INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date ... FN / AN Time 2 / 3 Hrs Full Marks 60 No. of Students 100

Autumn / Spring Semester, ... Deptt. E&ECE Sub. No. EC 21107

... Yr. B.Tech. (H) / B.Arch. (H) / M.Sc. Sub. Name Semiconductor Devices

Instruction ...

1. How many atoms are found inside a unit cell of a simple cubic, body centered cubic and face centered cubic crystal? How far apart in terms of lattice constant 'a' are nearest-neighbor atoms in each case, measured from center to center.

3+5

2. Calculate the densities of Ge and InP from the lattice constant, atomic weights, and Avogadro's niumber. Compare the results with the densities given below. Atomic weight of Ge = 72.6, In = 114.8, P = 31.

5+3

3. The de Broglie wavelength of a particle describes the wave-particle duality for small particles such as electrons. What is the de Broglie wavelength (in Å) of an electron at 10keV, which is typical of electron microscopes? Comparing this to visible light, comment on the advantages of electron microscopes.

5+5

4.

   a. A Si bar 0.1 cm long and 100 μm^2 in cross sectional area is doped with 10^{17} cm^{-3} antimony. Find the current at 300 K with 10 V applied.
   b. How long does it take an average electron to drift 1 μm in pure Si at an electric field of 100V/cm? Repeat for 10^5 V/cm.

8+8

5. Given m_n^* and m_p^* for GaAs are $0.067m_o$ and $0.48m_o$ respectively. Calculate the effective densities of states N_c and N_v for GaAs at 300 K (assume that m_n^* and m_p^* dose not vary with temperature). Calculate the intrinsic carrier concentration.

5+5

6. For Si with $(N_d - N_a) = 4 \times 10^{15}$ cm^{-3}, find E_f, hall coefficient, carrier concentration and majority carrier mobility.

8

	E_g (eV)	μ_n (cm²/V-s)	μ_p (cm²/V-s)	Transition	Lattice	a (Å)	ϵ_r	Density (g/cm³)	Melting point (°C)
Si	1.11	1350	480	*i*	*D*	5.43	11.8	2.33	1415
Ge	0.67	3900	1900	*i*	*D*	5.65	16	5.32	936
SiC(α)	2.86	500		*i*	*W*	3.08	10.2	3.21	2830
AlP	2.45	80		*i*	*Z*	5.46	9.8	2.40	2000
AlAs	2.16	180		*i*	*Z*	5.66	10.9	3.60	1740
AlSb	1.6	200	300	*i*	*Z*	6.14	11	4.26	1080
GaP	2.26	300	150	*i*	*Z*	5.45	11.1	4.13	1467
GaAs	1.43	8500	400	*d*	*Z*	5.65	13.2	5.31	1238
GaSb	0.7	5000	1000	*d*	*Z*	6.09	15.7	5.61	712
InP	1.35	4000	100	*d*	*Z*	5.87	12.4	4.79	1070
InAs	0.36	22600	200	*d*	*Z*	6.06	14.6	5.67	943
InSb	0.18	10^5	1700	*d*	*Z*	6.48	17.7	5.78	525
ZnS	3.6	110		*d*	*Z, W*	5.409	8.9	4.09	1650*
ZnSe	2.7	600		*d*	*Z*	5.671	9.2	5.65	1100*
ZnTe	2.25		100	*d*	*Z*	6.101	10.4	5.51	1238*
CdS	2.42	250	15	*d*	*W, Z*	4.137	8.9	4.82	1475
CdSe	1.73	650		*d*	*W*	4.30	10.2	5.81	1258
CdTe	1.58	1050	100	*d*	*Z*	6.482	10.2	6.20	1098
PbS	0.37	575	200	*i*	*H*	5.936	161	7.6	1119
PbSe	0.27	1000	1000	*i*	*H*	6.147	280	8.73	1081
PbTe	0.29	1600	700	*i*	*H*	6.452	360	8.16	925

All values at 300 K. Mobility is for pure material * vaporizes

Avogadro's number	$N_A = 6.02 \times 10^{23}$ molecules/mole
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ J/K
	$= 8.62 \times 10^{-5}$ eV/K
Electronic charge (magnitude)	$q = 1.60 \times 10^{-19}$ C
Electronic rest mass	$m_0 = 9.11 \times 10^{-31}$ kg
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-14}$ F/cm
	$= 8.85 \times 10^{-12}$ F/m
Planck's constant	$h = 6.63 \times 10^{-34}$ J-s
	$= 4.14 \times 10^{-15}$ eV-s
Room temperature value of kT	$kT = 0.0259$ eV
Speed of light	$c = 2.998 \times 10^{10}$ cm/s

	Prefixes:	
1 Å (angstrom) = 10^{-8} cm	milli-, m-	$= 10^{-3}$
1 μm (micron) = 10^{-4} cm	micro-, μ-	$= 10^{-6}$
1 nm = 10Å = 10^{-7} cm	nano-, n-	$= 10^{-9}$
2.54 cm = 1 in.	pico-, p-	$= 10^{-12}$
1 eV = 1.6×10^{-19} J	kilo-, k-	$= 10^{3}$
	mega-, M-	$= 10^{6}$
	giga-, G-	$= 10^{9}$

A wavelength λ of 1 μm corresponds to a photon energy of 1.24 eV.