Physics of Solar Cells: from basics principles to advanced characterization

Les Houches School of Physics, 1-6 March 2020

https://sunlit-team.eu/pv-school-2020/

This school will be focused on the physics of solar cells. The goal is to cover the fundamental and basic aspects of photovoltaic devices, the design and recent progress of the different technologies (silicon, thin-films,...), and the advanced concepts that enable the highest efficiencies. This year, a special emphasis will be given to the advanced characterization techniques and methods that are of primary importance for the development of all photovoltaic technologies.

Starting from a general introduction to the physics of photovoltaics, an overview of current technologies (Si, CIGS, CdTe, III-V, perovskite,...) will first focus on the main trends and challenges. Then, the key aspects of the design of solar cells will be reviewed: interfaces and heterostructures, modeling, and photonics. Then, most advanced characterization techniques will be described in detail: luminescence, Raman, microscopic and scanning probe techniques, X-ray diffraction and related techniques, device characterization at the cell/module scale, and data analysis... Several tutorials will also be proposed.

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 advanced characterization of materials and devices, are also very welcome.

Organized by the CNRS and IPVF:

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- Laurent Lombez (LPCNO, CNRS)
- Andrea Cattoni (C2N, CNRS, Univ. Paris-Saclay).
- Daniel Suchet (IPVF, Ecole Polytechnique)

For more information, check the school's website:
https://sunlit-team.eu/pv-school-2020/
or send an email to the organizers:
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Lectures (this program can be subject to changes):

Lectures will begin on Monday morning (9:00) and will end Friday noon (12:00). Two poster sessions will be organized (Sunday evening and Monday evening), and several tutorials will be proposed.

General introduction

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

Overview of technologies

The overview of the different technologies will focus on the description and limits of conventional devices, and the main trends of current researches: c-Si, CIGS, CdTe, CZTS, III-V, perovskite,...

Design of PV devices

Interfaces and heterostructures. 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 every technologies. The role of *interfaces* in Si, CIGS/CdTe and perovskite solar cells will be discussed.

Photonics. 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.

Modeling (tutorial). Initiation of device modeling with an evening *tutorial* will be proposed; it will illustrate the working principle of a PV cell.

Advanced characterization

A general description of fundamental characterization techniques and methods will be given. We will then focus the lecture on advanced methods.

X-ray diffraction and related characterization techniques

Optical characterization

Luminescence principles will be presented, and the recent progress in luminescence techniques and methods will be described: photoluminescence (PL) and time-resolved PL, cathodoluminescence (CL) and related techniques (LBIC/EBIC),... Other optical techniques, like Raman spectroscopy, will be introduced.

Microscopic and scanning probe techniques

TEM/STEM/EDX, EBSD, XPS/UPS,
AFM, STM, KPFM...

Statistical and combinatorial analysis

Device characterization at the cell/module scale

Calibrated characterization of solar cells, and characterization for modules, will be discussed.

Tutorial. We will propose a tutorial in small groups, with the aim to work on the fundamental analysis of characterization data.

High efficiency: above Shockley-Queisser

Advanced concepts. Efficiency of single junction cell is limited by the Shockley-Queisser 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. Keywords: hot-carriers, IBSC, up-/down-conversion and spectral shifting, multi-carrier generation...

Multi-junctions, tandems on Si. 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.