Physics 8510

Problem Set 9

1) Follow the tight binding (TB) method for an s-band (as done in class for the fcc) to find the band structure for a bcc lattice. Assume only the nearest neighbors interact.

If $\gamma = 1.0$ eV and a = 4 Å, find the electron effective mass, near the bottom and the top of the band. At what symmetry point the bottom of the band occurs? Derive the TB expressions along the principal symmetry directions. (Similar to Problem I in A&M which we did in class)

2) If the s-band model for an fcc lattice discussed in the class, has a nonzero second nearest neighbor interaction (γ_2 =0.2 eV), what is the electron effective mass at the bottom of the band? (γ_1 =1.0 eV, and a = 4 Å)

3) Using the Feynman model,

(a) Show that the energy in the band is $E = E_0 + 2A\cos(ka)$ and from this show the effective mass at the bottom of the band is inversely proportional to the width of the band.

(b) Find the group velocity of the electron at $K = n\pi / a$. Starting from the Kronig- Penny model E vs K relation and showing the calculation.

4) In general, the reciprocal of the effective mass is a tensor whose components are given by the mixed derivatives. a) Write the modified generalized classical equation of motion (in 3-D). (i.e. modify m dv/dt = F to include the effective mass tensor for 3 D for an electron)

5) If the reciprocal mass tensor for Bi close to the bottom of the conduction band is of the form

$$\begin{pmatrix} a_{xx} & 0 & 0 \\ 0 & a_{yy} & a_{yz} \\ 0 & a_{yz} & a_{zz} \end{pmatrix}$$

(a) Find the components of the effective mass tensor.

(b) Find the function $E(k_x, k_y, k_z)$.

(c) Write an expression for the constant energy surfaces. What will be the shape?

6) Assume that the energy vs K for electrons in the conduction band of a newly discovered tetravalent n-type semiconductor is described by $E = ak^2 + c$. (c is a constant). The cyclotron resonance for electrons in a field B = 0.1 T occurs at an angular frequency $\omega_c = 1.8 \times 10^{11}\ s^{-1}$.

(a) Find the value of a.

(b) Assume that the semiconductor is doped with pentavalent donors. Estimate the number of donors per m^3, given that the Hall coefficient at room temperature is $R_H = 6.25 \times 10^{-6} m^3 coul^{-1}$ and the relative dielectric constant is $\varepsilon_r = 15$. (Reminder: For n type semiconductor, n >> p)