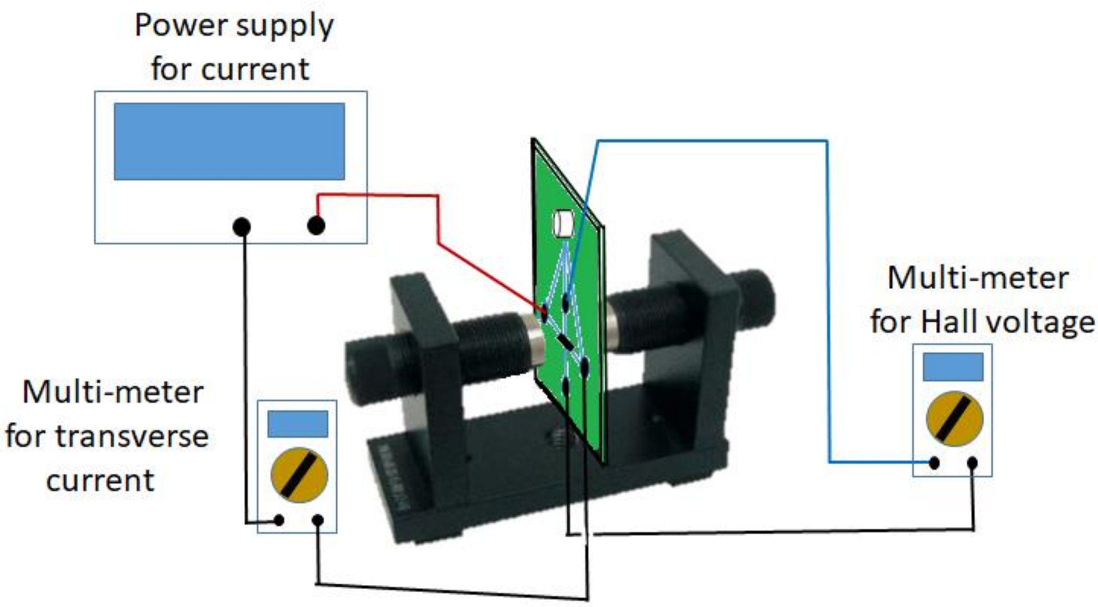

Fig 2. Experiment assembly for Hall Effect

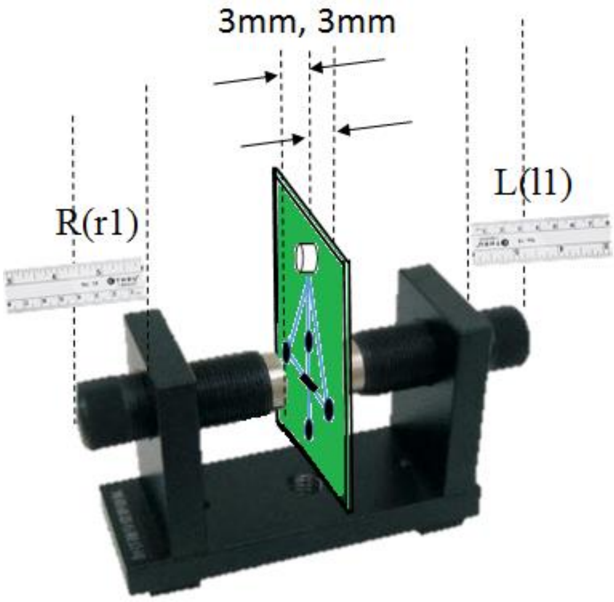

Fig 3a

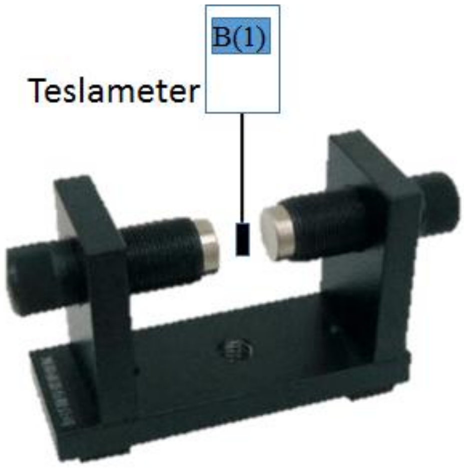

Fig 3b

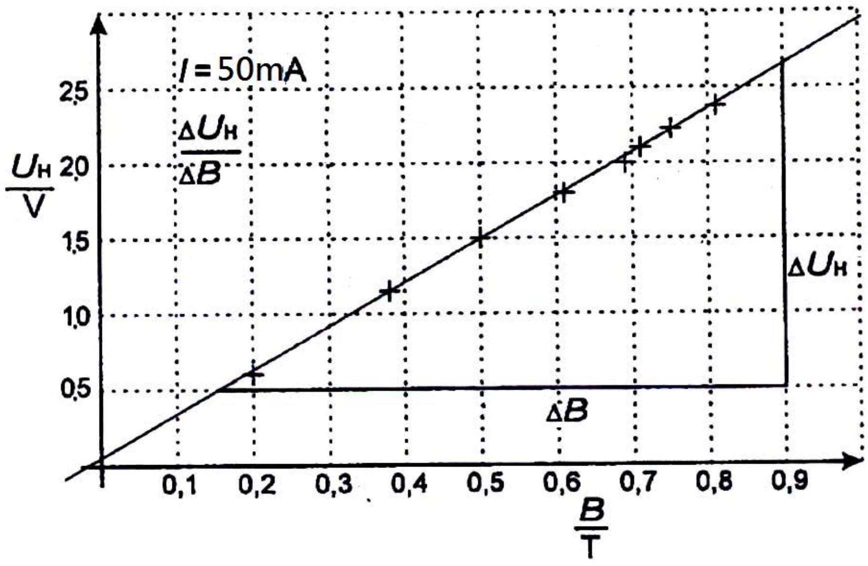

Fig3

	R(r1) (mm)	L(l1) (mm)	*B* (T)	U_H(V)
1	R(r1) = _______	L(l1) = _______		
2	R(r1+1) = _______	L(l1+1) = _______		
3	R(r1+2) = _______	L(l1+2) = _______		
4	R(r1+3) = _______	L(l1+3) = _______		
5	R(r1+4) = _______	L(l1+4) = _______		
6	R(r1+5) = _______	L(l1+5) = _______		
7	R(r1+6) = _______	L(l1+6) = _______		
8	R(r1+7) = _______	L(l1+7) = _______		
9	R(r1+8) = _______	L(l1+8) = _______		
10	R(r1+9) = _______	L(l1+9) = _______		

Table 1