NE 205: Semiconductor Devices and IC Technology
Indian Institute of Science, Bangalore.
Autumn Semester 2019, Digbijoy N. Nath
Homework II Total points: 40

Plots must be quantitative, calculated exactly. Label the Y- and X-axes clearly. Use MATLAB or Mathematica, etc. Hand-drawn plots will fetch ZERO marks.

1. Gallium Oxide (Ga_2O_3) is an emerging ultra-wide band gap semiconductor with a band gap of 4.8 eV and an expected critical breakdown field of F_{crit} = 8 MV/cm. Thus, Ga_2O_3 devices can block much higher voltage than what is possible with any other semiconductor known to us.
   In Fig. 1, schematic of a Ga_2O_3 Schottky diode is shown with the top layer of thickness 'W' and a moderate doping N_D where a Schottky contact is formed with ϕ_B = 1 eV. Assume 100% ionization of donors. The bottom layer is super heavily n++ doped and an Ohmic contact is formed as shown. The electron mobility in Ga_2O_3 is 250 cm^2/Vs and the dielectric constant is ε = 10.
   You need to design the diode [i.e. find the range of W and N_D] such that it can block at least 1 kV in the OFF state but the ON-resistance in the conducting state should be no more than 0.1 mΩ-cm^2. Remember, nowhere in the diode should the field exceed the value of F_{crit}.
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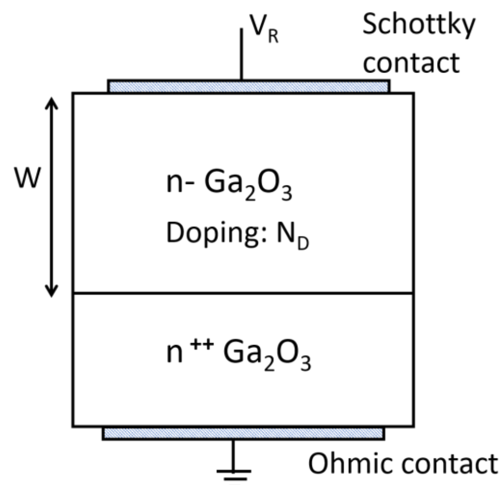

2. Consider a long silicon p-n diode with the following parameters:

   n-side doping = 10^{17} cm^{-3}

   p-side doping = 2×10^{17} cm^{-3}

   Minority carrier lifetime $\tau_n = \tau_p = 10^{-7}$ s

   Electron diffusion constant (D_n) = 40 cm^2/s

   Hole diffusion constant (D_p) = 10 cm^2/s

   Diode area = 10^{-4} cm^2

   Carrier lifetime in the depletion region = 10^{-8} s

a) Plot the total diode current (do not neglect generation-recombination component) from -5 V to +0.5 V, in semi-log plot. 2

b) Plot the maximum electric field in the junction as a function of applied reverse bias voltage. What is the reverse bias at which the junction breaks down? The breakdown field of silicon is 300 kV/cm. 2

3. Consider a piece of n-doped (N_D) silicon on which a metal is evaporated to make a Schottky junction with Schottky barrier height of ϕ_B = 0.35 eV. At room temperature, $N_C = 3.2\text{x}10^{19}$ cm^{-3}, and ε = 11.7 for silicon. For a fixed reverse bias of V_R = -2 V, plot the capacitance (F/cm^2) of this junction as a function of doping from $N_D = 10^{16}$ cm^{-3} to 10^{18} cm^{-3}. Also, plot the peak electric field of this junction for the same range of doping for the given V_R.
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[Note: Varying the doping means if the silicon had different doping densities from 10^{16} cm^{-3} to 10^{18} cm^{-3}; you may choose a few doping values in this range and estimate the capacitance and then do a scatter plot.]

4. Consider a slab of GaAs that is doped n-type with 10^{17} cm^{-3} with complete ionization of donors. For GaAs, $N_C = 5\text{x}10^{17}$ cm^{-3}. Consider a case where there are two surface defect levels of *equal* density – one donor-like, and one acceptor-like. The acceptor state is 0.3 eV below the conduction band edge and the donor state is 0.5 eV below the conduction band edge. How does the Fermi level pinning at the surface change as the areal density of each of these states is kept equal and varied from 10^{10} cm^{-2} to 10^{14} cm^{-2}? Plot the same to illustrate. Also, sketch the band diagram in equilibrium. 10

5.

a) An abrupt p+/n junction long-base diode is carrying a steady forward current I_F for t < 0. For t > 0, the diode current decays at $I_F \exp(-t/\tau p)$. Determine the stored charge $Q_p(t)$, and using the stored charge approximation, calculate the diode voltage as a function of time.
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b) An abrupt p+/n junction long-base diode has a reverse saturation current of 0.2 µA at 300 K. The diode is carrying a steady forward current of 5 mA for t < 0. At t = 0, the biasing battery is suddenly removed, and the circuit is left open. It is observed that the diode voltage reduces to two thirds of its steady-state value after 10 µsec. Calculate the hole lifetime in the neutral n-region of the diode. 6