Exam Physics of Electronic Devices (April 2006)

Exercise 1

A new undoped semiconducting material for application in light-emitting diodes has been developed. A device is constructed by putting electrodes on this material and a current voltage characteristic is recorded
a) What experiment would you suggest to determine whether the current is injection-limited or limited by the bulk conduction properties of the semiconductor.

For classical semiconductors a number of models have been developed to describe the injection of charges into the semiconductor
b) Explain the main difference between thermionic emission and diffusion theory
c) Which injection mechanism will dominate the current at very high fields?
d) For conducting polymers none of the classical theories are applicable, they strongly overestimate the temperature dependence of the injection current. Explain why.

Exercise 2

Conjugated polymers are presently used in a number of semiconducting devices as light-emitting diodes, transistors and solar cells. An important process in these devices is the charge transport.
a) Explain why the charge carrier mobility in conjugated polymers is orders of magnitude lower as compared to inorganic materials as silicon.
b) What is the origin of the strong temperature dependence of the charge transport in conjugated polymers?

In polymer LEDs it has recently been found that the charge carrier mobility not only depends on the electric field, but also on the charge carrier density. This will also affect the spatial distribution of the electric field in a single carrier (hole-only) device.
c) Explain why for a field-dependent mobility the electric field at the extracting contact is reduced , whereas for a density dependent mobility the field is enhanced (both compared to the case of a constant mobility).
d) Give suggestions how the efficiency of polymer LEDs can be further enhanced.

Exercise 3.

a) Describe the basic operation of a single electron transistor. Make a drawing and describe all the relevant charges.
b) Make an estimate of the smallest charge it can measure. Describe what the parameters of the system (size, temperature, capacitance etc.) should be to used be able to measure the smallest charge possible.
c) Describe how you would fabricate a single electron transistor. Describe in detail the various steps (lithography, etching, evaporation etc). In total some 10 fabrication steps should be described.

Exercise 4.

A Schottky diode is used to rectify an alternating (AC) current.

a) Compare a Schottky diode with a p-n diode. What are the most important differences?
b) Design a Schottky diode which has to be able to pass a current of 100 mA in the forward direction. The voltage drop in the forward direction should be as small as possible.

Take into account the following aspects:

- Choice of semiconductor
- doping (p or n) and doping concentration
- area of the junction
- choice of metal
- choice of Ohmic back contact

c) Give the band structure for the case of: no bias, forward bias, and reverse bias
d) Desrcibe the various mechanisms which can affect the transport.