# **Resistivity and Conductivity: Influencing Factors**

## **Introduction**

The electrical behaviour of materials is key in physics and engineering, crucial for many technologies. Resistivity measures a material's opposition to current flow, while conductivity measures its ability to conduct current. These are linked properties. Understanding influencing factors helps in material selection for electrical systems. Materials are conductors, semiconductors, or insulators based on resistivity and conductivity. Conductors allow easy current flow, insulators impede it, and semiconductors have controllable, intermediate properties. Now we explore factors affecting these properties and their influence on material behaviour.

## **Defining Resistivity**

Resistivity (ρ) is a material's resistance to current flow for a unit length and area. It's an intrinsic property, independent of sample size. The SI unit is ohm-meter (Ω⋅m). Low resistivity means easy current flow, high resistivity means strong opposition.

## **Defining Conductivity**

Conductivity (σ) measures a material's ability to conduct current. It's also intrinsic. Conductivity is the reciprocal of resistivity (σ = 1/ρ). The SI unit is siemens per meter (S/m). High conductivity means a good conductor; low means poor conductivity.

## **Resistance vs. Resistivity**

The resistance (R) of an object depends on its material resistivity and dimensions

**R = ρL/A.**

Resistance is proportional to resistivity and length and inversely proportional to cross-sectional area.

## **Factors Affecting Resistivity and Conductivity**

Several factors influence resistivity and conductivity, notably temperature, material composition and purity, and crystal structure.

## 1. Temperature:

## **Temperature Effe**cts on Conductors:

## Temperature significantly affects electrical properties by influencing charge carrier movement. Increased temperature in conductors (metals) raises lattice ion vibrations, scattering electrons more, increasing resistivity and decreasing conductivity. Metals have a positive temperature coefficient of resistivity (α).

| **Material** | **Resistivity (Ω⋅m) at 20°C** | **Conductivity (S/m) at 20°C** |
| --- | --- | --- |
| Silver | 1.59 × 10 ^ -8 | 6.30 × 10 ^ 7 |
| Copper | 1.68 × 10 ^ -8 | 5.95 × 10 ^ 7 |
| Aluminum | 2.65 × 10 ^ -8 | 3.77 × 10 ^ 7 |
| Gold | 2.44 × 10 ^ -8 | 4.10 × 10 ^ 7 |
| Iron | 9.71 × 10 ^ -8 | 1.03 × 10 ^ 7 |

## **Temperature Effects on Semiconductors**

In semiconductors, temperature has a different effect. Increased temperature provides energy to move electrons to the conduction band, increasing charge carriers (electrons and holes), decreasing resistivity, and increasing conductivity. Semiconductors have a negative temperature coefficient of resistivity.

## **Temperature Effects on Insulators**

Insulators show a slight resistivity decrease with rising temperature as more charge carriers are excited across the large band gap. However, due to the larger gap, the change is smaller than in semiconductors. Insulators also generally have a negative temperature coefficient of resistivity. erconductivity occurs in some materials at very low temperatures, where resistance drops to zero.

## 2. Material Composition and Purity

Material composition and purity determine inherent resistivity and conductivity. Metals have delocalized electrons, facilitating current flow. Insulators have tightly bound electrons and a large energy gap, hindering charge movement. Semiconductors have a smaller gap, allowing moderate charge carriers.

## **Impact of Impurities**

Impurities in metals generally increase resistivity by scattering electrons. Alloying can also change conductivity. Doping semiconductors by adding controlled impurities significantly alters conductivity, creating n-type (excess electrons) or p-type (excess holes) materials.

## **Impact on Conductors**

Conductors (metals) conduct electricity easily. Temperature increases their resistivity. Pure metals like silver and copper have high conductivity. Impurities or alloys usually decrease conductivity. Ordered crystal structures enhance conductivity.

*Table 1: Electrical Properties of Common Conductors at 20°C 1*

Conductors have overlapping valence and conduction bands, meaning free electrons are always available for conduction.

## **Impact on Semiconductors**

Semiconductors have intermediate conductivity. Temperature increases their conductivity. Doping precisely controls their conductivity. Ordered crystal structures are vital for their properties.

| **Material** | **Resistivity Range (Ω⋅m) at 300K** | **Conductivity Range (S/m) at 300K** |
| --- | --- | --- |
| Silicon | 0.1 - 60 | 1.67 × 10 ^-2 |
| Germanium | 0.001 - 0.6 | 1.67 - 1000 |
| GaAs | 5 × 10 ^ 7 - 10 ^ 3 | 1000 - 2 × 10 ^ 6 |

*Table 2: Electrical Properties of Common Semiconductors at 300K 7*

Semiconductors have a small energy band gap, influencing their conductivity based on the energy needed to excite electrons.

## **Impact on Insulators**

Insulators have very high resistivity and low conductivity. Their resistivity slightly decreases with temperature. They have tightly bound valence electrons and a large energy band gap, hindering charge movement. Ordered crystal structures contribute to their stable insulating properties.

| **Material** | **Resistivity (Ω⋅m) at Room Temperature** |
| --- | --- |
| Glass | 10 ^ 9 - 10 ^ 14 |
| Rubber | 10 ^ 13 - 10 ^ 16 |
| Teflon | 10 ^ 13 |
| Mica | 10 ^ 11 - 10 ^ 15 |
| Fused Quartz | 7.5 × 10 ^ 17 |

*Table 3: Electrical Resistivity of Common Insulators at Room Temperature 17*

Insulators have a large energy band gap, requiring significant energy for electrons to conduct, resulting in poor conductivity.

## **Conclusion**

Resistivity and conductivity are governed by temperature, material composition, and crystal structure. These factors affect charge carrier availability and mobility, defining conductors, semiconductors, and insulators. Conductors have high conductivity due to free electrons, increasing resistivity with temperature.

Semiconductors have intermediate, temperature-sensitive conductivity controlled by doping. Insulators strongly resist current due to their electronic structure. Understanding these factors is crucial for materials science and technological advancements in electronics, energy, and communications. Manipulating these factors allows the tailoring of material electrical properties.