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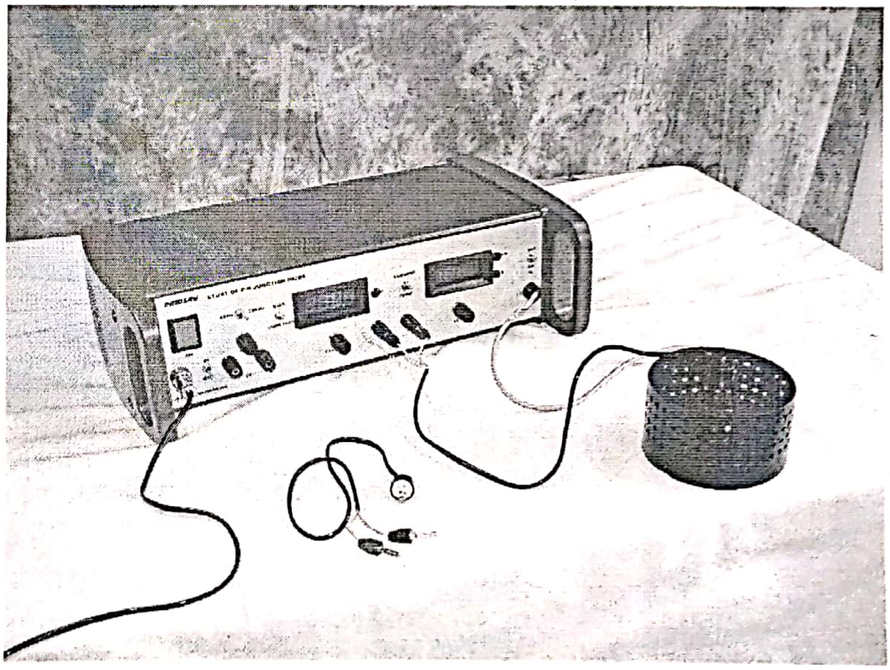
INSTRUCTION MANUAL

STUDY P-N JUNCTION



OSAW INDUSTRIAL PRODUCTS PVT. LTD.

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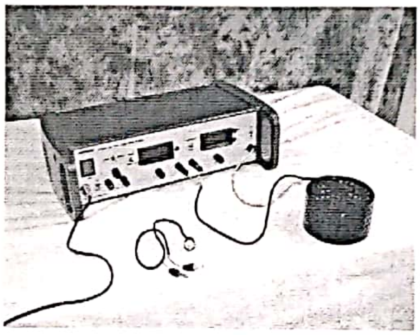
OBJECTIVES: To Study the Energy band gap & diffusion potential of P-N junction.

THEORY:

The three experiments which may be performed on the unit are described below:

PN JUNCTION SET-UP

The set-up consists of following:



1. PN junction set up.
2. Oven with thermometer.
3. A Samples of junction transistor with connecting leads
4. Diode 1N5402 to measure junction capacitance.
5. Connecting lead to connect oscilloscope for measure junction capacitance.

PROCEDURE:

1. Connect the PN junction set up to the ac mains.
2. Insert the oven knob to the oven socket provided on set up.
3. Connect the junction transistor lead to the terminals provided on the setup as polarity indicated on it.
4. Insert the junction transistor provided at other end of lead in the oven.
5. Switch on the PN junction set up.

EXPERIMENT 1: Determination of the reverse saturation current I_0 & material constant η .

The current I in the p-n junction is given by

$$I = I_O(e^{\frac{qV}{\eta kT}} - 1) \quad (1)$$

where,

q, electronics charge $= 1.602 \times 10^{-19} columb$

η , material constant =1 for Ge

=2 for Si

k,Boltzman constant $= 1.381 \times 10^{-23} J/K$

T, Temperature in Kelvin

V, Junction voltage in volts

The reverse saturation current is usually too small to measure directly. An indirect graphical method may be obtained by taking logarithm of eqn. (1)

for $(e^{\frac{qV}{\eta kT}} >> 1)$ as,

$$\ln I = \ln I_O + \frac{qV}{\eta kT}$$

If V & ln I are plotted on graph paper a straight line is obtained. This line intersects the current (ln I) axis at ln I0 & its slope may be solved to compute η ,

$$\eta = \frac{q\Delta V}{kT\Delta \ln I}$$

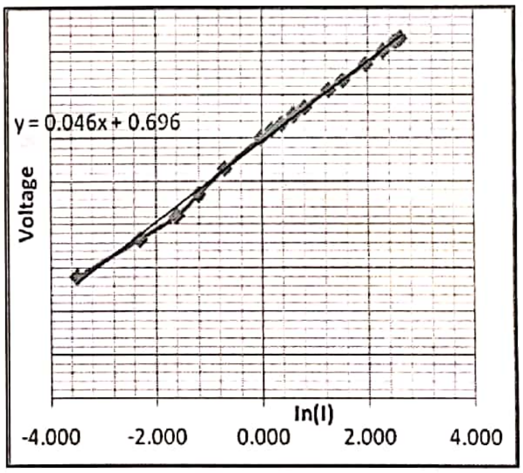
Note the junction voltage by varying the current source .The values of junction voltage & current are displayed on the panel display provided on the setup.

SAMPLE DATE: BC 109

S.No	Voltage (Volt)	Current (mA)	ln (I)
1	0.540	0.03	-3.507
2	0.584	0.10	-2.303
3	0.610	0.20	-1.609
4	0.635	0.30	-1.204
5	0.665	0.50	-0.693
6	0.700	0.97	-0.030
7	0.710	1.20	0.182
8	0.716	1.44	0.365
9	0.727	1.81	0.593
10	0.736	2.24	0.806
11	0.756	3.50	1.253
12	0.767	4.54	1.513
13	0.786	7.09	1.959
14	0.801	9.78	2.280
15	0.812	12.40	2.518
16	0.816	13.61	2.611

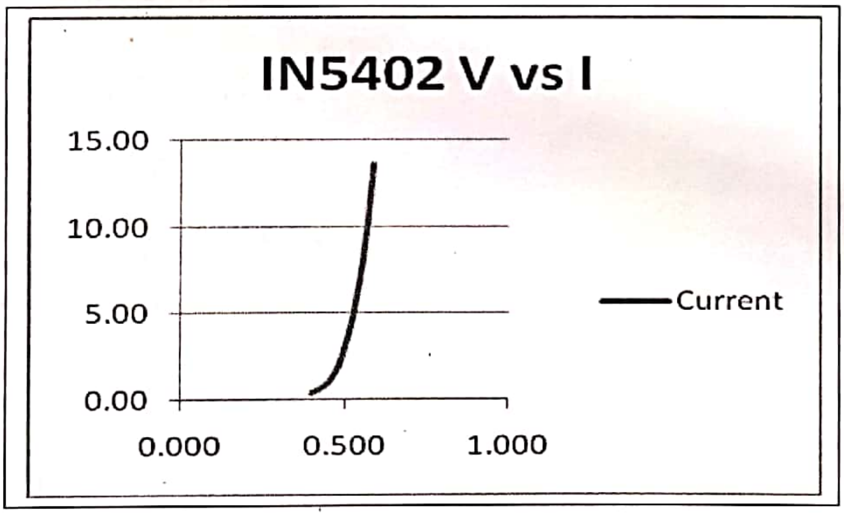
Slope = $\frac{\Delta V}{\Delta \ln I}$ =0.046

Therefore $\eta = \frac{q\Delta V}{kT\Delta \ln I}$ =1.8



SAMPLE DATA: IN5402 Forward Bias Characteristics

S.No	Voltage	Current
1	0.000	0.00
2	0.400	0.41
3	0.448	1.00
4	0.480	2.00
5	0.497	3.00
6	0.512	4.00
7	0.523	4.87
8	0.524	5.00
9	0.534	6.00
10	0.543	7.00
11	0.551	8.00
12	0.558	9.00
13	0.564	10.00
14	0.570	11.00
15	0.575	12.00
16	0.581	13.00
17	0.583	13.61



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EXPERIMENT 2: Determination of temperature Coefficient of junction Voltage & Energy band gap.

With the connections as in experiment –1 the oven & the sensor leads are inserted in the respective sockets. The diode is put in the oven & its forward current is set to a low value to avoid heating. The display-1 is now switched to TEMP, to read the oven temperature.

The oven temperature can now be varied room temperature to about 360 k in suitable steps and the junction voltage may be recorded. The temperature-controlled oven requires steps & 5 minutes to stabilized at every new setting. Before nothing any readings, one must ensure that a few ON/OFF cycles of the oven been completed as shown by the indicator.

The reverse saturation current is given by

$$I_O = kT^m e^{\frac{V - V_{GO}}{\eta V_T}}$$

& the diode forward current by

$$I = I_O\left(e^{\frac{V}{\eta V_T}} - 1\right) \approx I_O e^{\frac{V}{\eta V_T}}$$

$$= kT^m e^{\frac{V - V_{GO}}{\eta V_T}}$$

where for Si : m=1.5 η =2

for Ge: m=2.0 η =1

$$V_T = \frac{kT}{q},$$

Taking logarithm

$$\ln I = \ln k + m \ln T + \frac{V - V_{G0}}{\eta kT}$$

At I = constant, differentiating w.r.t T

$$0 = 0 + \frac{m}{T} + \frac{d}{dT}\left[\frac{(V - V_{G0})q}{\eta kT}\right]$$

$$0 = \frac{m}{T} + \frac{q}{\eta kT}.\frac{dV}{dT} - \frac{(V - V_{G0})q}{\eta k}.\frac{1}{T^2}$$

$$0 = \frac{m}{T} + \frac{q}{\eta kT}.\frac{dV}{dT} - \frac{q}{\eta kT^2}(V - V_{G0})$$

$$V_{G0} = V - T.\frac{dV}{dT} - \frac{m\eta kT}{q}$$

$$0 = \frac{\eta kT^2}{q}.\frac{m}{T} + T\frac{dV}{dT} - (V - V_{G0})$$

at 300k for Si

$$\frac{m\eta kT}{q} = \frac{(1.5 \times 2 \times 1.381 \times 10^{-23} \times 300)}{1602 \times 10^{-19}}$$

=0.078V

Where slope of the V-T curve is the temperature coefficient of the junction voltage & V_{G0} is the energy band gap.

With the connections as in experiment 1 the oven & the junction transistor leads are inserted in the respective sockets. The junction transistor is put in the oven & its forward current is set to a low value to avoid heating. The display –1 is now switched to temp, to read the oven temperature. The oven temperature can now be varied from room temperature to about 360 K in suitable steps & the junction voltage is recorded. Before noting any reading, one must ensure that a few on/off cycles of the oven have been completed as shown by the indicator.

SAMPLE: BC 109

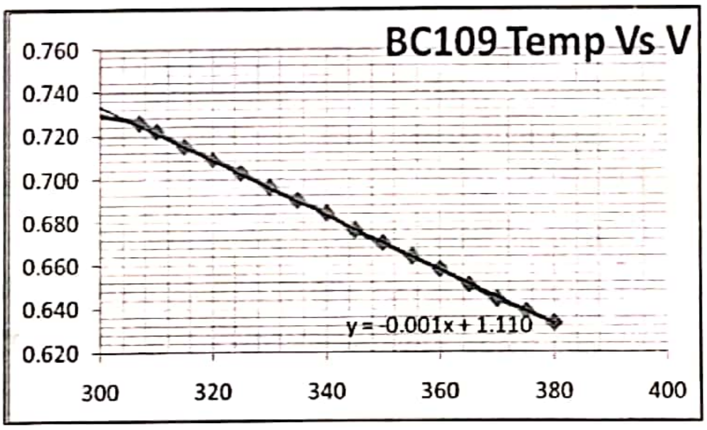
I_f = 2mA

S. No.	Voltage	Temp (K)
1	0.730	299
2	0.726	307
3	0.722	310
4	0.715	315
5	0.709	320
6	0.703	325
7	0.696	330
8	0.690	335
9	0.684	340
10	0.676	345
11	0.670	350
12	0.664	355
13	0.658	360
14	0.651	365
15	0.644	370
16	0.639	375
17	0.633	380

We know,

Energy Band gap V_{Go} =

$$V(T) - T\frac{dV}{dT} - \frac{m\eta\, kT}{q}$$



From graph no. 2

At T=299K, V(T) =0.730,

dV/dT= 0.001

& for Si at 299K,

$$\frac{m\eta\, kT}{q} =$$

V_{G0} =

EXPERIMENT 3: Study of the depletion capacitance & its variation with reverse bias

The measurement is based on Cd (depletion capacitance) & Gd (leakage resistance) of the diode under test.

The output voltages V1 & V2 at the two frequencies ω_1, ω_2 ($\omega_2 > \omega_1$) may be written as,

$$V_1 = -V(G_D + j\omega_1 C_D)R$$
$$V_2 = -V(G_D + j\omega_2 C_D)R$$

V is the input signal of same magnitude both for ω_1, ω_2.

Squaring & subtracting after taking magnitudes,

$$V_2^2 - V_1^2 = V^2 R^2 (\omega_2^2 - \omega_1^2) C_D^2$$

$$C_D = \frac{\sqrt{V_2^2 - V_1^2}}{VR\sqrt{\omega_2^2 - \omega_1^2}}$$

V_1 is the p-p output voltage in the mV at 5KHz & V_2 is the p-p output voltage in the mV at 20KHz

The measurement is based on C_d (depletion capacitance) & G_d (leakage resistance) of the diode under test.

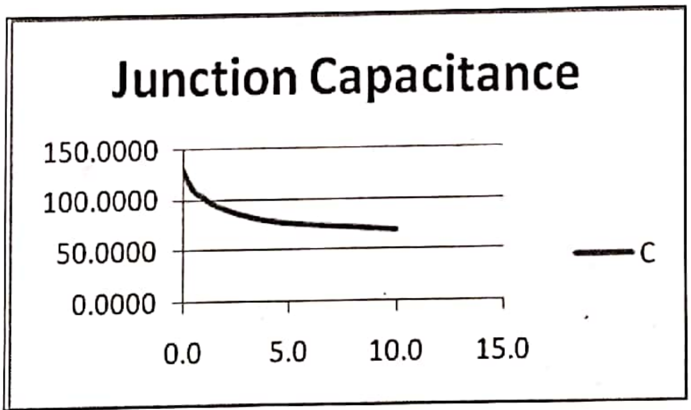
The test sample of the diode is connected to the junction capacitance at terminals provided at the left side of the set up. The display –2 is set to bias & CRO is connected to measure the input & output voltage pf the particular bias & frequency settings.

SAMPLE: SI DIODE IN5402

Vpp=680mV

Vin (V)	5kHz (mV)	20kHz (mV)	C
0.0	190	370	130.1710
0.5	110	290	110.0145
1.0	100	270	102.8275
1.5	90	250	95.6276
3.0	80	220	84.0250
5.0	70	200	76.8135
10.0	60	180	69.5793

$$C_D = 0.41\sqrt{V_2^2 - V_1^2}\ pf$$



CHECK POINTS:

1. In experiment 1&2, ordinary diodes used in power supplied should not be used due to poor material quality
2. In T-I mode, make sure that the oven switch is 'OFF' and SET temp knob is at minimum position before connecting the oven.
3. On each setting of temperature, please allow sufficient time for the temperature to stabilized, between 5-6 minutes
4. In experiment 3, junction capacitance of diode/ transistor junction, the devices should be directly connected with terminals, connections through leads would result in additional capacitance and pick ups.

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