COE 360, Term 071

Principles of VLSI Design

HW# 1

Q.1. Indicate whether the following is true or false, and if it is false indicate why it is false:

(i) An atom in an intrinsic silicon semiconductor has 5 valence electrons **(True, False)**.

(ii) Current density increases with the increase in the total charge and the decrease in area **(True, False).**

(iii) The applied voltage across a semiconductor increases with the increase in the length of the semiconductor **(True, False**).

(iv) With the addition of acceptor atoms to an intrinsic semiconductor, the hole concentration increases while the electron concentration remains the same **(True, False)**.

(v) An n-type semiconductor is doped with pentavalent impurity while a p-type semiconductor is doped with tetravalent impurity **(True, False)**.

(vi) The mass-action-law states that $n=p=n_i$, the intrinsic concentration **(True, False).**

(vii) The charge neutrality law states that $N_A + p = N_D + n$ **(True, False)**.

(viii) With increasing temperature, the density of electron-hole pairs, mobility and conductivity increase **(True, False).**

(ix) In a pn-junction, free electrons will diffuse from the n to the p side leaving negative ions, and free holes will diffuse from the p to the n side leaving positive ions **(True, False).**

(x) The width of the depletion region and the transition capacitance decrease with the increase in the doping concentration **(True, False)**.

(xi) In a forward-biased pn-junction, the depletion region width is smaller than in the reverse-biased pn junction **(True, False)**.

(xii) V_{IH} is the maximum input voltage which can be interpreted as high while V_{IL} is the minimum input voltage which can be interpreted as low **(True, False)**.

(xiii) V_{OH} is the maximum input voltage which can be interpreted as high **(True, False)**.

(xiv) V_{IH} is defined as, the maximum output voltage V_{OH} minus the noise margin NM_H. **(True, False)**.

(xv) V_{OL} is the output voltage produced when the input voltage is greater than or equal to V_{IH} **(True, False)**.

Q.2. Calculate the conductivity of a piece of silicon at 300K in the following cases:

(i) No impurities added.

(ii) The material is doped with Arsenic at a density of $4X10^{16}$ atoms/cm^3.

(iii) The material is doped with Boron at a density of $4X10^{16}$ atoms/cm^3.

(iv) The material is doped with both Arsenic and Boron, each at a density of $4X10^{16}$ atoms/cm^3.

Assume the following: Electron mobility at 300 K=1500 cm^2/V.s, Hole mobility at 300 K = 475 cm^2/V.s, Intrinsic concentration at 300 K=1.45X10^{10} cm^{-3}, q= 1.6X10^{-19}

Q.3. An intrinsic silicon bar is 4 mm long and has a rectangular cross section of 40X80 μm. The material has a resistivity of 200K Ω.cm. Determine the following:

(i) The concentration of Arsenic atoms added to the material to convert it to an n-type material with a resistivity of 20 Ω.cm.

(ii) The concentration of Boron atoms added to the material to convert to a p-type material with a resistivity of 20 Ω.cm.

(iii) Determine the electric field intensity in the intrinsic silicon bar and the voltage across the bar when a steady current of 1 μA is measured.

Q.4. Determine the fanout and the noise margins of a gate with V_{IL}=1.2V, V_{IH}=3V, V_{OH}=4.5V, V_{OL}=0.2, I_{IH}=30μA, I_{IL}=2mA, I_{OH}=600μA, and I_{OL}=30mA.