Kaferelsheikh University

Department of Electrical Engineering

Subject: Electronic Devices

Academic Number: ECE3107

Full Mark: 100 degree

Faculty of Engineering

Year: 3rd Electronics and Electrical Communications

Final Exam: 2 pages

Time allowed: 3 h

Date: 29 /12/2019

This exam measures ILOs no: a5, a13,b5,a8 ,b6, b8,c5, d1,d7, solve five questions only

k = 1.38E-23 J/K ...Boltzmann constant ε_0 = 8.854E-12 F/m ...dielectric constant e = 1.602E-19 C ...elementary charge ε_r = 11.9...dielectric constant for silicon n_i = 1.5E10 cm^{-3}...intrinsic carrier concentration for silicon

Question #1: (20 Mark)

(a) Draw the band diagram of schottky diode, indicating the valence band, the conduction band, the Fermi energy, and the built-in potential, V_{bi} assuming that no voltage is applied across the junction. Indicate on this diagram approximately where the depletion region would be.

(b) Then draw the band diagram in forward and reverse bias.

(c) The doping is $N_d = 5\times10^{15}$ 1/cm³ and $N_a = 1\times10^{17}$ 1/cm³. At 300 K, what is the concentration of holes on the p-side and the concentration of holes (minority carriers) on the n-side? For silicon, $n_i = 1.5\times10^{10}$ 1/cm³.

(d) How could you calculate the depletion width for this diode

Question #2: (20 Mark)

1-There are four currents to consider at the interface between two materials (like at a pn-junction or a Schottky contact). These four currents caused by thermionic emission, diffusion, drift, and tunneling.

a) In which cases is the tunnel current important?

b) What kinds of current are most important for a pn-junction and for a Schottky diode?

c) What is a diffusion current?

d) Usually the thermionic emission current in a pn-junction is ignored because it is small. How would it be calculated?

2- Calculate the theoretical barrier height and the built-in potential in a metal-semiconductor diode for zero applied bias. Assume the metal work function is 4.92eV, the electron affinity is 3.51eV, and Nd = $3*10^{16}$cm−3, Nc = Nv = 10^{25}m−3 and Eg = 1eV at 300K.

Question#3: (20 Mark)

1- Explain the following terms: accumulation, flatband voltage, depletion, threshold voltage, and inversion.

2- Sketch MOSFET small Signal model with write the mathematical equation of its parameters?

3- Draw an-channel MOSFET. Explain how it works. Then draw the charge density in the channel when the saturation voltage is applied.

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4-An N-type silicon sample has a uniform density $N_d = 10^{17} cm^{-3}$ of arsenic, and a P-type sample has $N_a = 10^{15} cm^{-3}$. A third sample has both impurities present at the same time.

a- Find the equilibrium minority carrier concentrations at 300 K in each sample.

b- Find the conductivity of each sample at 300 K.

c- Find the Fermi level in each material at 300 K with respect to either the conduction band edge (E_c) or the valence band edge (E_v).

Question #4: (20 Mark)

1-Assume a diode described by ID= I0 ($e^{qVA/nkT}$ −1) . Answer the following questions.

a- Assume that the diode is forward biased moderately (i.e. VA is large enough so that the -1 term can be neglected). Derive a general expression for the increase, ΔVA in VA needed to increase the diode current by a factor of 10.

b- Evaluate ΔVA assuming room temperature and n = 1 . Express your answer in mmv.

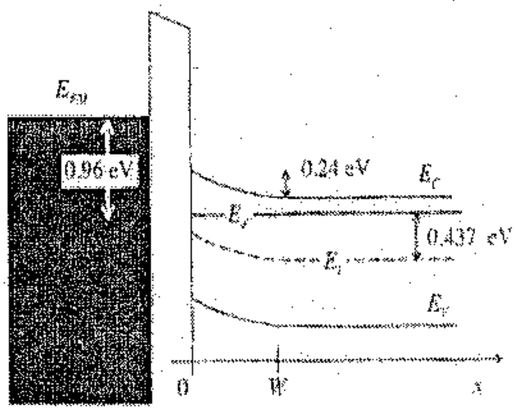
2- Why can you make ohmic contact to a lightly doped n region? Drive an expression for the specified resistance Rc.

3-Describe how charge is transported through all interfaces. (like if tunneling is involved).

4- Draw the band diagram (valence band, conduction band, Fermi energy) for a Schottky diode with a n doped semiconductor and a p doped semiconductor at zero bias. Assume that interface states pin the Fermi energy to the middle of the semiconducting gap at the interface.

Question #5: (20 Mark)

1- Answer the following questions about the energy band diagram sketched below. Assume that the zero for electrostatic potential is in the semiconductor bulk, at large x and that there is no metal semiconductor workfunction difference. Also assume thatthe relative dielectric constant of the oxide is Ko=3.9.



a- What it the surface potential, Φs?

b-What gate voltage, VG, is applied?

c-What is the voltage across the oxide $\Delta\Phi_{ox}$?

d-What is the doping density, Nd?

e-What is the width of the depletion region, W?

f-What is the thickness of the oxide?

2- In an MOS capacitor, everything depends on the band bending in the semiconductor. If ΦS is the potential at the surface, and Φ= 0 is the potential in the bulk, then −qΦs is the total band bending in the semiconductor. A negative Φs means the bands bend up, and a positive Φs means the bands bend down. This question helps familiarize you with surface potential and band bending.