Energy Band Gap of Semiconductor

Physical Significance: Semiconductor is a backbone of most of the electronic devices mainly in circuit designing. A recent technology is based on P and N type of semiconductors generally known as P-N junction diode. Communication technology, optical fiber, engineering labs, energy savings, automobiles and information technology are the basic applications of semiconductor.

Relevant Program Outcomes:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

3. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

4. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

5. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Relevant Course Outcomes: The students are able to understand the basics of semiconductor.

Practical Learning Outcomes:

After completion of this experiment the students can

- Determine the energy band gap of a given semiconductor.
- Understand the basic principle and know very well about apparatus used and what precautions should be taken during the experiment in work.

Practical Skills:

1. Students learned how to perform the experiment sincerely.
2. Understand the fundamental via hands on practice.
3. Improve his practical knowledge.

Affective domain related Outcomes:

Receiving: Awareness, willingness to hear, selected attention.!.

Responding: Active participation on the part of the learners. Attends and reacts to a particular phenomenon. Learning outcomes may emphasize compliance in responding, willingness to respond, or satisfaction in responding (motivation).

Theoretical background: P-N junction diode is a basic component of electronic devices which is used as regulator and rectifier. It is operated in forward and reverse mode. In reverse mode, the electric current is observed due to motion of minority charge carriers in junction. This current is strongly depends on temperature. The reverse saturation current is expressed as:

$$I_s = A.T^{3/2}\, e^{-Eg/KT}$$

Where,

A= constant term

I_s = saturation current in micro ampere

T = temperature of junction diode in Kelvin

Eg = band gap in eV

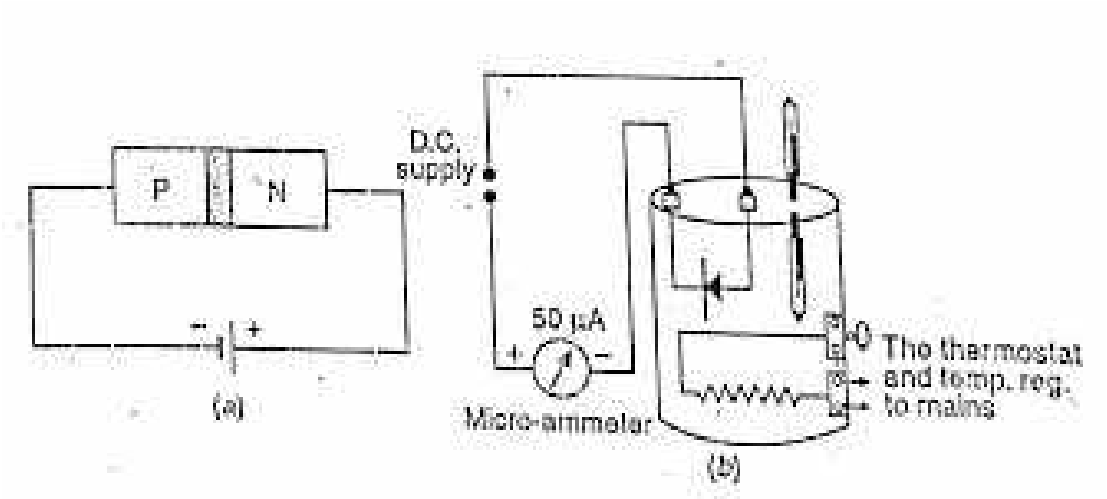
K = Boltzmann constant in eV per Kelvin

For small changes in temperature where log T can be treated as constant relation (1) can be written as

$\log_{10} I_s$ = constant – 5.04 Eg. 10^3 /T. Graph between 10^3 /T as abscissa and $\log_{10}$Is as ordinate will be a straight line having a slope = 5.04Eg.

Hence band gap Eg = slope of the line / 5.04 eV.

Circuit diagram:



Resources Required: The details of resources is given below in the table

S. No.	Name of resources	specifications	No. of required resources
1	P-N junction diode		
2	Thermometer		
3	Connecting wire		
4	Ammeter		
5	Voltmeter		
6	Battery		
7	Power Supply		
8	Thermocouple		
9	Table/Instrument stand		

Precautions:

1. The diode must be reverse biased.
2. Do not exceed the temperature of the oven above 100℃ to avoid over heating of the diode.
3. The voltmeter and ammeter reading should initially be at zero mark. If any error is showing, write down it.
4. Bulb of the thermometer should be inserted well in the oven.
5. Readings of ammeter should be taken when the temperature is decreasing.
6. Readings of current and temperature must be taken simultaneously.

Procedure:

1. Write down the room temperature.
2. Read the instructions carefully before start the apparatus for experiments.
3. Note the range of ammeter and voltmeter.
4. Write down the least count of ammeter, voltmeter and thermometer.
5. Put all the apparatus at proper place.

6. Connect all the apparatus using connecting wire with the help of circuit diagram.
7. Insert the thermometer in its proper place (hole) of the oven.
8. Switch on the power supply.
9. Check the indicator of voltmeter and ammeter whether it is initially in zero or not.
10. Fix the voltage value using voltmeter regulator and note down the corresponding values of Is.
11. Switch on heater or oven.
12. If the temperature of thermometer is reached at 72°C, switch of the heater.
13. Take the reading of saturation current I_s along with the decreasing temperature in 2-5^{0}C interval up to room temperature.
14. Taking 10^3 / T along X-axis and $\log_{10} I_s$ along Y-axis, plot a graph for a given voltage. Draw all the points; you will get straight line in the graph. Determine the slope of straight line from this graph and then calculate band gap using formula, Band gap (Eg) = $Slope$ /5.036 = _____ eV

Observations:

Least count of ammeter = SI unit

Least count of voltmeter = SI unit

Least count of thermometer = SI unit

V = ------ Volt

S. N.	**Temperature T (in °C)**	**Reverse Saturation Current Is (in A/mA)**	**Temperature T (in K)**	**10^3/T**	**$Log_{10}I_s$**
1.					
2.					
3.					
4.					
5.					

Calculations:

Results:

Interpretation of results:

Standard value Eg of Ge semiconductor = 0.7 eV.

Experimental Value = …eV.

$$\% \text{ Error} = \frac{\text{Standard Value} \sim \text{Experimental value}}{Standard\ value} \text{x } 100$$

Conclusions:

The calculated results is nearly close to standard value indicates that the difference is observed due to variation in temperature. Apart from that sensitivity of apparatus is another important parameter which can affect the results.

Recommendations:

1. Use properly calibrated instruments such as voltmeters, ammeters, and thermometers to minimize measurement errors.
2. Maintain uniform temperature variation while heating the semiconductor diode so that accurate temperature–current readings can be obtained.
3. Avoid overheating of the diode, as excessive temperature may damage the semiconductor device and affect the results.
4. Ensure good electrical connections in the circuit to prevent fluctuations in current and voltage readings.
5. Record readings carefully and allow sufficient time for the system to reach thermal equilibrium before taking each measurement.
6. Plot the graph accurately (log of reverse saturation current vs. inverse temperature) to obtain a precise value of the energy band gap.
7. Repeat the experiment multiple times and take the average value to reduce experimental uncertainty.

Assessment Process: Rubrics

S.N.	Scale ⇨ / Criteria ⇩	Poor	Satisfactory	Good	Excellent
1	**Understanding of Experiment**	Shows little understanding of the aim and theory of the experiment.	Basic understanding of the aim but explanation is incomplete.	Good understanding of the aim and theory with minor gaps.	Demonstrates clear and thorough understanding of the aim and underlying theory.
2	**Experimental Procedure & Handling of Apparatus**	Unable to follow procedure properly; improper handling of apparatus.	Follows procedure with guidance; handling of apparatus needs improvement.	Performs experiment correctly with minimal guidance.	Performs experiment independently with proper handling of apparatus.
3	**Observation & Data Recording**	Observations are incomplete or incorrect; data not properly recorded.	Records basic observations but with some errors or missing details.	Observations recorded correctly with minor mistakes.	Observations are complete, accurate, and systematically recorded.
4	**Graph / Calculations / Analysis**	Graphs or calculations missing or incorrect.	Graphs or calculations attempted but contain noticeable errors.	Graphs and calculations mostly correct with minor errors.	Graphs, calculations, and analysis are accurate and clearly presented.
5	**Neat and Clean Reporting of Practical Record**	Record is untidy with overwriting and missing diagrams or sections.	Record is somewhat neat but contains formatting or labeling issues.	Record is neat with properly drawn diagrams and organized content.	Record is very neat, well organized, and professionally presented.
6	**Viva / Conceptual Questions**	Unable to answer basic questions related to the experiment.	Answers some questions but lacks clarity in concepts.	Answers most questions correctly with reasonable explanation.	Answers confidently with clear conceptual understanding.
7	**Precautions**	Not known	Known but not understand	Known and understand	Known, understand and also know the importance
8	**Safety measures**	Doesn't follow	Follow but reason is not known	Follow and reason is known	Follow known and understand
9	**Team work ability**	Doesn't participate and perform the experiment	Perform but not interact with group	Perform and participate	Perform, participate, lead actively