Experiment 15

CONDUCTING PROPERTIES OF SEMICONDUCTORS

PURPOSE

- To study temperature dependence of the intrinsic semiconductor
- To establish the activation energy of semiconductor.

APPARATUS

Heated aluminium block with examined semiconductor element, digital voltmeter, ammeter, power supply, thermometer.

DESCRIPTION OF THE MEASUREMENTS.

Semiconducting materials exhibit non-linear current voltage dependence due to the specific mechanism of conduction. Conductivity of the intrinsic semiconductor depends on the width of the width of energy gap between valence band and conductance band E_G. For doped semiconductor the gap between valence band and acceptor level (in a ***p-type***) or donor level and conductance band (in a ***n-type***) – E_B. Activation of conduction (charge carrier generation) can be done by introducing the energy to the system The required minimum amount is called activation energy. It can be provided by electromagnetic radiation or thermal energy. Thus with an increase of temperature its resistance decreases nonlinearly.
Conductivity of intrinsic semiconductor depends exponentially on the temperature:

$$\sigma = \sigma_0 \exp\left(-\frac{E_G}{2kT}\right) \qquad (1)$$

where: E_G activation energy; k – Boltzmann's constant.

Since the observed resistance of an examined element is inversely proportional to its conductivity the relevant expression for the temperature dependence can be written:

$$R = R_0 \exp\left(\frac{E_G}{2 \cdot k \cdot T}\right) \qquad (2)$$

and activation energy of semiconductor can retrieved from the ***R(T)*** measurements.

In a present experiment resistance measurement is accomplished by the voltmeter-ammeter method i.e. by the simultaneous measurements of current flowing through the circuit and the voltage drop across the resistance – circuit is shown in Fig.1.
The resistance can be calculated from Ohm's law Eq. 3.:

$$R = \frac{U}{i} \qquad (3)$$

Changes of temperature affects the conductivity of intrinsic semiconductor placed inside the heated aluminium block. The resistance versus temperature dependence is described by activation function - Eq.2.

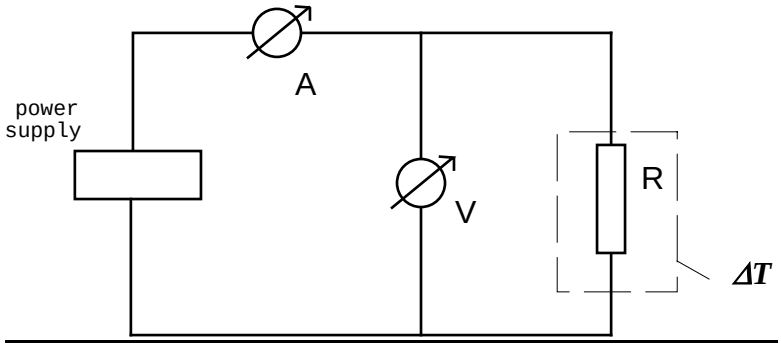

Figure 1. Experimental arrangement

MEASUREMENTS

1. Assembly the circuit as diagrammed in Fig 1 . The setting of the voltage control should be at minimum at first.
   Wait for supervisor's verification and approval.
2. Adjust the voltage according to the value given on the information sheet. Keep the voltage value at the same level during all measurements (possible demolition of semiconductor element may occur if overstep).
3. Take the readings of current - ***I*** - and voltage - ***U*** - with the voltmeter and ammeter respectively. Be sure to use meter range of the ammeter which allow accurate readings in the whole range of temperatures.
   Record the temperature - T - of the aluminium block.
4. Turn the heater on.
   Take the series of readings of current and voltage for 10-15 temperature values up to the 373[K] value.
5. Turn the heater off.
6. Repeat measurements from step 4 while systems cools down.

Record all values (***I***, ***U***, ***T***) for heating and cooling process separately in the data table.

CALCULATIONS AND PRESENTATION OF RESULTS

1. Calculate resistance values for all temperature points from Ohm's law (Eq.3).
2. Plot the resistance versus temperature dependence ***R (T)*** (two separate plots for heating and cooling of the system).
3. Recalculate the ***R*** values into the ***lnR*** and ***T*** values into the ***1/T*** respectively.
   Put new data on the data table .
4. Plot one, common ***ln R = f(1/T)*** dependence curve.
5. Calculate from the linear regression method the slope of ***ln R (1 / T)*** curve – ***A***.
6. Determine the method uncertainty (see part II -Lab Data Analysis.) – record ***ΔA*** value.

6. Determine the activation energy value - E_A - from Eq.4.

$$A = \frac{E_G}{2 \cdot k} \qquad E_G = 2kA \tag{4}$$

8. Calculate the experimental error:

$$\Delta E_G = E_G \frac{\Delta A}{A} \tag{5}$$

9. Present the result in form

$$E = E_G \pm \Delta E_G \tag{6}$$

Give its value in both [**J**] and [**eV**] units.

ANALYSIS AND INTERPRETATION

1. Discuss the linearity of ***ln R = f(1 / T)*** plot.
2. Compare obtained activation energy value with literature data.
3. Compare temperature dependence of semiconductor resistance with that one of metal resistor.

DATA TABLE

voltage U [V]	current I [A]	resistance R [Ω]	temperature T [K]	ln R	1 / T [K^{-1}]

REQUIREMENTS

1. Internal structure of intrinsic and doped semiconductors. Energy band model.
2. Principles of electrical conductivity of semiconductors.
3. Temperature dependence of resistance of different materials.