116048/ SHASHANK MAHALE

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

Experiment 6: Energy gap of Semiconductor

Aim: To measure energy gap of given semiconductor

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

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.*

Theory: 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 Pauli's exclusion principle. Crystalline solids are characterized

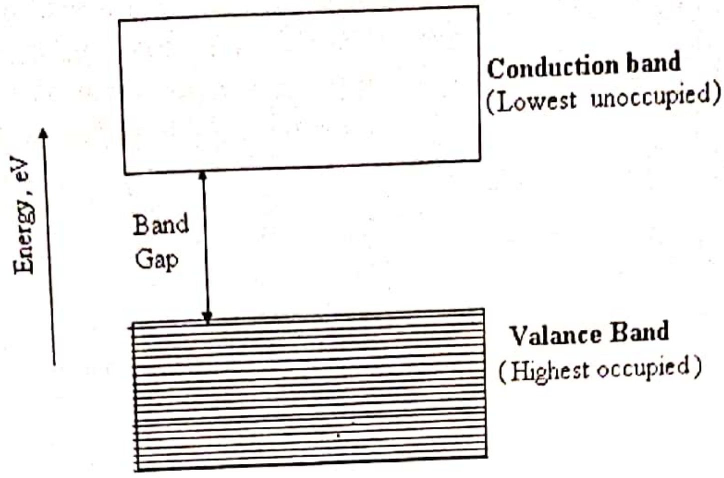


Figure 6.1: Concept of energy gap

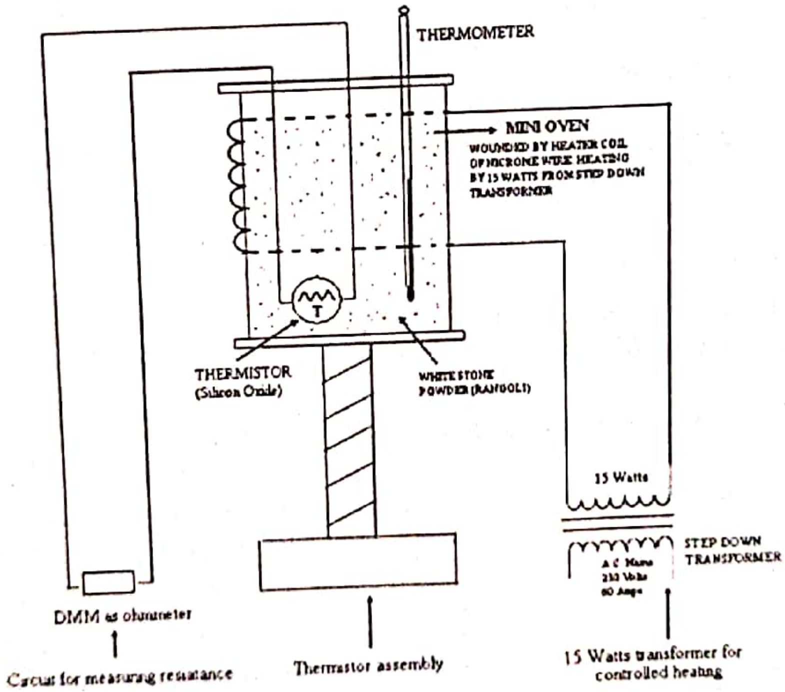


Figure 6.2: Experimental arrangement for the band gap experiment

by energy band diagrams. The energy band diagram of a solid is characteristic to it's 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 (R_T) of a semiconductor having energy gap (E_g) decreases with the temperature (T), according to following relation

$$R_T = R_{TO} e^{\frac{E_g}{2KT}} \quad \text{...(6.1)}$$

Where K is the Boltzmann's constant

By taking logarithms and rearranging

$$lnR_T = lnR_{TO} + \left(\frac{E_g}{2K}\right) \times \frac{1}{T} \quad \text{...(6.2)}$$

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

$$E_g = 2Km \quad \text{...(6.3)}$$

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

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.
1. Calculate various quantities such as T $(= t + 273\ K)$, $\frac{1}{T}$ and lnR_T
2. Plot the graph of R_T Vs T . This graph exhibits the NTC (Negative Temperature Coefficient) property of thermistor
4. Plot the graph of lnR_T Vs $\frac{1}{T}$. Calculate its slope (m) and the energy gap using Eqn (7.3)

ROUGH WORK

Observation table

Sr. No.	Observations		Calculations		
	Temperature T, °C	Resistance R_T, Ω	Temperature, T (K)	1/T (Expressed in 10^{-3} K^{-1})	lnR_T
1	R.T. = 30	1500	303	3.30	7.3132
2	35	1000	308	3.24	6.9077
3	40	900	313	3.19	6.8023
4	45	760	318	3.14	6.6333
5	50	680	323	3.09	6.5202
6	55	600	328	3.04	6.3969
7	60	525	333	3.003	6.2633
8	65	475	338	2.95	6.1633
9	70	440	343	2.91	6.0867

Calculations:

Slope of the graph of lnR_T Vs $\frac{1}{T} = m =$ 2.786 K

Energy gap, $E_g = 2Km$, where K = Boltzman's constant = 1.37×10^{-23} J/K

$= 2 \times 1.37 \times 10^{-23} \left(\frac{J}{K}\right) \times m\ (K) = 2 \times 1.37 \times 10^{-23} \left(\frac{J}{K}\right) \times 2.786\ (K)$

$= 7.6336 \times 10^{-20}$ J $= \frac{7.6336 \times 10^{-20} (J)}{1.6\times10^{-19}\frac{J}{eV}} =$ .477 eV

Result: The energy gap of given semiconductor (thermistor) is 0.477 eV

MIT-WPU

Dr. Vishwanath Karad
MIT WORLD PEACE UNIVERSITY PUNE
TECHNOLOGY, RESEARCH, SOCIAL INNOVATION & PARTNERSHIPS

FAIR WORK

Observation table

Sr. No.	Observations		Calculations		
	Temperature T, °C	Resistance R_T, Ω	Temperature, T (K)	$1/T$ (Expressed in 10^{-3}) K^{-1})	$\ln R_T$
1	R.T. = 30	1500	303	3.30	7.31
2	35	1000	308	3.24	6.90
3	40	900	313	3.19	6.80
4	45	760	318	3.14	6.63
5	50	680	323	3.09	6.52
6	55	600	328	3.04	6.39
7	60	525	333	3.00	6.26
8	65	475	338	2.95	6.16
9	70	440	343	2.91	6.08

Calculations:

Slope of the graph of lnR_T Vs $\frac{1}{T} = m =$ 2786 K

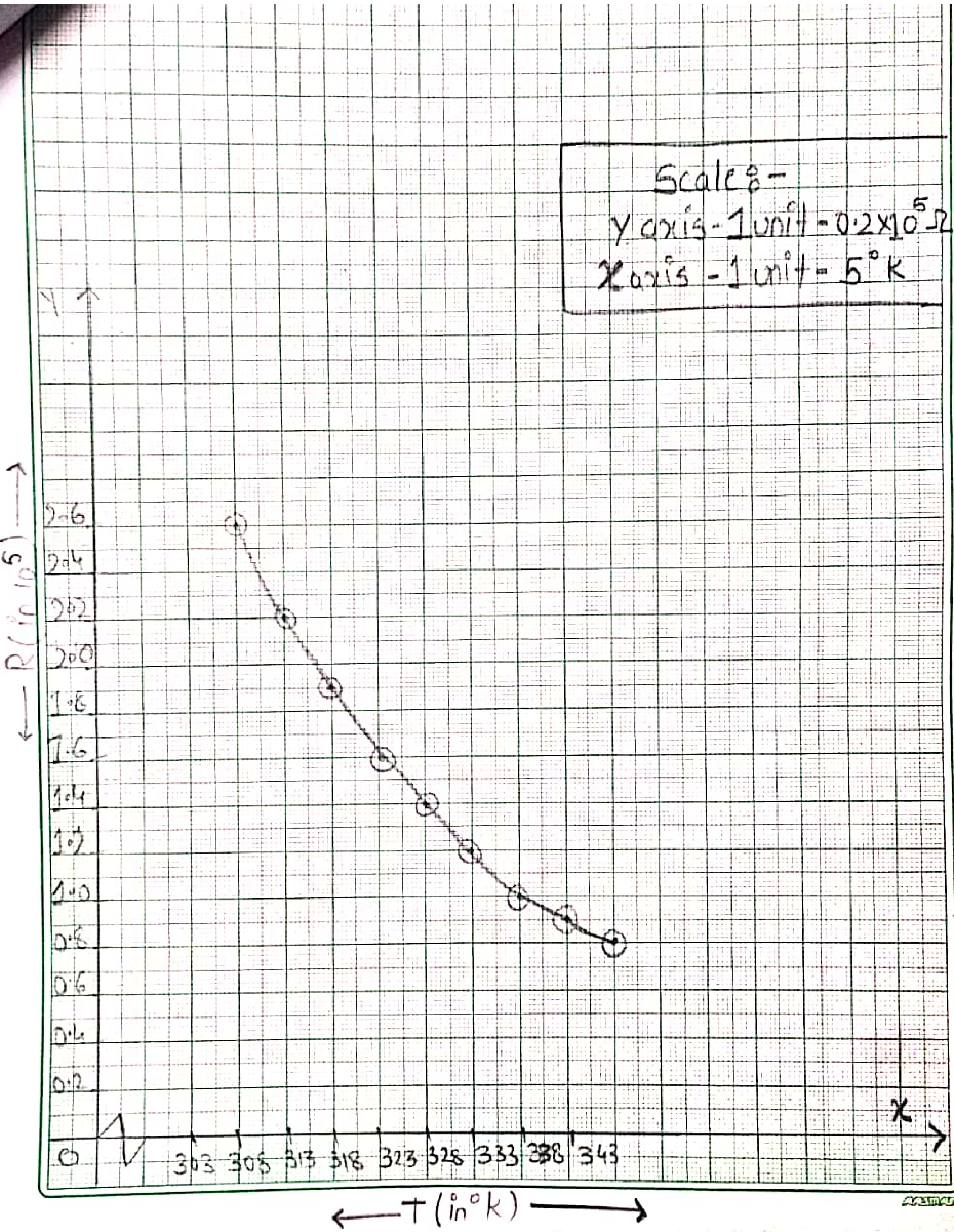
Energy gap, $E_g = 2Km$, where K = Boltzman's constant = 1.37×10^{-23} J/K

$$= 2 \times 1.37 \times 10^{-23} \left(\frac{J}{K}\right) \times m\ (K) = 2 \times 1.37 \times 10^{-23} \left(\frac{J}{K}\right) \times 2786\ (K)$$

$$= 7.6336 \times 10^{-20}\ J = \frac{7.6336 \times 10^{-20}\ (J)}{1.6\times10^{-19}\frac{J}{eV}} = 0.477\ eV$$

Result: The energy gap of given semiconductor (thermistor) is 0.477 eV

Scanned with CamScanner


Scale:-
y axis - 1 unit - 0.2x10^5 Ω
x axis - 1 unit - 5°K
R (in 10^5)
T (in°k)
Y
X
O
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
303
308
313
318
323
328
333
338
343

My understanding to this experiment

⇒ In this experiment we learnt about the study of variation in its conductance with respect to variation in temperature. The gap between valance band and conduction band is the factor that decides the conductivity of the given material. The conductivity of a semiconductor increases as we increase temperature