Technology for Si-CZTS tandem solar cells

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Introduction

Figure 1: Schematic of the Si-CZTS tandem structure

Traditional solar cells are based on a single semiconductor (single-junction). The most common semiconductor used in fabrication of solar cells is silicon (Si) whose technology is well-developed. In the recent years, the efficiency of single material solar cells are very close to practical and fundamental limits. As a result, the concept of Tandem (or Multi-Junction) Solar Cells is introduced to improve the efficiency even further.

Tandem solar cells are a unique form of solar cells consisting two or more sub-cells with different bandgaps stacked on top of each other. Each sub-cell is designed to produce electricity in response to certain parts of the solar spectrum (i.e., different wavelengths). In this manner, the solar spectrum is utilized more efficiently, and the energy losses corresponding to heat (thermalization) are minimized. Consequently, very high overall efficiencies (> 40%) can be obtained.
Description

We are now working on ALTCELL project in collaboration with DTU Fotonik, DTU Energy, two industrial partners, namely Haldor Tapsøe and Inmold. The ultimate goal of the ALTCELL project is to develop a technology for CZTS-Silicon tandem solar cell. CZTS, with a chemical formula of Cu$_2$ZnSnS$_4$, is a quartenary semi-conductor based on inexpensive and earth abundant elements. Therefore, CZTS-Si tandem cells can potentially realize high efficiency at the expense of small additional costs.

In this respect, several challenges are to be tackled to achieve a highly efficient device. This entails improvement of CZTS single cell technology to enhance the efficiency, development of a suitable silicon bottom cell, and solving issues related to integration of the two cells.

The improvement of the CZTS cell is mostly done elsewhere by other project partners at DTU Fotonik, while this project mainly involves:

1. Development and characterization of the bottom silicon cell.
2. Developing technology for transparent barrier layer(s) as intermediate layers between CZTS and Si sub-cell. The purpose of the barrier layer is twofold:
   (a) Electron currents from the silicon cell must be transformed into hole currents in the CZTS cell at the interface.
   (b) The interface must be a diffusion barrier to protect the silicon cell from in-diffusion of metals (particularly Cu) from the CZTS cell.

According to your interests, you can work on one or more of the following topics:

- Identifying and testing different materials to be used as the barrier layer.
- Optimization of thin surface passivating layers such as Al$_2$O$_3$, SiN$_x$, TunnelOxide/PolySilicon, etc., to be used in the silicon sub-cell.
- Optimization of Transparent Conductive Oxide (TCO) layer, such as Indium Tin Oxide (ITO) and Aluminum doped Zinc Oxide (AZO), for the top and bottom silicon sub-cells.
- Optical and electrical simulations to model the performance of the tandem structure based on experimental data.
- Semi-transparent CZTS solar cells for 4-terminal tandems with CZTS and Si.
- Fabrication of silicon cells based on the optimized layers.
We offer

Depending on the desired project, your research will make use of:

- State-of-the-art cleanroom facilities for silicon micro-and nanofabrication (examples: photo-lithography, dry-etching, etc.).

- Advanced thin-film deposition methods (examples: Atomic Layer Deposition (ALD), Sputter Deposition, Plasma Enhanced Chemical Vapor Deposition (PECVD).

- Advanced thin-film characterization methods (examples: Spectroscopic Ellipsometry, X-ray Reflectometry (XRR), etc.).

- Advanced material analysis methods (examples: X-Ray Photo-electron Spectroscopy (XPS), Scanning Electron Microscopy (SEM), X-ray diffraction (XRD), etc.).

Prerequisites

- Motivation and ability to collaborate in a dynamic research environment

- Knowledge in semiconductor physics and solar cells

In case you are interested, or if you would like to discuss the project in more detail, feel free to contact Alireza.