2019 spring OE Devices HW 5

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1.

(a) $h\nu_0 \sim E_g + \frac{1}{2}kT \Rightarrow E_g = h\nu_0 - \frac{1}{2}kT$

For $\lambda_0 = 822(nm)$, $T = 25 + 273 = 298(K)$

$\therefore E_g = 6.624\times10^{-34} \times \frac{3\times10^8}{822\times10^{-9}} - \frac{1}{2}\times1.38\times10^{-23}\times298 = 2.398\times10^{-19}(J)$

$= 1.499(eV)$

(b) For $E_g = 1.499(eV) \Rightarrow 1.424 + 1.266X + 0.266X^2 = 1.499$

$\Rightarrow 0.266X^2 + 1.266X - 0.075 = 0$

$\Rightarrow X = \frac{-1.266 \pm \sqrt{1.266^2 - 4\times0.075\times0.266}}{0.266\times2}$

取正值 $\Rightarrow X = 0.059$

$\therefore$ The composition of LED is $Al_{0.059}Ga_{0.941}As$

2.

(a) $\eta_{IQE} = \frac{1/\tau_r}{1/\tau_r + 1/\tau_{nr}} = \frac{1/\tau_r}{1/\tau} = \frac{\tau}{\tau_r}$

$\eta_{IQE} f_c = \frac{\tau}{\tau_r} \times \frac{1}{2\pi\tau} = \frac{1}{2\pi\tau_r}$

For a material, the life time of radiative process is fixed, and so is $\eta_{IQE} f_c$, η_{IQE} is inversely proportional to f_c

(b) $\eta_{IQE} = \frac{1/\tau_r}{1/\tau_r + 1/\tau_{nr}} = \frac{1/10\times10^{-9}}{1/10\times10^{-9} + 1/50\times10^{-9}} = 0.833$ $\quad f_c = \frac{1}{2\pi\tau} = \frac{1/\tau_r + 1/\tau_{nr}}{2\pi} = \frac{1/10\times10^{-9} + 1/50\times10^{-9}}{2\pi} = 1.91\times10^7$ (Hz)

For $\tau_{nr} = 25(ns)$:

$\eta_{IQE} = \frac{1/10\times10^{-9}}{1/10\times10^{-9} + 1/25\times10^{-9}} = 0.714$ $\quad f_c = \frac{1/10\times10^{-9} + 1/25\times10^{-9}}{2\pi} = 2.228\times10^7$ (Hz)

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3.

(a) For $\Phi_v = P_{out} \times 683 \times V(528nm)$

$\Rightarrow P_{out} = \frac{92}{683 \times 0.8} = 0.168\,(W)$

$\eta_{PCE} = \frac{P_{out}}{IV} = \frac{0.168}{(350\times10^{-3})\times3.4} = 0.141$ ※

$\eta_{EQE} = \frac{\Phi_{out}}{I/e} = \frac{P_{out}/h\nu}{I/e} = \frac{0.168 \times 1.6\times10^{-19}}{6.626\times10^{-34} \times \frac{3\times10^8}{528\times10^{-9}} \times 350\times10^{-3}} = 0.204$ ※

$\eta_{LE} = \frac{\Phi_v}{IV} = \frac{92}{350\times10^{-3}\times3.4} = 77.311\,(lm/W)$ ※

(b)

$\eta_{IQE} = \frac{1/\tau_r}{1/\tau_r + 1/\tau_{nr}} = \frac{1/25\times10^{-9}}{1/25\times10^{-9} + 1/106\times10^{-9}} = 0.8$

$\eta_{PCE} = \frac{P_{out}}{IV} = \frac{6.5\times10^{-3}}{30\times10^{-3}\times1.35} = 0.16$

$\eta_{EQE} = \frac{P_{out}/h\nu}{I/e} = \frac{6.5\times10^{-3}\times1.6\times10^{-19}}{30\times10^{-3}\times6.626\times10^{-34}\times\frac{3\times10^8}{870\times10^{-9}}} = 0.152.$

$\eta_{EE} = \frac{P_{out}/h\nu}{\eta_{IQE}\times\frac{I}{e}} = \eta_{EQE}\times\frac{1}{\eta_{IQE}} = 0.152\times\frac{1}{0.8} = 0.19$ ※