2008 Solar Annual Review Meeting

Session: CIGS
Company or Organization: SoloPower, Inc.
Funding Opportunity: PV Incubator

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Budget and Solar America Initiative Alignment

Company or Organization			
Project Beginning Date	**FY07 Budget**	**FY08 Budget**	**Total Budget**
9/28/2007	-	$ 1.07millions	$ 2.37millions*

- This project supports the Solar America Initiative by:
  - Development of a low cost CIGS thin film PV technology based on electrodeposition
  - Establishment of a 10-20 MW/yr capacity pilot plant operation by the end of the project period as a transitional step to full-scale manufacturing of 100 MW or more by 2010
  - Therefore, driving towards the overall goal of grid parity by 2015

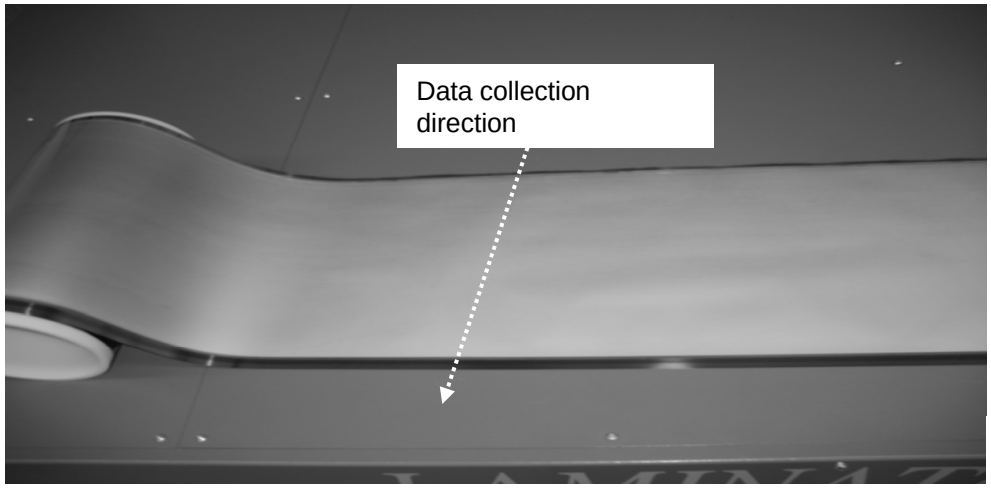
* NREL subcontract portion including FY09 amount

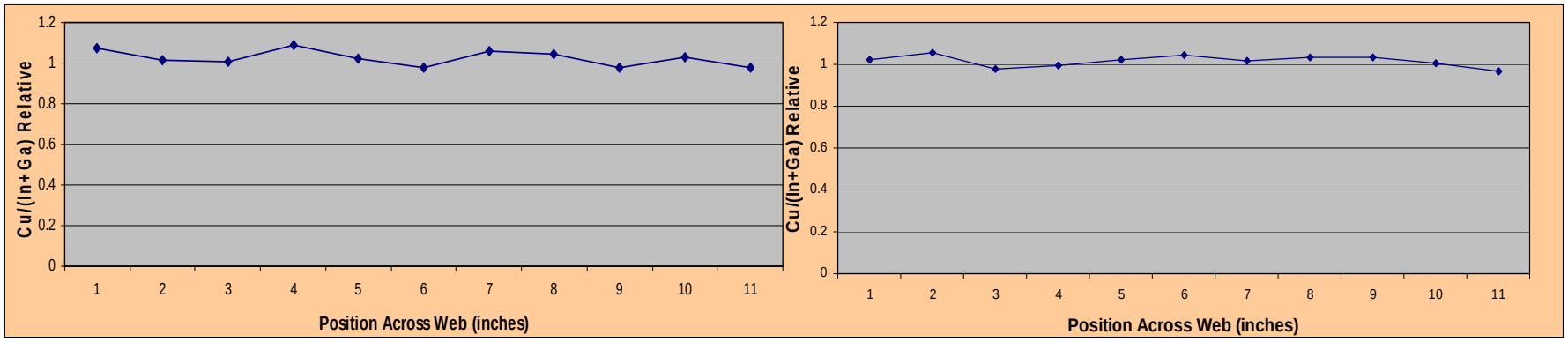
Project Overview

- SoloPower developed a low cost CIGS technology based on roll-to-roll electrodeposition technique
  - Electroplating hardware is low cost
  - Process is high throughput
  - Starting chemicals are low cost (no need for pre-formed materials)
  - Materials utilization is near 100%
  - Method is easily scalable
  - Compositional control is good
- Good large area cell efficiencies and modules have been demonstrated within 2 years of company start-up

Project Overview, cont'

- Compositional control in electroplating is good





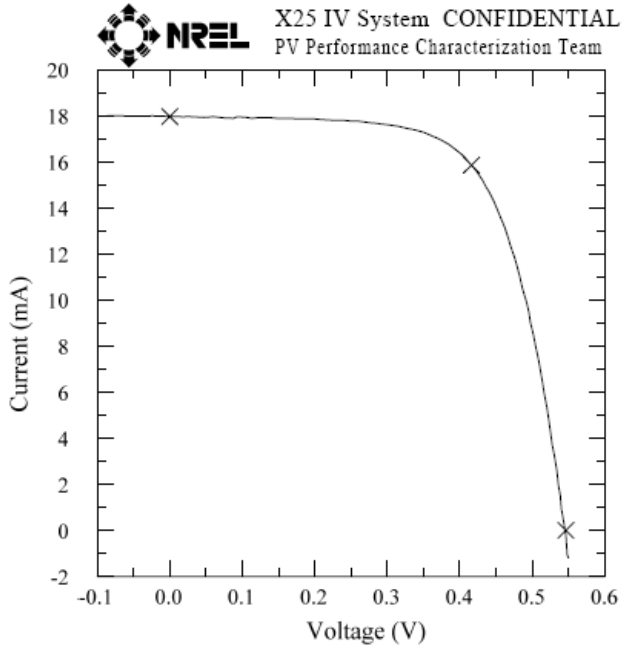
At 2ft

At 32ft

Project Overview, cont'

- Good cell efficiencies have been demonstrated

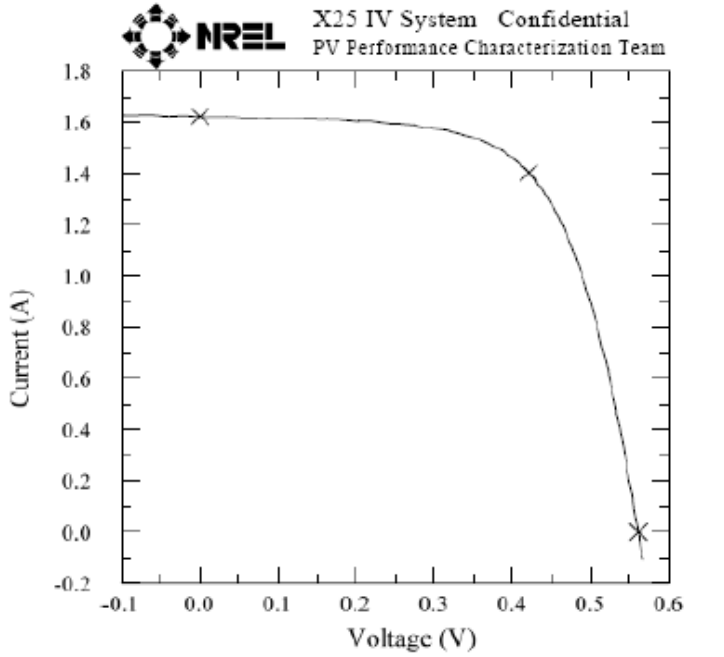
Device Temperature: 25.0 ± 1.0 °C
Device Area: 0.480 cm^2
Spectrum: AM1.5-G (IEC 60904) Irradiance: 1000.0 W/m^2



V_{oc} = 0.5463 V
I_{sc} = 17.987 mA
J_{sc} = 37.473 mA/cm^2
Fill Factor = 67.23 %

I_{max} = 15.876 mA
V_{max} = 0.4161 V
P_{max} = 6.6063 mW
Efficiency = 13.76 %

Device Area: 51.868 cm^2
Spectrum: AM1.5-G (IEC 60904) Irradiance: 1000.0 W/m^2



V_{oc} = 0.5613 V
I_{sc} = 1.6230 A
J_{sc} = 31.291 mA/cm^2
Fill Factor = 64.85 %

I_{max} = 1.4030 A
V_{max} = 0.4210 V
P_{max} = 0.5908 W
Efficiency = 11.39 %

Project Overview, cont'

- From cells to modules

- SoloPower made its first "proof of concept" solar cell in January 2006, using films plated in a beaker. This 0.5 cm^2 cell measured at IEC (U. Delaware) yielded about 7% efficiency
- SoloPower started module fabrication in late 2007/early 2008 period
- A module delivered to NREL measured to be 7.71% efficient
- Packaging materials and process of record have been developed and passed over 1500 hrs of 85C/85%RH test with no device degradation.

Project Alignment with Technology Roadmap

Need	Significance	SoloPower Approach
(1) Enhance Module Efficiency and Lower Module Cost		
(a) Comparative evaluation of production vs. high performance CIGS devices.	*Increasing module efficiency from 10-15% can reduce module cost to <$1/W with no change in production cost.*	◦ **Identify factors contributing to efficiency variation between small (0.47 cm^2) and large (100 cm^2) devices.** ◦ **Batch vs. R-t-R process.**
(c) Improve schemes outside the CIGS layer.	*Understanding necessary materials, devices, and processing changes to improve efficiency, yield and reliability.*	◦ **Develop/identify interconnect materials and processes compatible with CIGS devices.**
(d) Higher throughput from higher rates and/or lower thickness.	*Increase rates to the 30 um/h or greater required in vacuum processing for low equipment-depreciation rates.*	◦ **Work with 1 um thick absorber.** ◦ **Work on increasing throughput further.**
(e) Develop alternative fabrication processes	*Reduce manufacturing cost by using lower-cost and higher-performance processing.*	◦ **Using electrodeposition.**
(2) Science/Engineering Base: Discover New/Alternative Approaches		
(a) Characterize and model CIGS materials/device physics, determine pathways and kinetics for CIGS materials and cell growth.	*Understand the factors limiting cell and module performance; improved engineering basis for manufacturing processes.*	◦ **Study reaction kinetics during crystallization of CIGS absorber to improve absorber quality.**
(b) Develop improved in situ diagnostic tools	*Improved process monitoring and control*	◦ **Determine best in-situ techniques and embed them into R-t-R tools.**

Project Update

Past

Future

Planned work since last Program Review	Status	Deliverable
Optimize metal foil substrate, demonstrate 50cm2, >7% cells	Completed on time	**D2**
Absorber development (>8% cells)	Completed on time	**D1,D4**
Large area cell fabrication (100 cm2 cells, 10%)	Completed on time	**D5**
Roll-to-roll processing (composition control)	Completed on time	**D3,D6**
Module fabrication (0.5 m2 module, 7%)	Completed on time	**D7**
Building manufacturing line (move into facility and order tools)	Completed on time	
100 cm2 cells (R-t-R processing)		**D8**
11% efficient 100 cm2 cells		**D9**
Module fabrication (1 m2, 8%)		**D10**

Obstacle Discussion

- No fundamental obstacles or barriers have been identified that would cause problems for reaching the remaining milestones and delivery of the last three deliverables to successfully complete this Phase I program

Acknowledgement

- We acknowledge the critical support and quick response of the Measurement and Characterization Group at NREL in the areas of material characterization, electron microscopy, and surface analysis; and the Thin Film Group for bench-marking SoloPower thin films and devices