Solution Processed Copper Indium Diselenide Solar Cells

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Relatively low costs and the capacity to reach efficiencies of 15-20% have earned $CuInSe_2$ thin film solar cells increasing attention in recent years. The development of a solution based method for the deposition of Copper Indium Diselenide (CIS) thin films offers potentially great processing advantages over conventional vacuum deposition techniques. The successful development of a recipe for solution based module fabrication would be a significant step towards the arrival of cost-effective solar cells and the replacement of silicon as the world's most viable photovoltaic material.

Introduction

The Material

•$CuInSe_2$ has a direct band gap of ~1 eV, and is intrinsically p-type with a chalcopyrite lattice structure.

•Its band gap can be widened by the substitution of gallium or sulfur into the crystal lattice, allowing for efficiencies close to 20% to be achieved[3].

•Due to its direct and reasonably small band gap, CIS has one of the largest absorption coefficients at visible wavelengths of any known semiconductor. This allows for the fabrication of devices with extremely thin active layers and thus lower costs.

[3]Documented in: Contreras et. al. (2003)

Solution-Based Deposition

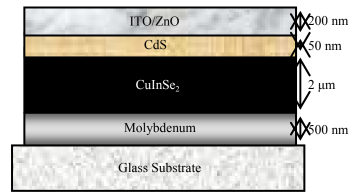
•Cu_2S and In_2Se_3 are dissolved in purified Hydrazine along with elemental Sulfur and Selenium.

•The precursor solution can be spun or dip-coated onto a chosen substrate in order to form a uniform film of precursors.

•Annealing at temperatures above 350° C causes the precursors to react and form a polycrystalline CIS layer[4] (verified by XRD) with properties and stoichiometry determined by the deposition and annealing parameters.

[4]Method originally presented in: Mitzi et. al. (2006)

The Device



Device schematic of a typical CIS solar cell. Record efficiency for this type of structure is around 15%

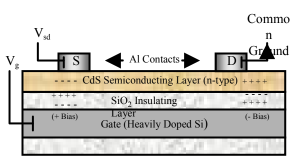
The Buffer Layer - CdS

CdS Overview

•The CdS layer acts as part of the n-type region of the diode.

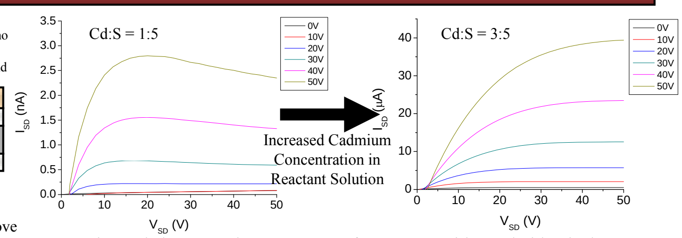
•Ideally, the CdS layer will be a transparent high quality n-type semiconductor that does not create an unacceptably high series resistance within the device.

•Deposition of our CdS layer is achieved by chemical bath deposition with Cadmium Acetate, Ammonium Acetate, and Thiourea as reactants. Temperature, reactant concentration, pH, solution stirring rate, and deposition time can be varied to achieve the desired results.



Characterization

Thin film transistors (TFTs) with the above structure were fabricated to test the properties of our deposited CdS films.



Pictured above are the I-V curves of two TFTs with nearly identical geometries fabricated through the use of two different reactant ratios. Noticeable in the y-axis is a tremendous increase in the conductivity of the CdS film.

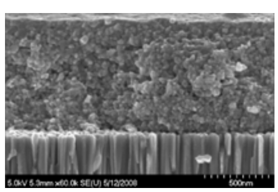
The Absorber Layer – $CuInSe_2$

CIS Overview

•The CIS layer absorbs sunlight and mediates charge carrier generation. It is the thickest layer of the solar cell and is thus the most significant region for recombination and series resistance.

•A large grain CIS layer with high carrier mobility is crucial for the successful fabrication of a high quality CIS solar cell.

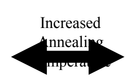
•SEM and EDX have been our primary tools for the analysis of the crystal quality with the CIS layer.



SEM image of a CIS layer deposited onto a sputtered Molybdenum Film

EDX

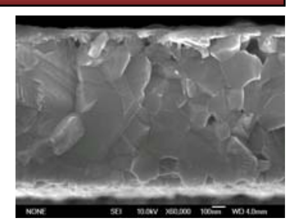
Copper: 22%
Indium: 27%
Selenium: 51%



EDX

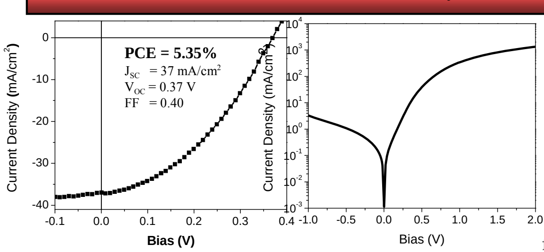
Copper: 26%
Indium: 28%
Selenium: 46%

By using a higher annealing temperature, we have obtained large grain size CIS film. However, severe Se loss is observed as a result of increasing annealing temperature. In the near future we hope to obtain a single film with both good crystallinity and accurate stoichiometry.



SEM image of a CIS layer annealed at a higher temperature. Significant Se loss is observed.

Preliminary Results: A Work in Progress



Pictured above are the I-V characteristics of a sample CIS-based solar cell deposited from solution. Our primary goal is to increase the V_{OC} and fill factor of the cells, which can likely be attributed to the small grain size present in our devices.

Stable in Air

All of our devices have exhibited little or no with exposure to ambient atmosphere. All measurements shown were taken in air and many samples were left exposed for several days before being characterized.

Summary and Future Goals

Power conversion efficiencies greater than 5% under AM1.5 illumination have been reproducibly observed from our solution processed devices. Our immediate goal is to understand the chemical reactions that take place during the formation of the CIS film. In addition, we are plan to expand the capability of hydrazinium-based processing to additional chalcogenide materials.

Acknowledgments

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