Author: Mudiaga Agbagidi
Thesis Title: TiO_2 electron transporting layers synthesized by ALD and USP methods for Sb_2S_3 absorber based solar cells

SUMMARY

Recently, the demand for sustainable, fossil free energy sources has become one of the most challenging topics among the researchers worldwide. **Photovoltaic** (PV) **energy** conversion technology is the leading renewable **energy** resource toward a more **sustainable** future. The building integrated photovoltaic (BIPV) technology, where solar cells are directly integrated into building elements, such as roofs, windows or roofs is a modern and promising PV technology branch. The semi-transparent solar cells enable simultaneous electricity generation and light transmission.

$Sb_2(S,Se)_3$ has proven to be a promising photovoltaic material for semi-transparent solar cells due to its' tunable bandgap, high absorption coefficient and nontoxic and earth-abundant constituents. However, material selection, fabrication, and device structure design, are standing challenges remaining to be addressed to improve the performance. One of the core components of solar cell structure is electron transport material which is primary responsible for achieving high-performance solar cells: it promotes the collection of photogenerated electrons from the absorber layer to the bottom electrode as well as suppresses charge carries recombination. Therefore, the properties and the thickness of ETL material, which largely depends on synthesis method and preparation technology is of highest importance.

The objective of this study was to manufacture and study the semitransparent solar cell core component, TiO_2, electron transport layer and estimate its suitability for the semi-transparent solar cell with FTO/TiO_2/Sb_2S_3/P3HT/Au structure. Two reliable synthesis techniques have been chosen to grow TiO_2 – Atom Layer Deposition (ALD) and Ultrasonic Spray Pyrolysis (USP). This study demonstrates that the introduction of an electron conducting layer, TiO_2 into the semi-transparent solar cell device structure is an important step in solar cell technology in order to supress charge carries recombination and to improve overall efficiency of the device. Both methods chosen for this study for TiO_2 ETL preparation, ALD and USP are reliable, robust and powerful techniques allowing to grow highly reproducible, uniform, pinhole-free TiO_2 thin films with excellent thickness accuracy and conformity at low temperatures. Independent of the growth method, TiO_2 belong to anatase, crystalline TiO_2 phase. However, USP TiO_2 has shown benefits over ALD TiO_2 in terms of better band alignment of SC structure. The CBM band position of USP TiO_2 is 0,39 eV closer to CBM of an Sb_2S_3 absorber compared to CBM of ALD TiO_2, resulting in a more efficient photogenerated charge-carries separation and more efficient recombination rate suppression. As a result, SC output parameters are somewhat 15%

above that those of ALD TiO_2 record sample. The average values of Jsc are 14 mA, FF-40% and Eff. 3,5 % of USP TiO_2 SC vs. 12 mA, 35% and 3,0 %, for a record ALD TiO_2 SC respectively. The performance of SC based on ALD TiO_2 ETL largely depends on a thickness of the later. Too thin layer, 100 deposition cycles or 5 nm thick layer, is obviously not enough to supress recombination of carries and be an efficient transport material. The optimal ALD TiO_2 thickness, resulted in highest output parameters corresponds to 400 ALD deposition cycles or 30 nm, resulting in the highest SC performance (max. eff. Ca. 3.3 %). Thicker ALD TiO_2 films, starting from 800 cycles and above with thicknesses larger than 60 nm have reduced shunt resistance, fill factor and short circuit current values, therefore cutting off the solar cell efficiencies down to 2-2.5%.

For semitransparent solar cell, where other components are synthesized by spray method as well, the USP method is obviously beneficial as it is cheaper, faster and can be produced sequentially on same deposition apparatus prior Sb_2S_3 absorber layer spraying process.