OPERATING INSTRUCTIONS

BAND GAP BY FOUR PROBE METHOD

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Energy Band Gap by Four Probe Method Apparatus has been designed to measure the value of energy band gap in germanium material.

The instrument comprises of the following built in parts:

1. Probes Arrangement: It has four individually spring loaded, coated with Zn at the tips. The probes are collinear and equally spaced. The Zn coating & individual spring ensure good electrical contacts with the sample. The probes are mounted in a teflon bush which ensure a good electrical insulation between the probe. A teflon spacer near the tips is also proiided to keep the probes at equal distance. The whole arrangement is mounted on a suitable stand and leads are provided for current and voltage measurements

2. Sample : Ge (Germanium) crystal in the form of a chip slice.

3. Oven: It is a small oven for the variation of temperature of the crystal from room temperture to about 20° Operating Temprature is 170°C.

4 Four Probes Set-up : (Measuring Unit) - It has three subunits all enclosed in one cabinet.

(i) Multirange Digital Voltmeter : In this unit 3.5 digit single chip A-D converter CL 7107 has been used. It has high accuracy. auto zero less than 10 uV, zero drift-less than 1 uV/°C, input bias current of 10 pA and roll over error of less than one count.

Since the use of internal reference causes the degradation in performance due to internal heating, an external reference has been used

SPECIFICATION

Range : (0 -200.0 mV) &(0 - 2.000 V)

Resolution : 100 1V at 200 rnV range

Accuracy : $\pm$ 0.1 % of reading $\pm$ 1 digit.

Impedence : 1OMohm

Display : 3.5 digit, 7 segment, LED(12.5 mm height) with auto polarity and decimal indication.

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(ii) Constant Current Generator :

It is a IC regulated current generator to provide a constant current to the outer probes irrespective of the changing resistance of the sample due to change in temperatures.

The basic scheme is to use the feedback principle to limit the load current of the supply to preset maximum value. Variations in the current are achieved by a potentiometer included for that purpose. The supply is a highly regulated and practically ripple free d.c. source. The current is measured by the digital panel meter.

SPECIFICATION :

Open circuit voltage : 18 Volts

Current range : 0-20 mA

Resolution : 10 uA

Accuracy : ± 0.25 % of the reading ± 1 digit

(iii) Oven Power Supply

Suitable voltage for the oven is obtained through a step down transformer with a provision for low nd high rates of heating. A qlowinq LED indicates. When the oven power supply is 'ON'.

INTRODUCTION

The properties of the bulk material used for the fabrication of transistors and other semiconductor devises are essential in determininq the characteristics of the completed devices. Resistivity and lifetime (of minority cacriels) measurements are gnerallv made on germanium crystals to to determine their suitability. The resistivity, in particular, must be measured accurately since its value is critical in many devices. The value of some transistor parameters, like the equivalent base resistance. are at least linearly related to the resitivity.

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ELECTRONIC CONDUCTION IN SOLIDS

The electrical properties of semiconductors involve the motion of charged particles within them. Therefore, we must have an understanding of the forces which control the motion of these, particles. It is of course, the physical structure of the solid which exerts their control. This topic is very large, and hence only the high lights wlbe covered.

Atoms, of which a solid is composed, consist of positively charged nuclei with electron orbiting around them. The positive charge is compensated by negatively charged electrons, so that a complete atom is electrically neutral. Electrons are arranged in shells, and the closer they are to the nucleus the more strongly they are bound. If we take the particular case of silicon, a well known semiconductor, we find that it has 14 electrons which are accommodated in the shells as (iS)2, (2S)2, (2P)6, (3S)2, (3P)2. Since the third shell is not even halif filled, the4 electrons are available for chemical binding giving silicon a valency of four. (Germnium also has a chemical valency of 4, but from the fourth shell).

Let us now concentrate our attention on solids, if we bring many atoms close to one another, interatomic forces become quite strong as eectronic orbits begin to overlap. The outer shell electons play an important role, because their orbits are the most disturbed. These electrons are no longer associated with a particuiar atom, the outer electron may make an orbit around one atom and continue about another. In this fashion, the outer shell or valency electrons are continually traded among atoms and wander all over the solid. The continuous interchange of valence electrons between atoms holds the solid together. This is the predominant type of bonding in silicon and germanium and is called the valence bonding.

FOUR PROBE METHOD

Many conventional methods for measuring resistivity are unsatisfactory for semiconductors because metal- semiconductor contacts are usually rectifying in nature. Also there is generally minority carrier injection by one of the current carrying contacts.

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An excess concentration of minority carriers will affect the potential of other contacts and modulate the resistance of the material.

The method described here overcomes the difficulties mentioned above and also offers several other advantages. It permits measurements of resistivity in samples having a wide variety of shapes, including the resistivity of small volumes within bigger pieces of semiconductor. In this manner the resistivity of both sides of PN Junction can be determined with good accuracy before the material is cut into bars for making devices. This method of measurement is also applicable to silicon and other semiconductor materials.

In order to use this four probe method in semiconductor crystals or slides it is necessay to assume that:

1 The resistivity of the material is uniform in the area of measurement.

2. If there is minority carrier injection into the semiconductor by the current - carrying electrodes most of the carriers recombine near the electrodes so that their effect on the conductivity in negligible. (This means that the measurements should be made on surface which have a high recombination rate, such as mechanical lapped surfaces).

3. The surface on which the probes rest is flat with no surface leakage.

4. The four probes used for resistivity measurements contact the surface at points that lie in a straight line.

5 The diameter of the contact between the metallic probes and the semiconductor should be small compared to the distance between probes.

6. The boundary between the current-carrying electrodes and the bulk material is hemispherical and small in diameter.

7. The surfaces of the semiconductor crystal may be either conducting or non-conducting.

(a) A conducting boundary s one on which a material of much lower resistivity than semiconductor (such as copper) has been plated.

(b) A non-conductibng boundary is produced when the surface of the crystal is in contact with an insulator.

EXPERIMENTAL PROCEDURES

1. Put the sample on the base olate 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 positon. Check the continuity between the probes for proper electrical contacts.

CAUTION: The Ge crystal is very brittle. Therefore, use only the minimum pressure required for proper electrical contacts.

2. Connect the outer pair of probes (Yellow and Green leads) leads to the constant current power supply and the inner pair to the probe (red and black leads) voltage terminals.

3 Place the four probe arrangement in the oven and fix the thermometer in the oven through the hole provided.

4 Switch ON the AC mains of Four Probe Set-up and put the digital panl meter in the current measuring mode through the selector switch. In this position LED facing mA would glow. Adjust the current to a desired value (Say 5mA).

5. Now put the digital panel meter in voltage measuring mode. In this position LED facing mV would glow and the meter would read the voltage between the probes.

6. Connect the oven power supply. Rate of heating may be selected with the help of a switch Low or High as desired. Switch on the power to the Oven. The glowing LED indicates the power to the oven is ON.

Now note down the reading of Milli Voltmeter at every increase in temprature. Note down reading in the Table No. (1). Plot a graph between $T^{-1} \times 10^3$ & $\log_{10} \rho$ by taking $T^{-1} \times 10^3$ along X-axis & along $\log_{10} \rho$ Yaxis.

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S. No.	Temp °C	Volt V	Temp (T in K)	ρ Ohm-cm	$T^{-1} \times 10^3$	$\log_{10} \rho$
1.	30	215	303	9.53	3.30	0.97
2	40	215	313	9.53	3.19	0.97
3.	50	213	323	9.44	3.10	0.97
4.	60	203	333	9.00	3.00	0.95
5.	70	179	343	7.93	2.92	0.89
6.	80	156	353	6.91	2.82	0.83
7.	90	126	363	5.58	2.75	0.74
8.	100	109	373	4.83	2.68	0.68
9.	110	088	383	3.90	2.61	0.59
10.	120	066	393	2.92	2.54	0.46
11.	130	047	403	2.08	2.48	0.31
12.	140	035	413	1.55	2.42	0.19
13.	150	028	423	1.24	2.36	0.09
14.	160	019	433·	0.84	2.25	-0.07

Current I = 8mA(constant)

0.97 Distance between probes ($) = 0.2 cm

Thickness of the crystal (W) = 0.08 cm

CALCULATION

$$\rho_0 = V/I \times 2\pi S$$

$$\rho_0 = V/I \times 1.256$$

The value above shown are only test results & may vary

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Since the thickness of the Crystal is very small compare to the probe distance, a correction factor for it has to be applied. In this present case the bottom surface is non-conducting, so the correction factor would be;

$$\rho = \frac{\rho_0}{G7 \ (W/S)}$$

Correction Factor corresponding to G7 = W/S = W/0.2 = 0.080/0.2 = 0.4

Corrective Factor (G7) = 3.54

or ρ = V/I x 1.256/G7 = V/8x10³ X 1.256/3.54 = V x44.35

Putting I = 8.00 mA (for whole set of Readings, constant)

ρ = V x 44.35   eq. (i)

Put the value of V (Voltage Read on DPM) n eq (i) and calculate the diff., value of ρ and Record in Table
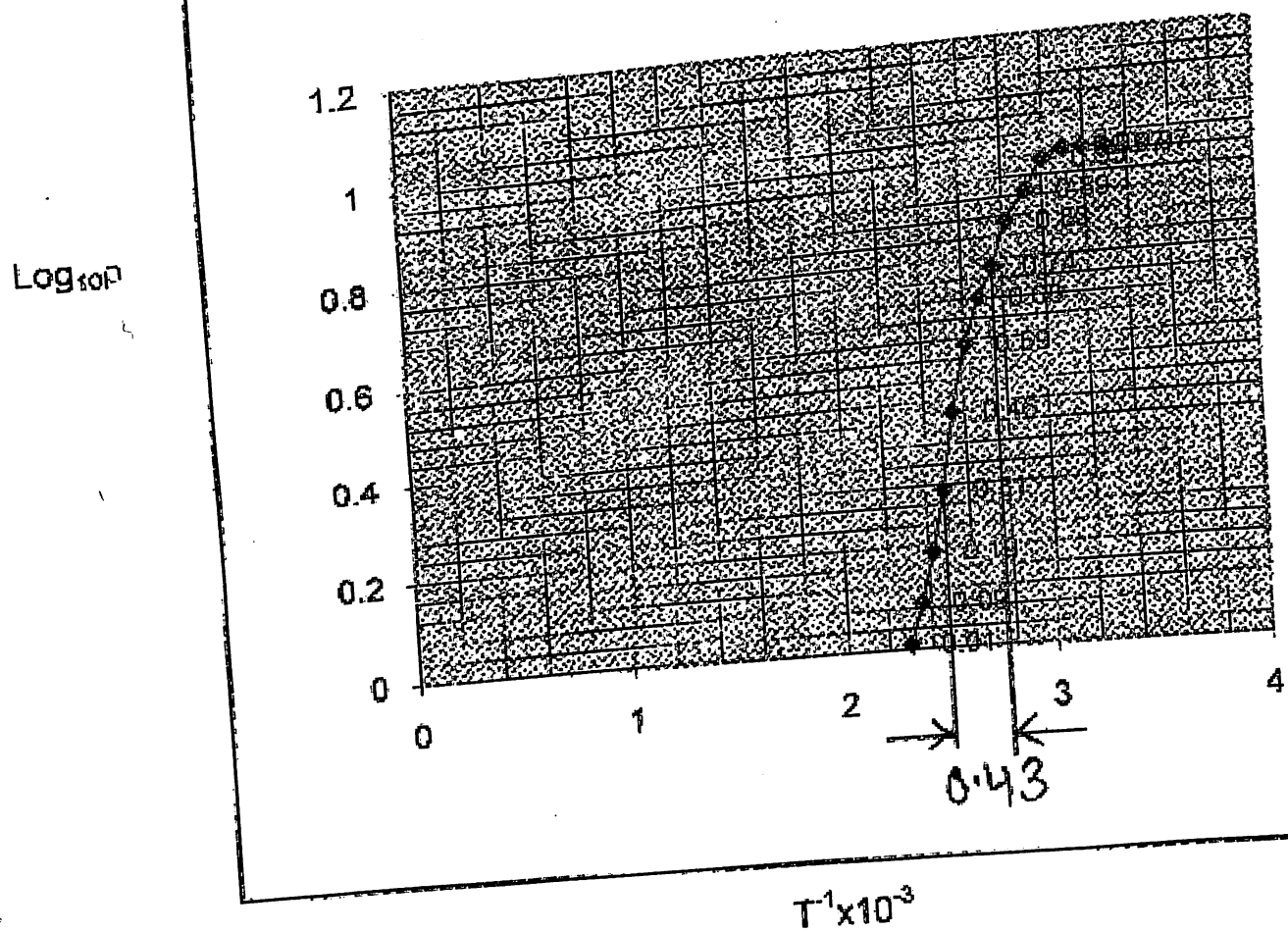
CALCULATIONS FOR ENERGY BAND GAP

We know that

$$E_g = \frac{2k \ Log_e \ \rho}{I/T}$$

Where K is Boltzamann's constant 8.6 x 10 ev/deg. & T is temperature in Kelvin, From the graph, slop of curve is

$$\frac{Log_e \ p}{1/T} = \frac{2.3026 x \ Log_{10}\rho}{I/T} = \frac{2.3026 x 0.74}{0.43 x 10^{-3}}$$

= 3962

Hence Eg = 2 x 8.6 x 10⁻⁵ x slope of the curve = 2 x 8.6 x 10⁻⁵ x 3962 = 0.68

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Graph to calculate slope for four Probe Method

$Log_{10}\rho$

$T^{-1}x10^{-3}$

0.43