Tampere University of Technology
FYS-6106 Basic Semiconductor Technology
Exam, Tuesday K1705 12.12.2017, 13:00-16:00
Examiner: Antti Tukiainen, Optoelectronics Research Centre/Laboratory of Photonics, SL202

Obs.: Non-programmable calculator is allowed! Attached you can also find a separate sheet of formulas, tables and physical constants that can be used in the exam.
!Please remember to give feedback through the Kaiku-system to get the credit points from the course!

Answer to <u>FIVE (5)</u> questions!

Question 1. Explain the following terms:

a) Quasi-Fermi level
b) Charge carrier effective mass
c) Zinc blende lattice
d) Electron-hole pair
e) Einstein relation
f) Recombination center

Question 2. Explain shortly the following terms:

a) Photoelectric effect
b) Direct and indirect band semiconductors
c) Formation of population inversion in pn-junction

Question 3.
You need to design the active region (light generation region) of a light emitting diode (LED). The active region is to be formed using a quantum well (QW) made of $Ga_{0.5}In_{0.5}P$. The $Ga_{0.5}In_{0.5}P$ QW is sandwiched between 200 nm thick barrier layers made of $(Al_{0.5}Ga_{0.5})_{0.52}In_{0.48}P$. Determine the thickness of the QW so that its emission wavelength is 630 nm (the base level transition). Use the infinite potential well approximation. $m_n^*(Ga_{0.5}In_{0.5}P)=0.11*m_e$, $m_p^*(Ga_{0.5}In_{0.5}P)=0.45m_e$, $m_n^*((Al_{0.5}Ga_{0.5})_{0.52}In_{0.48}P)=0.1*m_e$, $m_p^*((Al_{0.5}Ga_{0.5})_{0.52}In_{0.48}P)=0.55m_e$, The energy band gaps are: $E_g(Ga_{0.5}In_{0.5}P)=1.88$ eV and $E_g((Al_{0.5}Ga_{0.5})_{0.52}In_{0.48}P)=2.3$ eV. Draw the energy band profile in the given structure.

Tip! For an infinite potential well: $E_n = \frac{n^2\pi^2(h_bar)^2}{2mL^2}$

Question 4. Explain the formation of pn-junction. Draw also energy band diagrams/profiles for each voltage configuration. Indicate also the formation of the contact potential and how the applied voltage is linked with the energy band diagram through the Quasi-Fermi levels.

Question 5. Compare different (photo)lithography techniques. Give the pros and cons for each method. Indicate also the obtainable feature size range for each of the discussed method and physical background for the resolution.

Question 6. A Si p-n junction has a donor doping of 5×10^{16} cm^{-3} on the n-side and a cross-sectional area of 10^{-3} cm^2. If $\tau_p=1\mu s$ and $D_p=10$ cm^2/s, calculate the current with a forward bias of 0.5 V at 300 K.

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Question 7. A Schottky barrier is formed between a metal having a work function of 4.3 eV and p-type Si (electron affinity=4 eV) The acceptor doping in the Si is 10^{17} cm^{-3}.

a) Draw the equilibrium band diagram, showing a numerical value qV_0.
b) Draw the band diagram with 0.3 V forward bias. Repeat for 2 V reverse bias.