中原大學 96 學年度碩士班入學考試

96/03/25 16:00~17:30 電子工程學系固態組

誠實是我們珍視的美德，
我們喜愛「拒絕作弊，堅守正直」的你！

科目： 半導體基礎概論

（共　頁第　頁）

□可使用計算機，惟僅限不具可程式及多重記憶者　□不可使用計算機

1. **Figure 1 shows the X-ray diffraction θ-2θ scan pattern of a semiconductor wafer with a diamond crystal structure. The wavelength of the x-ray is 1.54Å.**

   (1) Please calculate the cubic lattice constant. (5%)

   (2) Calculate the atomic density (number of atoms per cm^3) of this semiconductor. (5%)

2. **Consider three materials as following :**

   A: n-type GaAs (E_g=1.42eV) with donor concentration of $5x10^{15}$ cm^{-3} and ionization energy of 0.006eV.

   B: p-type GaAs (E_g=1.42eV) with acceptor concentration of $1x10^{18}cm^{-3}$ and ionization energy of 0.03eV.

   C: n-type AlGaAs (E_g=1.79eV) with donor concentration of $1x10^{18}$ cm^{-3}.

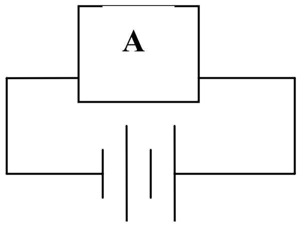
   (Note: The intrinsic carrier concentration of GaAs is $1.8x10^6$ cm^{-3}. The effective density of states in conduction band N_C of GaAs is $4.7x10^{17}cm^{-3}$. kT(at 300K)=0.0259eV)

   Please answer the following questions:

(1) Please sketch the energy diagram (E vs. x), indicating the position of conduction band E_C, Fermi level E_f and the donor level E_d respect to valence band E_V for material A at 300K. (5%)

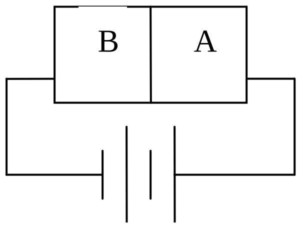
(2) Please sketch the energy diagram (E vs. x), indicating the position of E_C, E_f and the accepter level E_a respect to E_V for material B at 300K. (5%)

(3) Sketch the energy diagram (E vs. x), indicating the position of E_C, E_f respect to E_V for material A biased at 5V as figure 2 at 300K. (5%)



V=5V **Figure 2**

(4) Repeat (3) for material A-B junction at V=0 and V=5V (see figure 3.) (5%)

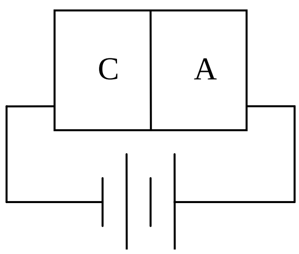


V=0V, or 5V

Figure 3

(5). Explain why semiconductor devices can be only operated in certain temperature range, for example 200K-400K. (5%)

(6). Sketch the energy diagram (E vs. x), indicating the position of E_C, E_f respect to E_V for heterostructural A-C junction (see figure 4) biased at V=0 and V=5V, assuming the conduction band difference $\triangle E_C$=0.2eV. (10%)



V=0V, or 5V

Figure 4

(7) According to the energy diagram in (6), describe the advantages of the heterojuction in terms of low temperature operation. (5%)

3. Based on the bandgap difference, please compare the forward and reversed biased I-V characteristics for Si (E_g=1.1eV) and Ge (E_g=0.66eV) p-n diodes, and explain your answer. Assume the doping concentration, junction area and diffusion coefficients for both materials are the same. (5%)

4. (1) Compare the reverse biased I-V characteristics for long pn diode and short diode, and explain your answer. (5%)

(2) Describe the advantage of making the base width of BJTs smaller according the result of (1). (5%)

(3) Describe two disadvantages of making base width of BJTs smaller. (5%)

5. The C-V characteristic curve of a MOS capacitor at 300K is shown in figure 5. The area of the capacitor is 2×10^{-3}cm^2.

(1) Is the semiconductor of the MOS capacitor n-type or p-type? Please describe how you get the answer. (5%)

(2) If the oxide is made of SiO_2, please determine the oxide thickness. (5%)

(3) Please draw the energy diagram (from metal, oxide, to semiconductor) for the point (A). Indicate the Fermi level position in the diagram. (5%)

(4) Repeat (3) for point (B). (5%)

(5) Assuming the fixed oxide charge $Q_{ss}=2\times10^{11}$cm^{-2}, and the metal-semiconductor work function difference φ_{ms} =-0.5V, can you derive the threshold voltage? If yes, get the answer. If not, describe what more information needs to be known, and how you would get that information. (10%)

(note: the dielectric constants of Si and SiO_2 are 11.7 and 3.9, respectively, permittivity of free space is 8.85×10^{-14} F/cm, intrinsic carrier concentration of Si is 1.5×10^{10}/cm^3, kT (at 300K)=0.0259eV)