ECE6453 HW 1 Solution

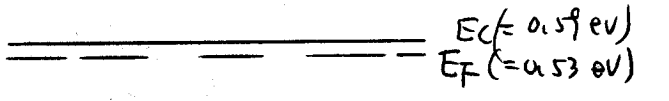
1. (a) $E_i = \frac{E_c + E_v}{2} + \frac{3}{4} kT \ln(m_p/m_n)$, Let the zero potential be E_v

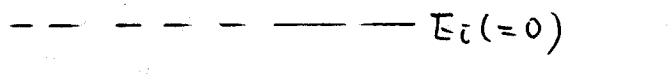
<i> 77k, $E_g = 1.16$ (eV)
$E_i = 0.583$ (eV)

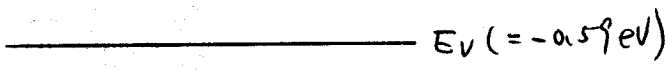
<ii> 300k, $E_g = 1.12$ (ev)
$E_i \approx 0.569$ (eV)

<iii> 373k, $E_g = 1.09$ (eV)
$E_i = 0.557$ (eV)

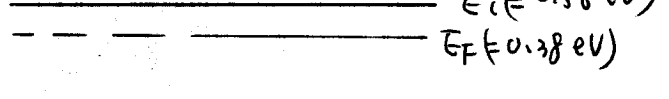
(b) (i) @ 77k

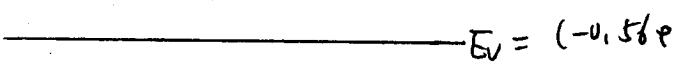




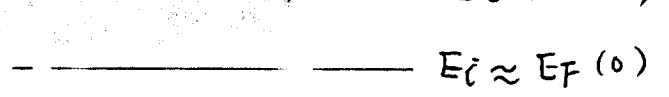


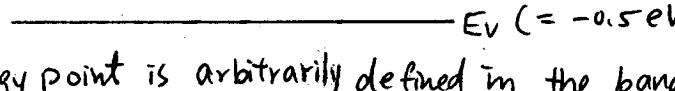
(ii) @ 300k





(iii) @ 600k





Note: ① The zero energy point is arbitrarily defined in the band diagram.

② High temperature drives semiconductor into "intrinsic region"

③ E_g is a fxn of temperature!

2. The reciprocal lattice vectors are:

$$\hat{a}_1^* = \frac{4\pi}{\sqrt{3}a}\left(-\frac{1}{2}\hat{y} + \frac{\sqrt{3}}{2}\hat{x}\right)$$

$$\hat{a}_2^* = \frac{4\pi}{\sqrt{3}a}\hat{y}, \quad \hat{a}_3^* = \frac{2\pi}{c}\hat{z}.$$

3. (a) $x = 0.47$, $In_{0.53}Ga_{0.47}As$ lattice matched to InP, using Vegard's law.

(b) The possible compositions are: (again, Vegard's law rules)

$$(In_{0.53}Ga_{0.47}As)_y (InP)_{1-y}$$

$$= In_{1-0.47y}Ga_{0.47y}As_y P_{1-y} = In_{1-x}Ga_x As_y P_{1-y}$$

$$\Rightarrow \boxed{x = 0.47y} \text{ for Quaternary material.}$$

(c) $Eg(In_{1-x}Ga_xAs) = 0.36 + 1.064x, \; c = 0$

$Eg(In_{1-x}Ga_xP) = 1.351 + 0.643x, \; c = 0.79$

$Eg(GaAs_yP_{1-y}) = 1.424 + 1.150(1-y), \; c = 0.18$

$Eg(InAs_yP_{1-y}) = 0.360 + 0.891(1-y), \; c = 0.101$

$$Eg(Ga_xIn_{1-x}As_yP_{1-y}) = x\,Eg(GaAs_yP_{1-y}) + (1-x)\,Eg(InAs_yP_{1-y}) - \Delta$$

Note: this is just an exercise for you to calculate Eg for Q-material. The real value of Eg should be determined experimentally.

$$\Delta = x(1-x)[(1-y)C_{GaInP} + y(C_{GaInAs}) + y(1-y)[xC_{GaAsP} + (1-x)C_{InAsP}]$$

→ You may simplify the equation ...

$$\boxed{Eg \cong (1.35(1-y) + 0.737y + 0.13y^2]\ (eV)} \; *$$