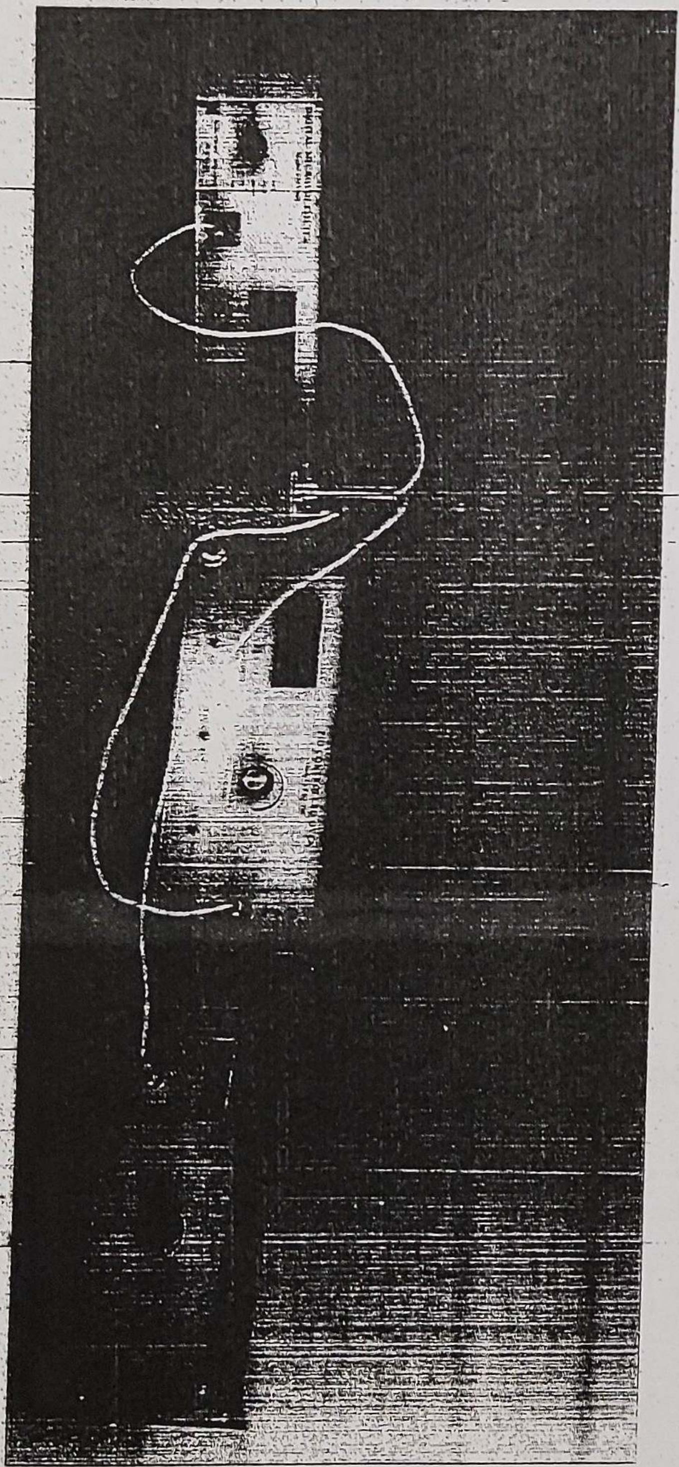
Exp

Exp. NO- 4

Exp. NO: 3 To measure the Energy band gap of a Semiconductor



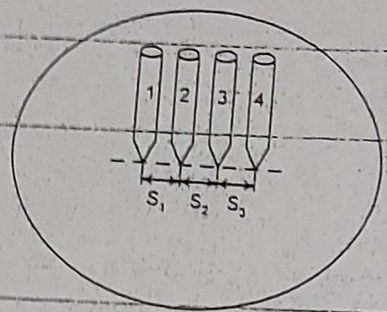


FIG 1. MODEL FOR THE FOUR PROBE RESITIVITY MEASUREMENT

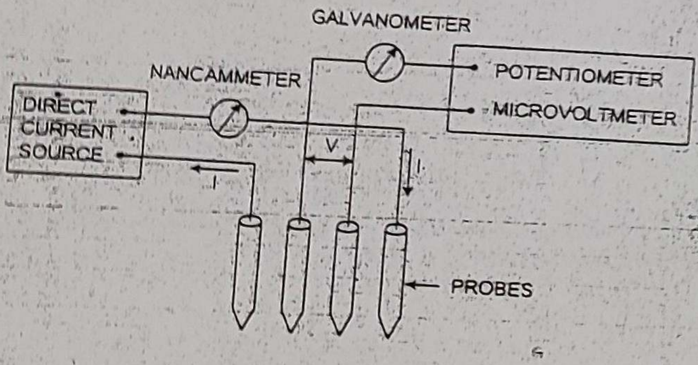


FIG 2. CIRCUIT USED FOR RESITIVITY MEASUREMENTS

CASE 1 - RESISTIVITY MEASUREMENTS ON A LARGE SAMPLE

One added boundary condition is required to treat this case namely; that the probes are far from any of the other surfaces of the sample and the sample can thus be considered a semi-infinite volume of uniform resistivity material. Fig. 1 shows the geometry of this case. Four probes are spaced S_1, S_2 and S_3 apart. Current I is passed through the outer probes (1 and 4) and the floating potential V is measured across the inner pair of probes 2 and 3.

The floating potential V_f a distance r from an electrode carrying a current I in a material of resistivity ρ_0 is given by

$$V_f = \frac{\rho_0 I}{2\pi r}$$

In the model shown in Fig. 1 there are two current-carrying electrodes, numbered 1 and 4, and the floating potential V_f at any Y point in the semiconductor is the difference between the potential induced by each of the electrodes, since they carry currents of equal magnitude but in opposite directions Thus:

$$V_f = \frac{\rho_0 I}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_4}\right) \tag{1}$$

Where r_1 = distance from probe number 1;
r_4 = distance from probe number 4.

The floating potentials at probe 2, V_{f2}, and at probe 3, V_{f3} can be calculated from (1) by substituting the proper distances as follows :

$$V_{f2} = \frac{\rho_0 I}{2\pi}\left(\frac{1}{S_1} - \frac{1}{S_2 + S_3}\right)$$

$$V_{f3} = \frac{\rho_0 I}{2\pi}\left(\frac{1}{S_1 + S_2} - \frac{1}{S_3}\right)$$

The potential difference V between probes 2 and 3 is then

$$V = V_{f2} - V_{f3} = \frac{\rho_0 I}{2\pi}\left(\frac{1}{S_1} + \frac{1}{S_3} - \frac{1}{S_2 + S_3} - \frac{1}{S_1 + S_2}\right)$$

and the resistivity ρ_0 is computable as

$$\rho_0 = \frac{V}{I} \cdot \frac{2\pi}{\left(\frac{1}{S_1} + \frac{1}{S_3} - \frac{1}{S_1 + S_2} - \frac{1}{S_2 + S_3}\right)} \qquad (2)$$

When the point spacing equal, that is, $S_1 = S_2 = S_3 = S$ the above simplifies to :

$$\rho_0 = \frac{V}{I} \times 2\pi S \qquad (3)$$

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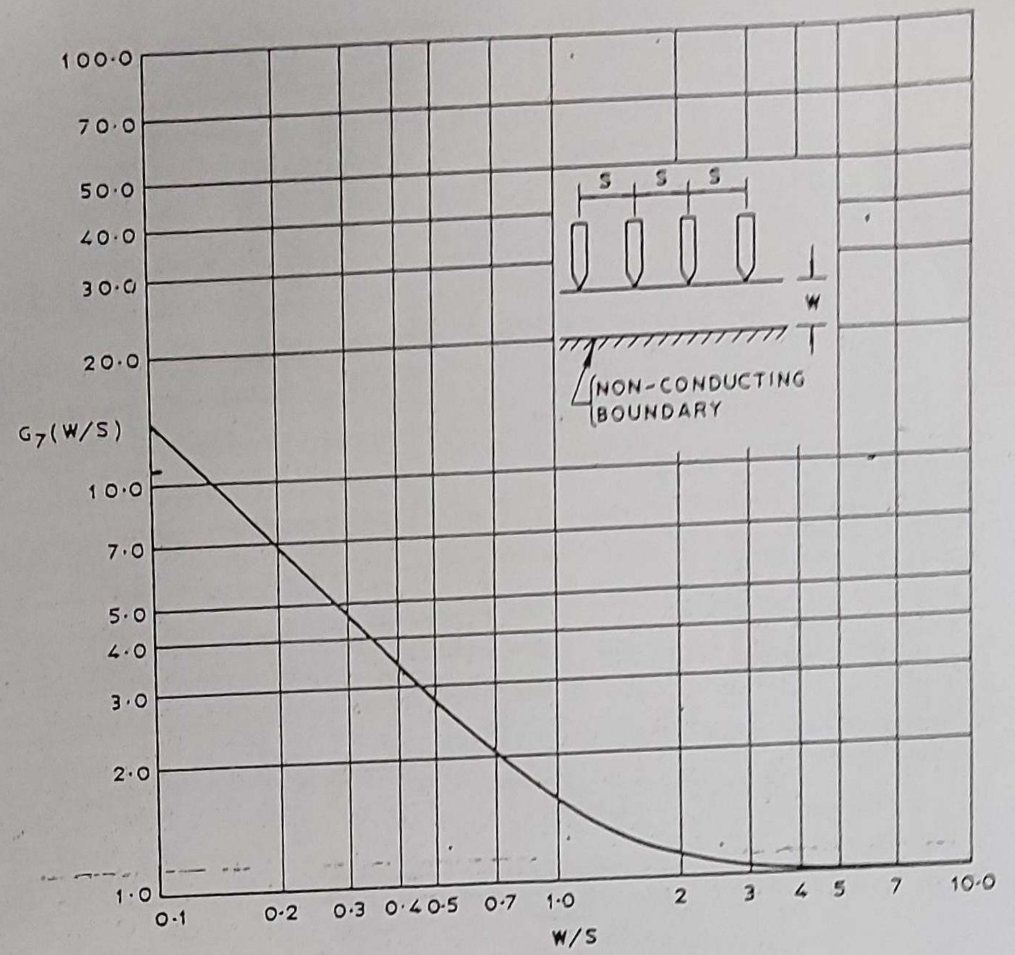

FIG. 5 CORRECTION DIVISOR FOR PROBES ON A THIN SLICE WITH A NON-CONDUCTING BOTTOM SURFACE

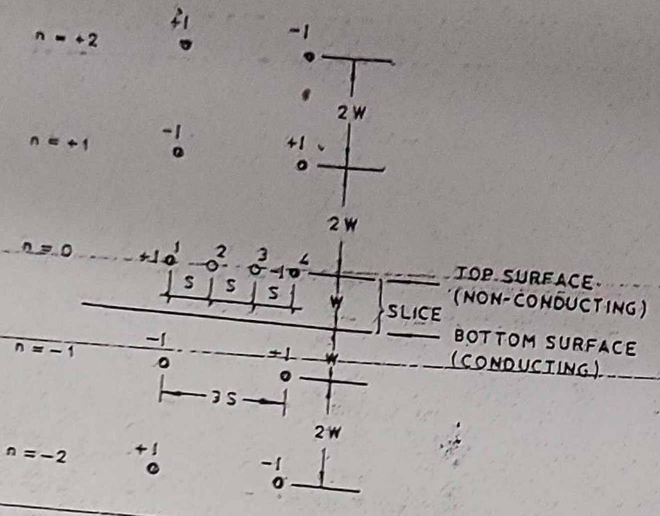

FIG. 3. IMAGES FOR THE CASE OF THE RESISTIVITY PROBES ON A SLICE WITH A CONDUCTING BOTTOM SURFACE

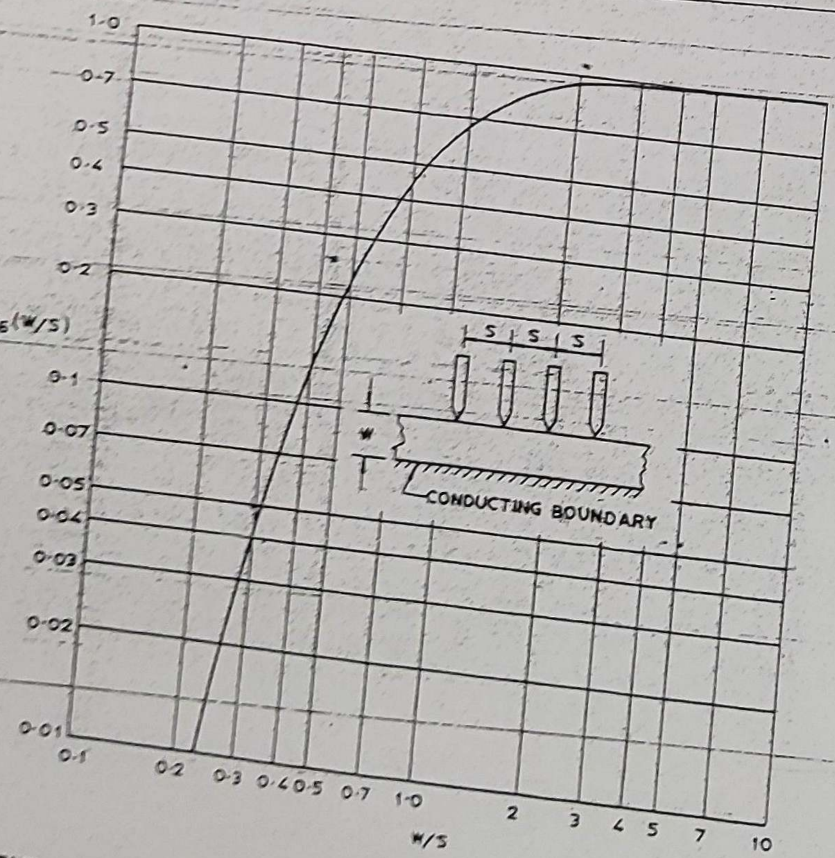

FIG. 4 CORRECTION DIVISOR FOR PROBES ON A SLICE WITH A CONDUCTING BOTTOM SURFACE

EXPERIMENTAL PROCEDURES

1. Put the sample on the base plate of the four·probe arrangement. Unscrew the pipe holding the four probes and let the four probes rest in the middle of the sample. Apply a very gentle pressure on the probes and tighten the pipe in this position. Check the continuity between the probes for proper electrical contacts.

> **CAUTION** : Use only the minimum pressure required for proper electrical contacts particularly for semiconductor wafers and thin films.

2. Connect the outer pair of probes to the constant current source through 3-pin socket and the inner pair to the D.C. Microvoltmeter through an amphenol connector.
3. Place the Four Probe Arrangement in the oven.
4. Switch 'ON' D.C. Microvoltmeter and allow about 5 minutes time for thermal stability. Adjust the zero of D.C. Microvoltmeter with the knob provided for it.
5. Switch 'ON' the Constant Current Power Supply/ Low Current Power Supply and check the zero reading of D.C. Microvoltmeter at zero current reading again. Adjust it, if required. In case it can not be adjusted-this may happen in very high resistive samples, note it down and treat it as zero error.
6. Increase the current gradually and take the corresponding readings of voltage developed. Subtract the zero reading if any and check for Ohm's Law ($\frac{V}{I} = R$). This would ensure that the system is working properly and the systematic readings could be taken.

7. For taking the reading at different temperature settings, PID Controlled Oven should be used.

8. Set the PID Controlled oven PID-200 as follows.

   (i) Connect the RTD sensor's 2-pin socket of Four Probe Arrangement and the oven socket to the PId Controller.

   (ii) Put the WAIT-RUN switch to WAIT Position, SET-MEASURE switch to MEASURE Position and switch 'ON' the mains power. Allow about 10 minutes time to stablized the circuit. The panel meter would read ambient temperature.

   (iii) Put the SET-MEASURE switch to SET Position, the panel meter would read the previously Set temperature, which could be changed to a desired value with the help of TEMPERATURE CONTROL knob provided.

   (iv) Put the WAIT –RUN switch to RUN position and SET-MEASURE switch to the MEASURE Position. This would switch on the power to the oven and bring the DPM in MEASURING MODE. Now the DPM would display the oven temperature after approximately 1-2 cycles of over shoot and under shoot.

   (v) Put the WAIT-RUN switch to the RUN Position and the SET-MEASURE switch to the MEASURE Position. This would switch on the power to the oven and bring the DPM in the measuring mode. Now the DPM would display the oven temperature. Gradually the temperature of oven would reach and stabilized very near the set temperature, after approximately 2 cycles of over shoot and under shoot.

   (vi) Because of thermal inertia of oven, there would be some over shoot and under shoot before a steady set-temperature is attained and may take 10 minutes for each reading.

   (vii) To save time, it is recommended to under adjust the temperature. Example, if it is desired to set at 50°C, adjusts the temperature set knob so that LED is OFF at 45°C. The temperature would continue to rise. When it reaches 50°C adjust the temperature set knob so that oven is just ON/OFF. It may go up 1 & 2°C, but would settle down to 50°C. Since the change in temperature at this stage is very slow and response of RTD and sample is fast, the reading can also be taken corresponding to any temperature without waiting for a steady state.

   (viii) Set temperature may be checked anu time by putting the SET-MEASURE switch to SET Position.

   (ix) In case the temp is set at 200°C, switch the RANGE switch ti X10 range when the display in DPM startsw going out of range.

CAUTION : In case the Four Probe Arrangement, which also contains the RTD sensor is to be taken out of the oven for adjustment, switch "OFF" the PID Controller first. Otherwise the oven may get damaged.

OBSERVATION & TABULATION

Current (I) = mA (Constant)

S.No.	Current (I)	Voltage (volts)	V/I
			mean value =

Distance between probes (S) = 2.0 mm

Thickness of the sample (W) = mm

CALCULATION

From Eq. (3)

$$\rho_0 = \frac{V}{I} \times 2\pi S$$

Since the thickness of the sample is small compared to the probe distance a correction factor for it has to be applied. Further the bottom surface is non-conducting in the present case, Eq. (9) will be applied.

$$\rho = \frac{\rho_0}{G_7(W/S)}$$

$G_7(W/S) = 5.89$

The function G_7 (W/S) may be obtained from Table-I or Fig. 5 for the appropriate value of (W/S). For sample W/S<0.25, correction factor may be obtained directly from Eqn. 10. Thus ρ may be calculated for various temperatures.

COMMON PROBLEMS IN MEASUREMENTS

1. Very high resistance (> 1MΩ) may cause high off-set in D.C. Microvoltmeter which can not be adjusted with the knob provided - Note it down and treat it zero error.
2. Unstable voltage reading may be
   (i) Improper contacts of probes with the sample
   (a) This may be due to insulating layer on the sample - Clean it.
   (b) It may be due to loose contacts of probes with the sample - Teghen the springs of 4-probes (1/2 thread only)
   (c) Check the earth point and see that the whole system, constant current power supply. D.C. Microvoltmeter and Four Probe Arrangement are properly grounded.

$$\text{slope} = \frac{E_g}{2k}$$