6.8A: Electrical Conductivity and Resistivity

Electrical resistivity and conductivity is an important property for materials. Different materials have different conductivity and resistivity. Electrical conductivity is based on electrical transport properties. These can be measured with multiple techniques by using a variety of instruments. If electricity easily flows through a material, that material has high conductivity. Some materials that have high conductivity include copper and aluminum. Electrical conductivity is the measure of how easily electricity flows through a material.

Conductivity vs Resistivity

Conductivity and resistivity are inversely proportional to each other. When conductivity is low, resistivity is high. When resistivity is low, conductivity is high. The equation is as follows:

$$\rho = \frac{1}{\sigma} \tag{6.8A.1}$$

where

- Resistivity is represented by ρ and is measured in **Ohm-meters** (Ωm),
- Conductivity is represented by σ and is measured in **Siemens** ($1/\Omega m$).

Since conductivity is the measure of how easily electricity flows, electrical resistivity measures how much a material resists the flow of electricity.

Electrical Transport Properties

Simply put, electricity is the movement of electrons through a material. As electrons move through a material, it comes into contact with atoms in the material. Collisions slow the electrons down. Each collision increases the resistivity of the material. The easier the electrons continue through a material, the fewer collisions that take place and the higher the conductivity.

When temperature increases, the conductivity of metals usually decreases, while the conductivity of semiconductors increases. This of course assumes that the material is homogenous, which is not always the case. You can calculate resistivity using the following equation

$$\frac{E}{J} = \rho \tag{6.8A.2}$$

As you already read, ρ is the symbol for resistivity. E is the electric field and has units of Volts per meter (V/m). J is the current density and has units of amps per meter squared (A/m2). The electric field is calculated by dividing the Voltage by the length, l, that voltage is applied.

$$E = \frac{V}{l} \tag{6.8A.3}$$

The current density is calculated by the equation below

$$J = \frac{I}{A} \tag{6.8A.4}$$

I is the current and is divided by the cross sectional area, A, over which the current flows.

Resistivity vs Resistance

Resistivity and resistance are two different things. Resistivity does not depend on size or shape. Resistance, however, does. You can calculate resistance with the equation below.

$$R = \frac{V}{I} \tag{6.8A.5}$$

R refers to resistance and is measured in Ω. V is the voltage and is measured in volts. I measures the current and its unit is amps (A).

References

1. Electrical Conductivity and Resistivity, Heaney, Michael, Electrical Measurement, Signal Processing, and Displays. Jul 2003
2. Levy, Peter M., and Shufeng Zhang. "Electrical Conductivity of Magnetic Multilayered Structures." *Physical Review Letters* 65.13 (1990): 1643-646. Print.

Problems

1. What is the current density of a material with a resistivity of 12.Ωm and an electric field of 64.V/m?
2. If the voltage of 6V is passed through a substance with a radius of 2m and a length of 3m, what is the electric field?
3. What is the electric field of a material when the current is equal to 25A, the resistance is measured to be 78Ω, the current density equals 24A/m2, and the length the current flows is 100m?
4. A material has a voltage of 150V and width of 24m. The material also has a current of 62A and travels a distance of 5m. What is the conductivity?
5. A metal originally has an electron colliding with every fifth atom and increases from a temperature of 6K to 100K. A semiconductor originally has an electron colliding with every fifth atom and increases from a temperature of 6K to 100K. What material will have a greater resistivity? Why?

Answers to Problems:

1. E/J = ρ ---> J=E/ρ = 64V/m /12Ωm = 5.33A/m^2

2. E=V/l = 6V/3m = 2V/m

3. E=V/l

V=IR ---> E=IR/l = 25A x 78Ω/100m = 19.5V/m

4. E/J = ρ

E=V/l

J=I/A ---> ρ=(V/l)/(I/A) = (150V/5m)/(62A/(24m x 5m) = 58Ωm

ρ = 1/σ ---> 1/ρ = σ = 1/58Ωm

5. The material that has the greatest resistivity is the metal because as temperature increases metals are more likely to increase in resistivity and semiconductors usually decrease in resistivity as temperature increase.

Contributors

- Michael Ford (UCD) and Alexandra Christman (UCD)