UConn, **ECE 4211 HW #11 MOS Devices-I 04/11/17 due on 04/14/17 Name\_\_\_\_\_\_\_\_\_\_\_\_\_**

Q.1. (a) Find the work functions for n and p-type Si for the doping levels given below. Show them in relation to vacuum energy level being zero as the reference. The electron affinity of Si is qχSi = 4.15 eV. **Pages 556-560.**

**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,

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.

**n+-side**: Donor concentration ND=1018 cm-3, minority hole lifetime τp=2×10-6 sec.

Minority hole diffusion coefficient Dp=12.5 cm2/sec.

(b) Compute the work function difference nSi-pSi (=nSi - pSi).

Q.2(a). The threshold voltage is altered by: Circle correct answers

Gate metal charge in the gate oxide source doping substrate doping

(b) For a given metal-oxide-pSi MOS capacitor, which one will have higher threshold? Circle

Al-SiO2-psi or Au-SiO2-pSi

(c) What is the advantage in replacing gate metal by doped poly Si layer as the gate layer?

(d) Why in 22 nm FETs poly Si is not used and TaN or TiN metals are used?

Q3. (a) Compute the drain current ID for VD = 0.5, 1.0, and 2.5 volts in a n-channel

MOSFET having a threshold voltage VTH = 0.533 V at a gate voltage VG = 2 and 4V. Given: Channel length L = 10 μm, channel width Z = 40 μm,

operating temperature T = 300K, and channel mobility μn = 800 cm2/Volt⋅sec.

Qox = 2.103 x 10-8 C/cm2 εSi = 11.8

Oxide thickness = d = 1000 Å (1 Å = 10-8 cm) ni = 1.5x1010 cm-3

qχSiO2 = electron affinity = 0.9 eV NA = 5x1016 cm-3

εox = 3.9 qχSi = 4.15 eV

# εo = 8.854x10-14 F/cm qAl = 4.1 eV

The intrinsic Fermi level Ef= Ei ~Eg/2.

(b) Determine the saturation current ID(sat) and voltage VD(sat) at the VG = 4V.

(c). Calculate the channel conductance gD and the transconductance gm at the following drain voltages VD = 0.5 V and VD = 2.5 V.

(d). If the gate is n+ poly Si (ND = 1x1019cm-3), calculate the flat band and threshold voltage assuming the same Qox as in part (a).

(e) Calculate the transconductance gm in the linear regime.

(f) What is the cut off frequency fT (= gm/(2 Cg)) of this FET? Cg is the gate capacitance.

HINT set: Vfb= ms – Qox/Cox (with oxide charge, assumed to be located in SiO2 near the SiO2-Si interface).

Vfb= ms if there is no oxide charge. ms = m  -s = Al - pSi . Find the work functions and compute ms.

1. ***Threshold voltage VT or VTH***

 This expression is valid for both channels, n- and p-type. Note the difference in Qsc for p-Si substrate and n-Si substrate. Sometimes we use Qd in place of QSC

**For p-Si (or MOS where an n- inversion channel is created)**

, Wm is the maximum width of the depletion region.

and is given by , .

**For n-Si (or MOS where a p-channel is created if Vg is greater than VT).**

, and , 