Homework #8

Reading

- Kasap 5.1, 5.2

Problems

1. Bandgaps and Photodetection

a. Determine the maximum value of the energy gap that a semiconductor, used as a photoconductor, can have if it is to be sensitive to yellow light (600 nm).

b. A photodetector whose area is 5×10^{-2} cm^2 is irradiated with yellow light whose intensity is 2 mW cm^{-2}. Assuming that each photon generates one electron-hole pair, calculate the number of pairs generated per second.

c. From the known energy gap of the semiconductor GaAs (E_g = 1.42 eV), calculate the primary wavelength of photons emitted from this crystal as a result of electron-hole recombination.

d. What part of the electromagnetic spectrum is the wavelength from part (c)?

e. Will a silicon photodetector be sensitive to the radiation emitted from a GaAs laser? Why or why not?

2. Intrinsic Ge

a. Using the values of the density of states effective masses m_e* and m_h* in Table 5.1 (below), calculate the intrinsic concentration in Ge.

b. What is n_i if you use N_c and N_v from Table 5.1?

c. Calculate the intrinsic resistivity of Ge at 300 K.

Table 5.1 Selected typical properties of Ge, Si, InP, and GaAs at 300 K

	E_g (eV)	χ (eV)	N_c (cm^{-3})	N_v (cm^{-3})	n_i (cm^{-3})	μ_e (cm^2 V^{-1} s^{-1})	μ_h (cm^2 V^{-1} s^{-1})	m_e^*/m_e	m_h^*/m_e	ε_r
Ge	0.66	4.13	1.04×10^{19}	6.0×10^{18}	2.3×10^{13}	3900	1900	0.12*a* 0.56*b*	0.23*a* 0.40*b*	16
Si	1.10	4.01	2.8×10^{19}	1.2×10^{19}	1.0×10^{10}	1400	450	0.26*a* 1.08*b*	0.38*a* 0.60*b*	11.9
InP	1.34	4.50	5.2×10^{17}	1.1×10^{19}	1.3×10^{7}	4600	190	0.079*a,b*	0.46*a* 0.58*b*	12.6
GaAs	1.42	4.07	4.4×10^{17}	7.7×10^{18}	2.1×10^{6}	8800	400	0.067*a,b*	0.40*a* 0.50*b*	13.0

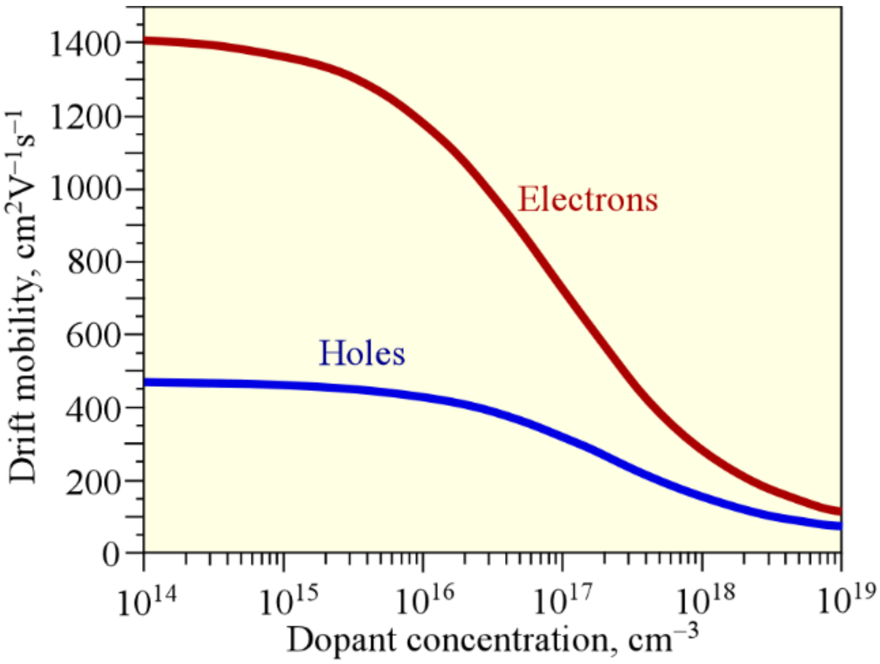
3. Extrinsic Si

a. A Si crystal has been doped with P. The donor concentration is 10^{15} cm^{-3}. Find the conductivity, and resistivity of the crystal. Use Kasap Table 5.1 (above) for carrier mobility.

4. **Extrinsic Si**

   a. Find the concentration of acceptors required for a *p*-type Si crystal to have a resistivity of 1 Ω cm. Use Kasap Table 5.1 (above) for carrier mobility.

   b. Near the doping concentration found in part (a), the carrier mobility is closer 350 $cm^2\ V^{-1}\ s^{-1}$ (see below Fig. 5.19 from Kasap). With this mobility, what is the necessary acceptor concentration?



Fig, 5.19. The variation of the drift mobility with dopant concentration in Si for electrons and holes at 300 K.

5. **Minimum conductivity**

   a. Consider the conductivity of a semiconductor, $\sigma = en\mu_e + ep\mu_h$. Will doping always increase the conductivity?

   b. Show that the minimum conductivity for Si is obtained when it is *p*-type doped such that the hole concentration is

$$p_m = n_i \sqrt{\frac{\mu_e}{\mu_h}}$$

   and the corresponding minimum conductivity (maximum resistivity) is

$$\sigma_{\min} = 2en_i\sqrt{\mu_e \mu_h}$$

   c. Calculate p_m and $\sigma_{\min}$ for Si and compare with intrinsic values.