Special Doctoral Program for Green Energy Conversion Science and Technology

Entrance Examination for 2012 (Solid State Physics)

Question 1

Consider a line of diatoms ABAB…AB, with an A-B bond length of $a/2$. The form factors are f_A, f_B for atoms A, B, respectively. The incident beam of x-rays is perpendicular to the line of atoms.

1. Show that the interference condition is $n\lambda = a\cos\theta$, where λ is the wavelength of the incident x-ray and θ is the angle between the diffracted beam and the line of atoms.
2. Find the intensities of the diffracted beam for (a) n odd, and (b) n even.
3. Explain what happens if $f_A = f_B$

Question 2

Strontium titanate ($SrTiO_3$, ST) has the cubic perovskite structure,
a = 0.391 nm with atomic coordinates:
Sr: 1/2 1/2 1/2
Ti: 0 0 0
O: 1/2 0 0; 0 1/2 0; 0 0 1/2

1. Draw a projection of the structure on the z planes (z=0 and 1/2).
2. What is the coordination environment of Sr, Ti and O?
3. Calculate Sr-O and Ti-O bond lengths.
4. Is the structure close packed? If so, describe the structure in terms of mutual atomic positions.
5. What compositional modifications may be made to ST in an attempt to induce ferroelectricity and ionic conductivity?

Question 3

Space charge layer is formed at the junction interface between p-type and n-type semiconductors. Explain “space charge layer”, using following five words; “diffusion”, “ionized donor”, “ionized acceptor”, “electric field”, and “depletion layer”.

Question 4

1. The effect of the spin-orbit interaction is to split the degenerate states into two discrete energy levels. Show the amount of energy splitting by the spin-orbit interaction in a one-electron atom and a two-electron atom, respectively.
2. The absorption spectrum of calcium, atomic number 20, contains a normal multiplet of six lines at 0, 14, 36, 106, 120, and 158 cm^{-1} above the lowest frequency line of this multiplet. From the analysis of these data in the L-S coupling approximation, what information can be obtained about the quantum number s of the states involved in the transitions?