Ve320 Introduction of Semiconductor Device
Homework 7
Due Date: Aug. 03

Ex 7.1

(a) Consider a Schottky diode at $T = 300\,K$ that is formed with tungsten on n-type silicon. Use following Fig.1 to determine the barrier height. Assume a doping concentration of $N_d = 10^{16} cm^{-3}$ and assume a cross-sectional area $A = 10^{-4} cm^2$. Given that $A^* = 120 A/K^2 \cdot cm^2$, determine the forward-bias voltage required to induce a current of

(i) $10\mu A$,
(ii) $100\mu A$,
(iii) $1mA$.

(b) Repeat part (a) for a temperature of $T = 350K$. (Neglect the barrier lowering effect.)

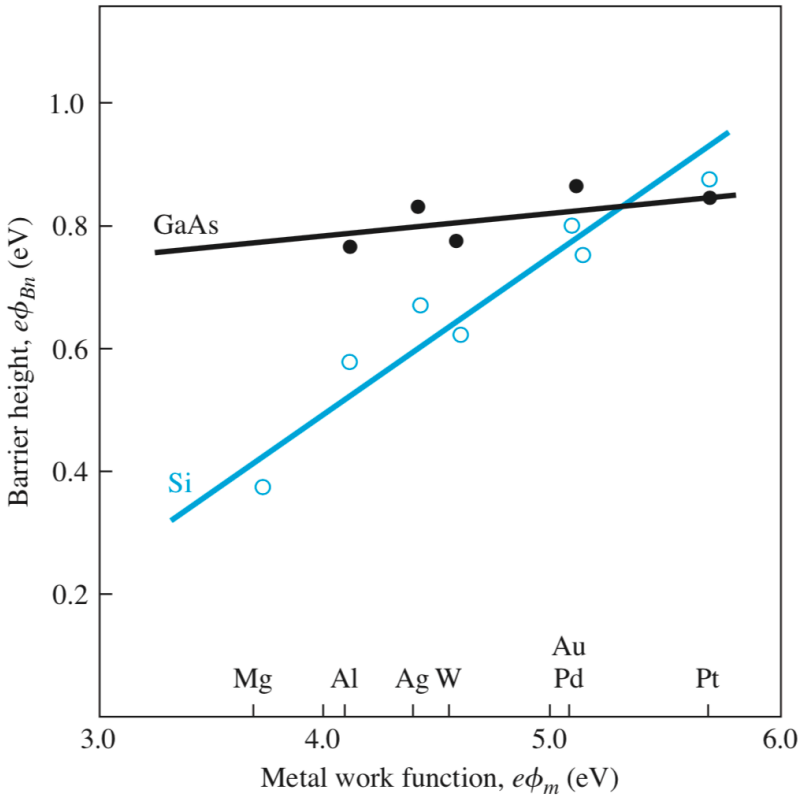

Figure 1. Experimental barrier heights as a function of metal work functions for GaAs and Si.

Ex 7.2

A pn junction diode and a Schottky diode each have cross-sectional areas of $A = 8 \times 10^{-4}\ cm^2$. The reverse saturation current densities at $T = 300\,K$ for the pn

junction diode and Schottky diode are $8 \times 10^{-13}\ A/cm^2$ and $6 \times 10^{-9}\ \mathrm{A/cm^2}$, respectively. Determine the required forward-bias voltage in each diode to yields currents of

(a) $150\mu A$,

(b) $700\mu A$,

(c) $1.2\ mA$.

Ex 7.3

The dc charge distributions of four ideal MOS capacitors are shown in the Following Fig.2. For each case:

(a) Is the semiconductor n or p type?

(b) Is the device biased in the accumulation, depletion, or inversion mode?

(c) Draw the energy- band diagram in the semiconductor region.

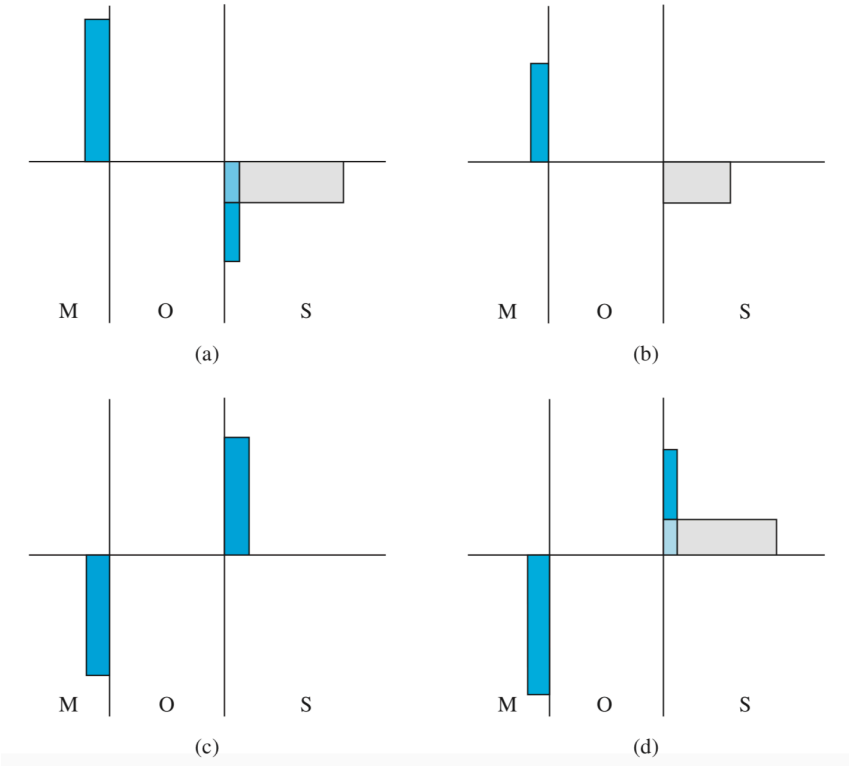

Figure 2. Figure for Ex 2.3.

Ex 7.4

(a) Consider an n^+ polysilicon–silicon dioxide–n-type silicon MOS structure. Let $N_d = 4 \times 10^{15} cm^3$. Calculate the ideal flat-band voltage for $t_{ox} = 20nm = 200\mathring{A}$.

(b) Considering the results of part (a), determine the shift in flat-band voltage for

(i) $Q'_{ss} = 4 \times 10^{10} cm^{-2}$, and

(ii) $Q'_{ss} = 10^{11} cm^{-2}$.

(c) Repeat parts (a) and (b) for an oxide thickness of $t_{ox} = 12nm = 120\mathring{A}$.

Ex 7.5

The high-frequency C–V characteristic curve of a MOS capacitor is shown in the following Fig.3. The area of the device is $2 \times 10^{-3} cm^2$. The metal–semiconductor work function difference is $\phi_{ms} = -0.50V$, the oxide is SiO_2, the semiconductor is silicon, and the semiconductor doping concentration is $2 \times 10^{16} cm^{-3}$.

(a) Is the semi- conductor n or p type?

(b) What is the oxide thickness?

(c) What is the equivalent trapped oxide charge density?

(d) Determine the flat-band capacitance.

(e) Indicate which points correspond to flat-band, inversion, accumulation, threshold, and depletion modes.

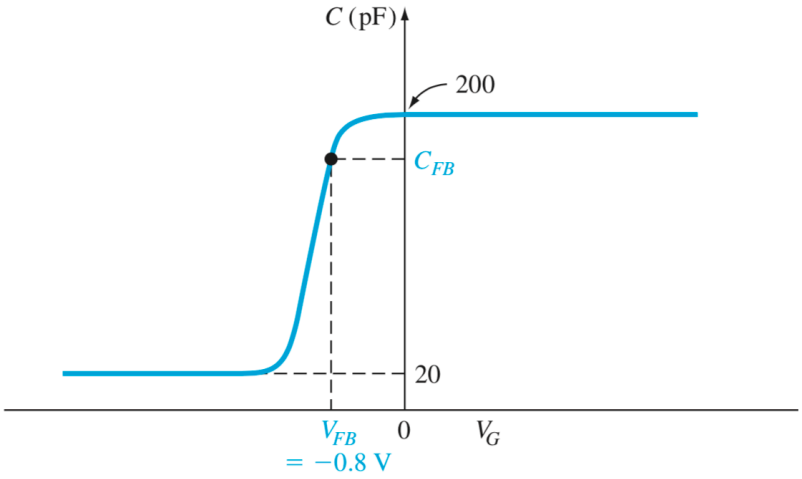

Figure 3. Figure for Ex 7.5.

Ex 7.6

The parameters of an n-channel MOSFET are $k_n' = 0.6mA/V^2$ and $V_T = 0.8V$. The drain current is $1mA$ with applied voltages of $V_{GS} = 1.4V$, $V_{SB} = 0$, and $V_{DS} = 4V$.

(a)What is the W/L value?

(b)What is the value of I_D for $V_{GS} = 1.85V$, $V_{SB} = 0$, and $V_{DS} = 6V$?

(c)Determine the value of I_D for $V_{GS} = 1.2V$, $V_{SB} = 0$, and $V_{DS} = 0.15V$.

Ex 7.7

Consider an ideal p-channel MOSFET with the following parameters: $V_T = -0.35V$, $\mu_p = 210 cm^2/V \cdot s$, $t_{ox} = 11\ nm = 110\ \text{Å}$, $W = 35\mu m$, and $L = 1.2\mu m$.

(a) Plot I_D versus V_{SD} for $0 \le V_{SD} \le 3\ V$ and for $V_{SG} = 0, 0.6, 1.2, 1.8$, and $2.4V$. Indicate on each curve the $V_{SD}(sat)$ point.

(b) Plot $\sqrt{I_D(sat)}$ versus V_{SG} for $0 \leq V_{SG} \leq 2.4\,V$.

(c) Plot I_D versus V_{SG} for $0 \leq VSG \leq 2.4\,V$ and for $V_{SD} = 0.1\,V$.

Ex 7.8

Assume that the subthreshold current of a MOSFET is given by:

$$I_D = 10^{-15}\, exp(\frac{V_{GS}}{(2.1)V_t})$$

over the range $0 \leq V_{GS} \leq 1$ volt and where the factor 2.1 takes into account the effect of interface states. Assume that 10^6 identical transistors on a chip are all biased at the same V_{GS} and at $V_{DD} = 5\,V$.

(a) Calculate the total current that must be supplied to the chip at $V_{GS} = 0.5, 0.7,$ and $0.9\,V$.

(b) Calculate the total power dissipated in the chip for the same V_{GS} values.

Ex 7.9

Consider an n-channel silicon MOSFET. The parameters are $k_n' = 75\mu A/V^2$, $W/L = 10$, and $V_T = 0.35V$. The applied drain-to-source voltage is $V_{DS} = 1.5\,V$.

(a) For $V_{GS} = 0.8\,V$, find

(i) the ideal drain current,

(ii) the drain current if $\lambda = 0.02V^{-1}$, and

(iii) the output resistance for $\lambda = 0.02\,V^{-1}$.

(b) Repeat part (a) for $V_{GS} = 1.25V$.

Ex 7.10

The parameters of an n-channel enhancement-mode MOSFET are $V_T = 0.40\,V$, $t_{ox} = 20nm = 200\text{Å}$, $L = 1.0\mu m$, and $W = 10\mu m$.

(a) Assuming a constant mobility of $\mu_n = 475cm^2/V \cdot s$, calculate I_D for $V_{GS} - V_T = 2.0\,V$ when biased at

(i) $V_{DS} = 0.5\,V$,

(ii) $V_{DS} = 1.0\,V$,

(iii) $V_{DS} = 1.25\,V$,

(iv) $V_{DS} = 2.0\,V$.

(b) Consider the piecewise linear model of the carrier velocity versus VDS shown in the following Fig.4. Calculate I_D for the same voltage values given in part (a). [You may refer to Equation (11.17) in textbook.]

(c) Determine the $V_{DS}(sat)$ values for parts (a) and (b).

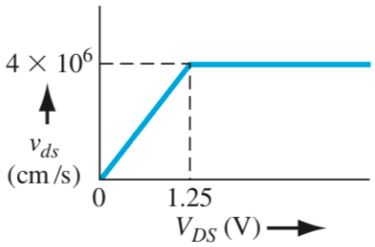

Figure 4. Figure for Ex 7.10.