Teacher's Preparatory Guide

The Effect of Temperature on the Electrical Resistance Properties of a Thermistor

Purpose

The purpose of this activity is to show that all resistors do not increase resistance when the temperature increases. This is a basic concept in electronics. Students will discover that themistors, which are semiconductors, do not follow ohms law and are therefore non-ohmic. This activity will introduce semiconductors so that future activities may build upon this idea to conclude with micro/nano-circuits.

Time required: 45 – 55 minutes

Level: High School

Teacher Background

Ohm's Law

Georg Simon Ohm discovered that materials have an ohmic, or linear region. His equation (Eqn 1) explains that as the potential difference (ΔV) increases, so does the current (I), and the relationship is linear to a point. The slope of a voltage vs. current plot yields the resistance (R). Temperature affects the resistance. If a resistor heats up, the value of its resistance increases, and the resistor is now considered non-ohmic. Non-ohmic materials have a non-linear relationship between voltage and current.

$$\Delta V = IR \qquad \text{Eqn 1}$$

Resistivity

Resistivity (ρ) is an electrical property of a material. Its relation to resistance (R) is shown in Equation 2. The equations that relate resistivity to temperature, and resistance to temperature, are shown below in Equation 3 & 4. The temperature coefficient of resistance is alpha (α) and it is a material constant. T_0, ρ_0, and R_0 represent the known temperature, resistivity, and resistance, respectively.

$$R = \rho \frac{L}{A} \qquad \text{Eqn 2}$$

$$\rho = \rho_0\left[1 + \alpha(T - T_0)\right] \qquad \text{Eqn 3}$$

$$R = R_0\left[1 + \alpha(T - T_0)\right] \qquad \text{Eqn 4}$$

Thermistors

Thermistors are sometimes used as temperature devices in the electronics industry. They have unique properties. In this lab it will be shown that thermistors have a negative coefficient of temperature (NTC), which is counter intuitive. Positive

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coefficient of temperature (PTC) thermistors also exist. Pure metals have positive coefficients of temperature, while alloys have coefficients near zero. However semiconductors like carbon, silicon, and germanium have negative temperature coefficients.

Materials (For each lab set-up)

- A variety of resistance level NTC thermistors
- Thermometer
- Hot plate
- Ohmmeter
- Ice
- Beaker
- Ring Stand
- Clamp

Advance Preparation

Thermistors need to be purchased. Possible venders include: Radio Shack, Digi-Key, or Mouser. Obtain hot plates and beakers from the chemistry teacher.

Safety Information

Goggles should be worn to prevent hot water from entering the eye.

Directions for the Activity

1. Discuss what happens to resistance when temperature increases. Perhaps do an activity where the temperature increases as the resistance increases.
2. Divide the class into pairs.
3. Explain to the students that they need to take measurements of the thermistor's resistance with an ohmmeter every 5° C increment.
4. Remind students to wear their goggles and tell them not to touch the hot plate when it has been heated.

Procedure (from Student Activity Guide)

Student Worksheet

The Effect of Temperature on the Electrical Resistive Properties of a Thermistor

Objective

A thermistor is a semiconductor, a group of materials classified as having properties of both conductors and insulators. This experiment illustrates how temperature affects electrical resistance of a semiconductor.

Materials

- A variety of resistance level NTC thermistors

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- Thermometer
- Hot plate
- Ohmmeter
- Ice
- Beaker
- Ring Stand
- Clamp
- Tongs

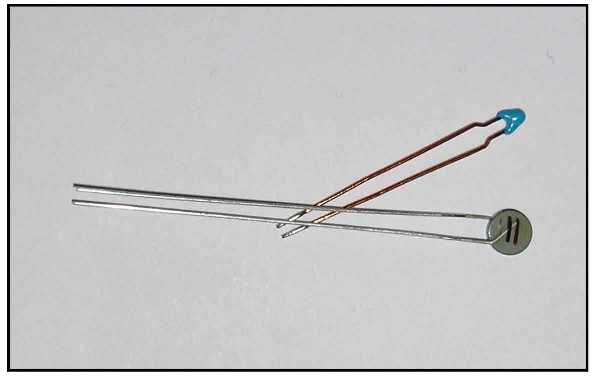

Figure 1. NTC thermistors.

Procedure

1. Place a clamp on a ring stand.
2. Affix a themistor to the clamp on the ring stand.
3. Place the ring stand over a cool hot plate.
4. Add water and ice to a large beaker.
5. With a thermometer record the temperature of the ice water. Try to obtain a temperature close to 0°C.
6. Place the beaker on a cool hot plate and lower the thermistor leads into the ice water.
7. Let the thermistor sit in the ice water for a few minutes to obtain equilibrium.
8. With an ohmmeter record the resistance of the thermistor across its leads. Enter this in Table 1.
9. Turn on hot plate.
10. Record the temperature and corresponding resistance at 5° C intervals in Table 1, until boiling occurs.

Data

Data Table 1. Temperature and resistance data.

Temperature (°C)	Resistance (Ω)
0	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	
65	
70	
75	
80	
85	
90	
95	
100	

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Resistance of a _____ Thermistor at Different Temperatures

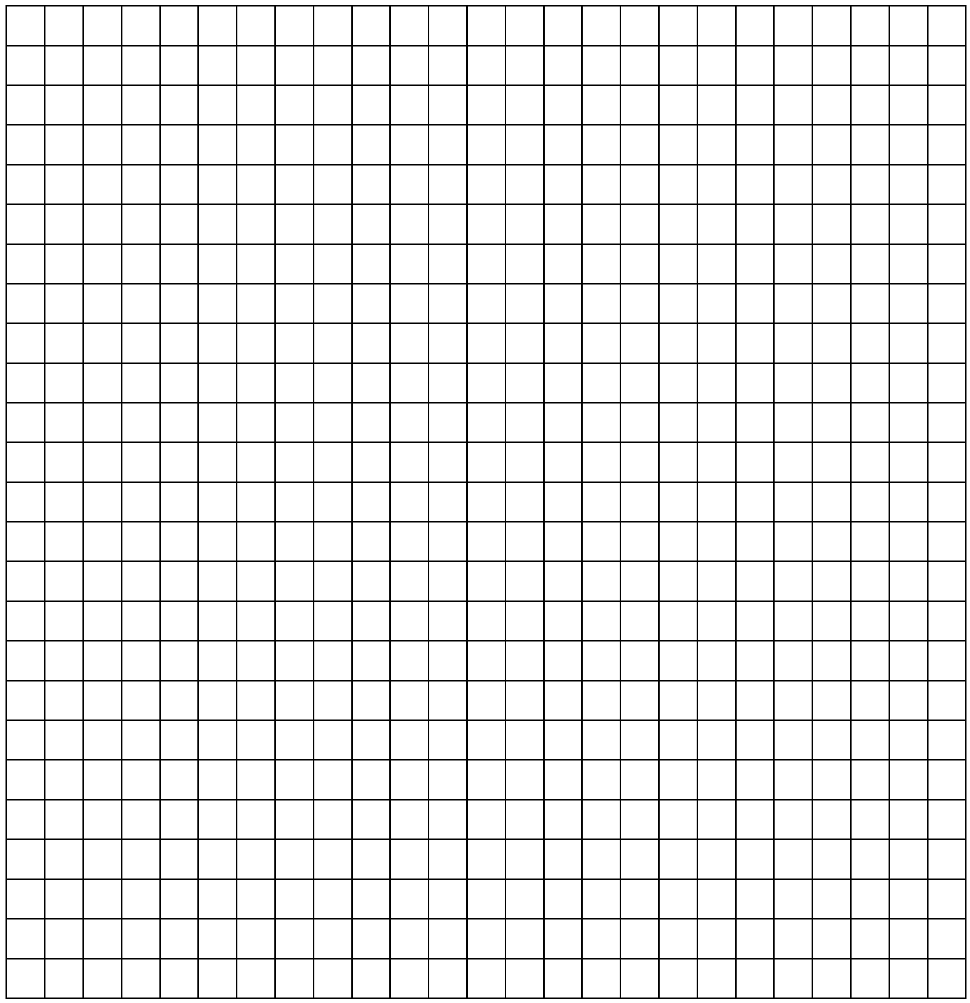

Figure 2. Resistance vs. Temperature data.

Analysis and Conclusion

1. Plot the data on excel and create a trendline. Which trend type (linear, logarithmic, polynomial, power, or exponential) has the highest R^2 value?
2. If a thermistor were placed in an electrical circuit with constant DC voltage applied, what would be the effect of current through the circuit if the thermistor was heated up?
3. What is the resistance on your thermistor at 22°C?
4. Is the thermistor an ohmic material?
5. When is the thermistor most sensistive to temperature?

Cleanup

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Do not let the students eliminate the boiling water. It is too dangerous to allow students to touch the boiling water. Ask students to return their goggles and thermistors when they are done.

Worksheet (with answers)

1. Plot the data on excel and create a trendline. Which trend type (linear, logarithmic, polynomial, power, or exponential) has the highest R^2 value?
   Depends on the data, but it should not be linear.
2. If a thermistor were placed in an electrical circuit with constant DC voltage applied, what would be the effect of current through the circuit if the thermistor was heated up?
   The current should increase because the heat is causing the temperature to decrease.
3. What is the resistance on your thermistor at 22°C?
   It depends on the data. Use the curve of best fit to calculate the answer.
4. Is the thermistor an ohmic material?
   It is non-ohmic because the relationship between temperature and resistance is not linear.
5. When is the thermistor most sensitive to temperature?
   It depends on the data, but it would be in the region where the resistance has the biggest difference between each degree celcius.

Assessment

The analysis and conclusion questions could be used or add a question on an exam or quiz relating to Ohm's Law and thermistors.

Resources:

To learn more about nanotechnology and thermistors, here are some web sites with educational resources:

http://www.facstaff.bucknell.edu/mastascu/elessonsHTML/Sensors/TempR.html
http://www.gcsescience.com/pe9.htm
http://www.temperatures.com/thermistors.html
http://www.nnin.org
http://mrsec.wisc.edu

Georgia Performance Standards

SP5. Students will evaluate relationships between electrical and magnetic forces.

b. Determine the relationship among potential difference, current, and resistance in a direct current circuit

National Science Education Standards

Physical Science Standards

- Structures and properties of matter
- Interactions of energy and matter

Science and Technology

- Understandings about science and technology

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