Prob. 4.2

Find the separation of the quasi-Fermi levels and the change of conductivity when shining light.

The light induced electron-hole pair concentration is determined by:

$$\delta n = \delta p = g_{op} \cdot \tau = 10^{19} \frac{1}{cm^3 \cdot s} \cdot 10^{-5} s = 10^{14} \frac{1}{cm^3}$$

$\delta n \ll$ dopant concentration of $n_o = 10^{16} \frac{1}{cm^3}$ so low level

$$n = n_o + \delta n = 10^{16} \frac{1}{cm^3} + 10^{14} \frac{1}{cm^3} \approx 10^{16} \frac{1}{cm^3}$$

$$p = p_o + \delta p = \frac{n_i^2}{n_o} + \delta p = \frac{(1.5 \cdot 10^{10} \frac{1}{cm^3})^2}{10^{16} \frac{1}{cm^3}} + 10^{14} \frac{1}{cm^3} \approx 10^{14} \frac{1}{cm^3}$$

$$kT \text{ for } 450K = 0.0259eV \cdot \frac{450K}{300K} = 0.039eV$$

$$F_n - E_i = kT \cdot \ln\left(\frac{n}{n_i}\right) = 0.039eV \cdot \ln\left(\frac{10^{16} \frac{1}{cm^3}}{10^{14} \frac{1}{cm^3}}\right) = 0.18eV$$

$$E_i - F_p = kT \cdot \ln\left(\frac{p}{n_i}\right) = 0.039eV \cdot \ln\left(\frac{10^{14} \frac{1}{cm^3}}{10^{14} \frac{1}{cm^3}}\right) = 0eV$$

$$F_n - F_p = 0.18eV$$

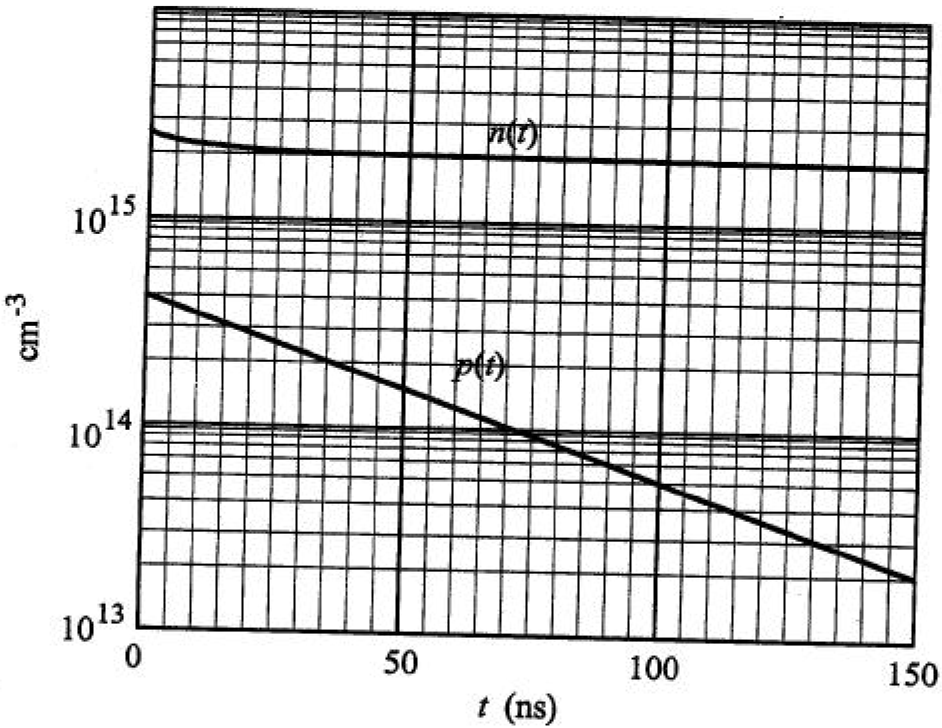
$$\mu_n = \frac{D_n}{\frac{kT}{q}} = \frac{36 \frac{cm^2}{s}}{0.039V} = 927 \frac{cm^2}{V \cdot s}$$

$$\mu_p = \frac{D_p}{\frac{kT}{q}} = \frac{12 \frac{cm^2}{s}}{0.039V} = 309 \frac{cm^2}{V \cdot s}$$

$$\Delta\sigma = q \cdot (\mu_n \cdot \delta n + \mu_p \cdot \delta p) = 1.6 \cdot 10^{-19} C \cdot (927 \frac{cm^2}{V \cdot s} \cdot 10^{14} \frac{1}{cm^3} + 309 \frac{cm^2}{V \cdot s} \cdot 10^{14} \frac{1}{cm^3}) = 0.0198 \frac{1}{\Omega \cdot cm}$$

Prob. 4.3

Plot n(t) and p(t) for τ=5μs Si with τ=5μs, $n_0 = 2\cdot 10^{15}\,\frac{1}{cm^3}$, *and* $\Delta n = \Delta p = 4\cdot 10^{14}\,\frac{1}{cm^3}$ *at t=0.*



Prob. 4.9

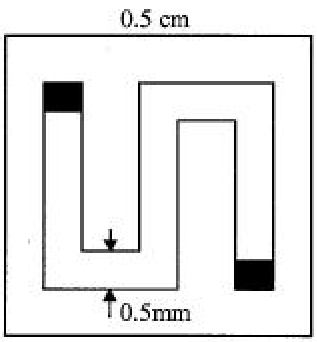
Design a 5μm CdS photoconductor with 10MΩ dark resistance in a 0.5cm square.

In the dark neglecting p_o,

$$\rho = \frac{1}{\sigma} = \frac{1}{q \cdot \mu_n \cdot n_o} = \frac{1}{1.609 \cdot 10^{-19}\mathrm{C} \cdot 250 \frac{\mathrm{cm}^2}{\mathrm{V \cdot s}} \cdot 10^{14} \frac{1}{\mathrm{cm}^3}} = 250\Omega \cdot \mathrm{cm}$$

$$R = \frac{\rho \cdot L}{w \cdot t} \rightarrow L = \frac{R \cdot w \cdot t}{\rho} = \frac{10^7\Omega \cdot w \cdot 5 \cdot 10^{-4}\mathrm{cm}}{250\Omega \cdot \mathrm{cm}} = 20 \cdot w$$

a number of solutions fulfill this L-w relation including that shown below with w=0.5mm and L=1cm



$$\rho = \frac{1}{\sigma} = \frac{1}{q \cdot [\mu_n \cdot (n_o + \delta n) + \mu_n \cdot \delta p]} = \frac{1}{1.609 \cdot 10^{-19}\mathrm{C} \cdot \left[250 \frac{\mathrm{cm}^2}{\mathrm{V \cdot s}} \cdot (10^{14} \frac{1}{\mathrm{cm}^3} + 10^{15} \frac{1}{\mathrm{cm}^3}) + 15 \frac{\mathrm{cm}^2}{\mathrm{V \cdot s}} \cdot 10^{15} \frac{1}{\mathrm{cm}^3}\right]} = 21.6\Omega \cdot \mathrm{cm}$$

$$R = \frac{\rho \cdot L}{w \cdot t} = \frac{21.6\Omega \cdot \mathrm{cm} \cdot 1\mathrm{cm}}{5 \cdot 10^{-2}\mathrm{cm} \cdot 5 \cdot 10^{-4}\mathrm{cm}} = 8.62 \cdot 10^5\Omega$$

$$\Delta R = 10^7\Omega - 8.62 \cdot 10^5\Omega = 9.14\mathrm{M}\Omega$$

Prob. 4.10

A 100mW laser (λ=632.8nm) is focused on a 100μm thick GaAs sample ($\alpha = 3\cdot10^4 \frac{1}{cm}$).
Find the photons emitted per second and the power to heat.

$$I_t = I_0 \cdot e^{-\alpha l} = 100\text{mA} \cdot e^{-3\cdot10^4 \frac{1}{cm}\cdot10^{-2}\text{cm}} \approx 0\text{mA so absorbed power is full } 100\text{mW} = 0.1\tfrac{J}{s}$$

$$\text{energy of one photon} = \frac{1.24\text{eV}\cdot\mu\text{m}}{0.6328\mu\text{m}} = 1.96\text{eV}$$

$$\text{power converted to heat} = \frac{1.96\text{eV-}1.43\text{eV}}{1.96\text{eV}}\cdot 100\text{mW} = 2.7\cdot10^{-2}\tfrac{J}{s}$$

$$\text{photons per second} = \frac{0.1\frac{J}{s}}{1.609\cdot10^{-19}\frac{J}{eV}\cdot 1.96\text{eV}} = 3.19\cdot10^{17}\,\frac{\text{photons}}{\text{second}}$$

or

$$\text{photons per second} = \frac{\text{power to photons}}{1.609\cdot10^{-19}\frac{J}{eV}\cdot\text{photon energy}} = \frac{0.073\frac{J}{s}}{1.609\cdot10^{-19}\frac{J}{eV}\cdot 1.43\frac{eV}{\text{photon}}} = 3.19\cdot10^{17}\,\frac{\text{photons}}{\text{second}}$$