S-69.3122 Semiconductor devices

Examination 8.3.2011

1. Explain the breakdown mechanisms in pn-diodes. (6 p)

2. (a) Explain the factors which determine the height of the Schottky barrier in a metal-semiconductor junction. (4 p)
   (b) Calculate the relative increase in the dc current in a metal-semiconductor diode at room temperature, when the applied voltage over the diode is increased from 0.5 V to 0.7 V. (2 p)

3. According to the simple model for the ideal bipolar junction transistor the dc current gain I_C/I_B (I_C = collector current, I_B=base current) does not depend on the collector current. However, in real transistors the measured current gain increases with increasing collector current at low currents and then decreases at high currents. Also the measured gain I_C/I_B is much smaller than the one predicted by the ideal model. Explain the reasons for the deviations of the above mentioned measured properties from those predicted by the simple model. (6 p)

4. In the modeling of the electrical properties of the semiconductor devices one typically uses either one-dimensional analytical models or two dimensional numerical simulations. Compare these two approaches and, especially, discuss the advantages and disadvantages of both modeling methods. (6 p)

5. Calculate the threshold voltage of a MOSFET, when the metal is aluminum (aluminum's work function ϕ_m =4.1V) and the electron concentration in silicon is $N_d = 10^{16}\ cm^{-3}$. The fixed oxide charge $Q_f/q = 5 \cdot 10^{10}\ cm^{-2}$ and the thickness of the oxide is $d = 0.1\,\mu m$, and except for the fixed oxide charge, the oxide is ideal. You can assume that V_{BS}=0 V. (6 p)

Constants:

$q = 1.602 \cdot 10^{-19}$ C $k_B = 1.38 \cdot 10^{-23}$ J/K $m_o = 9.109 \cdot 10^{-31}$ kg

$c = 2.998 \cdot 10^{8}$ m/s $h = 6.626 \cdot 10^{-34}$ Js $\mu_o = 4\pi \cdot 10^{-7}$ H/m

$\varepsilon_o = 8.854 \cdot 10^{-12}$ F/m

Silicon (T=300 K) : $N_C = 2.8 \cdot 10^{19}\ cm^{-3}$ $N_V = 1.04 \cdot 10^{19}\ cm^{-3}$

$n_i = 1.45 \cdot 10^{10}\ cm^{-3}$ $E_g = 1.12$ eV $\varepsilon_r = 11.9$ $qX = 4.05$ eV

$\mu_n = 1417\ cm^2/(Vs)$ $\mu_p = 471\ cm^2/(Vs)$

Silicon dioxide (T=300K): $\varepsilon_r = 3.9$ $qX = 1$ eV