Semiconductor devices

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Optical devices

absorption

Optical absorption

$$\lambda ? \frac{c}{\nu} = \frac{hc}{E}$$

When light goes thorugh a solar cell, if $E_{textup} < E_g$ The light is not absorbbed, otherwise an electron is forced into the conduting band.

$$E_{ads} = \alpha I_v(x) dx$$

Is the energy adsorbed pr time. Iv is the photon flux, α the adsorption coeficcient., from fig 14.2

$$I_\nu(x+dx) - I_\nu(x) = \frac{dI_\nu(x)}{dx} \cdot dx = -\alpha I_\nu(x) dx$$
$$\frac{dI_\nu(x)}{dx} - \alpha I_\nu(x)$$

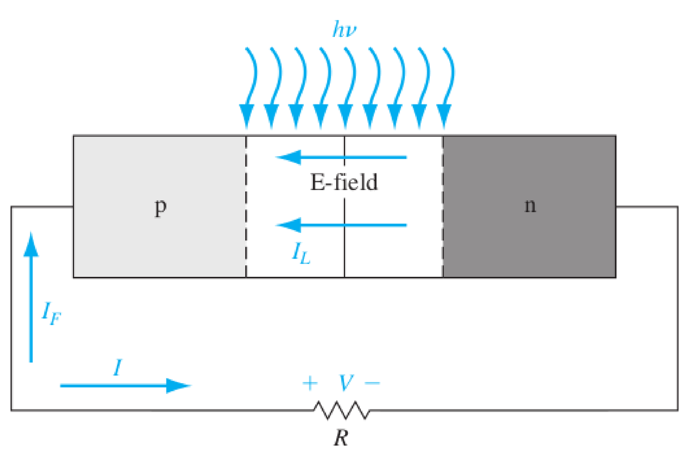
Initially $I_\nu(0) = I_{\nu 0}$

$$I_\nu(x) = I_{\nu 0} e^{-\alpha x}$$

Electron–Hole pair generation:

$$g' = \frac{\alpha I_\nu(x)}{h\nu}$$

Solar cells



A solar cell is a pn junction, with no voltage apllied. Consider a pn junction with a load:

$$I = I_L - I_F = I_L - I_S \left[\exp\left(\frac{V}{V_t}\right) - 1\right]$$

Where I_L is the photocurrent generated by the junction sweeping out the electrons generated in the space charge region, I_F is the forward bias generated by I_L going over the resistor. There are two limiting cases, Short circuit ($R = 0$, $V = 0$):

$$I = I_{SC} \qquad = I_L$$

And $R \to \infty$

$$I = 0 = I_L - I_S \left[\exp\left(\frac{V}{V_t}\right) - 1\right]$$
$$V_{OC} = V_t \ln\left(1 + \frac{I_L}{I_S}\right)$$
$$P = IV = I_L V - I_s \left[\exp\left(\frac{V}{V_t}\right) - 1\right] V$$
$$\frac{dP}{dV} = 0 = I_L - I_s \left[\exp\left(\frac{V_m}{V_t}\right) - 1\right] V - I_S \frac{V_m}{V_t} \exp\left(\frac{V_m}{V_t}\right)$$
$$1 + \frac{I_L}{I_S} = \left(1 + \frac{V_m}{V_t}\right) \exp\left(\frac{V_m}{V_t}\right)$$

The efficiency in solar cells is:

$$\eta = \frac{P_m}{P_{in}} \times 100\,\%$$
$$= \frac{I_m V_m}{P_{in}} \times 100\,\%$$
$$\text{fillfactor} = \frac{I_m V_m}{I_{SC} V_{OV}} \approx 0.7 - -0.8$$

To increase efficiency the solar cells multiple band gaps must be used. The real efficiency $\approx 10\,\% to 15\,\%$

Nonuniform absorption effects:

$$\text{number of adsorped photons} = \alpha \Phi_0$$
$$G_L = \alpha(\lambda)\Phi_0(\lambda)\left[1 - R(\lambda)\right] e^{-\alpha(\lambda)x}$$

generation

Photoluminescence and Electroluminescence

Electrons And holes can recombine in many ways, through doners/accepters, inbetween them nand through traps. As well as directly. The emmision range is:

$$I(\nu) \propto \nu^2 (h\nu - E_g)^{\frac{1}{2}} \exp\left[-\frac{h\nu - E_g}{kT}\right]$$

Efficiency:

$$\eta_q = \frac{R_r}{R}$$

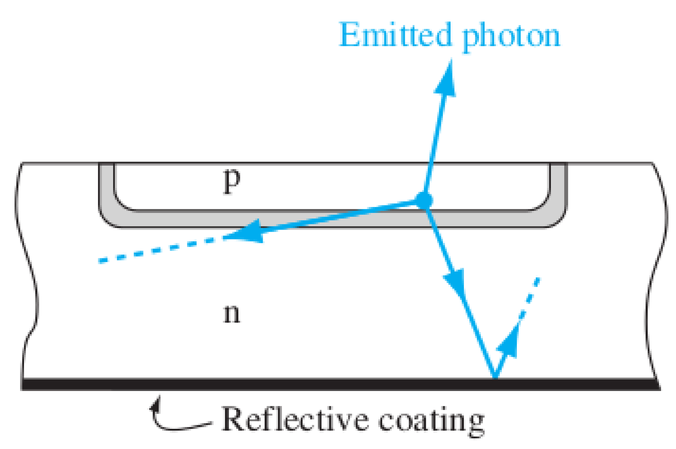
R_r is the radiating recombination rate

$$= \frac{\tau_{nr}}{\tau_{nr} + \tau_r}$$

τ_{nr} is nonradiative and τ_r is radiative

$$R_r = Bnp$$

Light emitting diodes



$$\lambda = \frac{hc}{E_g}$$

With applied voltage, minority excess carriers are injected and spewt to the natural area. If it's direct band to band light is emitted. (Ga is on p side). Internal quantum efficiency is the fraction of diode current that produces luminecence. three components are important:

$$J_n = \frac{eD_n n_{p0}}{L_n}\left[\exp\left(\frac{V}{V_t}\right) - 1\right]$$
$$J_p = \frac{eD_p p_{n0}}{L_p}\left[\exp\left(\frac{V}{V_t}\right) - 1\right]$$
$$J_r = \frac{en_i W}{2\tau_0}\left[\exp\left(\frac{V}{2V_t}\right) - 1\right]$$
$$\gamma = \frac{J_n}{J_n + J_p + J_R}$$

γ is the injection efficiency, now use a n^+p diode to make J_n largest

$$R_r = \frac{\delta n}{\tau_r}$$
$$R_{nr} = \frac{\delta n}{\tau_{nr}}$$
$$R = R_r + R_{nr} = \frac{\delta n}{\tau} = \frac{\delta n_r}{\tau_r} + \frac{\delta n_{nr}}{\tau_{nr}}$$
$$\eta = \frac{R_r}{R_r + R_{nr}} = \frac{\tau}{\tau_r}$$
$$\eta_i = \gamma\eta$$

External quantum efficiency: The fraction of generated photons that are *emitted*

$$\Gamma = \left(\frac{\bar{n}_2 - \bar{n}_1}{\bar{n}_2 + \bar{n}_1}\right)^2$$

Is the Fresnel loss, and describes the light lost through reflaction ($\bar{n}_1$ refraction index of air, $\bar{n}_2$ of the semiconductor). The critical angle:

$$\Theta_c = \sin^{-1}\left(\frac{\bar{n}_1}{\bar{n}_2}\right)$$