Homework #10

Reading and Watching and Doing

- Watch YouTube videos for weeks 12 and 13.
- Kasap 5.4 – 5.8, 5.10 – 5.11

Problems

1. **ABACUS (nanoHUB.org)**
   a. Register for an account at nanoHUB (https://nanohub.org/register/). Log in to your account.
   b. Visit the ABACUS toolkit page.
      i. Proceed to the Bulk Semiconductors page.
      ii. Open the Drift Diffusion Lab page and click "Launch" to run the ABACUS toolkit.
      iii. Select "Drift Diffusion Lab"
   c. Explore the Drift Diffusion Lab
      i. The default tab should show "1. Apply Bias Only" as the selected experiment type.
      ii. Click the "Structure" tab and change the "Type of doping" to N-type. Change the doping level to 1e+16/cm3.
      iii. Click "Simulate" at the top of the right panel. IV Characteristics should be shown.
      iv. From the "Result" drop-down menu, select "Energy Band Diagram (at equilibrium)"
      v. Use the mouse to determine the position of the Fermi energy (in eV) below the bottom of the conduction band.
      vi. Changed the doping to P-type with a doping level of 1e+16/cm3. Where is the Fermi energy with respect to the top of the valence band.
      vii. For both dopings, explore the "Result" option "Energy Band Diagram (under non-equilibrium)".
      viii. Explore other tools in the Drift Diffusion Lab.

   For this homework problem, report the Fermi energy values from parts c.v. and c.vi and comment on your observations when viewing the Energy Band Diagram (under non-equilibrium).

2. **Photoconductivity (Kasap 5.23)**

Consider two *p*-type Si samples both doped with 10^{15} B atoms cm^{-3}. Both have identical dimensions of length L (1 mm), width W (1 mm), and depth (thickness) D (0.1 mm). One sample, labeled A, has an electron lifetime of 1 μs whereas the other, labeled B, has an electron lifetime of 5 μs.

a. At time $t = 0$, a laser light of wavelength 750 nm is switched on to illuminate the surface ($L \times W$) of both the samples (as show in Fig. 5.29 below). The incident laser light intensity on both samples is 10 mW cm^{-2}. At time $t = 50$ μs, the laser is switched off. Sketch the time evolution of the minority carrier concentration for both samples on the same axes.

b. What is the photocurrent (current due to illumination alone) if each sample is connected to a 1 V battery? (Note, from Fig. 5.19, at a doping concentration of 10^{15} cm^{-3}, $\mu_h = 450 \times 10^{-4}$ m^2 V^{-1} s^{-1} and $\mu_e = 1350 \times 10^{-4}$ m^2 V^{-1} s^{-1}).

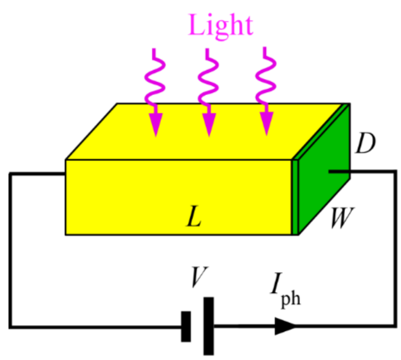

Figure 5.29 A semiconductor slab of length L, width W, and depth D is illuminated with light of wavelength λ. I_{ph} is the steady-state photocurrent.

3. **Schottky Junction (Kasap 5.34)**

a. Consider a Schottky junction diode between Au and *n*-Si, doped with 10^{16} donors cm^{-3}. The cross- sectional area is 1 mm^2. Given the work function of Au as 5.1 eV, what is the theoretical barrier height Φ_B from the metal to the semiconductor?

b. Given that the experimental barrier height Φ_B is about 0.8 eV, what is the reverse saturation current and the current when there is a forward bias of 0.3 V across the diode? (Use Equation 4.39.)

4. **Schottky and Ohmic Contacts (Kasap 5.36)**

Consider an n-type Si sample doped with 10^{16} donors cm^{-3}. The length L is 100 μm; the cross-sectional area A is 10 μm x 10 μm. The two ends of the sample are labeled as B and C. The electron affinity (χ) of Si is 4.01 eV and the work function Φ of the four potential metals for contacts at B and C are listed in Table 5.6 (below).

Table 5.6 Work functions in eV

Cs	**Mg**	**Al**	**Au**
2.14	3.66	4.28	5.1

a. Ideally, which metals will result in a Schottky contact?

b. Ideally, which metals will result in an Ohmic contact?

c. Sketch the *I-V* characteristics when both *B* and *C* are ohmic contacts. What is the relationship between *I* and *V*?

d. Sketch the *I-V* characteristics when *B* is ohmic and *C* is a Schottky junction. What is the relations-hip between *I* and *V*?

e. Sketch the *I-V* characteristics when both *B* and *C* are Schottky contacts. What is the relationship between *I* and *V*?