Solar cell technology

ECTS credits: 5hp

Course period: September 2016

Target group: PhD students from Engineering sciences, Physics and Chemistry. Master students at an advanced level.

Form of examination: Home exam. Pass is the only given grade.

Responsible: Tobias Törndahl (tobias.torndahl@angstrom.uu.se)

Goals:
After passed examination the student is expected to be able to:

- Describe the device structure and performance of CIGS-, CZTS-, Perovskite- and Si-based solar cells.
- Discuss the most recent development and future challenges within the field.
- Explain how solar cells are interconnected into solar cell modules and how a solar cell module behaves electrically as compared to a single solar cell.
- Evaluate several methods for electrical characterization of solar cell devices.
- Discuss the current situation for PV installations and the solar cell market.

Contents:
The course is given in autumn 2016 and consists of 10 lectures together with one home exam. The focus is on solid state solar cell technology, with emphasis on thin film solar cell devices based on $CuIn_{1-x}Ga_xSe_2$ (CIGS) and $Cu_2ZnSnS_{4-x}Se_x$ (CZTS). For both CIGS and CZTS, an introduction to the fundamental material and electrical properties is performed. Loss mechanisms for absorbers with varying thickness and different window layer structures are discussed. The most recent development in the field and future challenges for high efficiency solar cells are addressed.

In addition, overviews of recent device development within the fields of Silicon solar cell technology and Perovskite solar cells are presented.

Several fundamental electrical and electro-optical methods of analysis for characterization of the solar cell electrical device performance are outlined. The topic of module technology is discussed.

A presentation of the current solar cell market, installations and regulations is given.

Lectures:
An introduction to the course is given by Tobias Törndahl at the second lecture.

Lecture 1, 2016-09-06 at 13:15-15:00 in 3419 (Johan Lindahl)
Presentation of the solar cell market of today. Current trends in installations, economic support systems and legal regulations for commercial solar cell systems.

Lecture 2, 2016-09-07 at 13:15-15:00 in 3419 (Marika Edoff)
Introduction to the IV-curve and the equivalent circuit. Description of individual layers and their function in CIGS-based devices. Parallels to silicon solar cells and other types of thin film devices.

Lecture 3, 2016-09-09 at 13:15-15:00 in 3419 (Marika Edoff)
Introduction to CIGS solar cells – bad gap grading, high efficiency devices, loss mechanisms and KF post deposition treatment. Recent innovations and future challenges.

Lecture 4, 2016-09-14 at 13:15-15:00 in 3419 (Carl Hägglund)
Thin absorber layers for low cost solar cells. Light absorption in sub micrometer absorbers down to ultra-thin layers below 100 nm. Light management, nano-optics, plasmonic effects and trade-offs including interface losses.

Lecture 5, 2016-09-16 at 13:15-15:00 in 3419 (Jonathan Scragg)
Introduction to CZTS solar cells – fundamentals and methods. Current state of research and future challenges.

Lecture 6, 2016-09-19 at 13:15-15:00 in 3419 (Tobias Törndahl)
Available window layer structures for CIGS and CZTS solar cells and their respective properties. Interface formation, band alignment and loss mechanisms from quantum efficiency.

Lecture 7, 2016-09-20 at 13:15-15:00 in 3419 (Bart Vermang)
Silicon solar cell technology: A review of the technologies currently used for the fabrication of crystalline Si PV cells, from classic industrial Si solar cells to upcoming novel cell concepts (e.g. PERL, HIT, IBC …).

Lecture 8, 2016-09-22 at 13:15-15:00 in 3419 (Gerrit Boschloo)
Perovskite solar cells are a new emerging technology, which has reached certified efficiency values of 20.1% within a few years or active research. The organometallic semiconductor $CH_3NH_3PbI_3$ is solution processable and crystallizes in the perovskite structure. Complete solar cells can be made at low temperature using non-vacuum techniques at very low cost.

Lecture 9, 2016-09-27 at 13:15-15:00 in 3419 (Uwe Zimmermann)
Electrical and electro-optical measurement methods for characterization of solar cells. Current-voltage, current-voltage as a function of temperature, quantum efficiency, etc.

Lecture 10, 2016-09-29 at 13:15-15:00 in 3419 (Uwe Zimmermann)
Introduction to module technology. Module design based on wafer, substrate and superstrate configurations. Strategies for interconnects, encapsulation and chemical stability. Electrical characterization of modules.