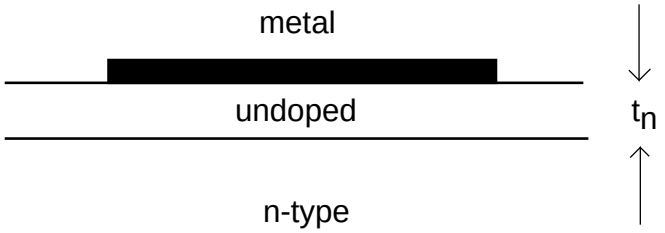
Homework #5 - October 11, 2002

Due: October 18, 2002 at lecture

1. *[30 points]* The **Mott diode** consists of a metal-semiconductor junction in which the semiconductor layer immediately adjacent to the interface is undoped, as indicated in the figure below. Consider a case in which $W_M > W_s$.



a) Sketch the space charge, ρ_o, electric field, $\mathcal{E}_o$, electrostatic potential, ϕ_o, and energy band diagram in thermal equilibrium.

b) Under the depletion approximation, calculate expressions for ρ_o, $\mathcal{E}_o$, and ϕ_o as a function of x in the semiconductor. Leave everything in terms of x_d, the depletion region extension into the n-type region.

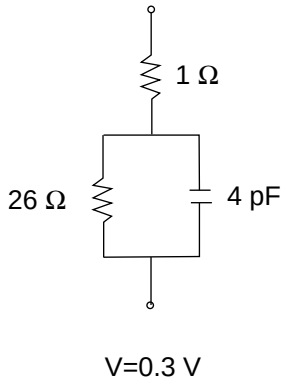
c) Compute an expression for x_d in terms of material parameters.

d) Modify the expressions for ρ, $\mathcal{E}$, ϕ, and x_d for forward and reverse bias.

e) Derive an expression for the C-V characteristics. Sketch.

2. *[20 points]* A Schottky diode biased at a forward voltage of $V = 0.3\ V$ has the small-signal equivalent circuit indicated below at room temperature. The Schottky barrier height

of this diode is $\varphi_B = 0.9\ V$.



a) Estimate the current through the diode for $V = -1\ V$. State any assumptions you need to make.

b) Estimate the forward voltage across the diode for $I = 100\ mA$. State any assumptions you need to make.

c) Estimate the capacitance of the diode for $I = 100\ mA$. State any assumptions you need to make.

3. *[30 points]* A certain IC foundry offers a process that includes a "nominal" Schottky diode characterized by the following set of SPICE parameters at 300 K: **IS**= $1e-13$, **N**= 1.0, **EG**= 0.9, **RS**= 10, **CJO**= $1e-12$, **VJ**= 0.7, **M**= 0.5, **XTI**= 2, **TT**= 0, and **BV**= 10. This "nominal" Schottky diode has a junction area of 10 μm^2. Estimate the 3 dB bandwidth, $f_{3dB} = \frac{\omega_{3dB}}{2\pi}$, of this "nominal" Schottky diode at a forward current of 1 mA and at 300 K.

4. *[20 points]* This problem is about making some early design decisions for a process for a Schottky diode varactor (variable capacitor). The output of this exercise is a first-order sense of the Schottky barrier height of the metal and the doping level of the semiconductor.

The room-temperature specifications of this varactor are: i) a capacitance per unit area at 0 V of $C_o = 1\ fF/\mu m^2$, and ii) the capacitance must change by a factor of 2 between 0 and 2 V (an 100% tuning range). To minimize power consumption, the Schottky diode must operate in reverse bias.

Assume a metal/n-Si structure. Provide values of N_D and $q\varphi_{Bn}$ that meet the design specs.