Detection of Light. Problem Set 7

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1 Well Capacity in Charged Coupled Devices (CCDs)

We have seen in the lectures that when a voltage V_g is applied on the electrode of a single element of a CCD, photoelectrons produced in the semiconductor substrate will collect near the semiconductor-oxide interface, because they can not penetrate the insulator (see notes). The number of electrons Q_W that the resulting MOS capacitor can hold is the well capacity:

$$Q_W = C_0(V_g - V_T)$$

where V_T is the treshold voltage for the formation of a storage well and the capacitance C_0 is that of a plane parallel capacitor with area A and separation d:

$$C_0 = \frac{A\kappa_0\epsilon_0}{d}$$

a How many electrons can be collected in a MOS if the thickness of the oxide layer is 0.1 μm and the elctrode dimensions are 15 μm $\times$ 15 μm? Assume that a voltage difference of $V_g - V_T = 3V$ is applied.

b Conceptually, why can't more electrons be collected in the MOS capacitor?

2 Charge Transfer Efficiency in CCDs

When considering charge transfer efficiency from pixel to pixel in a CCD, an important mechanism to take into account is the self-induced drifting of electrons due to their mutual electrostatic repulsion when there is a large amount of accumulatd charge. We can derive a time constant for this process if we calculate the time that it takes for the charge to drift through the separation L_e between two neighboring electrodes when the voltages are adjusted. Assume that there are initially N_0 electrons in one electrode and none in the other electrode.

a Show that this time is approximately given by:

$$\tau_{\mathrm{SI}} \approx \frac{L_e}{\mu\epsilon_{21}} = \frac{L_e^2 C_0}{\mu N_0 q}$$

where C_0 is the capacitance associated with the electrode (see Problem 1) and μ is the electron mobility.

b What is the value of τ_{SI} for the MOS capacitor in Problem 1 if $N_0 = 3 \times 10^5$?