Detection of Light. Problem Set 3

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1 Thermal excitation of extrinsic photoconductors

I a similar way as we did for intrinsic semiconductors, it can be shown from quantum mechanics that the concentration of negative carriers in a dopped n-type semiconductor is given by:

$$n = \left(\frac{N_D - N_A}{N_A + n}\right)\left(\frac{2}{\delta}\right)\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/2} e^{-E_i/kT}$$

where N_D and N_A are the concentrations of donors and acceptor respectively, δ is the ground state degeneracy of the donor impurity (very close to unity) adn E_i is in this case not the gap energy but the ionization energy for the n-type impurity.

Similarly, for p-type materials:

$$p = \left(\frac{N_A - N_D}{N_A + p}\right)\left(\frac{2}{\delta}\right)\left(\frac{2\pi m_p^* kT}{h^2}\right)^{3/2} e^{-E_i/kT}$$

Where it has been assumed that $E_i >> kT$.

a Consider a Si:Bo material. Is this a n-type, or p-type material? Use the value of the cutoff wavelength λ_c from the attached table to calculate the ionization energy of the impurity atoms. Is the latter assumption valid at room temperature? Is it valid at 77K, the temperature of liquid nitrogen?

b Use the attached table to calculate the absorption coefficient of a silicon crystal dopped with 10^{13} cm^{-3} boron atoms. How does this compare to the absorption coefficient calculated in Problem set 2 for intrinsic silicon? What would be a natural solution for the resulting low quantum efficiency?

c It is very hard to obtain a pure intrinsic material. Even at high purity levels obtained in the laboratory, boron impurities are very difficult to remove from the Si crystal. Typical concentrations of boron are of the order of 10^{13} cm^{-3}. What is the concentration of positive charges in such material if it is operated at 77K? What does this mean in terms of the conductivity of the material in dark conditions? What would be a possible solution for this situation?

2 Design of an extrinsic photoconductor

Design an arsenic-dopped photoconductor to operate near 20 μm at a temperature of 10K. Assume *transparent* contacts, a sensitive area of 1mm^2, an arsenic concentration of 10^{16} cm^{-3}, a mobility of 6×10^4 cm^2 V^{-1} s^{-1}, a recombination time of 3×10^{-9} s, and a breakdown voltage of 200 V cm^{-1}. Compute:

a The detector geometry that gives a thickness of one absorption length. What is the reflectivity of this material if we have determined that its quantum efficiency including reflection effects is 52%?

b The photoconductive gain.

c The responsivity.

d The detector resistance.

Compare this results with the intrinsic case.