Institut des Nanotechnologies de Lyon
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Master Thesis Project:

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

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Location: Institut des Nanotechnologies de Lyon, Bât. Irène JOLIOT CURIE, 1 rue Enrico Fermi, 69622 VILLEURBANNE CEDEX,

Goal

In recent years, solar cell fabrication at INL has depended on collaborations with other laboratories for high-temperature implementation and diffusion processes. With the "NextLayer" project, we aim to produce photovoltaic cells in-house, from wafer to device. We plan to move from conventional solar cells utilizing high-temperature diffusion to heterojunction cells employing oxide transport and passivation at lower temperatures. We aim to develop silicon-based solar cells optimized for both conventional and tandem configurations, using **environmentally friendly**, **low-cost materials** in low-temperature processes.

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.

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]

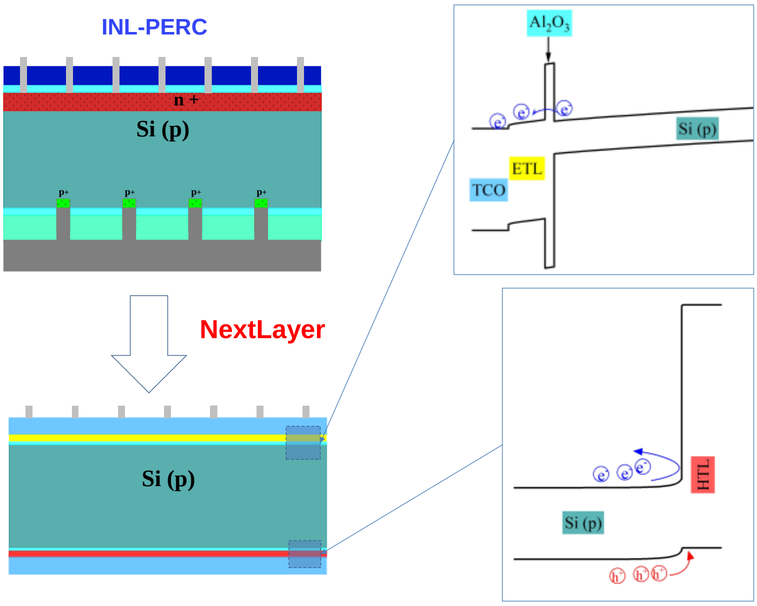

Figure 1: Moving from classic PERC structure (above left), to selective contact structure (below), with band-diagram example for Electron Transport Layer (ETL) with an Al_2O_3 *passivation layer and transparent conductive oxide (TCO) on front side, and Hole Transport Layer (HTL) on back side.*

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 tandem design 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 (MoO_x), tungsten oxide (WO_x), vanadium oxide (VO_x), and nickel oxide (NiO_x), while electron-selective contacts favors materials with a low work function like zinc oxide (ZnO), tin oxide (SnO_2), and titanium dioxide (TiO_2).[2–5] Our "NextLayer" proposal provides a roadmap for the development of advanced heterojunction solar cells. As shown in Figure 1, our proposal 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.

Methodology

This proposal aims 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 at INL La Doua. He/She will have access in that objective to several equipments:

- **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.

The ultimate goal is to demonstrate a roadmap for designing high-efficiency heterojunction-based solar cells suitable for both standard and tandem architectures. Along with research approaches, the original and innovative aspects of each pursued work package (WPs) are outlined in Table 1.

Research approaches	Innovative aspects
CTLs deposition and interface characterization (WP1)	Find out the most effective method and materials for controlling the band alignment at the CTLs/Si interfaces.
Fabrication of p-type heterojunction using TMOs as CTLs and indium-free TCO (WP2)	Identify the primary challenges associated with using TMOs as CTLs for **p-type heterojunctions for the first time.**

Team description

INL, Lyon Institute of Nanotechnologies, is a joint research unit between CNRS, Ecole Centrale de Lyon, INSA-Lyon and University Lyon-1. INL focusses on multidisciplinary research in the areas of micro and nanotechnologies and their applications. The pioneering research undertaken at the Institute ranges from materials and technology to devices and systems.

The INL i-Lum team is working in the field of solar cells elaboration and characterization and more precisely in Silicon solar cells. It is involved in different technological processes: the material and devices fabrication (study of contact, passivation, optical structuration…), the device simulation, and characterization. The laboratory benefits from the clean room facilities on the technological platform NANOLYON. It is already engaged in several research programs in the photovoltaics field: interdigitated back contacts cells (ANR THESIS, terminated in march 2023), High-Efficiency Epitaxial CIGS-Silicon Tandem Solar Cell (ANR EPCIS) and Electrically pumped hybrid perovskites-based light-emitting devices (ANR EMIPERO).

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