University of Technology

Department of Laser & Opto-electronic Engineering

Final Examination 2011-2012

Subject: Semiconductor Devices — *Class: 4^{th} year*

Division: Opto-electronic Eng. — *Time: 3 hours*

Examiner: Asis.Prof.Dr.Mohammed A.Mahdi — *Date: 5 / 6 /2012*

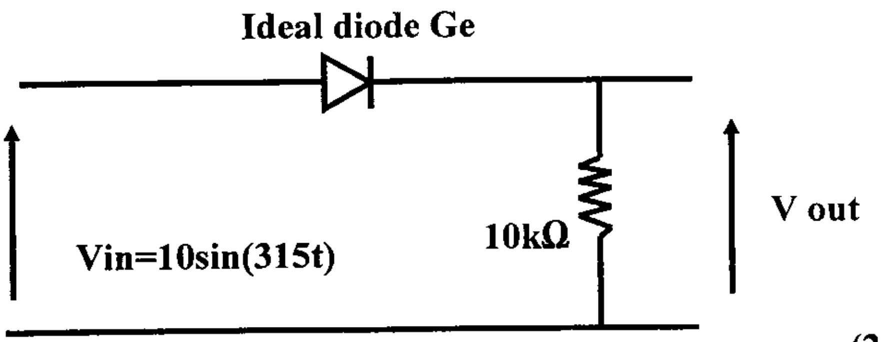
Answer five questions only

Q1/ The hole density in an n-type silicon wafer ($N_d=10^{17}$) decreases linearly from 10^{14} cm^{-3} to 10^{13} cm^{-3} between **x=0** and **x=1μm**. At room temperature, calculate the hole diffusion current density. **(20 mark)**

Q2/ A- Prove that J=σE is ohm's law. **(10 mark)**

B- Explain the (I-V) characteristics of the diode and draw it. **(10 mark)**

Q3/ Draw the output voltage waveform:



(20 mark)

Q4/ Prove that:

$$P = N_V \exp\left(-\frac{E_f - E_V}{kT}\right)$$

Where: P: hole concentration.

N_V: density of energy level in valance band.

E_f: Fermi- level energy.

E_V: energy level in valence band.

k: Boltzmann constant.

T: templeature. **(20 mark)**

Q5/ A bar of n-type **(10 × 1 mm²)** with electron density of 7×10^{14} m^{-3}. A magnetic field of **0.2 Tesla** is exerted on the bar. **1mv** applied across the long ends of the bar. Calculate the current through the bar, the hall coefficient and hall voltage. Knowing that μ_n=0.38 m^2/v.s.

(20 mark)

أقلب الصفحة رجاءً (2-1)

Q6/ The atomic weight of Ge is **72.6 gm/mol** and density is **5.32 gm/cm^3**. Find:

1- The resistivity of intrinsic Ge at **300K**.

2- If a donor type of impurity is added with doping level of **10^{-8}** find the new resistivity of the sample. Knowing that the intrinsic **concentration= 2.5×10^{13} cm^{-3}**, **Mobility of hole= 1800 cm^2/v.s**, and the **mobility of electron= 3800 cm^2/v.s.** **(20 mark)**

Good luck

حلول اسئلة النهائي اشباه موصلات نموذج (2)
رابع / الكترونيات بصرية

Q1/

$$D_p = V_t \mu_p$$

$$= 0.0259 * 317 = 8.2 \ cm^2/s$$

$$J_p = q D_p \frac{dP}{dx}$$

$$= 1.6 * 10^{-19} * 8.2 * \frac{9 * 10^{13}}{10^{-4}}$$

$$J_p = 1.18 \ A/cm^2$$

Q2/ (A)

$$R = \frac{V}{I} \quad , \quad \sigma = \frac{1}{\rho}$$

$$R = \rho \frac{L}{A}$$

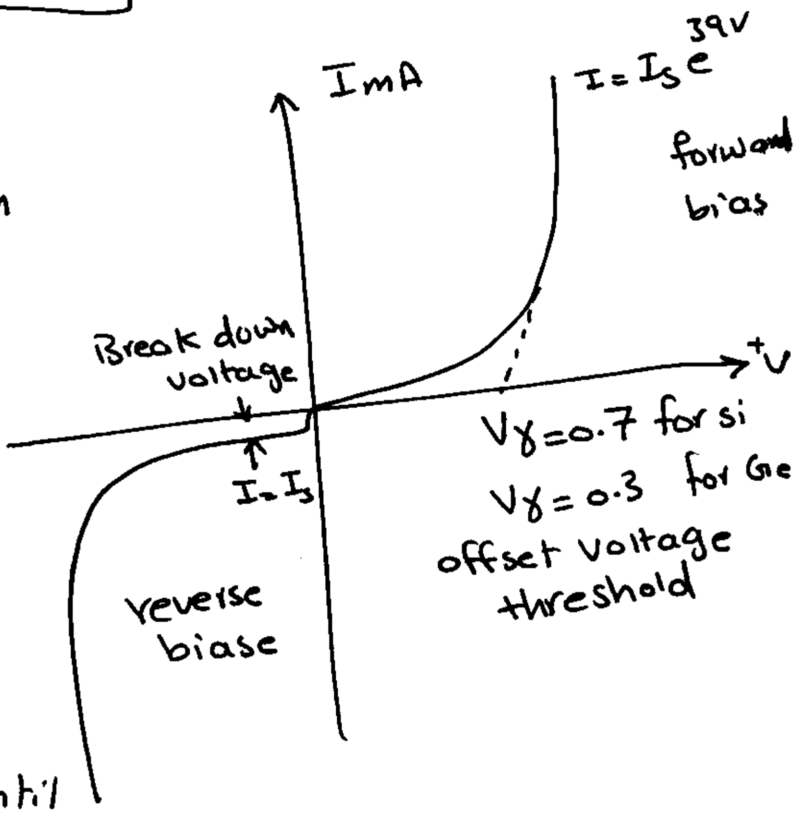
$$\rho = R \frac{A}{L}$$

$$\sigma = \frac{L}{RA} = \frac{L \cdot I}{V \cdot A} = \frac{L}{V} \cdot \frac{I}{A}$$

$$= \frac{1}{E} \cdot J$$

$$\sigma = \frac{J}{E} \qquad \boxed{J = \sigma E}$$

(B)



In forward bias : current begin increase when reaches the thershold voltage $V\gamma = 0.7$ for si and $V\gamma = 0.3$ for Ge this increase depend on $I = I_s e^{39V}$.

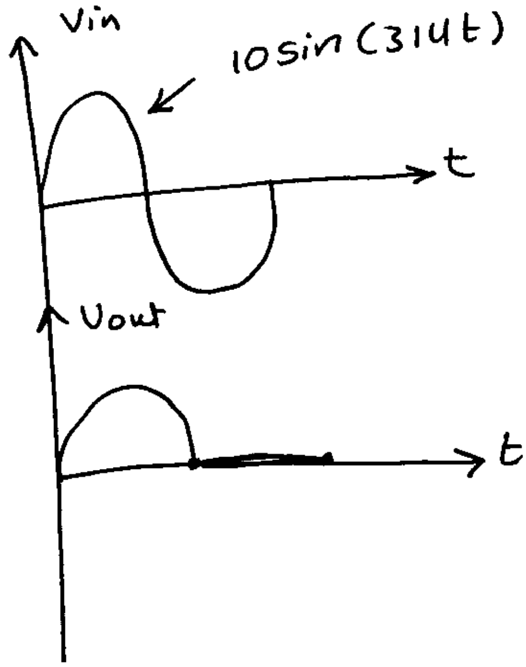
In reverse biase : current called (saturation current increase but very slowly until reach acertain value happend breakdown voltage.

Q3/

* Positive half cycle

  Diode is forward

  $V_o = V_i = 10 \sin(314t)$



* Negative

  Diode is reverse

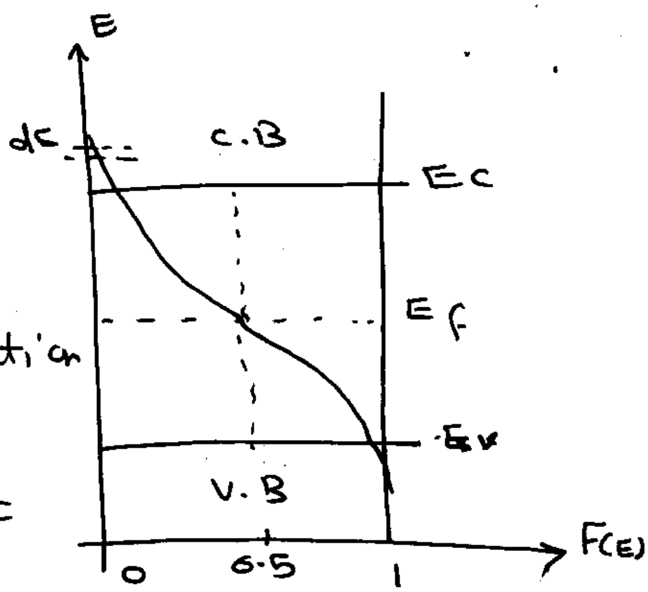
  $V_o = 0$

Q4/

P: hole density in V.B

$N_v(E)$ = density of energy levels in V.B.

To Drive the hole concentration



$$P = \int_{-\infty}^{E_V} N_V(E)\,[1 - F(E)]\,dE$$

$$= N_V\,[1 - F(E_V)]$$

where:

$F(E_V)$: Probability of energy level being filled by $\bar{e}$ in V.B.

$[1 - F(E_V)]$: Probability of energy level being empty of $\bar{e}$ in V.B

$$1 - F(E_V) = 1 - \frac{1}{1 + e^{\frac{E_V - E_f}{KT}}} = \frac{1}{1 + e^{\frac{E_f - E_V}{KT}}}$$

since $E_f > E_V$ $\therefore e^{\frac{E_f - E_V}{KT}} \gg 1$

$$\text{or } 1 - f(E_V) = e^{\frac{E_V - E_f}{KT}} = e^{-\frac{E_f - E_V}{KT}}$$

$$N_V = 2\left(\frac{2\pi m_p^* KT}{h^2}\right)^{3/2}$$

m_p^*: effective mass of holes

$m_p^* = m_n^* \Longrightarrow N_V = N_C$

$$\boxed{P = N_V\,e^{-\frac{E_f - E_V}{KT}}}$$

for both intrinsic & extrinsic

Q5/

$$R_H = \frac{1}{\rho}$$

$$\rho = nq = (7*10^{14})(1.6*10^{-19})$$

$$\rho = 1.12*10^{-4} \quad c/m^3$$

$$R_H = 0.892 \times 10^{4} \quad m^3/c$$

$$J = \sigma E$$

$$\frac{I}{A} = \rho \mu E$$

$$I = \rho \mu E A$$

$$E = \frac{v}{d} = \frac{1*10^{-3}}{10*10^{-3}} = 0.1 \ V/m$$

$$I = (1.12*10^{-4})(0.38)(0.1)(10^{-5})$$

$$I = 0.0425 \, nA$$

$$V_H = \frac{BI}{\rho w} = \frac{0.2*0.04*10^{-9}}{1.12*10^{-4}*10^{-2}} = 7 \mu V$$

Q6

ⓐ $\sigma = n_i q (\mu_e + \mu_h)$

$= (2.5*10^{13})(1.6*10^{-19})(3800+1800)$

$\sigma = 0.0224 \ (\Omega.cm)^{-1}$

$\sigma = 2.24 \ (\Omega.m)^{-1}$

$\rho = 0.446 \ (\Omega.m)$

ⓑ $n = \frac{\text{Avo. no.} * \text{density}}{\text{atomic weight}}$

$= \frac{6.02*10^{23} * 5.32}{72.6}$

$n = 4.4*10^{22} \ cm^{-3}$

$n = 4.4*10^{28} \ m^{-3}$

$N_D = n * 10^{-8}$

$= (4.4*10^{28}) \ 10^{-8}$

$= 4.4 * 10^{20}$

$\sigma_n = q N_D \mu_n$

$= (1.6*10^{-19})(4.4*10^{20})(3800*10^{-4})$

$= 26.75 \ (\Omega.m)^{-1}$

$\rho = 0.037 \ (\Omega.m)$