M2 Internship offer:

Next-Generation Customizable Inorganic Charge Transport Layers for High-Efficiency Photovoltaics

Research team: i-Lum, light engineering and conversion

Main location: La Doua campus

Keywords: Solar cells, thin films, transparent and conductive oxides, sustainability

Profile: Material science, thin film technologies, characterization

Duration: 4-6 month.

Contact: Erwann Fourmond, Erwann.fourmond@insa-lyon.fr

Context:
The photovoltaic market is currently dominated by crystalline silicon technology, particularly the so-called PERC (passivated emitter and rear cell) architecture. This architecture has also been developed in our laboratory over the years. PERC cell fabrication involves several steps, one of which includes high-temperature diffusion of dopants to establish the emitter and back surface field (BSF). A notable advantage of this design is that it reduces the metal-semiconductor (Si) contact area, thus minimizing recombination losses at these interfaces. The highest efficiency currently achieved with PERC technology at the cell level is around 25% [1]. In this configuration, the main loss is still due to recombination at the Si/metal interfaces. To improve efficiency, recombination must be reduced by further minimizing the contact areas, which complicates the process.

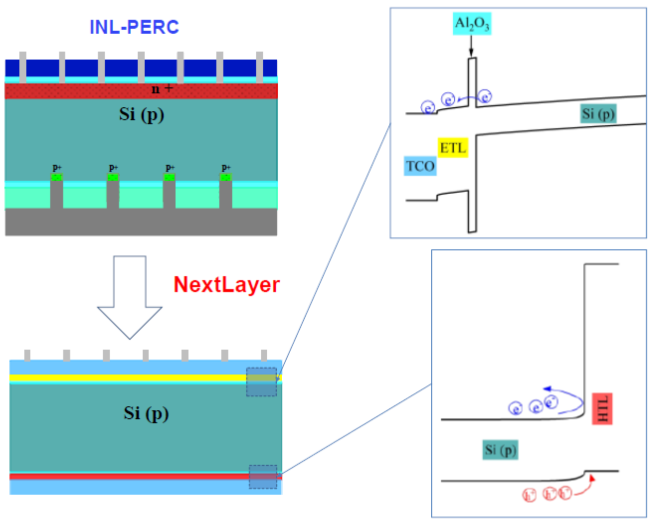

Figure 1: Moving from classic PERC structure (above left), to selective contact structure (below), with band-diagram example for Electron Transport Layer (ETL) with an Al2O3 passivation layer and transparent conductive oxide (TCO) on front side, and Hole Transport Layer (HTL) on back side.

In response to the difficulties presented by PERC design, a new approach has been adopted with heterojunction architecture. This architecture incorporates selective charge transport layers (CTLs) located between the silicon and the metal contact (Figure 1). This structure does not need a classical p-n junction, and thus eliminates the necessity of direct dopant diffusion or implantation into the silicon wafer. This new concept has considerably improved the efficiency of silicon-based solar cells, with a 26.8 % yield and a significant improvement in output voltage [1]. Transition metal oxides (TMOs) have emerged as promising candidates for both hole and electron-selective contacts in both n-type and p-type silicon heterojunction solar cells, inspired by research on perovskite and organic solar cells. These TMOs offer multiple benefits: the employment of a low-temperature process, a wide band gap, and temperature resistance – essential when considering a tandemdesign with top cells that are deposited at high temperatures >500°C, like chalcogenides (CIGS and CZTS). Typically, hole-selective contacts use materials with a high work function like molybdenum oxide (MoOx), tungsten oxide (WO_x), vanadium oxide (VO_x), and nickel oxide (NiO_x), while electronselective contacts favors materials with a low work function like zinc oxide (ZnO), tin oxide (SnO_2), and titanium dioxide (TiO_2) [2–5]. As shown in Figure 1, the approach to be developed in this internship focuses on a transition from high-temperature process technology to lower-temperature processes which are more environmentally friendly, more efficient and cost-effective. The aim is to implement appropriate CTLs with perfect band alignment to facilitate selective charge extraction, minimize recombination on interfaces and further improve solar cell efficiency.

Workplan:
The objective is to develop and analyze well-controlled CTLs on silicon surface. The M2 student will work on the deposition and optimization of TMOs layers, after training in NanoLyon facilities. He/She will have access in that objective to the following equipment:

- Deposition of TMOS contacts on silicon, using Atomic Layer Deposition and/or e-beam evaporation. UV-Lithography will also be used for contact structure formation.
- Optical and electronical characterization of the layers, using spectroscopic ellipsometry, Hall effect measurements for mobility and resistivity, and kelvin-probe analysis for work function extraction.

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