Detection of Light. Problem Set 4

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1 Depletion region in BIB detectors

Consider a Blocked Impurity Band (BIB) silicon detector dopped with n-type (arsenic) impurities in its absorbing infrared-active layer. There is always certain amount of p-type impurities that are compensated by the n-type atoms. This creates a negative space charge accross the active layer, and hence an electric field that counteracts the positive bias (see handouts). The depletion region ends where those two elecric fields cancel out.

a If N_A is the density of ionized acceptors (usually of the order of $10^{13}\mathrm{cm}^{-3}$), solve the one-dimensional Poisson equation across the detector to derive an expression for the width of the depletion region as a function of the bias voltage V_b and the thickness of the blocking layer t_B. (see Lecture notes for useful hints).

b Suppose the bias voltage applied accros the BIB detector is $V_b = 4\,\mathrm{V}$ and the thickness of the blocking layer is $t_B = 4\,\mu\mathrm{m}$. What is the width of the depletion region?

c What is the value of the critical bias voltage for which the thickness of the depletion region is the same as the thickness of the infrared active layer, t_{ir}? Discuss the effects of the bias voltage on the quantum efficiency of the device.

d How does the electric fiel varies across the active layer, as a function of distance from the interface between the blocking and the active layer?

Note: The dielectric constant κ_0 for Si at room temperature is 11.8. The permitivity of free space is $\epsilon_0 = 8.854 \times 10^{-12}\,\mathrm{F\,m^{-1}}$.

2 Usefulness of photodiodes

Suppose you want to construct an intrinsic photoconductor from InSb in the 1-5 μm region.

a From the lecture handouts or your notes, retrieve the values of the recombination time τ and the mobility μ for this material. How do they compare to the values for silicon?

b Compute the photoconductive gain for the device as a function of the separation between the electrical contacts. Do the same for the resistance of the material, assuming an intrinsic concentration of carriers similar to that of Si ($n_0 = 10^{10}$ cm^{-3}).

c The breakdown voltage of InSb is very small. What possible ways can you think of to maximize both the resistance and the photoconductive gain, for fixed values of the other two dimensions, w and d? Which type of noise dominates if G is too small? Which type of noise dominates if R is too small?

d From the basic principles of operation of photodiodes, how can they help to solve this dilemma? Think in terms of the electrical properties inside and outside the depletion region.