Alexandria University
Faculty of Engineering
Electrical Engineering Department

ECE 336: Semiconductor Devices
Sheet 4

1.
   a. Draw the energy band diagram for a metal–semiconductor contact (including the vacuum level) under 0.4 V applied forward bias. The metal has a work function ϕ_M of 4.8eV, and the semiconductor is N-type Si with uniform doping concentration of $10^{16}cm^{-3}$. Label clearly $q\phi_M$, $q\varphi_{Bn}$, $q(\varphi_{bi} + V)$, and χ_{Si} on your sketch. Assume no surface states are present. Find the numerical values for $q\phi_M$, $q\varphi_{Bn}$, $q(\varphi_{bi} + V)$.
   b. Sketch the charge density ρ, electric field ε, and potential φ, for the device in (a). For each diagram, draw two curves: one for equilibrium case and one for V = 0.4V. No numbers or calculations are required.

2. Consider a Schottky diode with the doping profile shown in Fig. 4–53. Assume that the built-in potential φ_{bi} is 0.8V.

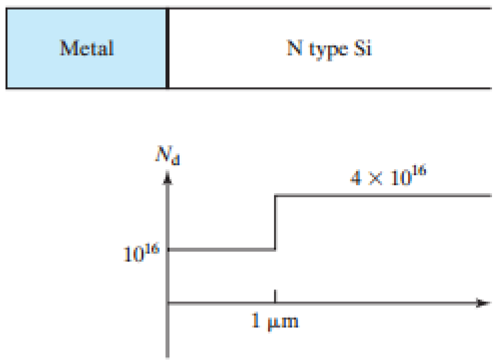

FIGURE 4–53

   a. Sketch $1/C^2$ vs. V(the reverse bias voltage) qualitatively. Do not find numerical values for C.
   b. Sketch the electric field profile for the bias condition when W_{dep} = 2 µm. Again, do not find numerical values for the electric field.
   c. What is the potential drop across the junction in part (b)?
   d. Derive an expression of C as a function of V for W_{dep}> 1 µm.

3.
   a. Calculate the small signal capacitance at zero bias and 300 K for an ideal Schottky barrier [see Eq. (4.16.2)] between platinum (work function 5.3eV) and silicon doped with $N_d = 10^{16}cm^{-3}$. The area of the Schottky diode is $10^{-5}cm^2$.
   b. Calculate the reverse bias at which the capacitance is reduced by 25% from its zero-bias value.

4. The doping profile inside the semiconductor of a Schottky diode is linearly graded, i.e., $N_d(x) = ax$. Derive expressions for ρ, ε, V, and W_{dep} inside the semiconductor. Indicate how φbi is to be determined and computed. Establish an expression for the junction (depletion layer) capacitance.

5. A metal/N-type semiconductor Schottky diode has the CV characteristic given in Fig. 4–54.

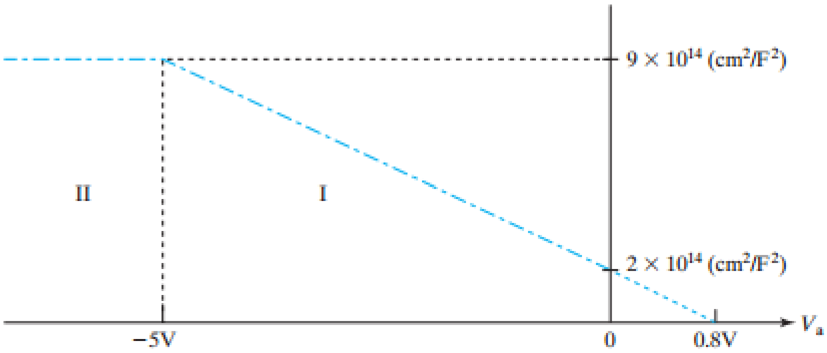

FIGURE 4–54

   a. What is the built-in voltage of the diode (from Region I data)?
   b. Find the doping profile of the N-type semiconductor.

6. Consider an aluminum Schottky barrier on silicon having a constant donor density N_d. The barrier height $q\Phi_B$ is 0.65eV. The junction will be a low-resistance ohmic contact and can pass high currents by tunneling if the barrier presented to the electrons is thin enough. We assume that the onset of efficient tunneling occurs when the Fermi level extrapolated from the metal meets the edge of the conduction band (E_c) at a distance no larger than 10 nm from the interface.
   a. What is the minimum N_d such that this condition would be met at equilibrium?
   b. Draw a sketch of the energy band diagram under the condition of (a).
   c. Assume that N_d is increased four times from (a).By what factor is the tunneling distance (W_{dep}) reduced? And by what factor is Rc reduced?