Detection of Light: Exercise 3

Set: Fri 16th Feb 2017,
Due: Fri 23rd Feb 2017
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1 Carrier Mobility [2 marks]

a Calculate the conductivity of intrinsic Si at room temperature (T=293K). What is the fractional contribution of holes to this value?

(Take the intrinsic carrier density at this temperature to be $n_i = 4.8 \times 10^9$ cm^{-3} and the relative mobilities of electrons and holes to be $\mu_n = 1.35 \times 10^3$ cm^2 V^{-1} s^{-1}, $\mu_p = 480$ cm^2 V^{-1} s^{-1} respectively.)

[1 mark]

b What is the electron mobility in the same photodetector cooled to T=150K? State the physical reason for this temperature dependence.

[1 mark]

2 Design of an intrinsic photoconductor [8 marks]

Consider an intrinsic silicon photoconductor operating at 1 μm and constructed as shown in Fig. 1. Let its surface area $w = l = 1$ mm in a square pixel configuration, operating at room temperature. Assume the detector breaks down when the bias voltage, V_{b}, exceeds 50 mV.

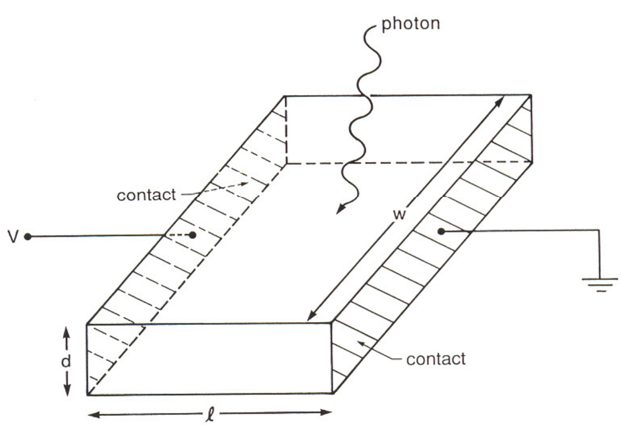

Figure 1: Photoconductor with transverse contacts.

a The minimum detector thickness required for good quantum efficiency corresponds to one absorption length (photon mean free path length) in the material.

i) Use the data in Fig. 2 to estimate the minimum detector thickness d for this detector. What is the corresponding quantum efficiency η of this detector, if reflection is neglected?

ii) What is a more realistic value of η, if reflection is now taken into account? Assume normal photon incidence on the detector surface and a refractive index for Si of $n = 3.4$.

[2 marks]

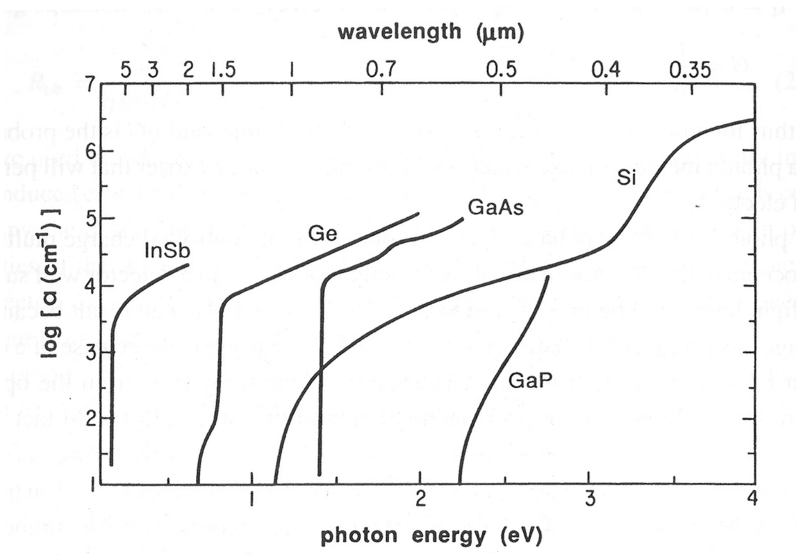

Figure 2: Linear absorption coefficients a for various semiconductors (on $\log_{10}$ scale).

b Calculate the responsivity S using your value of η in part a.ii, explicitly stating the units of your answer. The recombination time for Si under the given conditions is $\tau = 1 \times 10^{-4}$ s. Assume the detector is operated at 10 mV below the breakdown voltage. What is the probability of any given photon reaching the detector contact?

[2 marks]

c Calculate the dark resistance, and hence the dark current of our detector. Compare this to the photo-current obtained when illuminated by an astrophysical source with a photon flux of $\phi = 10^5\ \gamma/s$.

What do you notice? Why does your result *not* rule out this photoconductor for use as a detector?

(Again, take the electron concentration in Si to be $n_i = 4.8 \times 10^9$ cm^{-3}.)

[2 marks]

d Calculate the signal-to-noise ratio our photoconductor obtains for a 0.5s exposure of the source in part c), assuming only thermal Johnson (kTC) and G-R noise sources. State the factor limiting detector performance in this scenario, and suggest how this may be improved.

[2 marks]