VE320 HW5 周维凯 518021911039

1. (a). $E = \frac{hc}{\lambda} = \frac{6.625\times10^{-34}\times3\times10^{8}}{6300\times10^{-10}} = 3.15\times10^{-19}\ J$

$P = \frac{1}{3.15\times10^{-19}} = 3.17\times10^{18}$ photon/s

$g = \frac{P}{V} = \frac{3.17\times10^{18}}{0.1} = 3.17\times10^{19}$ pair/cm$^3\cdot$s

(b). $\delta n = \delta p = g\tau = 3.17\times10^{19}\times10\times10^{-16} = 3.17\times10^{4}\ cm^{-3}$

2. (a). $p_0 = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a-N_d}{2}\right)^2 + n_i^2} = 10^{16}\ cm^{-3}$

$n_0 = \frac{n_i^2}{p_i} = \frac{(1.5\times10^{10})^2}{10^{16}} = 2.25\times10^{4}\ cm^{-3}$

$\delta n = g'\tau_{n0}\left(1-e^{-\frac{t}{\tau_{n0}}}\right) = 8\times10^{20}\times5\times10^{-7}\left(1-e^{-\frac{t}{5\times10^{-7}}}\right) = 4\times10^{14}\left(1-e^{-\frac{t}{5\times10^{-7}}}\right)$

$\sigma = e\mu_p p_0 + e(\mu_n+\mu_p)\delta n$

$= 1.6\times10^{-19}\times380\times10^{16} + 1.6\times10^{-19}(900+380)\times4\times10^{14}\left(1-e^{-\frac{t}{5\times10^{-7}}}\right)$

$= 0.608 + 0.08192\left(1-e^{-\frac{t}{5\times10^{-7}}}\right)\ (\Omega\cdot cm)^{-1}$

(b) (i). $\sigma = 0.608 + 0.08192(1-1) = 0.608\ (\Omega\cdot cm)^{-1}$

(ii). $\sigma = 0.608 + 0.08192 = 0.68992\ (\Omega\cdot cm)^{-1}$

3. (a). $D_n = \left(\frac{kT}{e}\right)\mu_n = 0.0259\times1200 = 31.08\ cm^2/s$

$L_n = \sqrt{D_n\tau_{n0}} = \sqrt{31.08\times10^{-6}} = 5.57\times10^{-3}\ cm$

$\delta n(x) = \delta p(x) = 2\times10^{14}e^{-\frac{x}{5.57\times10^{-3}}}\ cm^{-3}$

(b). $J_n = eD_n\frac{\partial(\delta n)}{\partial x} = 1.6\times10^{-19}\times31.08\times2\times10^{14}e^{-\frac{x}{5.57\times10^{-3}}}\times\left(-\frac{1}{5.57\times10^{-3}}\right)$

$= -0.179\exp\left(-\frac{x}{5.57\times10^{-3}}\right)\ A/cm^2$

$J_p = 0.179\exp\left(-\frac{x}{5.57\times10^{-3}}\right)\ A/cm^2$

4. (a). $P_{p_0} = 1\times10^{14}\ cm^{-3}$

$$n_{p_0} = \frac{n_i^2}{P_{p_0}} = \frac{(1.5\times10^{10})^2}{1\times10^{14}} = 2.25\times10^6\ cm^{-3}$$

(b). $\delta_n = n_p - n_{p_0} = -2.25\times10^6\ cm^{-3}$

(c). $$D_n \frac{d^2(\delta_n)}{dx^2} - \frac{\delta_n}{\tau_{n0}} = 0$$

$$\frac{d^2(\delta_n)}{dx^2} - \frac{\delta_n}{L_n^2} = 0$$

$$\delta_n = A\exp\left(-\frac{x}{L_n}\right) + B\exp\left(\frac{x}{L_n}\right)$$

Since $x \geq 0$, we have

$$\delta_n = -2.25\times10^6\ \exp\left(-\frac{x}{L_n}\right)$$

5. (a). $E_F - E_{Fi} = kT\ln\left(\frac{n_0}{n_i}\right)$

$$= 0.0259\ \ln\left(\frac{4\times10^{16}}{1.5\times10^{10}}\right) = 0.38\ eV$$

(b). $\delta n = \delta p = g'\tau_{p0} = 10^{15}$

$$P_0 = \frac{n_i^2}{n_0} = 5625$$

$$E_{Fn} - E_{Fi} = kT\ln\left(\frac{n_0+\delta n}{n_i}\right) = 0.0259\ \ln\left(\frac{4\times10^{16}+10^{15}}{1.5\times10^{10}}\right) = 0.38\ eV$$

$$E_{Fi} - E_{Fp} = kT\ln\left(\frac{P_0+\delta P}{n_i}\right) = 0.0259\ \ln\left(\frac{5625+10^{15}}{1.5\times10^{10}}\right) = 0.29\ eV$$

(c). $$E_{Fn} - E_F = (E_{Fn} - E_{Fi}) - (E_F - E_{Fi}) = 0.0259\ \ln\left(\frac{4\times10^{16}+10^{15}}{1.5\times10^{10}}\right) - 0.0259\ln\left(\frac{4\times10^{16}}{1.5\times10^{10}}\right)$$

$$= 6.4\times10^{-4}\ eV$$

6. (a)(i). $$\delta_p = g'\tau_{p0}\left(1 - \frac{sL_p\exp\left(-\frac{x}{L_p}\right)}{D_p + sL_p}\right)$$

$$= 10^{21}\times10^{-7}(1-0) = 10^{14}\ cm^{-3}$$

(ii). $L_p = \sqrt{D_p\tau_{p0}} = 10^{-3}$

$$\delta p = 10^{21}\times10^{-7}\left(1 - \frac{2000\times10^{-3}\exp\left(-\frac{x}{10^{-3}}\right)}{10+2000\times10^{-3}}\right) = 10^{14}\left(1 - 0.167\exp\left(-\frac{x}{10^{-3}}\right)\right)$$

(iii). $\delta p = 10^{21} \times 10^{-7} \left(1 - \exp\left(-\frac{x}{10^{-3}}\right)\right) = 10^{14} \left(1 - \exp\left(-\frac{x}{10^{-3}}\right)\right)$

(b). (i). $\delta p = 10^{14}\ cm^{-3}$

(ii). $\delta p = 8.33 \times 10^{13}\ cm^{-3}$

(iii). $\delta p = 0$