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FOUR PROBE APPARATUS

Introduction

The purpose of 4-point probe method is to measure the resistivity of a semiconductor sample. The 4-probe setup consists of four equally spaced metal tips with finite radius. Each tip is supported by springs on the other end to minimize excessive pressure on the crystal. A high impedance current source is used to supply current through the outer probes; a voltmeter measure the voltage across the inner two probes to determine the sample resistivity and hence, the energy band gap of the semiconductor sample. Figure 1 shows the schematic diagram of 4- probe method

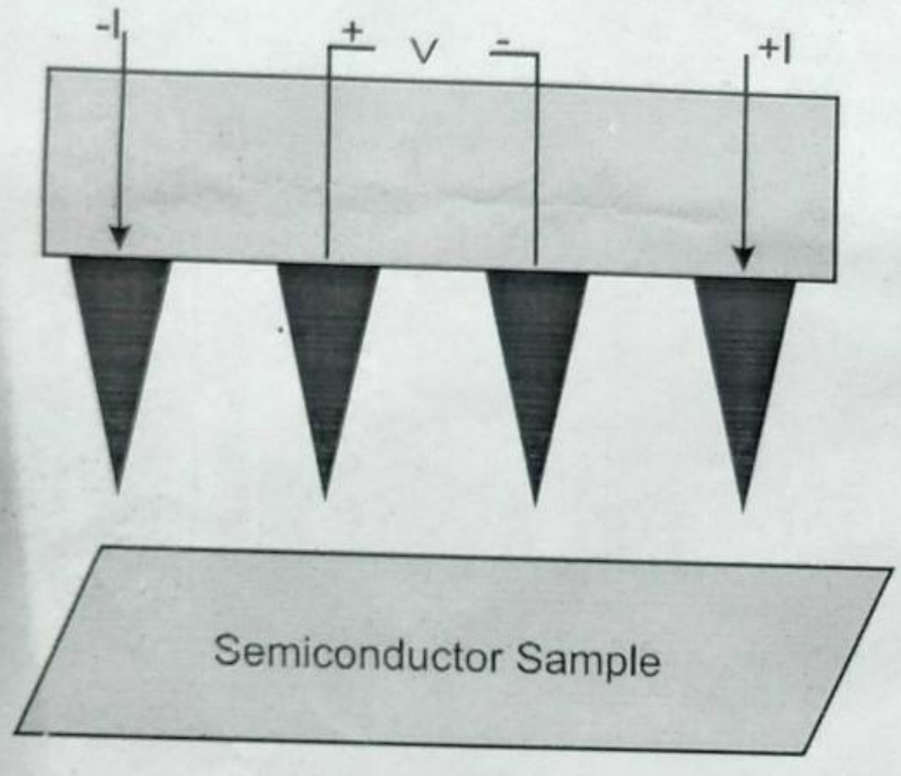

Fig. 1. Schematic diagram of 4-probe measurement.

Four sharp probes are placed on a wafer(Semiconductor sample) ,current is passed through the two outer probe and the floating potential is measured across the two inner probes to determine the sample resistivity.

Apparatus: SK012- FOUR PROBE APPARATUS

Formula used: The energy band gap,*E* of a semiconductor is given by

$$E_g = \frac{2k \; 2.3026 \times \log_{10} \rho}{T^{-1}} \quad eV$$

Where, $k=8.6 \times 10^{-5}$ eV/deg

ρ is resistivity of semiconductor sample

Given by $\rho = \rho_0 / f(W/s)$

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

W is thickness of sample,
s is the probe spacing,
f(W/s) function is the correction factor,
V is the voltage across the two inner probes,
I is the current through the two outer probes.

Description of apparatus

The four probe apparatus consists of a 4 point probe arrangement with a p-type Ge sample, oven. The basic unit contains digital display for voltmeter current & temp. is has inbuilt power supply for oven. Figure 2 shows various parts of apparatus.

Specifications:

Probe Arrangement: s=2.4 mm

Sample	: p-type Ge, 10x8x0.5 mm (l x w x t)
Oven	:temperature from ambient to 200°C max. (approx),
Voltmeter	:3½ digit, 7segment LED with auto polarity and decimal indication, Range: X1 (0 - 200.0 mV)DC & X10 (0 - 2.00 V) DC
Constant current source:	Range: 0 - 20.00 mA DC with 3½ digit, 7segment LED
Fuse	:1A,250 V

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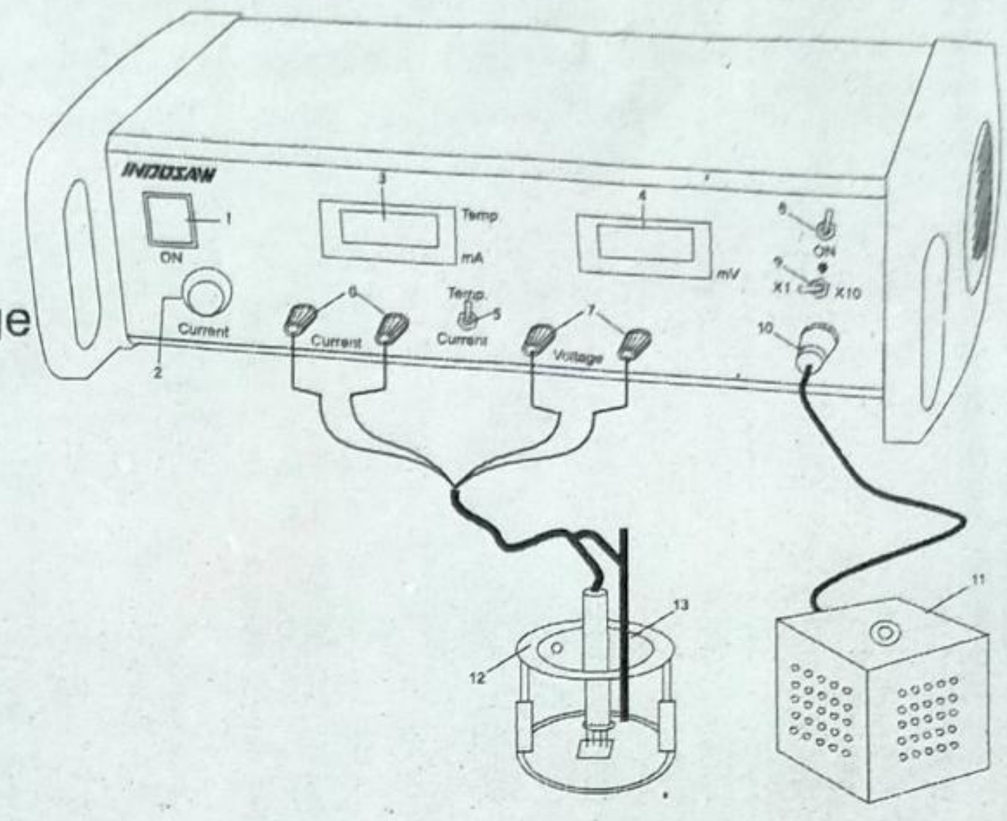
1. ON/OFF Switch
2. Current Knob for adjusting current
3. Current display/temperatue display
4. Voltage display
5. Switch to swipe current & temperature
6. 4 mm yellow safety sockets for current
7. 4 mm red & black safety sockets for measuring voltage
8. ON/OFF switch for oven, indicated by green LED
9. Voltage range multiplier, X1, X10
10. Socket for connecting oven.
11. Oven
12. 4-probe arrangement
13. PT-100 temperature sensor

Fig. 2 shows various parts of apparatus.



Procedure:

1. The p-type Ge sample is factory fitted. If there is any need for replacing or mounting a sample then, proceed as per following procedure . Unscrew the pipe of the four probe arrangement and place the sample on the base plate of 4-probe arrangement and adjust the pipe such that the 4-point probe lie in the middle of the sample as shown in figure 3.

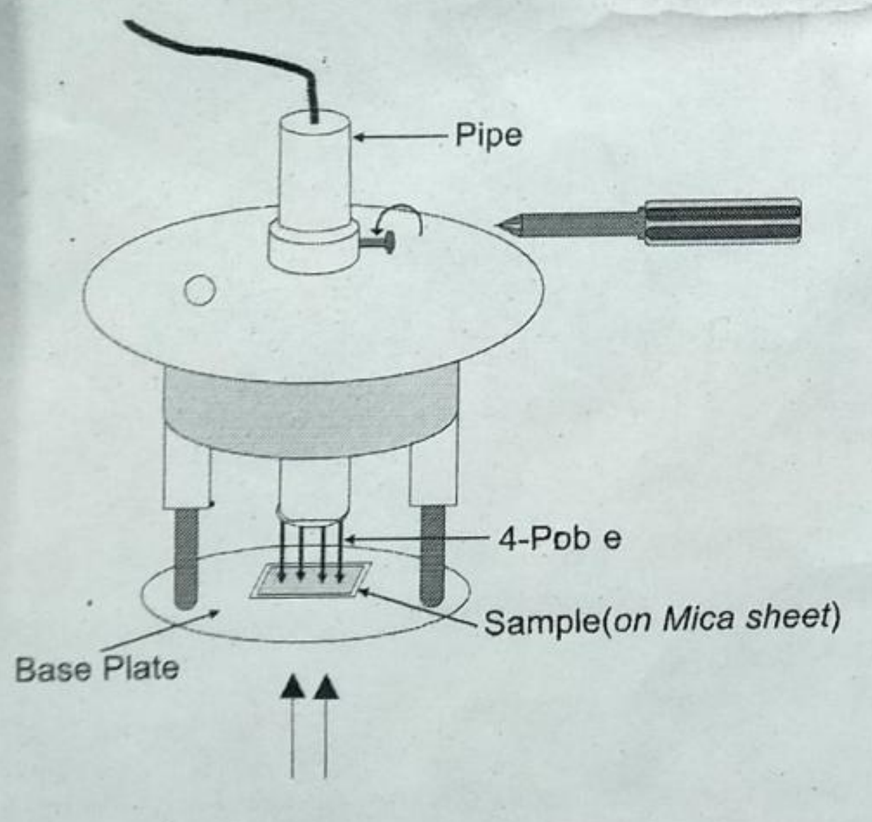


Fig. 3 shows four probe arrangement for mounting sample.

Gently applying some pressure and tighten the pipe in this position such that all the probes are in contact with sample.

(Warning! Applying excessive pressure may break the sample.)

2. Put the four probe arrangement in the oven and connect the lead of the oven to socket(10) as shown in figure 2. Also insert the PT-100 temp. sensor into the hole given at the top of the 4-probe arrangement.
(Note: Do not switch 'ON' the oven. Keep the switch of oven(8) in OFF position.)
3. Connect the RED and BLACK plug leads of 4-probe arrangement to 4 mm sockets(7) marked as "Voltage".
4. Connect the YELLOW plug leads to 4mm sockets(6) marked as " Current".
5. Change switch (5) to current, so display (3) show current reading.
6. Switch 'ON' the apparatus. Slightly increase the current using current knob (2), say 4mA and note that the voltage should be positive. If it is not, interchange the current leads (6).
7. Set the current to desired value (*say 8 mA*) using current adjusting knob(2) as shown in figure 2.Also select the range of multiplier using switch (9) to X1 or X10 on voltage display.(*It is always better to start with lower range i.e X1*)
8. Switch 'ON' the oven using switch(8) as shown in figure2.Green LED will glow ,showing that the oven is ON.
9. Change switch (5) to temperature, so display (3) show temperature.
10. Note the probe voltage on display (4) for different values of temperature as shown on display (3).

Observations:
(1) Current , I = 8.03 mA (constant)
(2) Distance between probes, s =0.24cm
(3) Thickness of sample , W = 0.05 cm

S. No.	Temperature (°C)	Voltage (mV)	Temperature T(K)
1	23	119.1	296
2	30	124.3	303
3	40	131.2	313
4	50	138.2	323
5	60	145.2	333
6	70	151.4	343
7	80	155.5	353
8	90	155.0	363
9	100	147.5	373
10	110	130.8	383
11	120	106.1	393
12	130	81.3	403
13	140	62.9	413
14	150	47.9	423

S. No.	$T^{-1} \times 10^3$	ρ (Ω cm)	$\log_{10}\rho$
1	3.38	3.31	0.52
2	3.30	3.45	0.54
3	3.19	3.64	0.56
4	3.10	3.83	0.58
5	3.00	4.03	0.61
6	2.92	4.20	0.62
7	2.83	4.31	0.63
8	2.75	4.30	0.63
9	2.68	4.03	0.61
10.	2.61	3.63	0.56
11.	2.54	2.94	0.47
12.	2.48	2.26	0.35
13.	2.42	1.74	0.24
14.	2.36	1.33	0.12

Calculations:
(1) Find the resistivity, corresponding to different temperatures using expression

$$\rho = \frac{\rho_0}{f(W/s)}$$

Where, f(W/s) can be found form the table T1.

$$\rho_0 = \frac{V}{I} \times 2\pi s = \ldots, \Omega \text{ cm}$$

[Note: For different values of V ,there will be different values of ρ_0]

(2) Calculate the value of resistivity ρ, for different values of ρ_0 and make an observation tableas

3. Plot a graph $(T^{-1} \times 10^3)$ versus $\log_{10}\rho$ and find the slope of the curve as shown in a typical graph figure 4

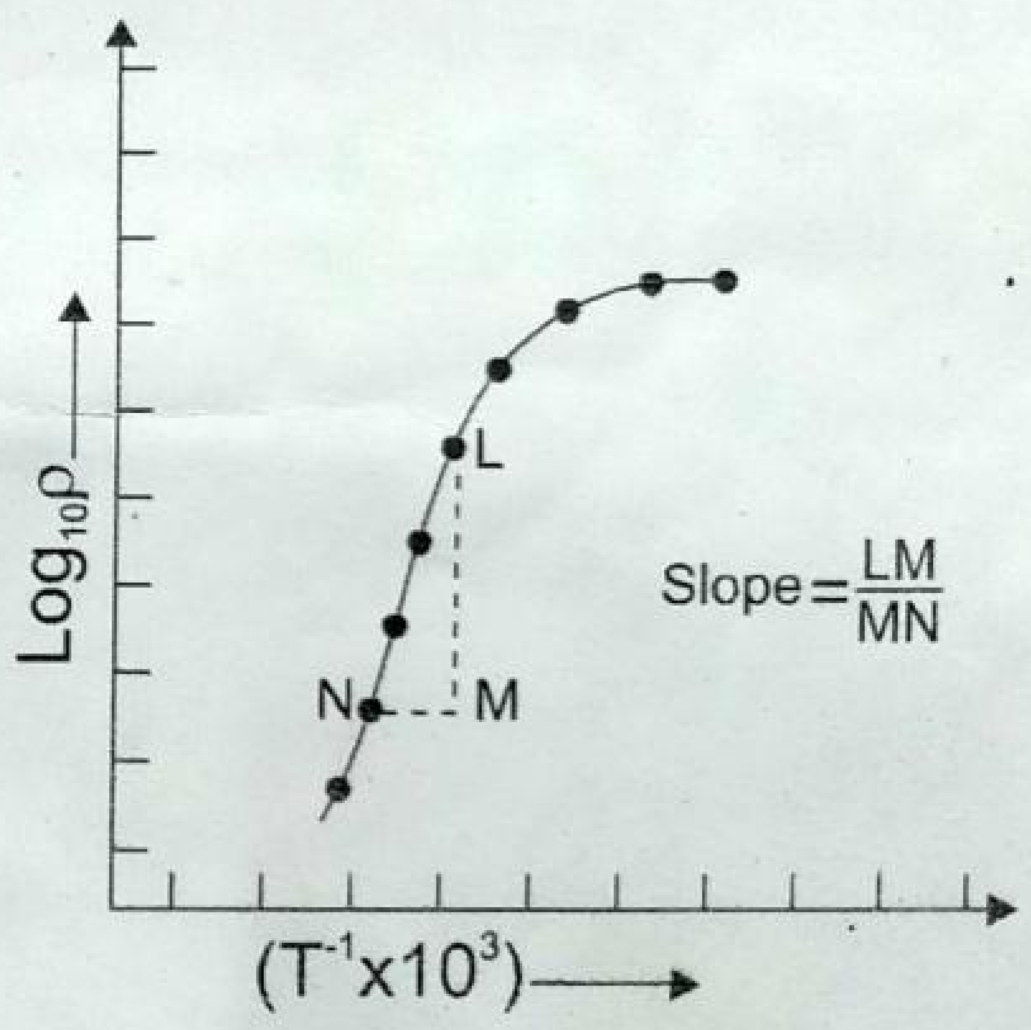


Fig.4 A typical graph showing the resistivity of Germanium crystal as a function of inverse temperature

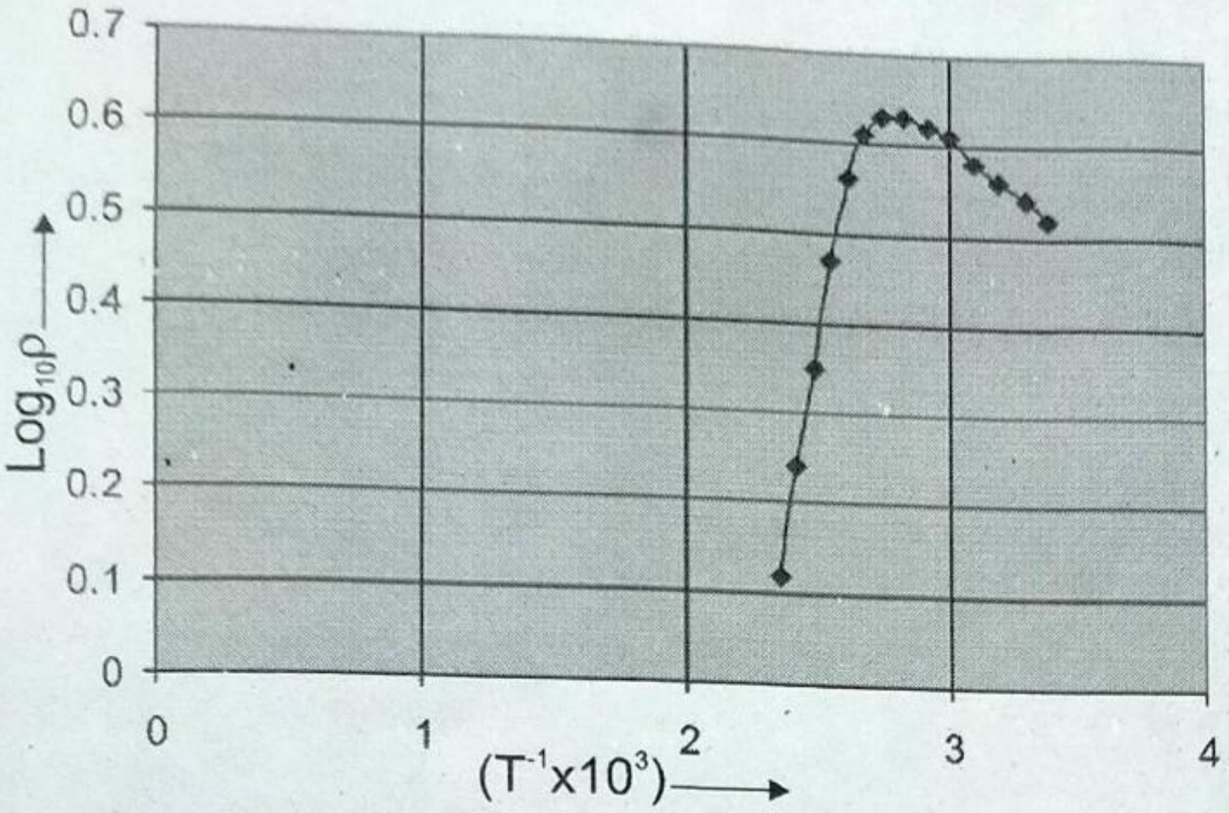
So, the energy band gap of germanium is

$$E_g = 2k \; 2.3026 \times \frac{\log_{10}\rho}{T^{-1}}$$

$$= 2k \times 2.3026 \times \frac{LM}{MN} \times 10^3$$

$$= 2 \times 8.6 \times 10^{-5} \times 2.3026 \times \frac{LM}{MN} \times 10^3$$

$$= 0.396 \times \frac{LM}{MN} \text{ eV}$$



From above graph the slope is found to be 1.78
Thus,
E_g =0.396 x 1.78 eV
=0.70 eV

Result : Energy band gap for Ge is 0.70 eV

TABLE T1 Values of f(W/s) for germanium crystal with non conducting base.
{Note: If any W/s *and its corresponding* f(W/s)*is not found in this table then, value can be found using interpolation }*

W/s	f (W/s)
0.100	13.863
0.141	9.704
0.200	6.931
0.333	4.159
0.500	2.780
1.000	1.504
1.414	1.223
2.000	1.094
3.333	1.0228
5.000	1.0070
10.000	1.00045

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FAULT FINDING

Problem1 : Current or voltage on the display panel remains zero.
Solution 1 : Ensure the contacts of the four- point probes. For this loosen the pipe as shown in figure 3 and mount the crystal and probes properly.

Problem 2 : The value of current as displayed on the panel is less than 18-19mA when the current knob is at maximum(fully clockwise) or current doesn't changes when current knob is a varied .
Solution2 : For this keep the oven switch(8)in OFF position and keep the Current knob(2) to maximum(i.e Fully clockwise). Keep the 4-probe arrangement in the oven and using a screw driver adjust the three screws1,2&3 (***as shown in figure5***) provided on the top plate of the 4-probe arrangement such that the current display shows an over range.

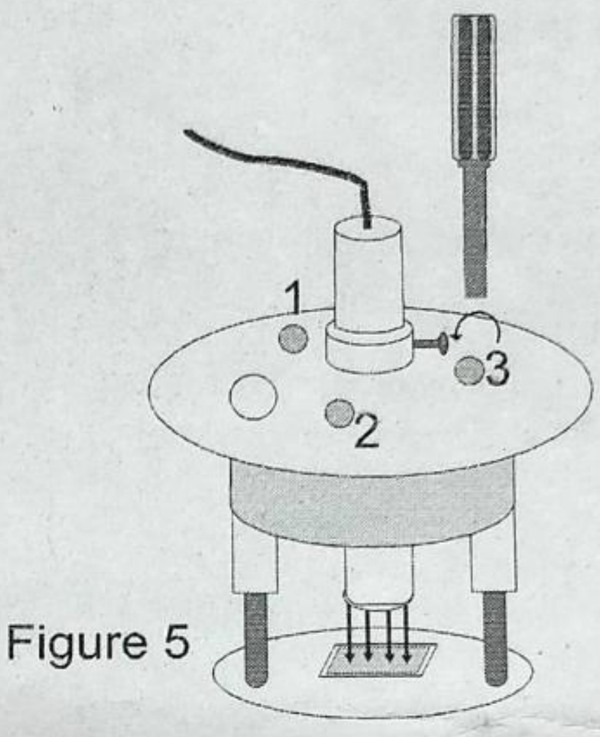

Figure 5

Problem3 : ON/OFF switch (1) doesn't glow when switched ON and equipment is not working .
Solution 3 : Check the fuse. If the fuse is blown off then change the fuse.
Replacement of fuse: Fuse is located in appliance power entry module provided on the rear side of appliance, take out the fuse carrier from power entry module,replace the fuse & insert it back. Always use the fuse of specified

REPLACE FUSE WITH
RATING 230V~, 1A
MAKE BUSSMAN