Thrust: Thin Film PV

Grand Challenges and Key Problems

Thin Film PV technologies have established themselves in commercial markets as a viable alternative to the dominant incumbent silicon-based PV products in some applications. As the global market continues to expand the competitiveness of thin film solutions faces four significant ***Grand Challenges*** in order to achieve widespread market acceptance and adoption: (1) increasing efficiency of modules (particularly decreasing the gap between lab scale champion cells and production modules), (2) reducing direct materials costs, (3) reducing capital intensity of manufacturing, and (4) design and validation for long-term field reliability. Thin film commercial competiveness with silicon is based on a favorable tradeoff between its lower direct materials cost but higher manufacturing capital intensity. This tradeoff tips in favor of thin film PV only when low-cost capital is available, so less capital intensive manufacturing is key to competitiveness. The single greatest problem confronting those seeking to introduce new thin film technologies into the market is to rapidly establish long-term reliability in order to address the legitimate sustainability concerns of both investors and customers.

Existing Projects in our Thrust

- *Bandgap Grading in CZTSSe Solar Cells and SnS*, Bruce Clemens and Stacey Bent (Stanford). This project seeks to reduce the cost of thin film materials by developing CZTSSe and SnS alternative absorber materials to CIGSe and CdTe.
- *Fundamental Modeling of Chalcopyrite Solar Cells*, Scott Dunham (UW). This project seeks to understand the native point defects and defect clusters in CIGSe and CZTSSe materials and the role that kinetics and processing play in their formation and may address the challenges of efficiency and reliability.
- *Laser Processing of CdTe Solar Cells*, Chris Ferekides and Mike Scarpulla (USF/Utah). This project seeks to develop laser-based techniques to enhance crystallization, reduce defects, and improve the contacts of CdTe devices. It has the potential to addresses the challenge of reducing the capital intensity of manufacturing by providing low-temperature high-throughput alternatives to existing CdTe processing steps.
- *Advanced Evaporation Source Design*, Greg Hanket (IEC). This project is focused on developing a better nozzle for co-evaporation of CIGSe which will allow high throughput processing and high efficiency modules.
- *Development of Multicolor Lock-in PL Methods*, Hugh Hillhouse (UW). This project is focused on developing new photoluminescence methods suitable for in-line characterization of PV materials during manufacturing. It addresses the challenges of increasing module efficiency and module reliability by enabling better process control and production on on-spec material.
- *Identifying Problem Areas in CIGSe and CdTe Based PV Devices*, Mark Lonergan (UO). This project if focused on capacitance-based characterization of defects in CIGSe and CdTe. It has the potential to address both the efficiency and reliability challenges.
- *In Situ Characterization of Grain Growth in Thin Film Semiconductors*, Delia Milliron and Paul Alivisatos (UT/LBNL). This project seeks to understand the grain growth in chalcogenide semiconductor films starting from nanocrystalline precursors. It has potential to address the challenge of reducing capital costs of manufacturing by allowing solution processing routes to high quality absorber layers.
- *Advanced Materials Characterization*, Mike Toney and Alberto Salleo (SLAC/Stanford). This project is developing advanced methods to characterize sub-bandgap absorption and absorber heterogeneity. It addresses the challenges of increasing efficiency and of reliability.
- *Non-Equilibrium Processing of CdTe Absorbers*, Colin Wolden (CSM). This project is focused on understanding the kinetics of processing CdTe. It has the potential to addresses the challenge of increasing module efficiency.
- *Applying Cation-Exchange Chemistry to Nanowire Array PV*, Peidong Yang (Berkeley). This project

is focused on developing copper sulfide nanowire PV. It may address the challenges of cost of materials since there is no indium or tellurium.

Potential Growth of BAPVC

Analysis of how effectively the projects address the grand challenges articulated above and reviews from the industrial partners have identified the following areas as important areas for expansion of consortium capabilities to leverage the value generated by the existing investigators' work, and to address risk issues critical to the consortium's industry adoption goal:

- *Theory and Modeling*. Current theory and modeling components of the thin film thrust area do not provide adequate collaborative device-modeling resources which in coordination with materials and device characterization will inform and guide the predominant materials and device architecture orientation of this thrust's current research.
- *Materials Chemistry of absorbers*. Currently, there is little focus on the basic materials chemistry of absorbers. Understanding defects and grain growth and their role is metastability, composition, morphology and heterogeneities present intra-grain and at interfaces and grain boundaries is critical to advancing device design and performance.
- *Thin Film Device Architecture*. Currently, there is little effort in the thrust to develop optimal (optimized both in cost and efficiency potential) heterojunctions, interfaces, transparent conducting layers, ohmic contacts, and interconnects. Efforts are also needed to explore means of de-coupling processes, e.g. separating of the "activation" of the absorber layer from intermixing at the CdS/CdTe interface which currently occur simultaneously during the $CdCl_2$ treatment. Advances on this front are crucial for both existing thin devices and the newer absorber materials being explored.
- *Device and Materials Stability*. Collaborative research is needed to proactively test innovative device and materials stability under operating conditions (temperature and bias) in order to screen for commercial viability.
- *Device Reliability*. Evaluation of packaged device reliability under combined thermo-mechanical, electro-chemical, and photo-chemical stresses in combination with commercial or BAPVC-developed encapsulants is needed to quickly identify interface adhesion issues and screen for commercial viability.
- *Low Capital Cost Manufacturing*. An expanded focus on developing new low capital cost processing routes to CdTe and CIGSe would help thin film technologies compete with crystalline silicon.