**UConn** **ECE4211 HW#3** 01/31/2017, Due 02/07/17, F. Jain,NAME\_\_\_\_\_\_\_\_\_\_\_\_\_

HW#2 Q. 11-Q12 to be solved as of part of this assignment. HW 3 has 4 questions.

HW2-Q11. Find the coefficient A and B for a p-n junction diode shown in Fig. 4 with a finite neutral n-region ln.

Fig. 4.HW2

Carrier distribution equation (53A) 



Boundary conditions (BCs) are:

OR

(BC#1) , and BC#2 .

Here, ln is the length of n-region. The n-region is finite (not ∞).

**Find A, B. using** BC#1 gives, and BC#2 gives.

HW2-Q12 (a) Write expression of junction capacitance CJ at:

Equilibrium (Wo) CJ

Forward bias (Wf) CJ

Reverse bias Wr. CJ

(b)Write expressions for diffusion capacitance Cdiff under forward bias.

Method I

Method II

**HW3-Q.1** Fig. 1 shows a p-n junction under equilibrium with doping parameters. Additional parameters below.

**Given** ni in Si at room temperature (T=300K) =1.5x1010 cm-3; the product of hole concentration p and electron concentration n outside the junction is constant pn = (ni)2 **Assume all donors and acceptors are ionized at 300K.**

**p-side**: Acceptor concentration NA=1018 cm-3, τn=10-5 sec. Dn=40 cm2/sec.

Effective mass: electrons me=mn=0.26mo, holes mh=mp= 0.64 mo,

**n-side**: Donor concentration ND=1015 cm-3, minority hole lifetime τp=2×10-6 sec.

Minority hole diffusion coefficient Dp=12.5 cm2/sec.

Junction area A=10-3 cm-2, ni (300K)=1.5×1010 cm-3. εr(Si)=11.8, ε0=8.85×10-14 F/cm, εs=εrε0. Assume all donors and acceptors are ionized at T=300 K. Eg = 1.1eV, kT/q = 0.0259V

(a) Find junction width Wo and its components xno and xpo. **HINT: Eqs. 33-35 Chapter 2.**

(b) Draw the junction boundaries for a forward biased p-n junction showing xp and xn. For this you need to find the new junction width Wf. Proportionately decrease Wo the values and obtain new xn and xp values.

**HINT**: Use junction width W=Wf under forward bias page 106 Eq. 41A; V=Vf=0.5V. New Eq. qANDxn = qANA xp.

(c) Find hole concentration pe at the n- region boundary xn and electron concentration ne at –xp under a forward bias of 0.7V.**HINT:** Use Eqs. 55 and 61 (pages 109-110). Electrons on p-side np(x=-**∞**)=npo and ne =np(-xp).

(d) Write the boundary conditions for carrier concentration at the junction boundaries for holes and electrons and at infinite distance away from the junction. We are assuming both n and p regions are much larger than the diffusion lengths Lp (for holes diffusing in n-region) and Ln for electrons diffusing in the p-region.

(e) Draw the carrier concentration profile pn(x) and np(x) as a function of x/Lp in n-region and x/Ln in p-region in Fig. 1 at a forward bias Vf = 0.7 V.



Fig. 1 Carrier distribution under forward biasing.

(f) Draw the carrier distribution under reverse bias of 2V in Fig. 2.



**Fig. 2 p-n junction under reverse bias.**

Q2 (a) Draw the energy band diagram under forward bias of 0.7V for the device of Fig. 1.**HINT:** Draw the Fermi level as a horizontal line under equilibrium; draw two vertical lines representing the junction with width Wf; draw a new Fermi level for p-side which represents forward bias that is p-side level is qVf below the n-side Fermi level; draw the p-Si conduction and valence bands with respect to the new Fermi level; draw the n-Si CB and VB with respect to old Fermi level.

Q2(b) Draw the energy band diagram for the device of Fig. 2 under reverse bias of 2.0V?

**HINT:** Draw a new Fermi level for p-side which represents reverse bias that is p-side level is qVr above the n-side Fermi level.

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|  |  |
| Energy band diagram for a forward biased diode | Energy band diagram for a reverse biased diode. |

Q 3 Figure 3 shows an n+-p Si diode.



Fig. 3 An abrupt n-p Si diode under forward bias.

**n+-side**: Donor concentration ND=1020 cm-3, minority hole lifetime τp=2×10-6 sec.

Minority hole diffusion coefficient Dp=12.5 cm2/sec.

**p-side**: Acceptor concentration NA=1016 cm-3, τn=10-5 sec. Dn=40 cm2/sec.

Effective mass: electrons me=mn=0.26mo, holes mh=mp= 0.64 mo, mo=9.1x10-31 kg

Junction area A=10-3 cm-2, ni (300K) =1.5×1010 cm-3. εr(Si)=11.8, ε0=8.85×10-14 F/cm, εs=εrε0. Assume all donors and acceptors are ionized at T=300 K. Eg = 1.1eV,

Boltzmann Constant k= 8.65x10-5 eV/K.

(a) Draw the energy band diagram under equilibrium, forward biasing Vf = 0.7V, and reverse biasing of Vr =-2 V.

**(b)** Find the reverse situation current Is.

(c) Plot current and carrier distribution in the entire diode at Vf = 0.7V. For x axis, plot carrier and current values at x=0 (that is at junction boundary) and x/Ln, x/2Ln and x/3Ln on p-side and x=-x/Lp and x/2Lp and x/3Lp on the n-side.

(d) What happens to the energy when electrons recombine in the p-region?

**BONUS:**Q.4(a) Level of doping in a diode that determines avalanche or Zener breakdown. (b) How do you calculate the breakdown voltage (see page 152)? (b) Draw the energy band diagram for a Zener diode. HINT: Zener diode has junction width is about 100Åor smaller.