Detection of Light: Exercise 2

Set: Fri 13th Feb 2015,
Due: Fri 20th Feb 2015

1 Carrier Mobility [3 marks]

a The mobility of electrons in a Si photodetector at room temperature (T=300K) is $\mu = 1.35 \times 10^3\,\mathrm{cm^2\,V^{-1}\,s^{-1}}$. What is its conductivity in $\mathrm{A}V^{-1}\,\mathrm{m}^{-1}$, given that the intrinsic carrier concentration of electrons in Si at this temperature is $n_0 = 1.5 \times 10^{10}\,\mathrm{cm}^{-3}$.

[2 mark]

b What is the electron mobility in the same photodetector T=250K? State the physical reason behind this temperature dependence.

[2 marks]

2 Design of an intrinsic photoconductor [11 marks]

Consider an intrinsic silicon photoconductor operating at 1 μm and constructed as shown in Fig. 1. Let its surface area, $wl = 1\,\mathrm{mm}^2$ in a square pixel configuration, operating at 300 K. Assume the detector breaks down when the bias voltage, V_b, exceeds 60 mV.

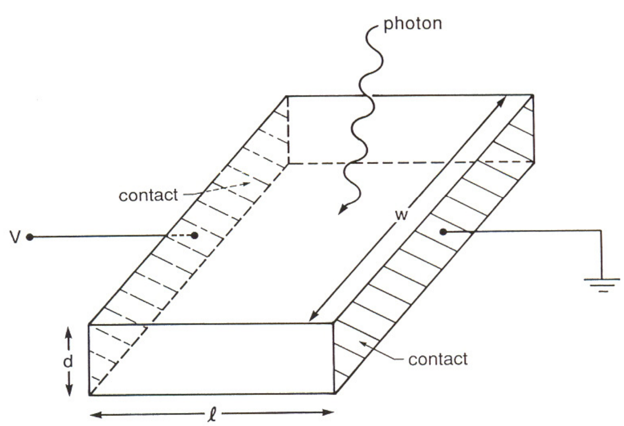

Figure 1: Photoconductor with transverse contacts.

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 calculate the minimum detector thickness d for this detector. What is the corresponding quantum efficiency η of this detector, if reflection is neglected?

[3 marks]

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 $n = 3.4$.

[1 marks]

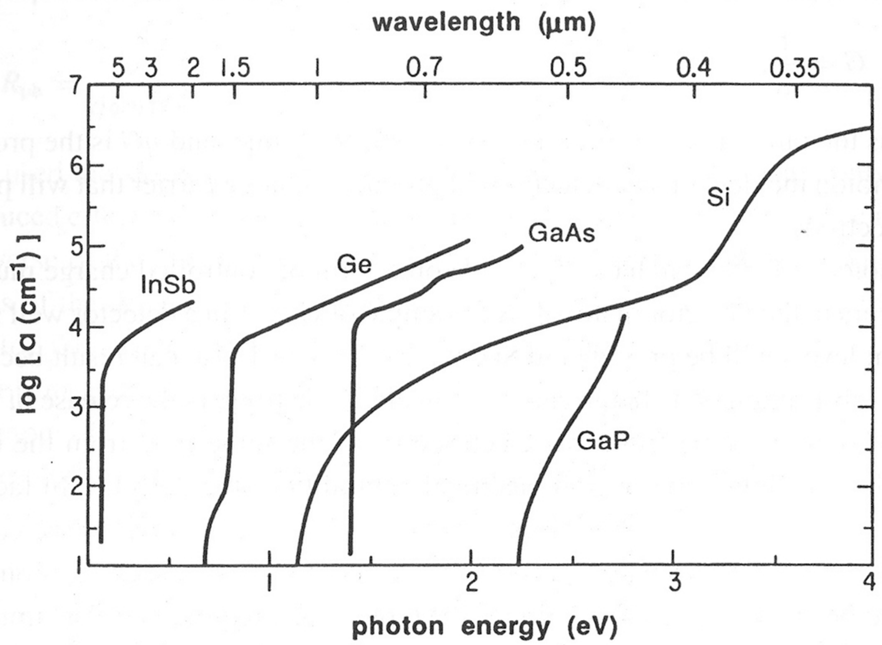

Figure 2: Linear absorption coefficients a for various semiconductors (on $\log_{10}$ scale).

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 photo-electron reaching the detector contact?

[3 marks]

c i) Calculate the dark resistance and hence dark current of the detector. Again, take the electron concentration in Si to be $n_0 = 1.5 \times 10^{10}$ cm^{-3}.

ii) Calculate the photo-current when the detector is illuminated by an astrophysical source with a photon flux of $\phi = 10^5\ \gamma/s$. What does this imply about the performance of a CCD made from these photoconductors, operating at room temperature?

[4 marks]

3 Detector Noise [6 marks]

For this question assume that the contribution of 1/f noise is negligible in all cases.

a Calculate the relative contributions of G-R and kTC noise for the detector in part 2, for an exposure time of 0.5s. In which noise regime is the detector operating?

[3 marks]

b i) Derive an expression for the Noise-Equivalent Power (NEP) in the high-temperature regime, and calculate its value.

ii) The detector is now cooled such that it operates in the the background-limited regime - calculate the new NEP value and contrast this with the answer to part i.

[3 marks]