

ECEn 555, Fall 2009
Homework #4
Due October 26, 5:00 pm

4.1 Estimate the average luminance of a CRT screen of area 0.05 m^2 when it is operated with a beam current of $1 \text{ }\mu\text{A}$ and an accelerating potential of 15 kV . Assume the phosphor used has a power efficiency of 10% and peak emission at a wavelength of 500 nm .

4.2 It is desired to make a photodiode based on $\text{Ga}_x\text{In}_{1-x}\text{As}_y\text{P}_{1-y}$ grown on an InP substrate. Determine a suitable composition given that it is to be used at $1.55 \text{ }\mu\text{m}$. You may assume that lattice matching occurs when $y = 2.16x$, and that the lattice-matched bandgap is given by

$$E_g(\text{in eV}) = 1.36 - 0.72y + 0.12y^2$$

4.3 InGaAsP on InP substrate. The ternary alloy $\text{In}_{1-x}\text{Ga}_x\text{As}_y\text{P}_{1-y}$ grown on an InP crystal substrate is a suitable commercial semiconductor material for infrared wavelength LED and laser diode applications. The device requires that the InGaAsP layer is lattice matched to the InP crystal substrate to avoid crystal defects in the InGaAsP layer. This in turn requires that $y \approx 2.2x$. The bandgap E_g of the ternary alloy in eV is then given by the empirical relationship,

$$E_g \approx 1.35 - 0.72y + 0.12y^2; 0 \leq x \leq 0.47.$$

Calculate the compositions of InGaAsP ternary alloys for peak emission at a wavelength of $1.3 \text{ }\mu\text{m}$.

4.4 Direct bandgap pn junction. Consider a GaAs pn junction that has the following properties: $N_a = 10^{16} \text{ cm}^{-3}$ (p-side), $N_d = 10^{16} \text{ cm}^{-3}$ (n-side), $B = 7.21 \times 10^{-16} \text{ m}^3 \text{ s}^{-1}$, cross-sectional area $A = 0.1 \text{ mm}^2$. What is the diode current due to diffusion in the neutral regions at 300K when the forward voltage across the diode is 1 V ? You will need to look up the mobilities for GaAs from a reference source.

4.5 Crystal growth methods. What crystal growth techniques(s) would you employ and why if you were asked to grow the following:

- (a) a very pure layer of GaAs $20 \text{ }\mu\text{m}$ thick
- (b) a GaAs/AlGaAs heterostructure, where each layer is $0.2 \text{ }\mu\text{m}$ thick
- (c) a 50-period multiquantum well in which the well and barrier regions are each 20 monolayers thick.

4.6 Critical thickness. We would like to grow different compositions of SiGe on silicon. Assume that the lattice constant for the $\text{Si}_x\text{Ge}_{1-x}$ alloy is given by

$$a = a_{\text{Si}}x + a_{\text{Ge}}(1-x).$$

Plot the critical thickness for the SiGe layer grown on silicon as a function of Germanium percentage for the layer.