Exam Device Physics 3-4-2014 14:00-1700

Write the answer to each of the 6 questions on a separate sheet. Please put your name and study number on each sheet. Total 100 points

Question 1

Consider a PN junction with doping donor concentration N_D and acceptor concentration N_A

a) Draw and explain the band structure of a PN junction. Describe why depletion regions are formed. Give the expression for the widths of the depletion regions in the P and N regions. (4pt)

b) Describe how/if the band diagram changes for equilibrium, forward and reverse direction. Make drawings. (4pt)

c) Give the expression for the I/V characteristics of a PN junction. (3pt)

d) Describe a few mechanisms which can lead to non-ideal behavior of the PN junction. (3pt)

Consider a NPN system, where a P doped semiconductor (thickness D) is in between two N-doped semiconductors. Assume that the doping concentrations in N and P are equal.

e) Give the schematic band diagram for two cases: 1) The depletion width is (much) shorter than the thickness D. 2) The thickness D is (much) shorter than the depletion width. Please explain if there is a difference and why. (4pt)

f) Describe (approximately) the I/V characteristics for both cases. (4pt)

Question 2

Electrons (with effective mass m*) are confined (by hard wall potentials) in a box with length L, width W and thickness D. The Fermi energy is E_f.

a) Describe what the thickness D should be to realize a two-dimensional electron system (assume that L and W are large (or infinite)) (4 pt)

b) Describe what the thickness D and W should be to realize a one-dimensional system (assume that L is large (or infinite)) (4 pt)

c) Calculate the electrical conductance of a one-dimensional ballistic electron system, which connects two reservoirs. Show that it is quantized. (3pt)

d) The conductance can be different from the quantized value. Give some reasons why it can be lower, and why it can be higher. (3pt)

Now impurities are added, which can scatter the electrons. The mean free path is l. The length of the one-dimensional channel is L.

e) Give an expression (or estimate) for the electrical conductance for two cases: $l \ll L$, and $L \gg l$. (3pt)

Question 3

a) Define magnetization of a ferromagnetic material. (5 pt)

b) Name three important contributions to magnetic anisotropy. (4 pt)

c) Give a key difference between electrical conduction in a ferromagnetic material (such as Co) and a metal (such a Cu). (5 pt)

Question 4

a) Describe a simple giant magneto resistance (GMR) device and briefly explain the phenomenon of GMR. (7 pt)

b) What are the two common device configurations used for measuring a GMR device? (3 pt)

c) Give a practical application of a GMR device. (3 pt)

Question 5

a) Describe briefly the difference in physical properties (electronic structure and transport properties) between organic, inorganic semiconductors and nanocrystals. (6pt)

b) Optical transitions are fundamental in determining the working mechanism of optoelectronic devices. Which are the main optical transitions and how their efficiency is defined? (6pt)

Question 6

a) Describe the working mechanism and draw the energy/band diagrams of organic and inorganic LEDs. (6 pt)

b) Which are the absolute and physiological figure-of-merit for the efficiency of a LED? (5 pt)

c) Describe the working mechanism and draw the energy/band diagrams of organic and inorganic solar cells. (6 pt)

d) Discuss their similarities and differences between the 2 classes of solar cells. (5 pt)