University of Technology

Department of Laser&Optoelectronics Engineering

Final Examination 2011-2012

Subject: Solid State Electronics
Division: Optoelectronics
Examiner: Lac . Makram .A. Fakhri

Class: 4th year
Time: 3 hours
Date: 13/06/2012

Answer only five questions

Q1:

A: Find miller indices for plane whch intercept (a_1 at $\bar{1}$) , (a_3 at 1) and (c at $\bar{1}$) .

B – Within acubic unit cell sketch the four of the following direction $[\bar{1}01]$, $[2\bar{1}1]$, $[0\bar{1}2]$, $[313]$, $[11\bar{1}]$ and $[2\bar{1}2]$.

C – Find the density for Simple Center Cubic .

Q2: Copper has an radius of 0.140 nm , an FCC crystal structure and an atomic weight of 36.5 g/mol . Compute its theoretical density and compare the answer with its measured density .

Q3 : Define five only :- Atom , Free electron , Work function , Fermi energy , Electron emission, Ionization , Quantum numbers , Absorption spectrum .

Q4 :

A- State that when the electron became free ?

B : What is the Braggs low .

C : Classified and explain the types of Bonds in materials .

Q5 :

A- Prove that $1/\lambda = R\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$.

B – What is the thermionic emission and drive its equation .

C - Find the density for Face Center Cubic .

Q6 :

A – Determined of FCC Unit Cell Volume .

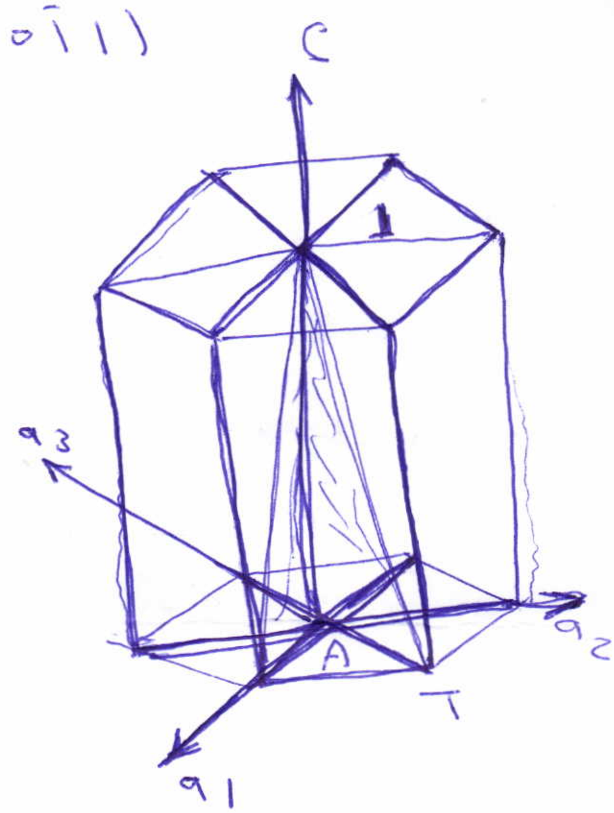
B – Drive the Bohar radius .

C – What is the Schottky theory and its current .

Sol Q1 A/

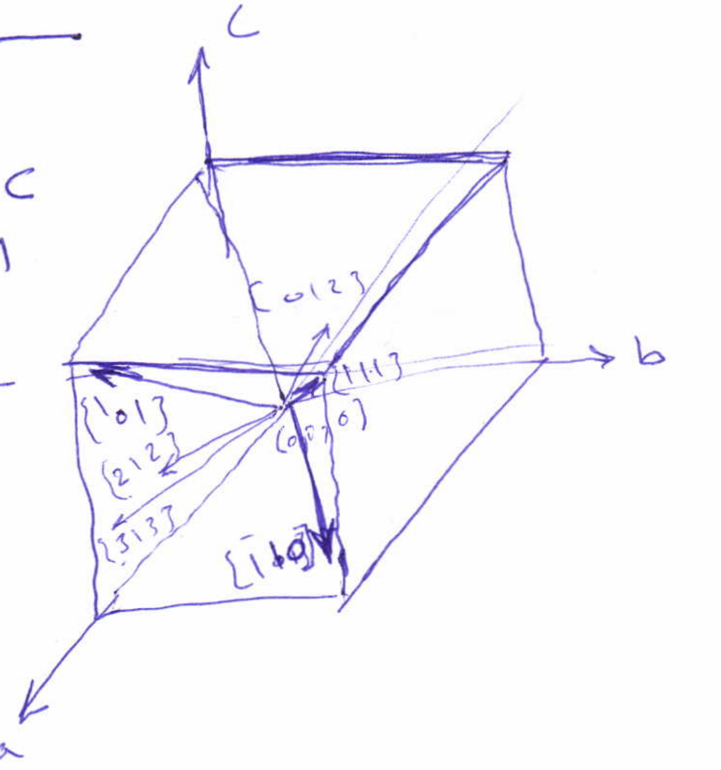
coordinate	a_1	a_2	a_3	c
intersection	1	∞	$\bar{1}$	1
reciprocal	1	0	$\bar{1}$	1

∴ miller indices $(10\bar{1}1)$



Sol/
Q1 B

coordinate	a	b	c
intersection	1	∞	1
reciprocal	1	0	1
Miller indesc	1	0	1



coor	a	b	c
inter.	$\frac{1}{2}$	1	1
recipro	2	1	1

Mill, ind. {2 1 1}

Coor	a	b	c.
inter	0	1	$\frac{1}{2}$
recip	0.	1	2

Mill ind {0 1 2}

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coor	a	b	c
inter	$\frac{1}{3}$	1	$\frac{1}{3}$
recip	3	1	3

Miller ind. {3 1 3}

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coor	a	b	c
inter	1	1	1
recip	1	1	1

Mill ind. {1 1 1}

Q1 c/

$a = 2r$

$V_s = \frac{4}{3} \pi r^3$

$V_{unit\ cell} = (2r)^3$

$\%\ \text{Packing factor} = \frac{V_s}{V_c} = \frac{\frac{4}{3}\pi r^3}{(2r)^3}$

$= \frac{4\pi}{6r} = 0.52 = 52\%$

Q2/ $\rho = \frac{nA_{Cu}}{V_C N_A} = \frac{nA_{Cu}}{(16R^3\sqrt{2})N_A}$

$= \frac{(4\ \text{atoms/unit cell})(36.5\ \text{g/mol})}{[16\sqrt{2}(140\times10^{-8}\ \text{cm})^3/\text{unit cell}](6.023\times10^{23}\ \text{atoms/mol})}$

$= 5.8\ \text{g/cm}^3$

Q3/ Atom :- is a basic unit of matter that consist of a dense, central nucleus surrounded by a cloud of negatively charged electrons

free ellectron: when the electron would behave

Like an ideal gas each one would

contribut 3/2 KT to the total

work function:- is the minimum energy

(usually measured in electron volts)

needed to remove an electron from

a solid to point immediately

outside the solid surface.

fermi energy :- ~~The~~ fill the obtained energy

Level with conduction electrons.

:. the energy of the highest filled.

Level at T=0.

Electron Emission :- an electron exists in a higher

Level (Large value of n)

when he get an energy.

Ionization: the electron extract from

the atom after providing by energy.

enough to broken the binding energy with

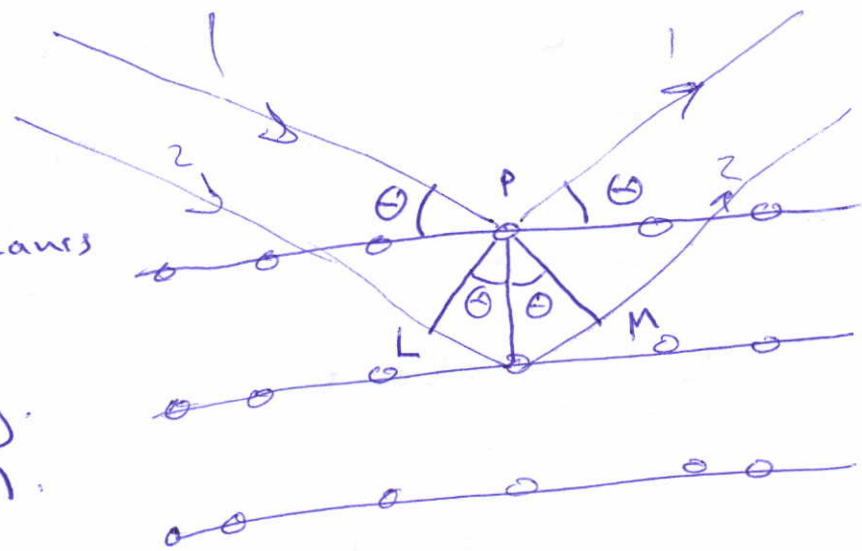
its atom

Quantom Number:- each electron has ~~a~~ a set of fournumber called quanto numbers that specify it completely! no two electrons in the same atom can have the same four.

absorption spectrum:- accurs Light through dilute a cold gas ~~and absor~~ and atoms in the gas absorb at ~~chara~~ characterists frequencies. since the reemitted Light in unLikely to be emitted in the same diraction as the absorbed photon.

Q4 A/ The electron be came free when the energy of photon more than the work function: the energy state on, on motion energy $\phi = hf_0$

Q4 B/



Consider a set of parallel atomic planes with interplaner spacing d and having Miller indices (hkL). The path difference between rays 1 and 2 is therefore, given by (LQ + QM). Since LQ = QM = d sin θ

∴ path differance = 2d sin θ

Qu c/ ① Metallic

- relative weak bond (1-2)ev
- complicated mixture
- nodirection to bonds.
- examples, Fe, Ni, Cr

② ionic.

- strong bonds.
- Coulomb attraction of charged.
- 〃 and quantum. repulsions.
- nodirection to bonds.
- examples NaCl, MgF, Zns.

③ Covalent

- strond
- sharing of electrons.
- directional
- examples Si, Ge, GAAs.

④ Vander Waals,

- weak bonds.
- often neglected
- from distortion of electron
- examples gasses, organics.

Q5A/

$$h\nu = E_f - E_i$$

$$= \frac{-Z^2 e^4 m}{8 h^2 \epsilon_0^2 n_f^2} - \frac{-Z^2 e^4 m}{8 h^2 \epsilon_0^2 n_i^2}$$

$$= \frac{-Z^2 e^4 m}{8 h^2 \epsilon_0^2} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{hc}{\lambda} = \frac{-Z^2 e^4 m}{8 h^2 \epsilon_0^2} \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

$$\frac{1}{\lambda} = \frac{-Z^2 e^4 m}{8 h^3 c \epsilon_0^2} \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

$\because$ $$\frac{Z^2 e^4 m}{8 h^3 c \epsilon_0^2} = R = 1.1 \times 10^7 \, m^{-1}$$

$\therefore$ $$\frac{1}{\lambda} = R \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right).$$

Q5 B

it is the process where electrons are emitted across a barrier.

$$J_x = \int q\, n(E)\, v_x(E)\, dE$$

$$n(E)\, d(E) = f(E)\, g_c(E)\, dE$$

$$= \frac{8\pi\sqrt{2}}{h^3} m \frac{\sqrt{E}\, dE}{1+\exp\left(\frac{E-E_f}{kT}\right)}$$

$$E = \frac{mv^2}{2} \rightarrow \sqrt{E}\, dE = \frac{m^{3/2}}{\sqrt{2}} v^2\, dv$$

$$n(E)\, dE = \frac{8\pi m^3}{h^3} \frac{v^2\, dv}{1+\exp\left(\frac{E-E_f}{kT}\right)}$$

$$= \frac{2m^3}{h^3} e^{-(E-E_f)/kT} 4\pi v^2 dv.$$

$$E = \frac{mv^2}{2} = \frac{m}{2}(v_x^2 + v_y^2 + v_z^2)$$

$$E_{min} = q\phi_B + E_f = \frac{mv_x^2}{2}$$

$$J_x = \frac{2qm^3}{h^3} e^{-\frac{q\phi_B}{kT}} \frac{kT}{m} \sqrt{\frac{2\pi kT}{m}} \sqrt{\frac{2\pi kT}{m}}$$

$$= A_R T^2 e^{-\frac{q\phi_B}{kT}}$$

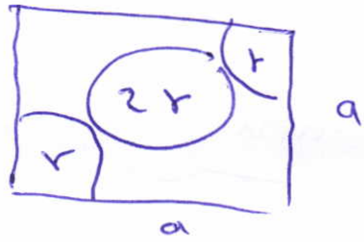
$$A_R = \frac{4\pi q m k^2}{h^3}, \quad v_R = \sqrt{\frac{kT}{2\pi m}} \Rightarrow J_n = q v_R N_c \exp\left(-\frac{\phi_B}{V_t}\right.$$

Q5c/

$a^2 + a^2 = (4r)^2$

$2a^2 = (4r)^2$

$\therefore a = \frac{4r}{\sqrt{2}}$



Packing factor $= \frac{\text{sphere volume}}{\text{unit cell volume}}$

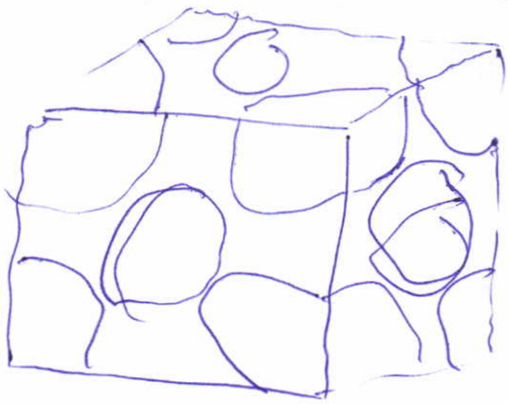
$= \frac{4 * \frac{4}{3} r^3 \pi}{\left(\frac{4r}{\sqrt{2}}\right)^3}$

$= 0.74 = 74\%$

Q6A/ $a^2 + a^2 = (4R)^2$

$a = 2R\sqrt{2}$

FCC UCV $= V_c = a^2 = (2R\sqrt{2})^3$



$= 16R^3\sqrt{2}$

26 B/

$$h\nu = E_i - E_f$$

$$K\frac{q_1 q_2}{r^2} = \frac{m v^2}{r} \Rightarrow K\frac{q_1 q_2}{r} = m v^2$$

But/ $$v^2 = \frac{n^2 h^2}{4 m^2 \pi^2}$$

$$\therefore \frac{n^2 h^2}{4 m^2 h \pi^2} = \frac{q_1 q_2}{4 \pi m \epsilon_0 r}$$

$$q_1 = Ze, \; q_2 = e \Rightarrow \frac{n^2 h^2}{\pi m r} = \frac{Ze^2}{\epsilon_0}$$

$$\therefore r = \frac{n^2 h^2 \epsilon_0}{Z e^2 m \pi}$$ = Bohr radius.

$$r = r_0 n^2 \; , r_0 = 0.53 \text{Å}$$

Q6 C/ A closer Look at a current_voltage characteristic of a real diode show that it doesn't really saturate.

$$J = A(1-r)T^2 \exp[-(\phi - f^{\frac{1}{2}})/kT]$$