MIT World Peace University

Physics
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Measurement of the Energy Band Gap of a Semiconductor

Experiment No. 6

Prepared By

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Pledge

I solemnly affirm that I am presenting this journal based on my own experimental work. I have neither copied the observations, calculations, graphs and results from others nor given it to others for copying.

Signature of the student

1 Aim

To measure energy gap of given semiconductor

2 Apparatus

1. Semiconductor (thermistor with NTC)
2. Heating arrangement with mini-oven filled with sand powder and secondary windings of a step down transfer for controlled electrical heating,
3. Digital Multimeter (DMM) (Refer Fig 7.2)

3 Significance of the Experiment

The energy gap, i.e. the gap between valance band and conduction band decides the conductivity of a material. The typical energy gaps of the semiconductors which are in the range 1 eV to 3 eV impart many useful properties to the semiconductors. The ability of the semiconductors to conduct due to electrons as well as holes, their ability to convert light in to electricity and electricity in to light, decrease in the resistance with temperature are all due to their typical energy gaps. The electronics (PN junction diode, NPN or PNP transistor), photonics (LED, laser diode, photodiode, solar cell, LDR etc.) and thermistors, are all based on the typical energy gaps of semiconductors. The energy gap of silicon (1.1 eV) makes it more applicable than germanium (0.72 eV). This experiment demonstrates one of the simplest methods of measuring the energy gap of semiconductors.

4 Theory

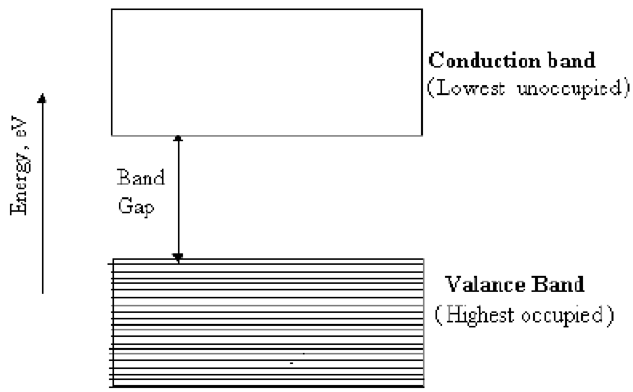


Figure 6.1: Concept of energy gap

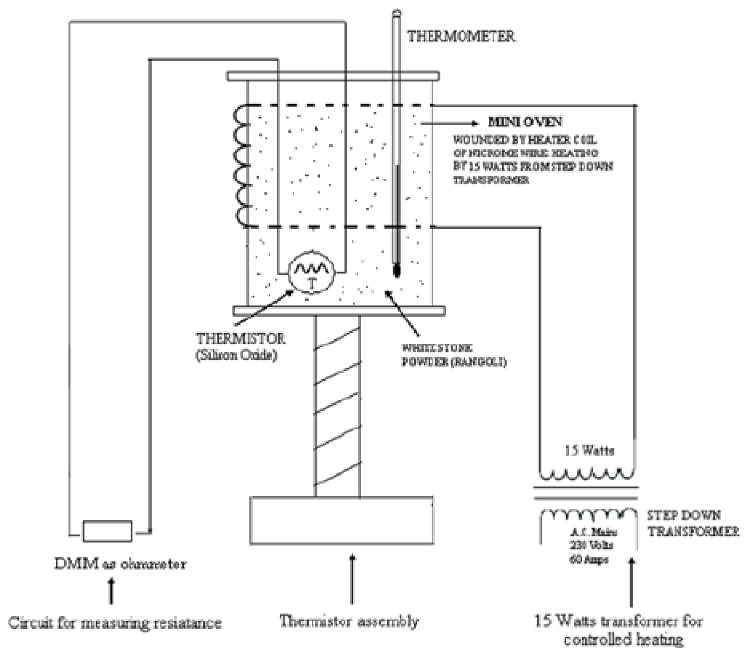


Figure 6.2: Experimental arrangement for the band gap experiment

Individualatoms are characterized by discrete energy levels. When atoms come together and form bonds, their energy levels split and become bands. This happens due to the overlapping of electron wave-functions and Paulis exclusion principle. Crystalline solids are characterized by energy band diagrams. The energy band diagram of a solid is characteristic to its atom and inter-atomic spacing. The highest occupied band in such energy bands is called as valance band while the lowest unoccupied band is called as conduction band. The valance band and conduction band are separated by a group of quantum mechanically forbidden energy levels called as energy gap (refer Fig 7.1). The size or value of this energy gap varies with the material. In conductors like copper, aluminum, gold, silver etc. the energy gap is zero, while it is high in insulators like diamond (5 to 6 eV). Elemental semiconductors such as silicon, germanium and compound semiconductors such as gallium arsenide, zinc sulphide, gallium phospide, etc are characterized by intermediate energy gaps (0.66 to 3.6 eV). The resistance (RT) of a semiconductor having energy gap (Eg) decreases with the temperature (T), according to following relation

$$R_T = R_{TO} e^{\frac{E_g}{2KT}}$$

Where K is the Boltzmann's constant By taking logarithms and rearranging

$$\ln R_T = \ln R_{TO} + \left(\frac{E_g}{2K}\right) \times \frac{1}{T}$$

Eqn (7.2) signifies a straight line ($\Rightarrow y = mx + c$) Thus the graph of $\ln R_T Vs \frac{1}{T}$ is a straight line having slope $m = \frac{E_g}{2K}$. Thus

$$E_g = \text{2Km}$$

Eqn (6.3) provides a simple and straightforward method of measuring energy gap of a semiconductor.

5 Procedure

1. Connect the circuit as shown in the circuit diagram and get it checked. Connect the terminals of the thermistor to the DMM. Operate DMM in resistance mode and with appropriate scale.

2. Record the room temperature and corresponding resistance (R_T) of thermistor. Express resistance in Ω (not in kΩ or MΩ).

3. Start heating the oven by making AC mains ON. Record decreasing values of resistances (in Ω) at different temperatures as shown in the observation table.

4. Calculate various quantities such as $T(= t + 273\text{ K})$, $\frac{1}{T}$ and $\ln R_T$

5. Plot the graph of $R_T V s T$. This graph exhibits the NTC (Negative Temperature Coefficient) property of thermistor

6. Plot the graph of $\ln R_T V s \frac{1}{T}$. Calculate its slope (m) and the energy gap using Eqn (7.3)

6 Observations

Sr. No.	Observations		Calculations		
	Temperature T, ^{O}C	**Resistance R_T, Ω**	**Temperature, T (K)**	***1/T*** *(Expressed in 10^{-3})* **K^{-1})**	**lnR_T**
1	R.T. =				
2					
3					
4					
5					
6					
7					
8					
9					

7 Calculations

Slope of the graph of $\ln R_T Vs \frac{1}{T} = m =$ K Energy gap, $E_g =$ 2Km, where K = Boltzman's constant = 1.37×10^{-23} J/K

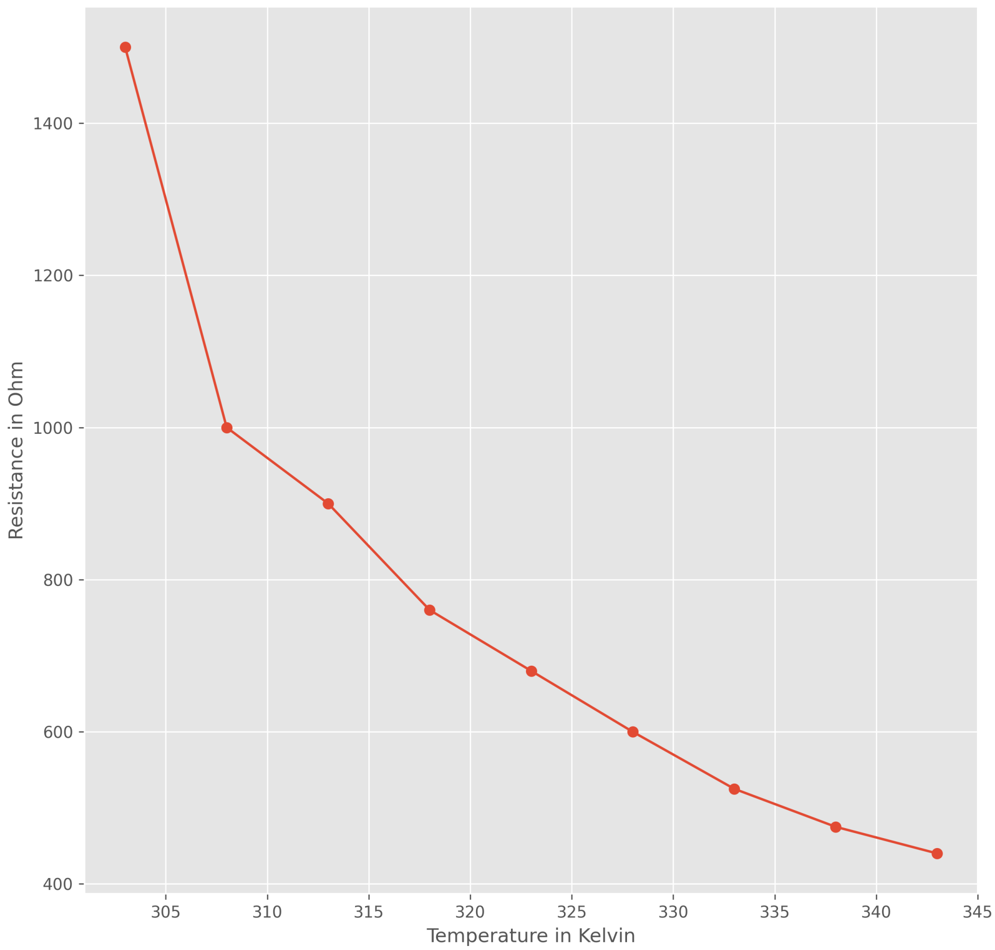
$$= 2 \times 1.37 \times 10^{-23}\left(\frac{J}{K}\right) \times m(K) = 2 \times 1.37 \times 10^{-23}\left(\frac{J}{K}\right) \times \ldots\ldots\ldots(K)$$

$$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots J = \frac{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(J)}{1.6 \times 10^{-19}\frac{J}{eV}} = \ldots\ldots\ldots eV$$

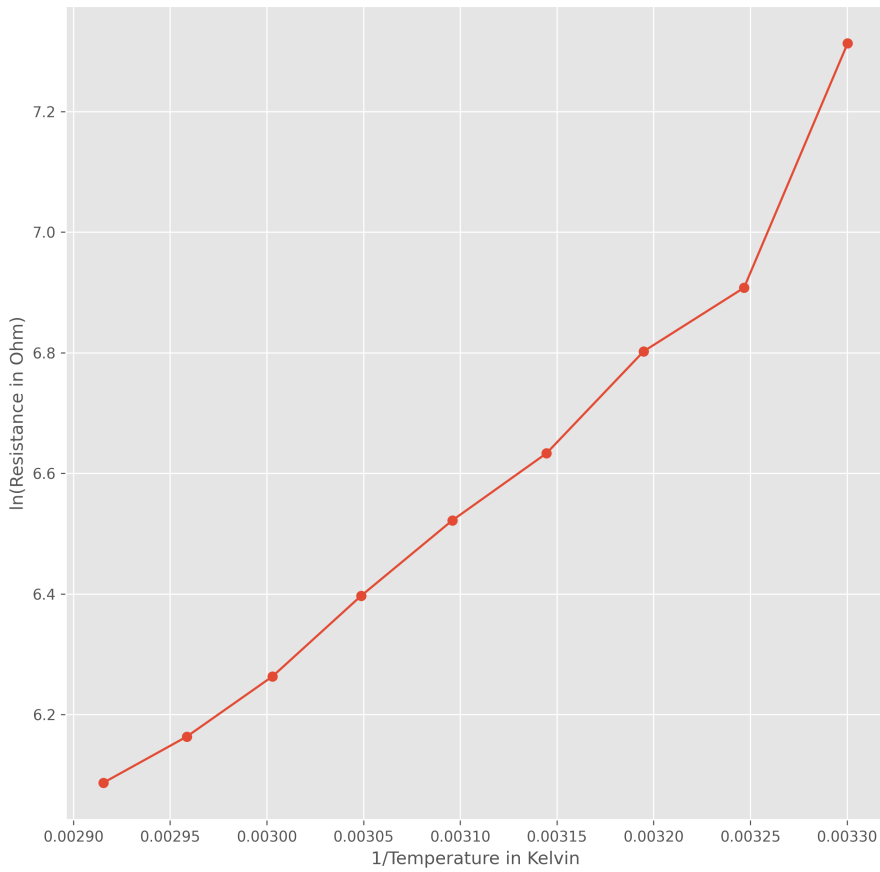
Result: The energy gap of given semiconductor (thermistor) is eV

8 Graphs

8.1 Plot between Temperature in Kelvin and Resistance in Ohm



8.2 Plot between $1/Temperature$ in kelvin vs $ln(Resistance)$ in Ohm



9 My Understanding of the Experiment

Semiconductors are special in that their resistance decreases upon increase in temperature due to higher number of electrons being present in the conduction band. The rise in temperature basically provides thermal energy to those electrons, so that they can jump across the forbidden band gap, and go to the conduction band. So naturally for every substance, having its own unique band gap, the temperature required to bring them to the conduction band is also unique. So there exists a relation between the band gap, and the temperature. It is using this relation, and property that the energy band gap of a semiconductor can be calculated, and different semiconductors can be recognized based on it.