University of California, Irvine EECS-170A Midterm Exam November 14th, 2007 4:00-5:20PM

Name: Student Id #

QUESTIONS

(20pt) 1. Two intrinsic silicon samples are tested at room temperature, T=300K, and T=X. The Fermi level at room temepreature is determined to be 0.1eV below the Fermi level measured at T=X
   a. Calculate temperature X
   b. What is the ratio of hole concentartions in both temperatures
   c. In order to achieve the same hole density by doping, how much and what type dopant per cm^3 should be added?

2. The effective mass of holes in a particular semiconductor is 10x larger than the effective mass of electrons at room temperature. If the bandgap of the semiconductor is 1.5eV and the intrinsic carrier concentration is 10^5 cm^{-3}, where is the Fermi level located with respect to the conduction band? Calculate to impurity concentration which is required to make this semiconductor p type with 0.2eV shifted Fermi level.

(20pt) 3. The mobility of holes in silicon drops linearly from 420 cm^2/V-s to 300 cm^2/V-s at room temperature when impurity level is increased from 10^{15} to 10^{17}. When 5V is applied to a 1cm long cylindrical p-type silicon rod with 0.1mm diameter how much current would be drawn from the source if the doping concentrations are N_d = 10^{13} and N_a = 0.5×10^{17} cm^{-3}. In the same semiconductor, an excess hole concentration of $p(x) = 10^{17} e^{-x/L_p}$ is created by an external excitation. Electron and hole recombination times are 0.2μs and 0.5μs, respectively. Calculate the total hole diffusion current passing through x=0 point (the front end) in the absence of the external voltage source.

(20pt) 4. A piece of silicon with 10^{16} cm^{-3} donor density forms a metallurgical junction with another piece of silicon where acceptor density is 10^{15} cm^{-3}. Calculate:
   a. Carrier concentrations and location of Fermi level before they form a junction at thermal equilibrium at 300K
   b. Calculate the width of the space charge region, built in voltage, total charge density at $x<-x_p$, $-x_p<x<$, $0<x<x_n$, $x>x_n$ and maximum electric field.
   c. Draw the band diagram and indicate your findings on the band diagram clearly.

(20pt) 5. A p-n junction silicon diode has a cross sectional area of $10^5 \mu m^2$ and operating at room temperature. Majority carrier concentrations in p and n regions at thermal equilibrium are given as 8×10^{15} and 1×10^{16} cm^{-3}, respectively. Minority carrier lifetimes and diffusion constants in n and p regions are 0.1μs, 1μs, 8cm^2/s and 23cm^2/s, respectively. Calculate
   a. Reverse saturation current of this diode
   b. The total number of excess electron distribution in p region under 0.5V forward bias voltage
   c. Total electron densities at $x=-x_p$ -1μm under 0.5V forward bias voltage
   d. Total electron and hole currents passing through $x=-x_p$ -1μm under 0.5V forward bias voltage

(4 pt) 6. What are the commonly used acceptors and donors in silicon? (4pt bonus question. 1pt per element).

$h = 6.626 \times 10^{-34}$ J-s	$k = 1.38 \times 10^{-23}$ J/K	$E_{g\text{-}Si} = 1.12$ eV
$m_0 = 9.11 \times 10^{-31}$ kg	1eV = 1.6×10^{-19}J	
$\epsilon_0 = 8.85 \times 10^{-14}$F/cm	$m_n^* / m_0 = 1.08$ in Si	

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$\in_{Si}$=11.7x$\in_0$ $m_p^* / m_0 = 0.56$ in Si