Multiscale characterization of photovoltaic materials

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Context

In the past years, photovoltaics (PV) became one of the cheapest sources of energy. 95% of commercial solar cells are made of silicon, and their lab-scale record efficiencies of 27.3 % are now close to the theoretical limit (29.4 %). Yet, expectations of both the society and the PV industry are still high, and most of the research efforts are now dedicated to pushing forward the efficiency of solar cells. **Silicon-based tandem devices are the most-regarded solutions for next-generation photovoltaics. To keep low costs and preserve the silicon bottom cell, low-temperature deposition is mandatory for the top cell. Current options are polycrystalline, high-bandgap semiconductors like hybrid perovskites and inorganic $Cu(In,Ga)(S,Se)_2$ -CIGS- or CdTe thin films, but they are still limited by both efficiency and/or stability issues that are hardly explained by current models.** Further developments require a better understanding of the properties and limitations of low-cost thin-film materials. In particular, it is necessary to differentiate the properties of grain interiors and grain boundaries, and the macroscopic fluctuations that may occur in semiconductor alloys.

Scientific project

The goal of this project is twofold. From the one side combining CathodoLuminescence (CL) and PhotoLuminescence (PL) techniques would provide a multi-scale analysis tool for elementary processes and properties of bulk materials (doping levels, diffusion length, carrier lifetime, defect levels and densities...) and surfaces (surface recombination velocity, density of defects, surface charges…). The host team has been using CL extensively to study - down to the nanometer scale - some of the aforementioned systems such as Cd(Se)Te cells (Selenium diffusion/passivation[1], lifetime increasing[2]), GaAs thin-films and nanowires (doping assessment[3,4]), or hybrid perovskite (degradation[5]). On the other side, given this experimental background, we aim at pushing our analysis a step further by calibrating our tool in absolute terms, i.e. extracting the number of CL photons emitted by the sample. Another long-term objective is to use advanced computational methods for correlative data analysis, and simulation to build a realistic model of thin-film solar cells using the measured quantities.

This internship will first focus on the unique CL tool available at C2N. Its basic principle is the following: a material is excited with an electron beam in a scanning electron microscope (SEM), providing a spatial resolution of 10 nm. Secondary electrons are collected to form an SEM image, and emitted photons (CL) are collected simultaneously to acquire an hyperspectral image (luminescence spectrum at each point of the map). Time-resolved CL (TRCL) is also available to measure the luminescence decay after a pulsed excitation.

The candidate will be first trained on the CL/TRCL tool. Then, she/he will use this technique to perform and analyze multiscale CL/TRCL mapping, with the goal to develop new methods to reveal the dynamics of carriers and correlate these properties to the functional parameters of solar cells.

The institute

The candidate will work with several members of the *sunlit* team (C2N) and in close collaboration with the *Institut photovoltaïque d'Ile-de-France* (IPVF).
Websites: https://sunlit-team.eu , https://www.c2n.universite-paris-saclay.fr/en , https://www.ipvf.fr
Description of the CL setup and recent publications: https://sunlit-team.eu/resources/cl-and-trcl-tool/

Profile

Student in M2 with a solid knowledge in semiconductor physics and optics.
Possibility to continue with a PhD grant in 2026.

References

[1] Frouin B. et al., **APL Materials 12**, 031135 (**2024**)
[2] Ablekim T. et a, **Solar RRL 5**, 2100173 (**2021**)
[3] Chen H.-L. et al., **Phys. Rev. Applied 15**, 024006 (**2021**)
[4] Chen H.-L. et al., **Phys. Rev. Applied 15**, 024007 (**2021**)
[5] Mejaouri S. et al., **Small Methods 8**, 2300901 (2024)

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Starting date: 02/2026 (adjustable).