ORNL Manufacturing Demonstration Facility
Technical Collaboration **Final Report**

Path towards a Marketable, High Performance Cu2ZnSn(S,Se)4 Heterojunction Thin Film Solar Cell[1]

Sisom Thin Films

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Summary
ORNL and Sisom Thin Films collaborated on the integration of unique thin film processing (Sisom Thin Films) and low thermal budget pulse thermal processing (ORNL) techniques for disruptive PV technology development.

Background
The production cost of solar power must be reduced to less than 20% of its current expenses before it can become market competitive with fossil fuels. In this context, Cu2ZnSn(S,Se)4 (CZTSSe) quarternary semiconductor compound has emerged as one of the promising candidates. Sisom TF's Streaming Process for Electroless and Electrochemical Deposition (SPEED) is a patented technique that allows the substrate to be coated with nanoparticles at a high growth rate, with no limitation of film thickness. The high density plasma arc lamp facility at ORNL offers Pulse Thermal Processing (PTP) capabilities. We proposed the combination of SPEED processing and PTP annealing as a key solution to overcome the major limitations of the current technology while meeting the critical requirements of manufacturing technology integration: lower manufacturing cost, and enhanced device reliability and yield.

Impacts
DOE's mission is to bring the total costs of utility scale solar energy systems down about 75% by 2020, a feat that would make large scale solar energy cost competitive, and help reach the President's goal of doubling our clean energy in the next 25 years. The proposed R&D is in-line with the major emphasis of various DOE projects: increase solar cell efficiency, reduce production costs, open new markets for solar energy and make solar electricity more accessible to consumers. As proposed; the PV technologies based on earth-abundant thin film solar cell materials have the potential to displace existing technologies based on CdTe, CIGS, and Si materials while meeting

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the requirements of low cost processing, non-toxic composition, earth-abundant elements, optimal bandgap, and high optical absorption for PV applications targeting future requirements of terawatt (TW) level power generation capacities.

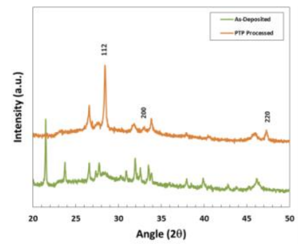
Technical Results

The investigation focused on the following issues to establish the feasibility of CZTSSe based thin film solar cell technology: (1) Grain growth at low temperatures, (2) Optical bandgap control, and (3) Mobility and Carrier concentration in nanoparticle thin films.

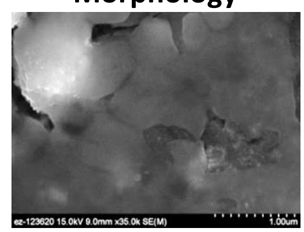
Growth, Structure and Morphology

- Large area, scalable deposition technique for roll-to-roll manufacturing
- Direct self-assembled nanomaterial thin films employing environmentally friendly water soluble reagents
- Two orders reduction in annealing thermal budget by PTP processing
- Large grain growth exceeding 1µm observed in nanoparticle CZTSSe thin films: Critical for High Efficiency Solar Cell Development

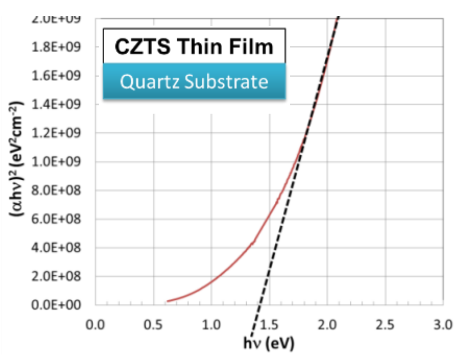
Crystallinity



Morphology



Optical Transmittance



Optical Bandgap: 1.41 eV

Near absorption edge: $\alpha > 10^4$ cm^{-1}

Electrical Performance: Hall Effect Measurements

Parameter	Value
Bulk Resistivity	1.398 Ω-cm
Hall Mobility	11.7 cm^2/V-s
Carrier Concentration	3.81×10^{17} cm^{-3}

Optimum bandgap (1.4-1.5 eV) for high performance (Efficiency>10%) PV cell development: Path towards terawatt level power generation

High Electrical Performance, Earth Abundant Nanomaterial Thin Films: Matching Vacuum Deposited Thin Film Characteristics

Conclusions

Accomplishments

Combination of novel nanoparticle thin film deposition technology and low thermal budget pulse thermal processing technology shows promise for the realization of low-cost PV Cell employing earth abundant materials.

Future Work

Construct a solar cell to demonstrate the path towards a sustainable CZTSSe based PV cell technology meeting the cost, performance, and manufacturing technology demands.

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