ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Electrical Resistivity: Concept And Measurement.

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ABSTRACT

Electrical resistivity has been one of the crucial characteristics of conductive materials. The measurement of electrical resistivity has become very important, and its importance stems from the fact that almost all conductive materials possess an electrical resistivity which differs from one into another. Herein, we illustrate the concept of electrical resistivity, and two common methods of determining it. Namely, two and four-probe measurements with further clarification to each of which
Keywords: electrical resistivity, conductivity.

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INTRODUCTION

Electrical resistivity (also known as resistivity, specific electrical resistance, or volume resistivity) is a measure of how strongly a material opposes the flow of electric current. A low resistivity indicates a material that readily allows the movement of electric charge. The SI unit of electrical resistivity is the ohm·metre (Ω·m). It is commonly represented by the Greek letter ρ (rho)(1).

Electrical resistivity *ρ* (Greek: rho) is defined by,

$$\rho = \frac{E}{J}$$

Where, *ρ* is the static resistivity of the conductor material (measured in ohm·metres, Ω·m), *E* is the magnitude of the electric field (in volts per metre, $V \cdot m^{-1}$), *J* is the magnitude of the current density (in amperes per square metre, $A \cdot m^{-2}$) in which *E* and *J* are inside the conductor.

Conductivity is the inverse of resistivity:

$$\sigma = \frac{1}{\rho}$$

which gives an equivalent equation:

$$\sigma = \frac{J}{E}$$

As a matter of fact, some resistors and conductors have a uniform cross section with a uniform electric flux. They are composed of one material normally as shown in figure 1. In this case, the above definition of *ρ* leads to:

$$\rho = R\frac{A}{\ell},$$

Where:

R is the electrical resistance of a uniform specimen of the material (measured in ohms, Ω)
ℓ' is the length of the piece of material (measured in metres, m)
A is the cross-sectional area of the specimen (measured in square metres, m^2).

The reason resistivity has the dimension units of ohm·metres can be seen by transposing the definition to make resistance the subject (Pouillet's law):

$$R = \rho\frac{\ell}{A}$$

The resistance of a given sample increases with the length, but decreases with greater cross-sectional area.
Resistance is measured in ohms. Length over area has units of 1/distance. To end up with ohms, resistivity must be in the units of "ohms×distance" (SI ohm·metre, US ohm·inch).

In a hydraulic analogy, increasing the cross-sectional area of a pipe reduces its resistance to flow, and increasing the length increases resistance to flow (and pressure drop for a given flow).

Electrical Resistivity Measurements

Electrical resistivity is a key physical property of all materials. It is often necessary to accurately measure the resistivity of a given material. The electrical resistivity of different materials at room temperature can vary by over 20 orders of magnitude. No single technique or instrument can measure resistivities over this wide range. This chapter describes a number of different experimental techniques and instruments for measuring resistivities. The emphasis is on explaining how to make practical measurements and avoid common experimental errors. More theoretical and detailed discussions can be found in the sources listed at the end of this chapte Electrical resistivity is a key physical property of all materials. It is often necessary to accurately measure the resistivity of a given material.

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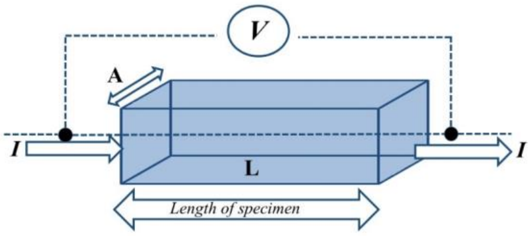
Two probes measurements

This is the simplest method of measuring resistivity and is illustrated in Figure.1. In this method, voltage drop V across the sample and current through the sample I are measured. Then the resistivity is given as:

$$\rho = \frac{VA}{IL}$$



This method is useful when the sample has large resistance.

Figure 1: Electrical resistivity measurement by two probe method.

Four probes measurements

The potential probe is the most widely used method for resistivity measurements on the low resistive samples. In this method the potential drop is measured across two probes and distance between these probes D replaces the sample length L. When the probes are not point contacts, in that case, the most accurate value for the probe distance is the distance between the centers rather than the closest distance between the probes. Figure. 2 shows the schematically arrangement for this method. In this case ρ is given by:

$$\rho = \frac{V_D\, A}{D\, I}$$

Four probe method can be used to determine the resistance of the single crystal as well as the bulk specimen also. Here current passes through the outer contacts which are close to the edges of the sample. The potential difference is measured across the inner contacts. This method can eliminate the effects of contact resistance between the sample and electrical contacts and therefore is most suitable for low and accurate resistance measurements. Contact and lead resistances are cancelled out by the four point method, however the contact resistance can still cause error if these are produce enough heat. Thus it is imperative that the contacts should have low resistance. Instrumental DC offsets also contributes to the error, but this can be easily corrected by subtraction. Self-induced voltage offsets in the circuit further add to the error. This problem can be corrected by reversing the flow of current through the sample. When the low level of the voltage (in the range of μV) is produced across the sample, signal noise also adds to the error. By using the proper shielded cables and low thermal contactors, as well as making single point grounding, noise problem can be reduced.

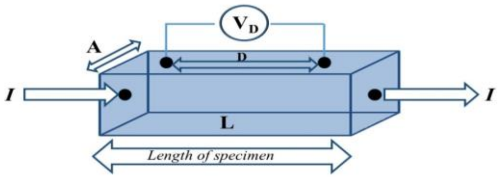


Figure 2: Electrical resistivity measurement by four probe method.

CONCLUSION

In summary, we presented the main concept of electrical resistivity and the more accurate ways of measuring it. A detailed description of the instruments and techniques used to measure resistvity were discussed with an additional elucidation to the potential source of errors in the two and four probe measurements

ACKNOWLEDGMENT

The authors extend their appreciation to the department of Chemistry, College of Science, Al-Nahrain University for continued support.

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