INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Semiconductor Devices
EC21107

Total: 60
Time duration: 2 hrs

1A. The lattice constant of a face-centered-cubic structure is 4.75 Å. Calculate a) Atoms per unit cell b) Nearest neighbor distance c) volume of each sphere d) packing fraction

1B. What is epitaxial growth? Define heteroepitaxy. **(7+3)**

2A. The width of the infinite potential well is 8 Å. Calculate the first three energy levels in terms of electron volts for an electron.

2B. What do you mean by quantum tunneling? Describe tunneling through a potential barrier of finite height. Define the wave function for a "Particle in a box".

2C. Calculate the radius of the electron orbit around the donor, assuming a ground state hydrogen-like orbit in Si. Compare with the Si lattice constant. Given $m_n^* = 0.26\ m_0$ for Si. **(3+4+3)**

3A. To calculate the intrinsic carrier concentration in gallium arsenide at T=300K and a T=550K. The values of N_c and N_v at 300K for GaAs are 4.7×10^{17} cm^{-3} and 7.0×10^{18} cm^{-3}, respectively. Assume the bandgap energy of GaAs 1.42 eV and does not vary with temperature over this range.

3B. Calculate the position of the Fermi energy level in n-type silicon at T=300K with respect to the intrinsic Fermi energy level. The doing concentrations are $N_d=4 \times 10^{17}$ cm^{-3} and $N_a=6 \times 10^{16}$ cm^{-3}. **(6+4)**

4A. Consider p-type silicon at T= 300K doped at $N_a=4.5 \times 10^{16}$ cm^{-3}. Given that $\tau_{n0}= 6 \times 10^{-7}$ s, $D_n= 30$ cm^2/s, and assume that 10^{14} electron-hole pairs per cm^3 have been created at t= 0. Find the minority carrier diffusion length and calculate the steady-state excess carrier concentration as a function of x.

4B. A 0.46 µm thick sample of GaAs is illuminated with monochromatic light of hν= 2eV. The absorption coefficient α is 5×10^4 cm^{-1}. The power incident on the sample is 10mW. What is the total energy absorbed by the sample per second (J/s)? **(6+4)**

5. Boron is implanted into an n-type Si sample ($N_d= 10^{16}$ cm^{-3}), forming an abrupt junction of square cross section, with area= 2×10^{-3} cm^2. Assume the acceptor concentration in the p-type region is 4×10^{18} cm^{-3}. Calculate built in potential, penetration of transition region into n and p materials, charge in the depletion region of n side and the electric field in the n side. **10**

6. **A.** Mobility that is due to lattice scattering increases as the temperature increases---- true or false?

B. The conductivity and resistivity of an extrinsic semiconductor are a function primarily of the minority carrier parameters--- true or false?

C. What is Einstein relation?

D. Electron mobility is directly proportional to the mean free time---- true or false?

E. What is the unit of Hall coefficient?

F. Light hole band has small curvature---- true or false?

G. AlGaAs is a direct or indirect semiconductor?

H. Reverse bias increases junction capacitance increases---- true or false?

I. For Hyperabrupt junction what is the value of m in $N=Bx^m$?

J. Write down the continuity equation. **(1x10)**

Some important values

Boltzmann's constant (k)	1.38×10^{-23} J/K
Electronic charge (q)	1.60×10^{-19} C
Electronic rest mass (m_0)	9.11×10^{-31} Kg
Permittivity of free space (ε_0)	8.85×10^{-14} K/cm
Relative permittivity of silicon (ε_r)	11.8
Plank's constant (h)	6.63×10^{-34} J-s
Room temperature value of KT	0.0259 eV
Intrinsic carrier concentration in silicon (n_i) at 300K	1.5×10^{10} cm^{-3}