HW5 Solution Mar,2003

Problem1: *Describe how MOSFET works, including 4 regions talked in the class.*

Main point: list 4 regions (Cutoff, Subthreshold, Triode, Saturation), and give the working conditions for those 4 region and explain it in relative detail, follow the lecture notes.

Note: There is a subtle difference from what we talked Accumulation, Depletion, Weak/Strong Inversion in the MOS cap. Don't mixed those two models up, although they do have strong relationships.

Problem 5.2

Ans: From Eq (5.8), the number of acceptor atoms in the substrate

$N_A = n_i \exp(|\phi_F|\, q/KT) = 8.354 \times 10^{14}$ atoms/cm^3

Use Eq (5.20),

$C'_{ox} = (2 \times q \varepsilon_{si} N_A)^{0.5}/\lambda = 369.72$ aF/μm^2

The KP of this n-channel MOSFET is

$KP = \mu_n \times C'_{ox} = 550\text{cm}^2/\text{V} \times 369.72\ \text{aF}/\mu\text{m}^2 = 20.33\mu\text{A}/\text{V}^2$

From Eq. (5.36), $\beta = KP \times W/L = 20.33 \times 10/2 = 101.56$

From Eq. (5.21), $V_{THN} = 0.8V + 0.45 \times ((.57+1)^{0.5} - (.57)^{0.5}) = 1.024V$

Since $V_{DS} > V_{GS} - V_{THN}$ and $V_{GS} > V_{THN}$, the MOSFET is operated in saturation region.

With λ=0, use Eq (5.39),

$I_D = \beta (V_{GS} - V_{THN})^2 /2 \approx$ **48.4μA**

If use CN20 process, the C'_{ox} is 800 aF/μm^2, and KP = 44 μA/V^2, I_D = 104.78μA

For Vsb=0V

Clearly, Vthn=Vthn0=0.8V, and Vgs-Vthn=2-0.8=1.1V, Vds=1.1V, so Vds<Vgs-Vthn, it works in Triode region, so we need to use the equation of Ids in Triode region to calculate Ids,and the result is Ids=72.7uA.

Problem 5.5

$C'_{ox} = \varepsilon_{ox} / TOX = (8.85 \times 3.97\ \text{aF}/\mu\text{m}) / (400 \times 10^{-10}\ \text{m}) =$ **878.4aF/μm²**

Problem 5.8

The electrostatic potential of the oxide semiconductor interface when $V_{GS} = V_{THNO}$ is: $\phi_S = -\phi_F = \frac{kT}{q} \ln \frac{N_A}{N_i}$

Where N_A is the number of acceptor atoms in the substrate, N_i is the intrinsic carrier concentration of silicon.

Problem 5.13

Since every MOSFET shown in Figure P5.13 has the same V_{DS}, V_{GS}, KP, L and V_{THN}, the current flowing through every MOSFET is

$$I_{Dn} = (KP \times W_n \times /L) \times [(V_{GS} - V_{THN})V_{DS} - V_{DS}^2/2],\ n = 1,2, ..., N$$

(neglect the body effect and for both triode and saturation region, this equation is effective.)

Therefore, the total current from drain to source is

$$I_D = [KP \times (W_1+W_2+...+W_N)/L] \times [(V_{GS} - V_{THN})V_{DS} - V_{DS}^2/2]$$

This I-V characteristic is the same as one single MOSFET with a width equal to the sum of each individual MOSFET's width.

Problem 5.15

From Figure P5.14, we assume that both MOSFET are in the triode region. Neglecting the body effects,

1) $I_D \times L1/(KP \times W) = (Vgs1 - Vthn)\ Vds1 - Vds1^2/2 = (Vg - Vthn)V1 - V1^2/2$

2) $I_D \times L2/(KP \times W) = (Vgs2 - Vthn)\ Vds2 - Vds2^2/2$

$= (Vg - Vthn - V1)(Vd - V1) - (Vd - V1)^2/2$

1)+2)

$$I_D \times (L2+L1)/(KP \times W) = VgVd - VthnVd - Vd^2/2 = (Vg - Vthn)Vd - Vd^2/2$$

Re-arranging this equation,

$$I_D = [KP \times W/(L2+L1)] \times [(V_{GS} - V_{THN})V_{DS} - V_{DS}^2/2]$$

From this equation, Figure P5.14 does behave as a single MOSFET with the length equal to the sum of the individual MOSFET's length.

Problem 5.19

For the Fig. P5.19, the layout of an n-channel MOSFET is equal to 5 MOSFETs, each with W/L=4/25, connected serially. Therefore, the device's width is 4 μm and length is 5×25=125μm.

You could relate problem 5.15 with Problem 5.19, just like you could relate the layout example on the book Page 103 with the problem 5.13.