Physics of Solar Cells: from basics to nanoscience

Les Houches School of Physics, 25-30 March 2018

http://sunlit-team.eu/pv-school-2018/

This school will be focused on the physics of solar cells. The goal is to cover the fundamental and basic aspects of photovoltaic devices, and the most advanced concepts that enable the highest efficiencies. It will be shown that the recent progress of the different technologies (silicon, thin-films,…) are based on similar concepts and should mutually inspire each other. A special emphasis will be given to nanoscience and nanotechnologies, which bring new tools and concepts to break the limits of conventional solar cells.

Starting from a general introduction (thermodynamic and device engineering approaches), an overview of the technologies (Si, CIGS, CdTe, III-V, perovskite,…) will first focus on the main trends and challenges. Then, the key aspects of the design and fabrication of solar cells will be reviewed: modeling, photonics, fabrication processes, advanced characterization, interfaces and heterostructures. Initiation of device modeling with an evening practical work will be proposed. Beyond the Shockley-Queisser limit, advanced concepts for high-efficiency solar cells will be also discussed: multi-junction solar cells (including tandem on Si), hot-carriers, intermediate-band, spectral conversion,…

The targeted audience is focused on young scientists (PhDs or post-docs), but senior scientists new to the field of PV, or wishing to enlarge their knowledge in nanoscience and nanotechnologies are also very welcome.

Organized by the CNRS and IPVF:

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Financial support: The PV School 2018 is supported by the Center for Nanoscience and Nanotechnology (C2N), CNRS, the NanoSaclay labex, the Institut Photovoltaïque d'Ile-de-France (IPVF), and the MultiScale COST European program.

For more information, check the school's website: ***http://sunlit-team.eu/pv-school-2018/***
or send an email to the organizers: mailto:pvschool2018@c2n.upsaclay.fr

Lectures (this program can be subject to changes):

Lectures will begin on Monday morning (9:00) and will end Friday noon (12:00). Most topics will begin with an overview, followed by focus on advanced techniques, "hot" topics or "nanoscience" aspects.

(1) General introduction

Keywords: thermodynamics approach, theoretical limits, fundamental working principles…

Description: The goal will be to introduce the general principles of solar cell operation using different approaches: a thermodynamic point of view, and a description of the basic operating principles closer to an engineering approach.

(2) Overview of technologies

Keywords: c-Si, CIGS, CdTe, CZTS, III-V, perovskite,…

Description: The overview of the different technologies will focus on the description and limits of conventional devices, and the main trends of current researches.

(3a) Modeling

Keywords: Multiscale modeling. Device and optical modeling.

Description: This lecture will be focused on device and optical modeling. A special care will be given to multiscale modeling, and to the domain of validity of each method. Initiation of device modeling with an evening practical work will be proposed; it will illustrate the working principle of a PV cell.

(3b) Photonics

Keywords: Theory of light trapping. Random scattering. Periodical patterns. Ultrathin solar cells.

Description: Sunlight absorption is a prerequisite for any solar cell. The goal of this lecture is to describe the different strategies for light trapping, from a theoretical and practical point of view. Applications to ultrathin solar cells will be reviewed.

(4) Fabrication

Keywords: Bottom-up and top-down techniques. Micro- and nano-fabrication technologies.

Description: A general introduction to solar cell fabrication will be presented, and bottom-up and top-down techniques will be detailed. Beyond conventional fabrication techniques, micro- and nanostructures can be implemented in solar cell devices to improve light management and carrier collection. The lecture will present a selection of unconventional scalable and cost-effective micro- and nano-fabrication technologies and their application in PV cell fabrication.

(5) Advanced characterization

Keywords: Overview of the main characterization techniques. Nanoscale characterization. AFM, Luminescence, EBIC/LBIC, XPS, NanoAuger,…

Description: A general description of fundamental characterization techniques and methods will be given. We will then focus the lecture on advanced methods based on luminescence signal and techniques allowing characterization at a micro and nano-scale.

(6) Device engineering: interfaces and heterostructures

Keywords: Carrier collection, passivation, heterostructures, interfaces, contacts,…

One part on Si heterostructures that could include oxides as collecting layers. One part on interfaces and heterostructures in thin-film photovoltaics.

Description: For efficient carrier collection, a special care should be devoted to the design and realization of the passivation and contact layers. Heterostructures based on wide-bandgap semiconductors and TCO are at the forefront of recent advances and designs of both silicon and thin-film solar cells. The role of interfaces is a key.

(7) Multijunctions, tandems on Si

Keywords: III-V tandems for CPV, III-V on Si and other/Si.

Description: Multi-junction (MJ) solar cells are the only architecture that has overcome the Shockley-Queisser (SQ) limit, to date. III-V semiconductors are at the core of most multi-junction devices, and serve as a model for high-efficiency solar cells. Tandem structures on Si are considered as the most promising approach to push the limits of conventional silicon solar cells. The different options (III-V/Si, perovskite/Si, CIGS/Si) will be described and discussed.

(8) Advanced concepts

Keywords: Beyond Shockley-Queisser without stacking cells! Hot-carriers, IBSC, up-/down-conversion and spectral shifting, multi-carrier generation…

Description: Efficiency of single junction cell is limited by the SQ limit. We will present original physical concepts to overcome this limit without using MJ cells. We will see how it is possible to reduce the two main losses in PV conversion (transparency and heat dissipation) as well as how one can do photon management to modify the sunlight.