NATIONAL UNIVERSITY OF TECHNOLOGY

COMPUTER ENGINEERING DEPARTMENT

Applied physics Lab (PHY13002)

Experiment No:6

Title: Experiment to investigate Dielectric constant of different materials.

Submitted to: Prof Ayesha

Submitted by: Muhammad Hamzah Iqbal

Nutech ID: F24604018

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Objectives:

1. Understand the characteristics of a diode.
2. Analyze the significance of resistance in a diode.
3. Explain the concept of diode resistance.

Apparatus:

1. Temperature control device
2. PHYWE power source
3. Submersion sensors
4. Thermostatic bath
5. Digital Multimeter
6. Resistance components
7. Connection cables
8. Tubing link

Theoretical explanation:

In restricted temperature ranges, the change in resistance of electrical components is approximately linear, described by the formula:

$$R(T)=R20+R20\cdot\alpha\cdot(T-20)$$

where:

- R(T): Resistance at temperature T,
- R_{20}: Resistance at 20°C,
- α: Temperature coefficient of resistance.

Rearranging and substituting measured values allow determination of α\alphaα. For copper wires, increasing temperature shortens the electron means free path, increasing resistance as:

$$R_{total}=R_{20}+R(T)$$

For NTC and PTC resistors, resistance changes non-linearly due to alloy compositions. In semiconductors, resistance decreases with temperature as carrier density increases. The intrinsic conductivity (σ) increases as:

$$\sigma=e\cdot n\cdot\mu$$

This experiment highlights linear and non-linear resistance behaviors across various materials and temperature ranges.

Procedure:

a) Fill the water bath and connect it to a thermostat to maintain temperatures from 20°C to 70°C.
b) Place the probe in a waterproof bag and immerse it in the water bath.
c) Set the multimeter to kilo-ohms, measure resistance for PTC, NTC, and metallic resistors, and record values.
d) Gradually increase water temperature by 10°C increments using a heating element.
e) Apply 10 V across diodes with a series resistor and measure current and forward voltage for Si and Ge diodes.
f) Optionally, configure diodes in reverse bias to measure breakdown voltages.
g) Repeat measurements at all temperature intervals and record the data.
h) Plot resistance and voltage against temperature to analyze trends.
i) Ensure safe handling of equipment and secure all connections.

Observations and Calculations:

Temperature	Voltage		Resistance (kΩ)					
			NTC		PTC		METAL	
	Silicon	Germanium	R_0	R_T	R_0	R_T	R_0	R_T
20	0.64	4.4	2.29	2.34	1.92	1.92	2.11	2.11
30	0.62	4.5	2.27	2.07	2.0	2.4	2.42	2.42
40	0.61	4.7	2.25	1.8	2.19	3.0	2.74	2.74
50	0.59	4.90	2.21	1.41	2.59	4.1	3.06	3.06
60	0.58	4.95	2.15	1.07	3.38	6.0	3.24	3.24
70	0.55	5.02	2.09	0.78	3.42	6.84	3.39	3.39

Observations:

1. Voltage:
   i. Silicon: The voltage decreases with temperature, starting from 0.64 V at 20°C and dropping to 0.55 V at 70°C.
   ii. Germanium: The voltage also decreases with temperature, starting from 4.4 V at 20°C and reaching 5.02 V at 70°C.

2. Resistance:

    i. NTC Resistor: Resistance (R_T) decreases significantly with temperature, from 2.34 kΩ at 20°C to 0.78 kΩ at 70°C, indicating a negative temperature coefficient.
    ii. PTC Resistor: Resistance increases with temperature, from 1.92 kΩ at 20°C to 6.84 kΩ at 70°C, showing a positive temperature coefficient.
    iii. Metal Resistor: Resistance shows a slight increase with temperature, from 2.11 kΩ at 20°C to 3.39 kΩ at 70°C, following a near-linear trend.

3. The data is consistent with the behavior of the materials:
    i. NTC (Negative Temperature Coefficient): Decreasing resistance with temperature.
    ii. PTC (Positive Temperature Coefficient): Increasing resistance with temperature.
    iii. Metal: Small, steady increase in resistance.

Calculations:

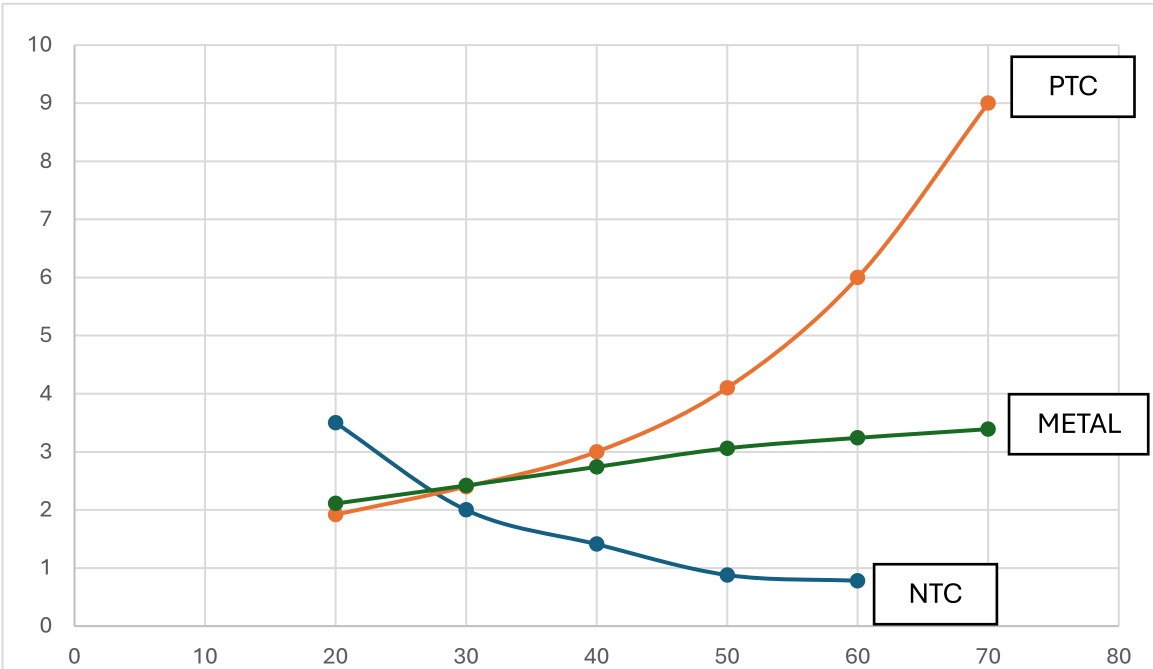
Using the formula:

$$R(T)=R_{20}+R_{20}\cdot\alpha\cdot(T-20)$$

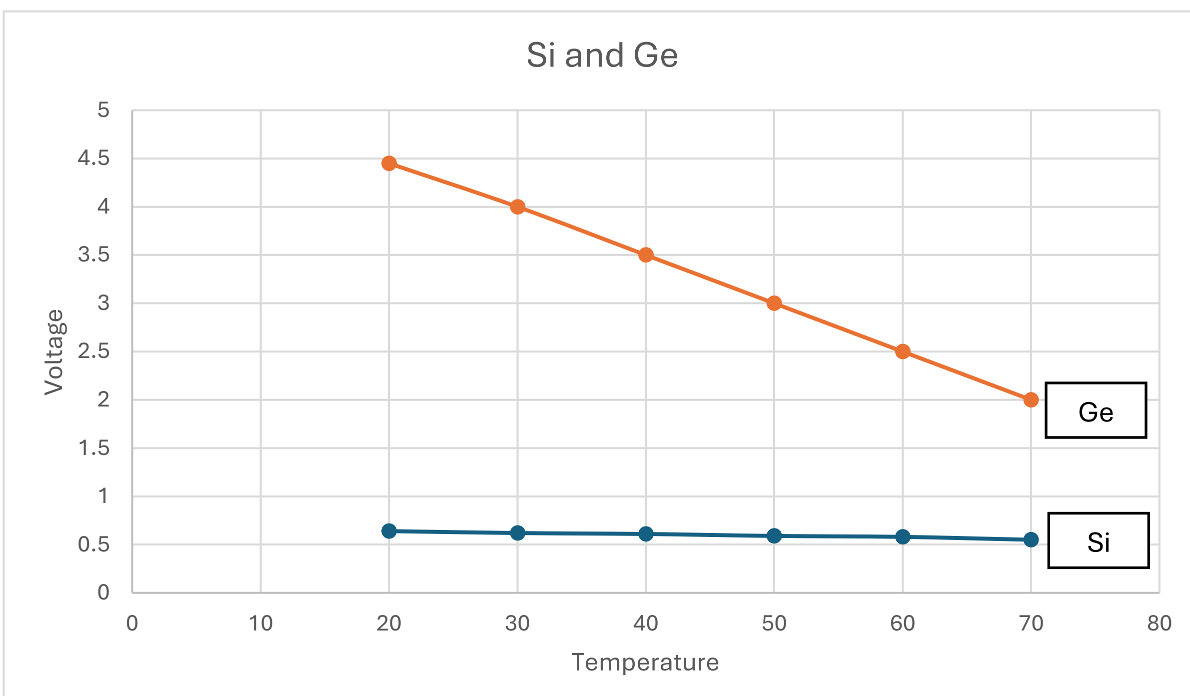
We have calculated R_T for each of the following material:

1. For NTC Resistor:
    - $R_{20}=2.34$ kΩ
    - R_T decreases with temperature, consistent with the negative coefficient.
2. For PTC Resistor:
    - $R_{20}=1.92$ kΩ
    - R_T increases with temperature due to a positive coefficient.
3. For Metal Resistor:
    - $R_{20}=2.11$ kΩ
    - R_T shows slight, consistent increases with temperature.

Graph of Temperature vs Resistance



Graph of Temperature vs Voltage



Result and Analysis:

The experimental results demonstrate the varying resistance and voltage behaviors of silicon, Germanium, NTC, PTC, and metal resistors over a temperature range of 20°C to 70°C. The resistance values R_T were calculated using the formula:

$$R(T)=R_{20}+R_{20}\cdot\alpha\cdot(T-20)$$

For silicon and germanium diodes, the forward voltage decreases as temperature increases. This behavior is expected due to the rise in charge carrier density with temperature, reducing the energy required for conduction.

The NTC resistor exhibited a significant decrease in resistance with temperature, from 2.34 kΩ at 20°C to 0.78 kΩ at 70°C, consistent with its negative temperature coefficient. In contrast, the PTC resistor showed a large increase in resistance, from 1.92 kΩ to 6.84 kΩ over the same range, confirming its positive temperature coefficient.

The metal resistor displayed a slight, steady increase in resistance, from 2.11 kΩ to 3.39 kΩ, aligning with the nearly linear relationship between resistance and temperature in metals.

This experiment validates the distinct temperature-dependent behaviors of resistors and semiconductors. NTC and PTC resistors exhibit non-linear changes, while metal resistors and diodes demonstrate more predictable trends. These findings highlight the relationship between temperature, material properties, and electrical behavior, critical for designing temperature-sensitive circuits.

Precaution:

1. Ensure the probe assembly is securely sealed in a waterproof bag to prevent water damage to the components.
2. Gradually increase the water temperature to avoid thermal shocks to the resistors and diodes.
3. Confirm that all electrical connections are secure and insulated to prevent short circuits or inaccurate measurements.
4. Calibrate the digital multimeter before use for precise resistance and voltage readings.
5. Monitor the thermostat and heating element closely to maintain consistent temperature increments.
6. Avoid touching the water bath or heated components directly to prevent burns or accidents.

Comments:

- The resistance changes for NTC and PTC resistors were more pronounced compared to metal resistors, demonstrating their suitability for temperature-sensitive applications.
- Silicon and germanium diodes showed expected decreases in forward voltage with temperature, consistent with increased carrier generation.
- The experiment highlighted how material properties influence the behavior of electrical components across varying temperatures.
- NTC and PTC resistors demonstrate distinct behaviors, highlighting the importance of material properties in temperature-sensitive designs.
- The plotted curves provide a clear visualization of resistance and voltage changes with temperature, aiding in understanding component behavior.
- Metal resistors are ideal for applications requiring minimal thermal variation, ensuring consistency in performance.
- The decrease in forward voltage in diodes supports their efficiency in high-temperature environments.

Conclusion:

This experiment demonstrated the impact of temperature on the electrical properties of various components, providing insights into their behavior and practical applications. The resistance of NTC and PTC resistors showed significant temperature dependence, with NTC resistors decreasing in resistance and PTC resistors increasing, aligning with their respective temperature coefficients. These findings highlight their suitability for applications such as temperature sensing, thermal management, and safety systems. Metal resistors exhibited minimal resistance changes, confirming their reliability in circuits requiring stability across varying temperatures.

For semiconductors, silicon and germanium diodes displayed a decrease in forward voltage with temperature, consistent with theoretical predictions of increased charge carrier density. This validates their use in temperature-sensitive devices and high-temperature environments.

The data, when plotted, clearly illustrated these trends, supporting the theoretical model $R(T)=R20+R20\cdot\alpha\cdot(T-20)$. Overall, the experiment emphasized the importance of understanding temperature-dependent behaviors in designing and selecting components for various applications.