BITS PILANI DUBAI CAMPUS
SECOND SEMESTER 2011-12

COMPREHENSIV EXAMINATION (CLOSED BOOK)

Course No: EA C416 **Duration: 3HRS** **Weightage: 40%**

Course Name: Introduction to Nanoscience **Max Marks:40** **Date: 7.6.2012**

Note: All the questions are compulsory.

Given: mass of electron= 9.1×10^{-31} Kg, Planck's constant h = 6.62×10^{-34} J.s, Boltzman constant k= 1.38×10^{-23} J/K

Q1(A) The spacing between successive {100} planes in NaCl nanocrysral is $2.820A^0$. Suppose that a given X-ray, when shown upon the surface, is found to give rise to first order Braggs reflection at a grazing angle of $8^0\ 35'$. If the same X-ray bean is being used, calculate the angle at which the second order Bragg reflection would occur. (2)

(B) Fe forms a bcc nanocrystal with a = $2.86A^0$. The mass of Fe atom is 9.27×10^{-26} Kg. Calculate the mass density of Fe crystal. (2)

Q2(A). Consider the lattice vibration of a nanocrystal of a diatomic linear chain. Calculate the group velocity at the zone boundary of the optic branch as well as acoustic branch. (2)

(B) Show that the wavelength associated with an electron having energy = E_F is given by

$\lambda_F = (8\pi V/3N)^{1/3}$. If this wavelength is $4.6A^0$, find the Fermi temperature. (2)

Q3. For a superconducting specimen of Ga the critical fields are respectively 0.176 and 0.528T for 14 K and 13 K. Calculate the transition temperature and critical field at 4.2K? (4)

Q4(A). The wave function of a particle is given by $\psi(x) = Ne^{-\alpha x^2}$; $-\infty < x < +\infty$

Where N and α are constants. Calculate the probability of finding the particle in the region $0< x < \infty$.(2)

(B).Consider an electron of energy 342eV confined in a one dimensional box of length 10^{-10} meter. Calculate (a) the quantum number n of this state of the system (b) the energy required to take the system to its next excited state. (2)

Q5(A). Consider a beam of electrons of energies (i) 0.03eV and (ii) 0.045eV incident on a one dimensional potential barrier of height 0.035eV. Calculate the percentage of electrons transmitted in each case. (2)

(B).A beam of electrons of energy 2.5eV falls on one dimensional rectangular potential barrier of heights 5eV and width $1A^0$. Calculate the percentage of electrons transmitted. (2)

Q6. Describe in detail the operation of molecular beam epitaxy method for fabrication of nanostructure. (4)

Q7. Describe in detail the operation of scanning tunneling microscope, used for the characterization of nanomaterial. (4)

Q8.(a)) Describe important steps involved in fabrication of carbon nano tube using laser evaporation technique. (2)

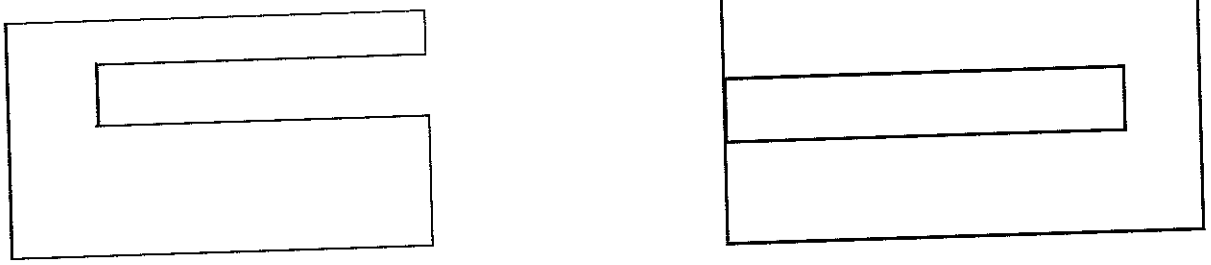
(b) Describe in detail the application of carbon nano tube for (i) Field emission and shielding (ii) as a chemical sensor (2)

Q9.(A) What are the different components of a Nanobiosensor?

(B) Mention at least three important application of Nanobiosensor?

(C) How Nanobiosensor is used for cancer monitoring? (1+1+2=4)

Q10. It is desired to fabricate a micro cantilever on a silicon substrate using silicon dioxide as a sacrificial layer. The top and side views of the cantilever are shown in Figure 1.



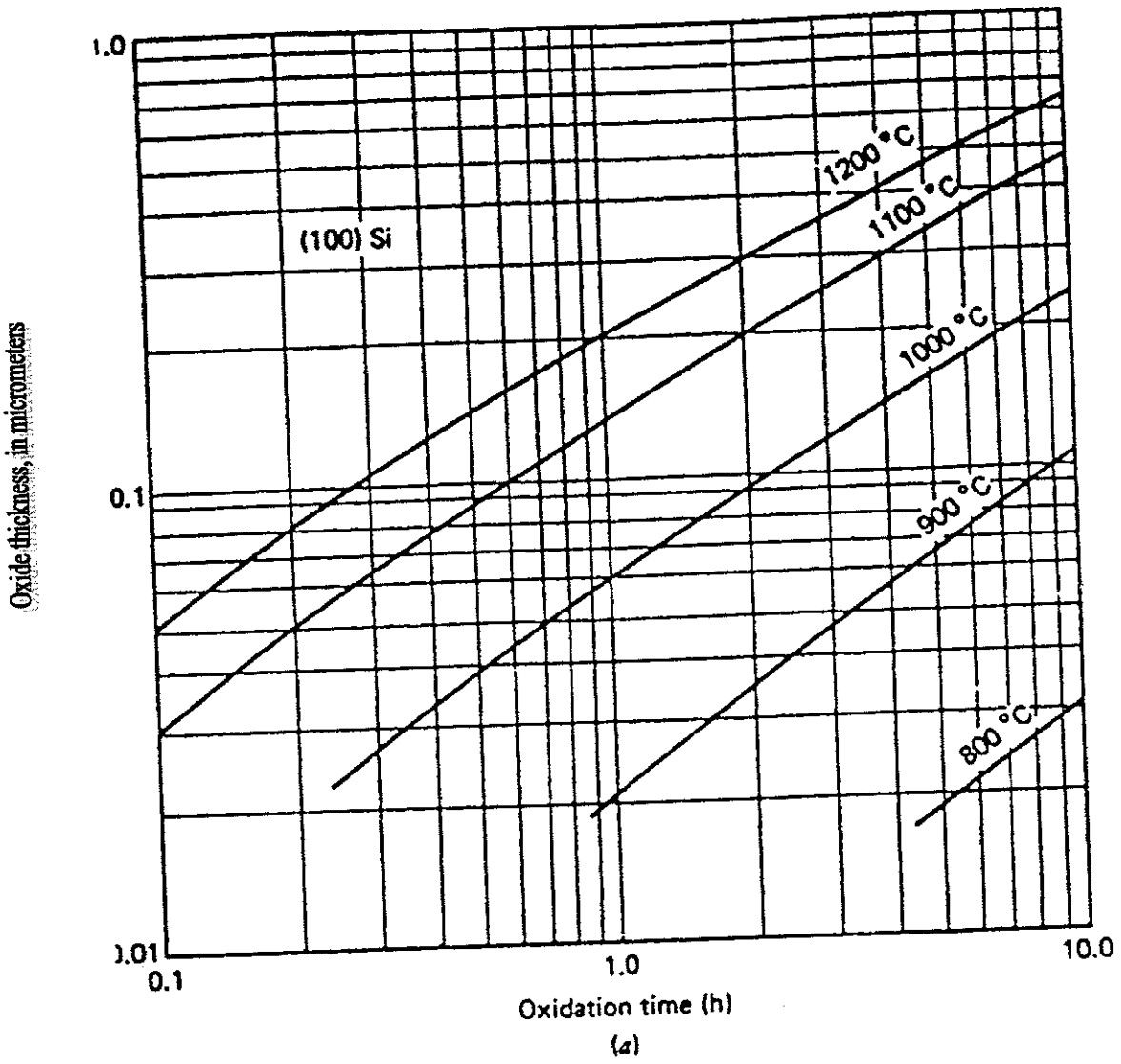
(a) (b)

Figure 1: (a) Side view (b) Top view

Describe the micro fabrication process involved and the role of the sacrificial layer.

(2 marks)

Q11. Figure shows the oxide growth chart on (100) silicon using dry thermal oxidation. Oxide was first grown on bare (100) silicon for 12 minutes at 1200°C followed by 48 minutes at 1000 °C. What is the overall oxide thickness obtained? (2 marks)



(a)

BITS PILANI DUBAI CAMPUS
SECOND SEMESTER 2011-12

Test-2(Open Book)

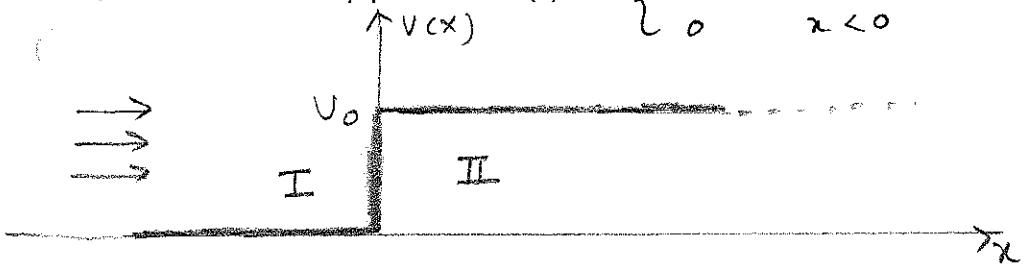
Course No: EA C416 **Duration: 50 Mints** **Weightage: 20%**

Course Name: Introduction to Nanoscience **Max Marks:20** **Date: 30.4.2012**

Note: All the questions are compulsory.

Q1. Consider a particle of mass m held in a one dimensional potential V(x). Suppose in some region V(x) is constant, V(x)= V. For this region, find the stationary states(wave function) of the particle when (a) E > V, (b) E<V, and (c) E=V, where E is the energy of the particle. Answer can be given in terms of unknown coefficients. (3)

Q2. Consider the step potential $V(x) = \begin{cases} V_0 & x > 0 \\ 0 & x < 0 \end{cases}$



Consider a current of particles of energy $E > V_0$ moving from $x = -\infty$ to the right. Write stationary state solution for each of these regions. Compute the probability current in the regions I and II. All the results can be given in terms of unknown coefficients. Given the probability current (J(x)) for any wave function ψ is

$$J(x) = \frac{\hbar}{2mi}\left[\psi^*(x)\frac{\partial\psi(x)}{\partial x} - \psi(x)\frac{\partial\psi^*(x)}{\partial x}\right] \quad (4)$$

Q3. The wave function of a particle in a one dimensional box is, represented by $\psi(x) = \sqrt{\frac{2}{a}}\sin\frac{n\pi x}{a}$ where a is the dimension of a box. What are the expectation values of the position and the momentum of the particle. (4)

Q4. Describe the important steps involved in lithography technique for fabrication of nanostructure. (3)

Q5. (a) In the electron probe microscopy what happens when an electron beam interacts with the nano material. Mention all the possible processes involved. (2)

(b) Describe in detail the operation of scanning electron microscope, used for the characterization of nanomaterial. (4)

BITS PILANI DUBAI CAMPUS
SECOND SEMESTER 2011-12

Test-1(Closed Book)

Course No: EA C416 **Duration: 50 Mints** **Weightage: 20%**

Course Name: Introduction to Nanoscience **Max Marks:20** **Date: 12.3.2012**

Note: All the questions are compulsory. Given, mass of the electron= 9.1×10^{-31} Kg,

Planck's constant $h=6.62 \times 10^{-34}$J.s, Boltzmann constant $k=1.38 \times 10^{-23}$ J/K

Q 1. Find the Miller indices of a plane that makes intercepts in the ratio 2:3:4 on the coordinate axes of an orthorhombic crystal with a:b:c = 4:3:2. (2)

Q 2. The lattice constant of Al is $4.05A^0$. s

(a) How many unit cells are there in an Al foil 0.1mm thick and side 20cm square?

(b) If the foil weighs 10g, how many atoms are present . Given Molecular wt=26.9, Avogadro Number = 6.02×10^{23} (2)

Q.3. Consider a set of crystal planes of a nanomaterial which are separated by $1.95A^0$. If we use x-rays of wavelength $1.542A^0$, find all possible Bragg angles for reflection from these planes. (2)

Q 4.Derive the dispersion relation for vibrations of one dimensional monoatomic chain in a nanocrystal. (4)

Q 5.In the case of vibrations of a monoatomic linear chain, for small ka, the phase velocity is 5000 m/s. Calculate the group velocity at $k=\pi / 2a$ where a is the lattice spacing. (2)

Q 6.What is the Fermi energy (in eV) for the free electron gas inside a nanomaterial, if the density of conduction electrons is 5.8×10^{28} m^{-3} . What is the Fermi speed? (4)

Q 7. Calculate the intrinsic concentration of charge carriers in a nanomaterial at 300K. Given $E_g=0.67$eV, $m_e^* =0.12m$, $m_h^* = 0.28m$ where m is the rest mass of the electron. (4)

Good luck