VAKGROEP ELEKTRONISCHE COMPONENTEN, TECHNOLOGIE EN MATERIALEN

Examination Solar Cells (ET4-149)

This examination consists of 7 tasks. Give short and concise answers to the tasks. Use the enclosed appendices A and B to carry out the calculations.

TASK 1: (15 points)

a) Working of a solar cell is based on the photovoltaic effect. What is the photovoltaic effect and which are the fundamental processes behind this effect?
b) Demonstrate these processes schematically using a sketch of a solar cell (use a single junction amorphous silicon solar cell on glass as an example).
c) Draw the corresponding band diagram of an amorphous silicon solar cell.

TASK 2: (20 points)

A 350-micrometer thick crystalline silicon wafer is doped with 1×10^{17} acceptors per cubic centimeter. An emitter layer of 1 micrometer is formed at the surface of this wafer with a uniform concentration of 5×10^{20} donors per cubic centimeter. Assume that all doping atoms are ionized. The intrinsic carrier concentration in silicon at 300 K is $n_i = 1.18 \times 10^{10}$ cm^{-3}.

How large is (at 300 K and thermal equilibrium):

a) The electron and hole concentration in the p-type and n-type region, respectively? Which charge carriers are the majority carriers in the p-type region and what is their concentration?
b) What is the position of the Fermi level (in eV) in respect to the conduction band in the p-type and n-type region, respectively? Draw the corresponding band diagram of the p-n junction.
c) the built-in voltage of the p-n junction?
d) the width of the depletion region of the p-n junction. Give your answer in micrometers and also as a percentage of the total thickness of the Si wafer. Which doped region forms the larger part of the depletion region?

TASK 3: (10 points)

a) Draw a schematic structure of an amorphous silicon (a-Si:H) single junction solar cell. Sketch the IV characteristics of a typical a-Si:H solar cell at the standard illumination and discuss the external parameters of the cell.
b) The measurements of the illuminated IV characteristics of an a-Si:H solar cell show that the fill factor of the cell is low. Give at least 2 possible reasons for the low fill factor.
c) One of the problems in a-Si:H solar cells that lowers the performance of the cell is the high series resistance. Explain what the cause of the series resistance can be and point out two places in the a-Si:H solar cell where the problem of a high series resistance can occur.

TASK 4: (20 points)

a) Explain the fundamental difference in the working between a crystalline silicon and an amorphous silicon solar cell.

b) Draw the band diagrams for both types of solar cells. Sketch the IV characteristics in dark and under standard illumination for both types of solar cells. How can you determine from the IV characteristics, which type of solar cell you measure?
c) What is a typical thickness of the active silicon layers in a conventional crystalline silicon solar cell and in a single junction amorphous silicon solar cell? Which material properties determine the thickness of the active layers?
d) Explain the approaches how to make the crystalline silicon solar cell thinner without influencing the efficiency.

TASK 5: (15 points)

a) Family Black has on the roof of their house place for 4 solar modules (the description of the modules is given below). They decide to place 4 solar modules on their roof using a campaign of Greenpeace, in which their offer a complete solar cell system (with 4 modules) for the price of 1000 €. How many years has to use family Black the solar system to earn the costs of the system back?
b) The total use of electricity in the Netherlands is at the moment 80 TWh per year. What is the total area of solar cells that is needed to generate this electricity consumption in the Netherlands. (Use the same modules as family Black)

Given:
The module efficiency is 12 % and the area of the module is 1 m^2. The lifetime of the module is 25 years. The PV system is placed in The Netherlands where an average price of conventional electricity is 0.22 € per kWh.

TASK 6: (10 Points)

a) Name at least three other types of solar cells than the solar cells based on silicon. What is the status of these solar cells (efficiency)?
b) Draw the basic structure of a Dye-Sensitized solar cell. Explain how the carriers are generated in a Dye-Sensitized solar cell.

TASK 7: (10 Points)

a) What are the major steps in the production of crystalline silicon solar cell (start with the natural source of silicon)?
b) Name four major efficiency losses in a crystalline silicon solar cell? Explain them briefly.