DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

Module-IV Lecture 1

Concepts of Electrical measurements **&** Two point probe technique

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Concepts of Electrical measurements

General Introduction:

Electrical property of the materials is one of the most important properties, which helps to classify the materials. For instance, solids may be classified in terms of their resistivity or conductivity as conductors, semiconductors or insulators.

Ohm's law: If physical conditions such as temperature, stress, strain remains unchanged in the materials, then potential difference *(V)* across two ends of a conductor is proportional to current *(I)* flowing through a conductor, i.e.,

$V \propto I$ (or)

$V = I R$

The constant of proportionality, *R*, is called resistance of the material.

Resistivity:

At a given constant temperature, the resistance *R* of the conductor is (i) proportional to its length *(L)* and (ii) inversely proportional to its area of cross-section *(A)*, i.e.,

$R \propto L / A$ (or) $R = \rho L / A$

Resistivity is important for devices because it contributes to the device series resistance, capacitance, threshold voltage, hot carrier degradation of MOS devices, latch up of CMOS circuits, and other parameters.

- A material's conductivity, σ, (or the inverse property, resistivity, ρ = 1/σ), relates to its ability to conduct electricity. In metals, conduction of electricity is tantamount to conduction of electrons, which depends on charge density and on scattering of the electrons by the crystal lattice (phonons) or by lattice imperfections.

- In semiconductors, conductivity is determined by the number of available charge carriers (electrons or holes) and the carrier mobility. Because of the different mechanisms for conductivity, its dependence on temperature also differs. Conductivity increases with increasing temperature for semiconductors (more carriers are generated) and it decreases with increasing temperature for metals (more scattering by the lattice).

- Conductivity also depends on physical structure. In crystals, the crystal type and orientation affect conductivity because the electronic structure is intimately tied to the crystal structure. The size of the crystallites (grains) in polycrystalline materials is also important as it affects the scattering of carriers, and, at very small sizes may also affect electronic structure.

Concepts of Electrical measurements

Table 1. General Characteristics for Conductivity Measurement Methods

Method	Favoredmaterial Type	Favored Material Form	Estimated Measurement Range
Two-point measurement	High-resistance metals	Solid bar	10^{2}–$10^{9}\,\Omega$
Four-point measurement	Metals	Solid bar	10^{-7}–$10^{4}\,\Omega$
Four-point probe	Semiconductor surface, thin metallic films	Planar solid	10^{-3}–$10^{5}\,\Omega$-cm
Van der Pauw	Semiconductor surface, thin metallic films	Planar solid	10^{-3}–$10^{5}\,\Omega$-cm

I-V Characteristics in a Diode

Resistivity is important for devices because it contributes to the device series resistance, capacitance, threshold voltage, hot carrier degradation of MOS devices, latch up of CMOS circuits, and other parameters. The wafers resistivity is usually modified locally during device processing by diffusion and ion implantation.

Two general methods involved for measuring the resistance of the materials are:

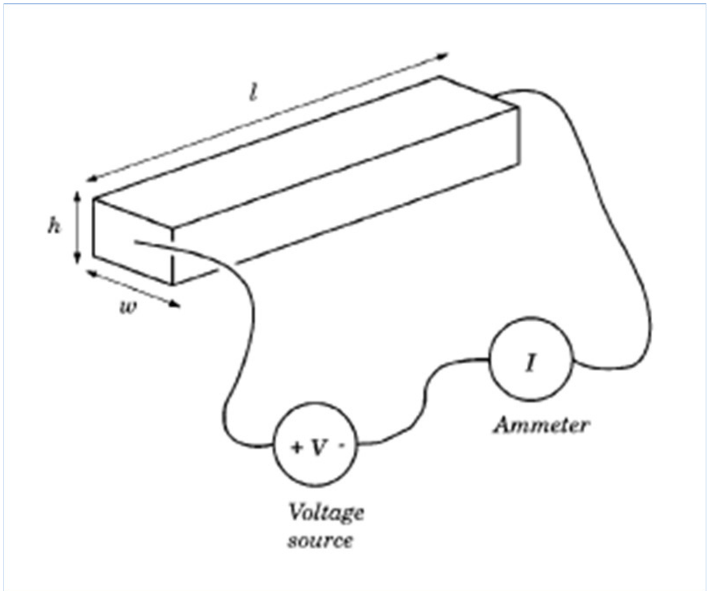
(i) Two point probe method

(ii) Four point probe method

linear method & Van der pawu method

Two-probe method:

Let us consider a rectangular bar of length l, height h and width w as shown in figure. copper wire are attached both ends of the bar.



The resistivity of the bar can be measured by measuring voltage drop across the wire due to passage of known current supplied by the battery *E* through the probes 1 and 2. The potential difference *(V)* between the two contacts at the ends of the bar can be measured by a voltmeter. Therefore, the resistivity of the wire is, i.e.,

$$\rho \equiv \frac{Rwh}{l}$$

In general, we use a multimeter for measuring the resistance of the materials. The typical range of resistance measured using the multimeter is 1 Ω to 2 MΩ, but varies with the models and company.

While the two-probe method is a simple and advantageous method for measuring resistance above 1Ω directly, this method suffers from certain issues.

Two-probe method:

❖ Error due to contact resistance of the measuring leads,
❖ Materials having random shapes,
❖ Soldering of the test leads on some materials would be difficult,
❖ Heating of the leads during soldering may inject additional impurities in materials such as semiconductors and thereby affecting the intrinsic electrical resistivity largely.

In order to overcome the above problems, four-probe method is widely proposed.