Band gap of Silicon and Germanium

Objectives:

1-To determine the ideality constant of the material.

2-to find the band gap of Germanium and Silicon.

Theory:

The p-n junction is an important element of most electronic devices, from a simple diode to a transistor to a sophisticated integrated circuit. The current I through a p-n junction is strongly dependent on the polarity of the applied voltage V. In one direction, the current increases exponentially with the voltage, while in other direction the current approaches a very small value with increasing applied voltage. This dependence is given by the diode equation,

$$I = I_0 \left(e^{\frac{qV}{\eta kT}} - 1 \right) \qquad (1)$$

where ,

I_0 is the reverse saturation current

q,electronic charge =1.602 x10^{-19} Coulomb

η,material ideality constant

k,Boltzman constant =1.38x10^{-23} J/K

T,temperature in Kelvin

V,junction voltage in volts

The reverse saturation current is usually too small to be measured directly .An indirect graphical method may be obtained by taking logarithm of equation (1)for $e^{qV/\eta kT} >> 1$ as,

$$\ln I = \ln I_0 + \frac{qV}{\eta kT} \qquad (2)$$

If ,V is plotted against lnI a straight line is obtained. This line intersects the current lnI axis at I_0 and its slope may be solved to find η

$$\eta = \frac{q}{kT} \frac{\Delta V}{\Delta lnI} \qquad (3)$$

The study of the band gap structure of semiconductors is also important because it is directly proportional to its electric properties. It has been observed experimentally that, within a certain temperature range ,the relation between temperature and voltage is almost linear. This proportionality can be used to determine the band gap.

The reverse current depends strongly on the temperature and given by

$$I_0 = kT^m e^{\frac{-V_{G_0}}{\eta V_T}} \qquad (4)$$

And the diode forward current by

$$I = I_0 \left(e^{\frac{qV}{\eta kT}} - 1\right) \approx I = I_0 \, e^{\frac{qV}{\eta kT}} \qquad (5)$$

$$= kT^m e^{\frac{V-V_{G_0}}{\eta V_T}} \qquad (6)$$

Also $V_T = \frac{KT}{q}$ taking logarithm

$$\ln I = \ln k + m \, lnT + \frac{V-V_{G_0}}{\eta V_T} \qquad (7)$$

At constant current Differentiating w.r.t.T

$$0 = 0 + \frac{m}{T} + \frac{d}{dT}\left[\frac{(V-V_{G_0})q}{\eta kT}\right] \qquad (8)$$

$$0 = 0 + \frac{m}{T} + \frac{q}{\eta kT}.\frac{dV}{dT} - \frac{(V - V_{G_0})q}{\eta k}.\frac{1}{T^2}$$

$$0 = \frac{m}{T} + \frac{q}{\eta kT}.\frac{dV}{dT} - \frac{q}{\eta kT^2}(V - V_{G_0})$$

$$0 = \frac{\eta kT^2}{q}.\frac{m}{T} + T\frac{dV}{dT} - (V - V_{G_0})$$

$$V_{G_0} = V - T\frac{dV}{dT} - \frac{m\eta kT}{q} \qquad (9)$$

where slope of the V-T curve is the temperature coefficient of the junction voltage ,M is the junction gradient coefficient ,and V_{G_0} is the energy band gap.

The experimental set-up :

1-study of P-N junction ,model PN-1

2-Transistor (base emitter Ge or Si)

3-Fast temperature controlled oven with sensor.

Part I: I-V measurements

1-The junction to be tested connected to the terminals with the polarity as indicated.

2-Readings are recorded from the two displays set to Junction and current respectively with the current source adjusted in steps from 100 µA to 10 mA.

Part II: V-T measurements

1-With the connections as in experiment I ,the oven and sensor leads are inserted in the respective sockets.

2-The transistor is put in the oven and its forward current is set to a low value(1mA)then switch the display to read the oven temperature.

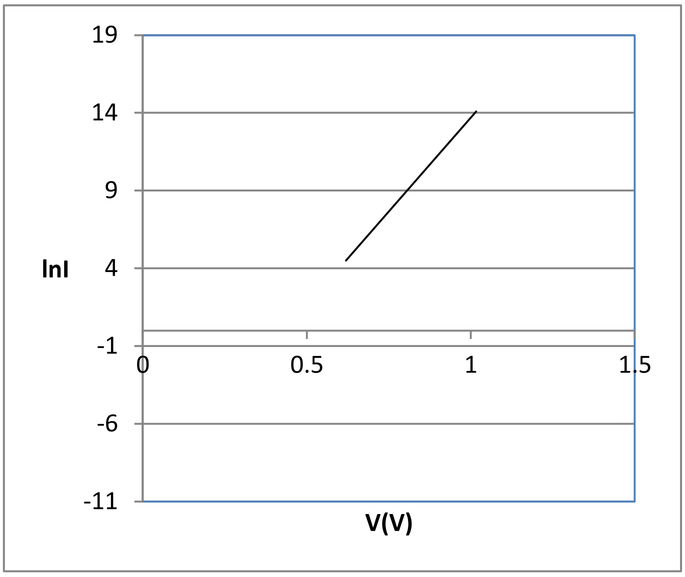
3- .Readings of the temperature and junction voltage are recorded ,while the temperature is adjustable in the range from room temperature to about 360 K

Results:

using lnI-V graph :

-find the slope and I_0

-calculate η



-using V-T graph find V_{G_0} from equation 9.

where m=1.5 for Silicon and 2 for Germanium.