ECSE-2210 Microelectronics Technology
Homework 8 – Solution

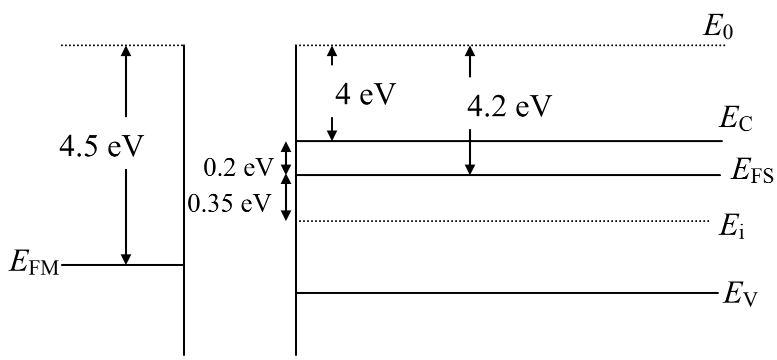
Reading list: Chapters 14 (pages 477 – 487). Hand in your solutions in class.

1. Assume that an ideal Schottky barrier is formed on n-type Si having $N_D = 10^{16}$ cm^{-3}. The metal work function is 4.5 eV, and the Si electron affinity is 4 eV.

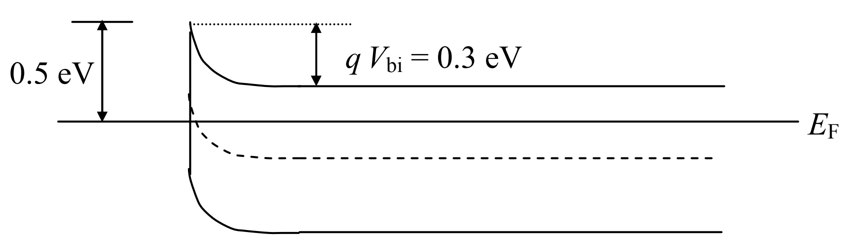
   (a) Draw equilibrium band diagrams such as in Fig 14.2 to scale. What is the barrier height $q V_{bi}$ (where V_{bi} is called the built-in voltage) for electron flow from the semiconductor to metal (S → M)? What is the barrier height (Φ_B) for electron flow from the metal to semiconductor (M → S)? What is the depletion layer width formed in the semiconductor? What is the maximum electric field $\mathcal{E}_0$ in the depletion layer?

   First draw the equilibrium band diagram for the metal and the semiconductor being separated.

   Note: For the metal: $\Phi_M = 4.5$ eV
   For the semiconductor: $\Phi_M = \chi + (E_C - E_F)$ with $E_C - E_F = 0.2$ eV



   Then draw the equilibrium band diagram for the metal and the semiconductor being in contact:



Barrier height from M → S: 0.5 eV

Barrier height from S → M: $q\,V_{bi} = 0.3$ eV

Depletion layer width:

$$W = [2\varepsilon V_{bi} / (q N_D)]^{1/2} =$$
$$= [(2 \times 11.8 \times 8.85 \times 10^{-14}\ \text{F/cm} \times 0.3\ \text{eV}) / (1.6 \times 10^{-19}\ \text{C} \times 10^{16}\ \text{cm}^{-3})]^{1/2} =$$
$$= 0.19\ \mu\text{m}$$

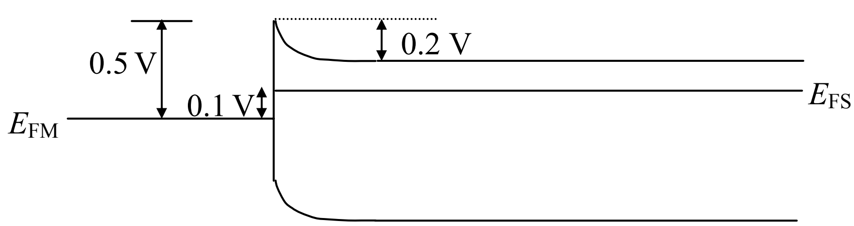
Maximum $\mathcal{E}$-field $\mathcal{E}_0$:

$$\mathcal{E}_0 = q N_D W / \varepsilon = 2.9 \times 10^4\ \text{V/cm}$$

(b) Draw the forward- and reverse-bias diagrams, as in Fig 14.3 to scale, for $V_A = 0.1$ V and $V_A = -3$ V respectively. What are the barrier heights for electron flows from S → M and M → S for each case now? Note that this junction will behave like a p^+-n rectifying junction.

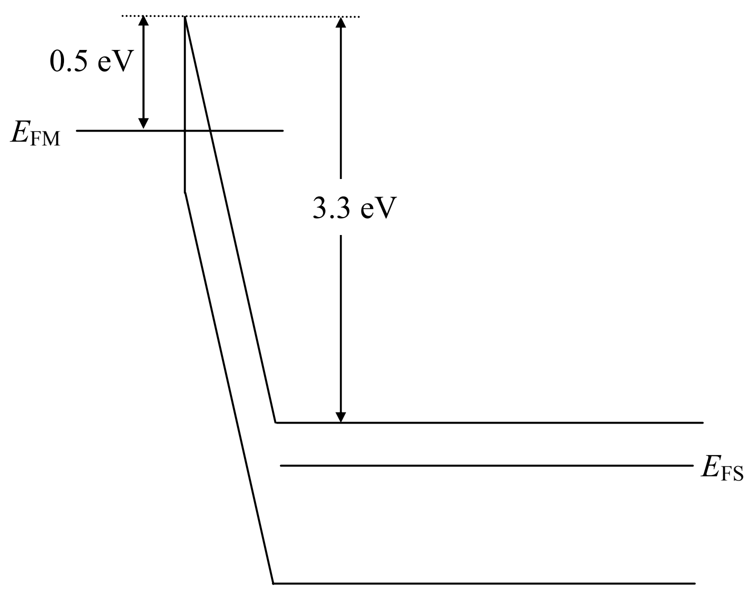
2. Suppose for the above case, we used a metal with a work function of 4.0 eV. Now, draw the band diagram at equilibrium. Is the metal-semiconductor contact ohmic or rectifying? Explain.

<u>Forward voltage 0.1 V (metal positive w.r.t. Si):</u>



Barrier for electron flow from S to M reduced to 0.2 V. Barrier for electron flow from M to S is the same as before.

Reverse voltage 3.0 V (metal negative w.r.t. Si):



Barrier for electron flow from S to M increased to 3.3 V. Barrier for electron flow from M to S is the same as before.

Note: Current is the reverse saturation current I_0 and depends on the barrier height (here 0.5 V) and remains constant with applied reverse voltage → behaves just like a p^+-n junction.

3. Explain why MS diodes switch very rapidly from the forward bias "on state" to reverse bias "off state" (where as p-n diodes do not!).

   In MS diodes we do not have minority carriers to deal with. It is a majority carrier device. Hence the turn-off will be very fast.