Exam Solar Energy (195740040)

Master Sustainable Energy Technology, University of Twente

Date: April 12, 2016
Time: 8:45-11:45 h
Location: Sportcentrum

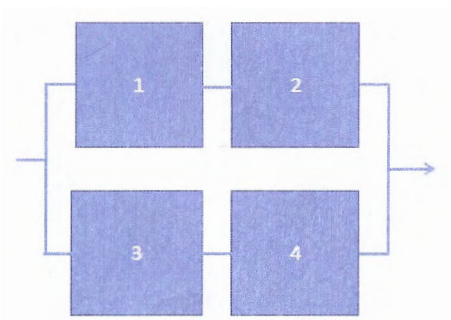
This exam consists of 4 questions each yielding 25 points out of a total of 100 points.Please indicate on each page your name and initials, your student number and the number of the exercise. It is allowed to fill in your answers in Dutch.

1. **Irradiance**
   a. What is an AM0 spectrum?
   b. What is an AM1.5 spectrum?
   c. Calculate the Sun's zenith angle at AM1.5 conditions.
   d. What is diffuse irradiance?
   e. What is the percentage of diffuse irradiation with respect to the global irradiation over one year?

2. **Solar cells' energy band diagrams**
   a. Draw and explain in words the energy band diagram of a solar cellwhich:
      1. contains a homojunction made of an inorganic semiconductor material with a band gap of 1.1 eV,
      2. contains a heterojunction made of inorganic semiconductor materials with band gaps between 0.9 and 1.8 eV, and
      3. which is made of polymer organic semiconductor materials.

   b. In a triple junction solar cell, solar cells are stacked in series to increase their efficiency. If E_{g1} is the band gap of the top cell (which is exposed to irradiance), E_{g2} the band gap of the middle cell and E_{g3} the band gap of the bottom cell, how do these band gaps relate to each other and how these cellsuse the available AM1.5 solar spectrum? Which cell out of 3 will have the highest current and which one will have the highest voltage?

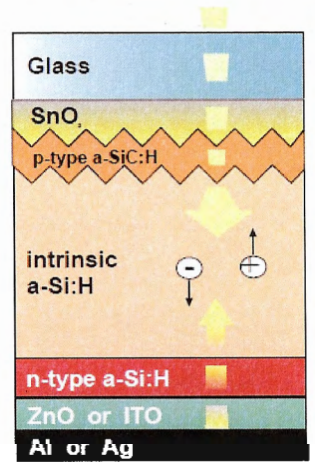
3. **IV curves and shading**
   a. Give the formula for the two-diode equation.
   b. Draw a schematic IV curve for a crystalline silicon solar cell with a theoretical V_{oc} of 0.7 V and a J_{sc} of 30 mA/cm^2 under one sun at AM1.5 conditions.
   c. Below an electrical circuit for a combination of 4 identicalstandard sized solar cells (with a $V_{oc}$and a J_{sc}similar to b) is shown. What are the $V_{oc}$and $I_{sc}$for this circuit under AM1.5 conditions?



d. 50% of the surface of the solar cell which is numbered 4, will be fully shaded by a piece of card board. How will the IV curve of solar cell 3 be, compared to an IV curve of a fully lit solar cell? Please draw and explain your answer in words.
e. Given the situation described at d, how will this circuit's IV curve be, compared to the IV curve of a fully lit circuit of 4 solar cells? Please draw and explain your answer in words.

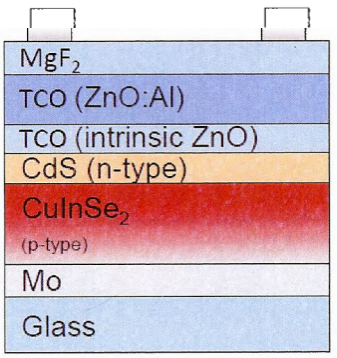
4. Thin film photovoltaic solar cells

1. Below a schematic cross section of a typical amorphous silicon solar cell is shown:



a. Describe, or draw if necessary, four significant differences of amorphous silicon solar cells comparedto crystalline silicon solar cells regarding amorphous silicon's material structure, the design of the a-Si solar cell, its thickness and its electrical functioning.
b. What is the typical efficiency of a-Si solar cells made in an R&D lab and as applied in commercially available PV modules?

2. Below a schematic cross section of a typical CIGS solar cells is shown:



a. What does CIGS mean?
b. Describe, or draw if necessary, two significant differences of CIGS solar cells compared to crystalline silicon solar cells regarding CIGS's material structure andCIGS solar cells' energy band diagram.
c. What is the typical efficiency of CIGS solar cells made in an R&D lab and as applied in commercially available PV modules?