DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

3.225 Electronic and Mechanical Properties of Materials

Summer Term 2002

Problem Set #4
Due: Day #6

1. A silicon step junction diode with a cross-sectional area $A = 10^{-4}$ cm^2 has a doping of $N_A = 10^{17}$ cm^{-3} and $N_D = 10^{15}$ cm^{-3}. Let $\mu_e = 801$ cm^2/V·s and $\tau_e = 0.1\mu$s on the p-side; and let $\mu_h = 477$ cm^2/V·s and $\tau_h = 1\mu$s on the n-side.

   a) Calculate the current through the diode at room temperature ($KT/q = 0.026$ V) if

      (i) $V_A = -50$ V,
      (ii) $V_A = -0.1$ V, and
      (iii) $V_A = 0.2$ V.

   b) Assuming that the mobilities and lifetimes do not vary significantly with themperature, repeat part (a) for $T = 500$ K.

   c) Summarize in your own words what has been exhibited by this problem.

2. A forward-biased silicon diode is sold commercially as a temperature sensor. To use it to measure temperature, it is forward biased with a constant current source and V_A is measured as a function of T.

   a) Derive an equation for $V_A(T)$ by letting D/L for holes and electrons be independent of T using the energy gap dependence of

$$E_G = 1.17 - \frac{(4.73\times10^{-4})T^2}{(T+636)}(eV), \qquad \text{where } T \text{ is in K.}$$

   b) If $n_i = 1.5\ (10^{10})$ cm^{-3}, $kT = 0.026$ eV, $I_0 = 10^{-15}$ A, and $I = 10^{-4}$ A at room temperature (300 K), calculate a formula for $V_A(T)$ and plot it vs. T from 20ºC to 200ºC. Note it is nearly linear.

   c) Derive a formula for dV_A/dT (in mV/K) and determine the slope of the plot of part (b).

3. *P-n* junctions serve as the basis of photovoltaic solar cells. Sketch the I-V characteristics of a junction with

   a) no illumination,

   b) illumination with generation rate $G_L = G_{L0}$, and

   c) illumination with generation rate $G_L = 2G_{L0}$.

4. (Livingston) 16.10