Experiment No.-9b

OBJECTIVE: TO DETERMINE THE RESISTIVITY OF THE GIVEN SAMPLE USING FOUR PROBE METHOD.

INTRODUCTION

Determination of resistivity ρ of semiconductors and insulators presents special problems. Conventional two probe method used to determine the resistivity of material give unsatisfactory results, due to problems such as poor contact between electrode and samples and rectifying nature of the metal sample contacts for non-conducting specimens. Also there is generally minority career injection by one of the current carrying contacts. An excess concentration of minority careers will affect the potential of other contacts and modulate the resistance of the material.

To obviate these problems, four probe method is employed. This method also permits measurements of resistivity in samples having a variety of shapes. By this method resistivity of small volumes in the bulk of material can also be determined. In our experimental setup a graphite/phenolic sample is provided in the form of a rectangular slab. This sample has a thickness of few millimeters. The basic setup is shown in fig.1. Four sharpened probes fixed to an adjustable screw head or brought in close contact of the sample. This is placed on an insulating base which can be leveled with the help of the leveling screws. The current (I) to the sample is passed through the two outer electrodes (I & IV) and floating potential difference is measured across the inner probe pairs (II & III).

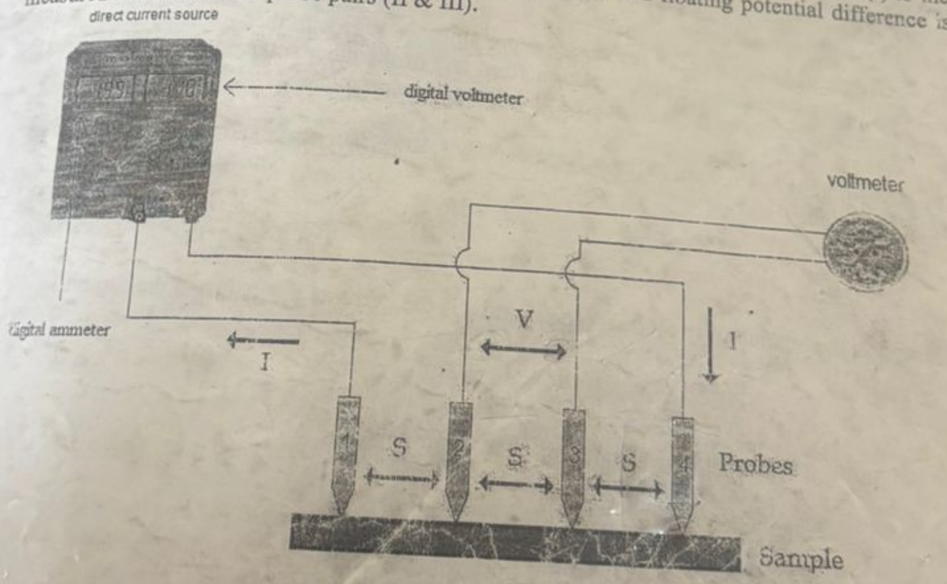

Figure 1 showing the four probe for given simple

The probe I and IV are connected to dc regulated constant current source. And the potential between the probes II and III is to be read. From the measurements of potential (V) (across II & III) and current (I) (across I and IV), the resistance R between probe II and III is determined as V/I.

It should be noted that for a given magnitude of T, the corresponding potential V should be noted at a number of positions on the sample and an average taken. Then the observed resistivity (ρ_o) is given by

$$\rho_o = 2\pi sR \tag{1}$$

Where "s" denotes inter probe spacing.

THEORY:

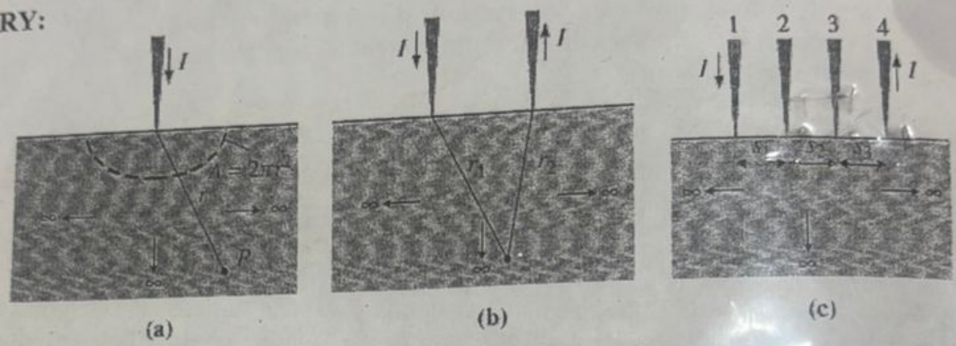

Fig. 2 (a) one-point probe, (b) two-point, and (c) collinear four-point probe showing current flow and voltage measurement.

To derive the four-point probe resistivity expression, we start with the sample geometry in Fig. 1.2(a). We consider that the probes are far from any of the other surfaces of the sample i.e. the sample dimensions to be large compared with the probe spacing 's'.

The electric field E is related to the current density J, the resistivity ρ, and the voltage V through the relationship:

$$E = J/\sigma$$
$$= -\frac{dV}{dr}$$

Where σ is the conductivity of the material and J is the current density due to the current I entering at '1'.

$$J = I/2\pi r^2$$

(r is the radius of the area the current, I, gets injected into)

$$E = I/2\pi\sigma r^2$$

The voltage at point P at a distance r from the probe, is then

Hence,

$$\int_0^V dV = -\frac{I\rho}{2\pi}\int_0^r \frac{dr}{r^2}$$

$$V = I\rho/2\pi r$$

For the configuration in Fig. 1.2(b), the voltage is

$$V = \frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2} = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

where $r1$ and $r2$ are the distances from probes 1 and 2, respectively. The minus sign accounts for current leaving through probe 2.

For probe spacings s_1, s_2, and s_3, as in Fig. 1.2(c), the voltage at probe 2 is

$$V_2 = \frac{I\rho}{2\pi}\left(\frac{1}{s_1} - \frac{1}{s_2+s_3}\right)$$

and at probe 3 it is

$$V_3 = \frac{I\rho}{2\pi}\left(\frac{1}{s_1+s_2} - \frac{1}{s_3}\right)$$

The total measured voltage $V = V_{23} = V_2 - V_3$ becomes

$$V = \frac{I\rho}{2\pi}\left(\frac{1}{s_1} - \frac{1}{s_2+s_3} - \frac{1}{s_1+s_2} + \frac{1}{s_3}\right)$$

The resistivity ρ is given by

$$\rho = \frac{2\pi}{(1/s_1 - 1/(s_1+s_2) - 1/(s_1+s_2) + 1/s_3)}\frac{V}{I}$$

ρ expressed in units of Ω-m, with V measured in V, I in A, and s in m.

For $s = s_1 = s_2 = s_3$, the above equation reduces to

$$\rho = 2\pi s\frac{V}{I}$$

In the given setup the probes are equally spaced and are 1.5 mm apart.

This equation (1) is valid only for materials whose dimensions are large compared with the probe spacing S. If this is not the case, for example, when measurements are made on thin slices or small disc of materials, then a correction factor G is introduced.

The true resistivity ρ is related to the observed resistivity ρ_o through a correlation function G which corrects for the finite thickness, b, of the sample. Exact value of G for the given sample depends on the ratio b/s. For the insulating base the value of G given in table (1) can be employed to affect thickness correction.

Thus

$$\rho = \rho_o / G \qquad (2)$$

TABLE –1

b/s	G
1.0	1.094
2.0	1.015
2.5	1.009
3.0	1.000
3.5	1.000

For the current setup Graphite sample thickness is b = 2.8 mm and s =1.5 mm.

G, approaches unity as b/s approaches 5. Thus for our arrangements a specimen having thickness greater than 7.5 mm requires no correction.

EXPERIMENTAL PROCEDURE:

1. Vary current through the probes and measure the voltage (20 readings or more).
2. Plot I vs V (Y-axis). Calculate resistance from the slope of the graph.
3. Determine ρ and ρ_o.

Repeat the experiment at different current setting taking four sets for observations corresponding to different locations on the samples at each current setting. It should be noted, whether for the given sample resistivity is independent of location of the probe and probe current.

[illegible]	I	V [illegible]

Complete your report by answering the following questions:

1. Discuss the observed behavior and given your inference conclude your report by answering the following questions.
2. What is the limitation of conventional two probe method for resistance determination in case of non conducting specimens?
3. Thus the voltage across II and III probes change with the change in position of the samples? Give reasons.
4. Why is it necessary to apply a correction to resistivity for thin samples?
5. Why do not we use power supply as current source rather than the constant current generator? How is the later different from a power supply?