VE320 Intro to Semiconductor Devices Summer 2022 — Problem Set 7

July 17, 2022

Exercise 7.1

(a) A Schottky barrier diode formed on n-type silicon has a doping concentration of $N_d = 5 \times 10^{15}$ cm^{-3} and a barrier height of $\phi_{B0} = 0.65$ V. Determine the builtin potential barrier V_{bi}.

(b) If the doping concentration changes to $N_d = 10^{16}$ cm^{-3}, determine the values of ϕ_{B0} and V_{bi}. Do these values increase, decrease, or remain the same?

(c) Repeat part (b) if the doping concentration is $N_d = 10^{15}$ cm^{-3}.

Exercise 7.2

For a p type semiconductor in contact with a metal, when does it form a Schottky contact, and when does it form an Ohmic contact? Please draw the energy band diagram for each case, and explain using your own words

Exercise 7.3

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 8×10^{-13} A/cm^2 and 6×10^{-9} A/cm^2, respectively. Determine the required forward-bias voltage in each diode to yields currents of

(a) 150μA

(b) 700μA

(c) 1.2 mA

Exercise 7.4

A metal, with a work function $\phi_m = 4.2$ V, is deposited on an n-type silicon semiconductor with $\chi_s = 4.0$ V and $E_g = 1.12$eV. Assume no interface states exist at the junction. Let $T = 300$ K.

(a) Sketch the energy-band diagram for zero bias for the case when no space charge region exists at the junction.

(b) Determine N_d so that the condition in part (a) is satisfied.

(c) What is the potential barrier height seen by electrons in the metal moving into the semiconductor?

Exercise 7.5

A metal-semiconductor junction is formed between a metal with a work function of 4.3eV and p-type silicon with an electron affinity of 4.0eV. The acceptor doping concentration in the silicon is $N_a = 5 \times 10^{16}$ cm^{-3}. Assume $T = 300$ K.

(a) Sketch the thermal equilibrium energy-band diagram.

(b) Determine the height of the Schottky barrier.

(c) Sketch the energy-band diagram with an applied reverse-biased voltage of $V_R = 3$ V.

(d) Sketch the energy-band diagram with an applied forward-bias voltage of $V_a = 0.25$ V

Exercise 7.6

The dc charge distributions of four ideal MOS capacitors are shown in Figure P10.1. 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 energyband diagram in the semiconductor region.

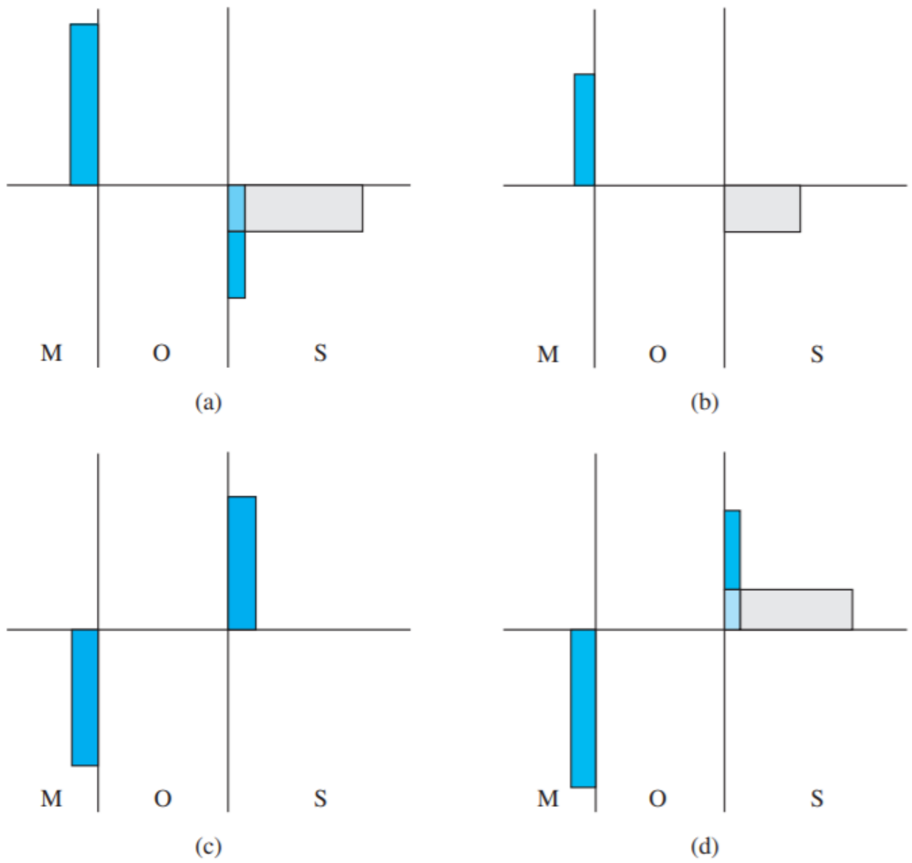

Figure 1: Figure for Problem 7.6

Exercise 7.7

(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 $t_{ox} = 20$ nm $= 200\mathring{A}$

(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 $t_{ox} = 12$ nm $= 120\mathring{A}$.

Exercise 7.8

Consider an n^+polysilicon gate on silicon dioxide with a p-type silicon substrate doped to $N_{\mathrm{a}} = 3 \times 10^{16}$ cm^{-3}. Assume $Q_{\mathrm{ss}}{}' = 5 \times 10^{10}$ cm^{-2}. Determine the required oxide thickness such that the threshold voltage is $V_{\mathrm{TN}} = +0.65$ V. Please provide the process of derivation.

Exercise 7.9

Draw the C-V curves of a MOS capacitor with n-type Si as the substrate, at low frequency and high frequency, respectively. Explain why they are different.

Reference

1. Neamen, Donald A. Semiconductor physics and devices: basic principles. McGraw-hill, 2003.