Fabrication, Characterization, and Simulation of Solar Cells

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ABSTRACT

Three different projects are pursued on this project. The first is to fabricate CdTe-based solar cells of with ordered polycrystallites, the second is to characterize those and other thin-film solar cells using CCD imaging of electroluminescence, and the third is to develop an intelligent interface to a device simulator.

1. Objectives

Project 1 proposes to develop an intelligent interface to a device simulator. Genetic algorithms are used to provide the "intelligence." The simulation tool is a Fortran-based program called ADEPT, though we previously were intending to use STEBS2D; both are based on fundamental physics. This tool will enable researchers to ask general questions of a device simulator such as "What is the design that results in the highest efficiency?" rather than being limited to one simulation at a time.

Project 2 proposes a nanofabrication technique as a method to fabricate an ordered array of high quality nanocrystals to overcome the problems inherent with random polycrystalline thin films. This project proposes to develop a method to fabricate an ordered array of high quality nanocrystals of CdTe on CdS for the purpose of advancing the state-of-the-art in conversion efficiencies of CdS/CdTe solar cells.

Project 3 is to perform spatially resolved studies of CdTe solar cells by observing electroluminescence. The major results of these studies will be an increase in the understanding of how CdTe/CdS solar cells behave and an increase in conversion efficiencies. These projects support the Solar Program Multi-Year Technical Plan by exploring new technologies and by seeking to improve the efficiencies of existing devices.

2. Technical Approach

Project #1: The interface was developed in Java and connected to the ADEPT device simulation program running on Unix cluster. The artificial intelligence is a genetic algorithm, parallelized to run on the cluster. To keep it simple at the beginning, we used a less powerful simulation tool as a test. We have made the connection and the system works. The next step was to install the more complete simulation tool and make it work on moving our system to a cluster of computers that will enable faster computation of the problem.

Statement-of-Work #2

This project is divided into two phases. In phase one, nanoscale lithography and selective area growth will be combined to develop a new technology to fabricate an ordered array of high quality single crystals of CdTe on CdS. In phase two, the ordered polycrystalline technology are applied to advance the state-of-the-art in fabrication of CdS/CdTe solar cells.

Statement-of-Work #3

This is a proposal to continue spatially resolved studies of CdTe solar cells. This type of fundamental work is not being done, and a big reason is that the available methods are very time-consuming, and there is no knowledge base available to which one can compare. The major results of these studies will be an increase in the understanding of how CdTe/CdS solar cells behave and in conversion efficiencies.

3. Results and Accomplishments

The first milestone of Project 1 was to design the Java interface to ADEPT (the high-end, 2-D device simulator), and that is accomplished. We also made the genetic algorithm and parallelized it to work on a Unix Cluster. The next milestone is a key one, and that is to develop and test algorithms for automatic creation of the input file to ADEPT, including material constants and especially node placement in order to automate the simulation process. ADEPT does some of the node placement automatically, but it must be given a good start by the user.

For Project #2 we have been able to accomplish the following tasks stipulated for the project.

- Deposition of patterned array of SiO_2 and Si_3N_4 on CdS with varying window sizes
- Refinement of parameters for the selective deposition of CdTe.
- Characterization of the quality of the selectively deposited CdTe crystals by SEM.
- Fabrication of full devices using the technique.

Close-spaced sublimation was used for the deposition of the CdTe. The selectivity of CdTe deposition was studied as a function of temperature and different growth mask materials. Figures 1 and 2 show SEM images of one of the samples showing the selectivity of the growth.

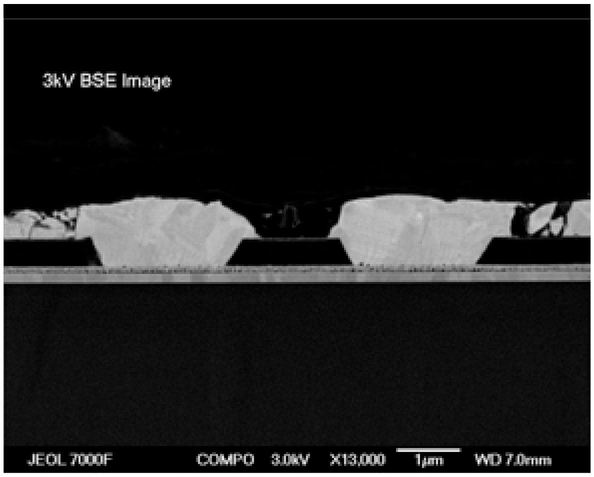

Figure 1. SEM image of cross section of CdTe.

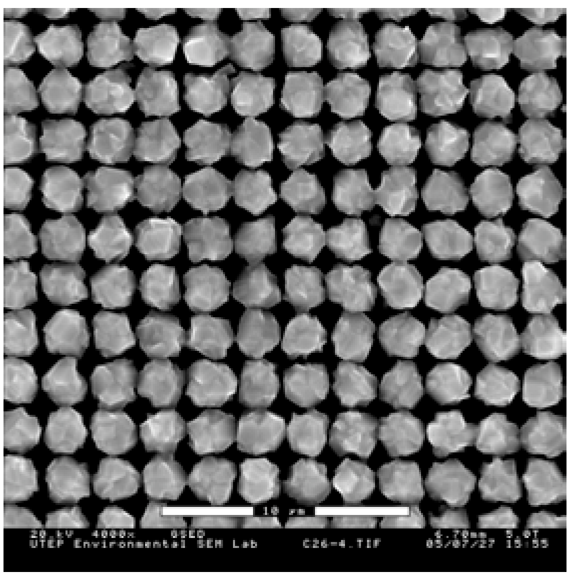

Figure 2. Top view of selectively grown CdTe.

We are excited about the selective growth, and have improved the technique further. We are also exploring using “Natural Lithography” which uses polystyrene balls of order one micron or smaller, suspended in liquid, spun onto a substrate, in order to make patterns on the substrate. We can combine this with photoresist to create CdTe grains of the order we need and the process will be less expensive than

Project 3 looks at the electroluminescnence (EL) of finished devices and tries to relate their EL performance to solar cell performance. Figure 3 shows a color map of the intensity of the pixels of an image captured from a device fabricated at NREL. Figure 4 shows histograms of the number of pixels at each intensity. The half-width of the near-Gaussian plots give an indication of the non-uniformity of performance of the devices—thinner means more uniform—higher uniformity means higher efficiency. Uniformity also correlates with series resistance, and the variation across these devices was with the contacting methods. We are still trying to understand the implications for these cells.

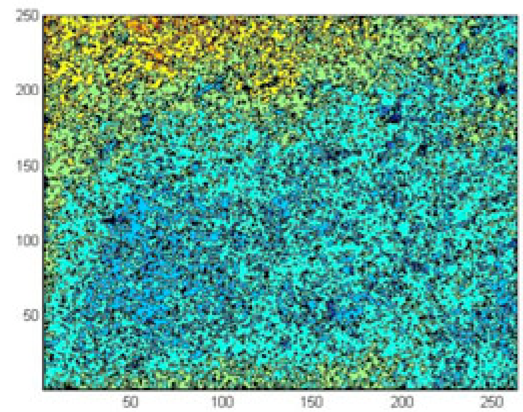

Figure 3. EL image of CdTe Solar Cell

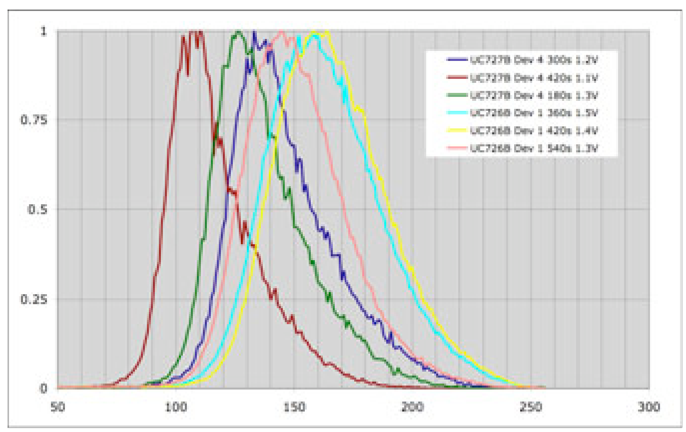

Figure 4. Histograms showing intensity variation

PUBLICATIONS

Fifteen presentations and publications, including:

David Zubia, Franz Kuhlmann, Aaron Rodriguez, Javier Terrazas, Cesar Lopez, Umesh Uthaman, Sergio Gutierrez, Jacob Rascon, John McClure and Greg Lush, “Ordered Nanocrystalline Materials for Solar Cell Applications,” **invited talk**, presented at the International Material Research Congress, Cancun, Mexico August 22 – 26, 2004.

G. B. Lush, “Design of GaAs Solar Cells Using Genetic Algorithms,” International Energy Conversion Engineering Conference, Portsmouth, Virginia, September 2003