

# 2008 Solar Annual Review Meeting

**Session: CIGS**

**Company or Organization: National Center for Photovoltaics  
Funding Opportunity: EE&RE**

**Miguel Contreras**

1617 Colde Blvd., MS 3219  
Golden, CO 80401  
Phone: 303 384 6478  
Fax 303 384 7600  
[miguel\\_contreras@nrel.gov](mailto:miguel_contreras@nrel.gov)



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April 22-24, 2008 in Austin, Texas



**NREL National Renewable Energy Laboratory**

*A national laboratory of the U.S. Department of Energy  
Office of Energy Efficiency & Renewable Energy*

*Innovation for Our Energy Future*

# Budget and Solar America Initiative Alignment



## *Company or Organization*

<b>Project Beginning Date</b>	<b>FY07 Budget</b>	<b>FY08 Budget</b>	<b>Total Budget</b>
10/1/06	\$ 1.851 millions	\$ 1.750 millions	\$3.601 million

- This project supports the Solar America Initiative by carrying out work on target topics identified for Photovoltaic Systems:
  - Improving cell and module efficiency of thin film Cu(In,Ga)Se<sub>2</sub> materials
  - Implementing the Science and Technology Facility (S&TF) and the Process Development and Integration Laboratory (PDIL) to facilitate laboratory/industry interaction in developing PV manufacturing technologies
  - Addressing industrial issues in materials and manufacturing processes with the objective to lower the cost of PV power.
  - Providing technology transfer efforts to accelerate transition of thin film PV technology to market and deployment.
  - Assisting R&D efforts to assess and improve reliability and stability of thin film PV products.
  - Assist the SAI TPPs in technical matters related to CIGS PV technology

# Project Overview



## FY07 activities and FY08 planning

### FY07 Non technical

- ✓ Move CIGS operations from SERF to S&TF

### FY07 Technical

- ✓ Design and build the CIGS cluster tool for the Process Development and Integration Laboratory at the S&TF
- ✓ materials cost reduction studies: thin CIGS
- ✓ Sensor development for Quality Control and Intelligent Processing
- ✓ Improve quality of materials and processes
- ✓ Develop new materials for PV applications

### FY08 Plan and status report

- ✓ Tasks and milestones

# Project Alignment with Technology Roadmap



What needs in the Technology Roadmap are your projects responding to?

- *Enhance module and cell efficiency*
- *Improve cell/module manufacturing processes*
- *Discover alternative approaches and new materials*
- *Align with TPPs identified in SAI to assist them in their commercialization efforts; work on industry relevant issues*

What approaches are you using to address those needs?

- *Assist with priority the TPPs in the development their technologies toward commercialization*
- *In-house R&D work aimed at improving materials and processes to lower the cost of CIGS thin film PV*
- *Develop new materials to be used in thin film solar cells and modules*
- *Address stability and reliability issues to improve commercial CIGS products*
- *Will begin studies in processes identified as potentially low-cost approaches (non-vacuum processes) to effectively aid TPPs that have adopted such technologies*

# Project Update



## Planned work since last Program Review

Move CIGS operations from SERF to S&TF

Design and build the CIGS chamber for the CIGS cluster tool to be located in the Process Development and Integration Laboratory at the S&TF

Materials cost reduction studies; thinner CIGS films to reduce Indium usage

Improve quality of materials and processes

Develop new materials for PV applications: SWCN to replace TCOs

Sensors development for quality control and process control

Finalize specification and engineering for remaining components of CIGS PDIL platform

Begin installation of CIGS cluster tool in PDIL: start operations of stand-alone CIGS chamber

Sensors: Assess strategies that can establish key metric for ultimate device performance

Expand research of alternative processes for CIGS layer deposition (non-vacuum processes)

Collaborate and assist TPPs identified in SAI Conversion Technologies area

Improve quality of materials and processes

Develop new materials for PV applications: alternative substrates (foils, sheets, etc.)

Partner with industry to develop new products based on CIGS thin films: CRADA

## Past

### Status

Completed on June 2007

PO for CIGS chamber placed on Dec 2006

Completed on Feb 2007 and ongoing in FY08

Completed Sep 07 and ongoing in FY08

Completed on Sep 2007

Delayed until FY08

Completed on Dec 2007

FY08: Ongoing

FY08: Started Oct 2007 and Ongoing

FY08: Start June 2008

FY08: Ongoing

FY08 Ongoing

FY08: start May 2008

FY08: start May 2008

## Future

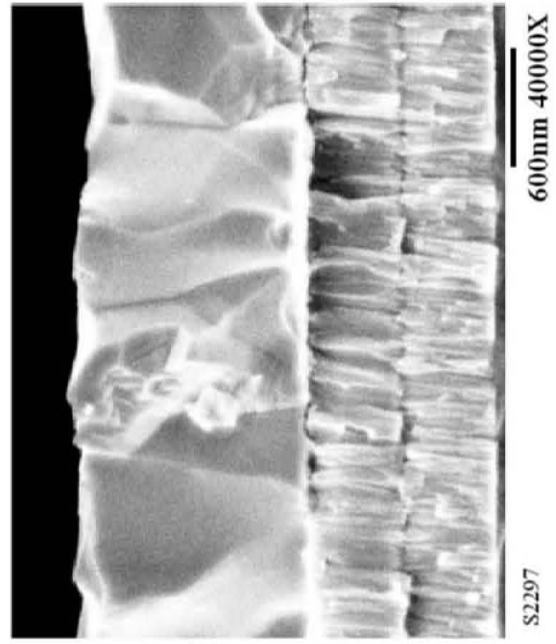
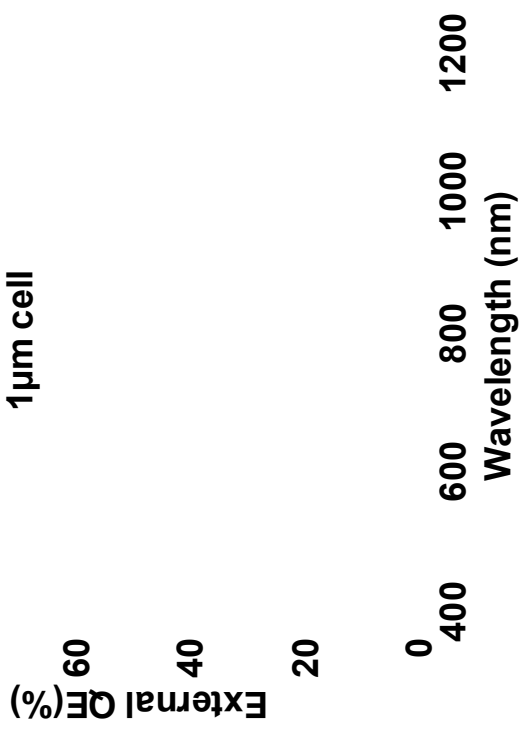
# Project Update: technical results and contributions



The issue of Indium cost:  
one solution is the use of  
thinner layers of CIGS



	1µm cell	Std cell	Thickness (µm)	Voc (V)	(mA/cn	FF (%)	Eff. (%)
			<b>1</b>	<b>0.678</b>	<b>31.9</b>	<b>79.2</b>	<b>17.1</b>
			1	0.699	30.6	75.4	16.1
			0.6	0.658	26.1	73.1	12.6
			0.4	0.565	21.3	75.7	9.1
		Control	2.5	0.728	31.87	80.3	18.7



NREL Publications/presentaions generated on this subject:

- Proc. Of the 2006 IEEE PVSC
- Report to Thin Film Partnership
- Preliminary report to DOE in 2006 Progm. Review

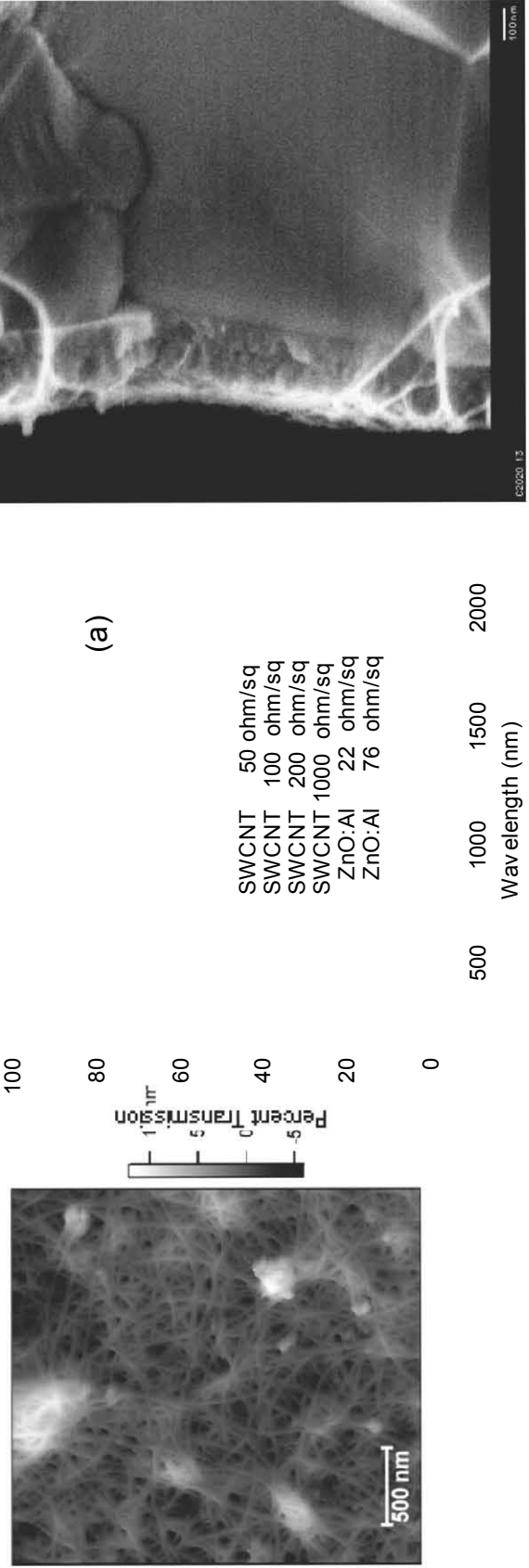




# New materials for PV: Replacement of TCOs by layers of carbon nanotubes

Device Results for Solar Cells with Structure of Invisicon/I-ZnO/CdS/CIGS/Mo Using Varying Sheet-Resistance Values for the SWCNT Layers;  
State-of-the-Art ZnO/CdS/CIGS Values Are Shown in the First Row for Reference

SWCNT ( $\Omega$ /sq)	Voc (V)	Jsc (mA/cm2)	FF (%)	eff. (%)	Rs ( $\Omega$ -cm)	Rsh ( $\Omega$ -cm)
ZnO	0.693	35.34	9.4	19.5	1.449	8798.10
100	0.674	31.21	61.66	12.98	5.826	596.70
75	0.622	29.12	64.93	11.7	3.22	510.78
50	0.598	25.02	62.13	9.30	3.656	265.05

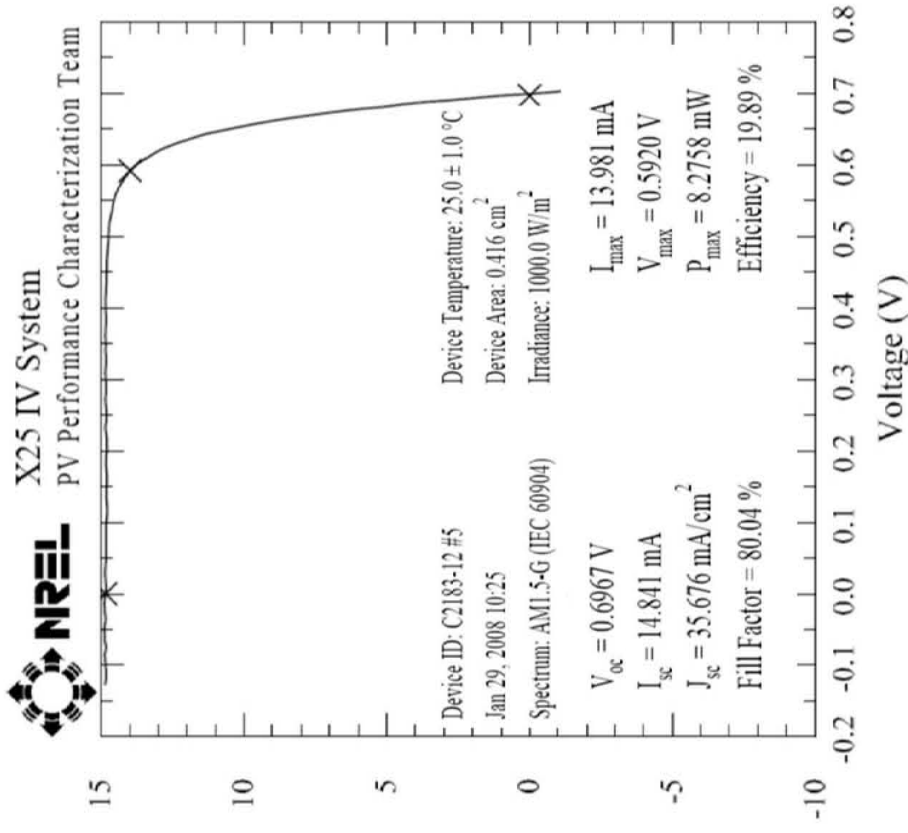
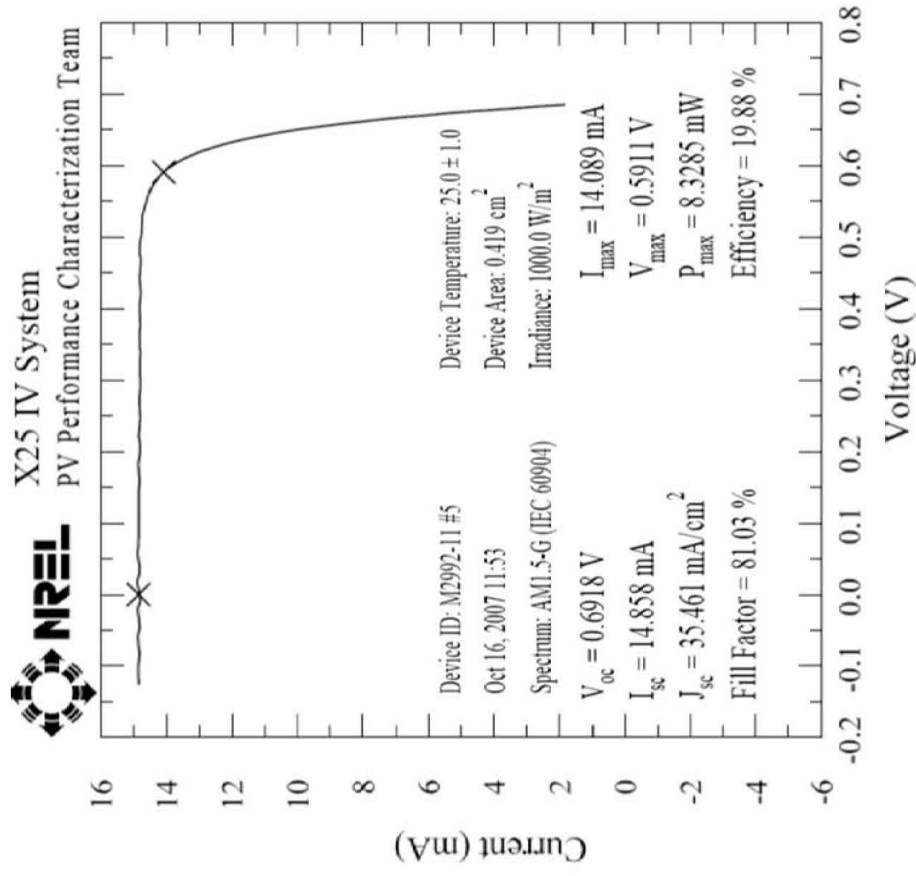


NREL Publications/presentations generated on this subject:  
Proc. Of the 2006 IEEE PVSC  
J. Phys. Chem. C, Vol. 111, No. 38, 2007

# Project Update: technical results and contributions

## Improvements to CIGS materials, processes and lowering the cost of thin film PV:

### New world record in conversion efficiency attained



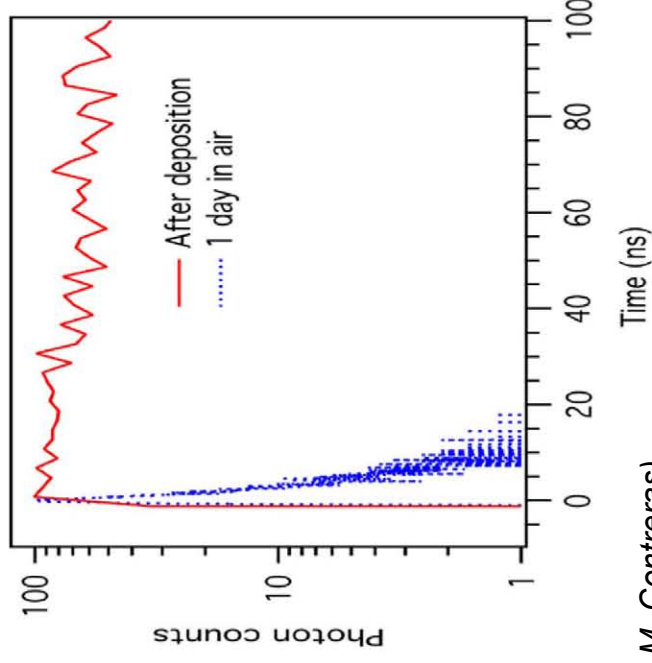
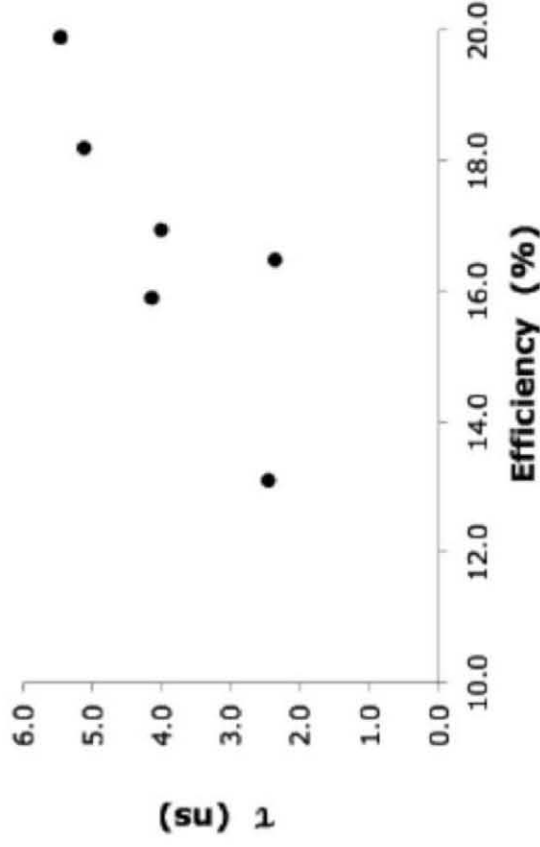


# Project Update: technical results and contricutions



## Sensors: identification of a key metric to use as quality control and/or process control

*A tentative correlation has been found between calculated carrier lifetimes (as determined by TRPL) and device performance. \Ongoing work is testing the correlation over the wide variety of film qualities that might be found in industry, and developing this measurement (and others) into sensors that can reliably and accurately predict a priori device performance and/or CIGS quality.*

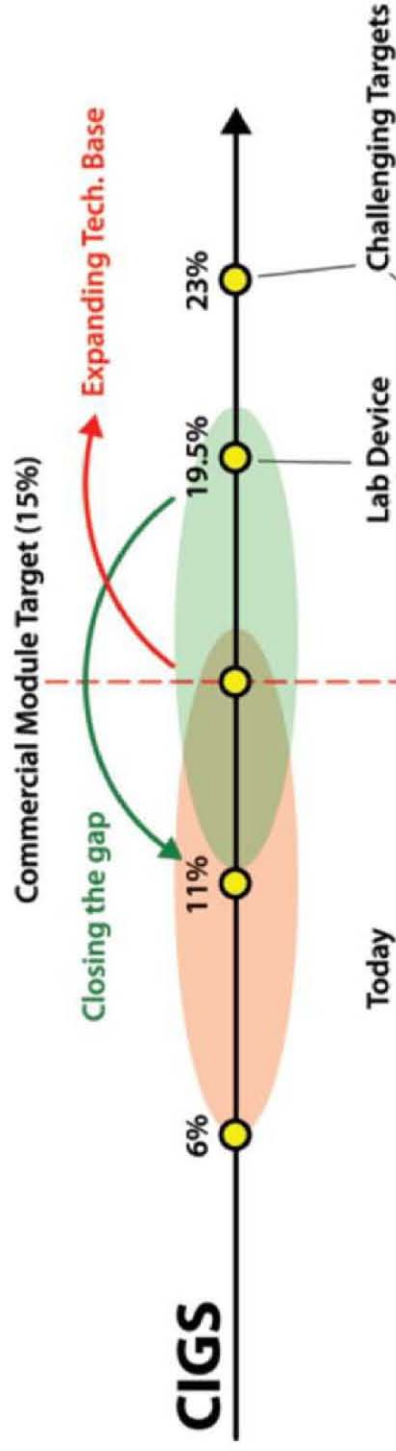


NREL publications/presentation on the subject:  
*Manuscript submitted to Appl. Phys. Lett. (W. Metzger, I. Repins and M. Contreras)*  
*Manuscript and oral presentation at the upcoming IEEE PVSC and E-MRS Conferences*

## Project Update: technical contributions



The CIGS group will assist SAI TPPs and other industrial partners in narrowing the energy conversion efficiency gap between laboratory results and commercial products by directly collaborating, assisting and advising on technical matters related to CIGS technology



# Obstacle Discussion



- Barriers encountered or anticipated that may inhibit success of programs
  - ✓ Success may be inhibited by limited human resources. From FY05 the CIGS Group at NREL has lost more than half of its scientists. Currently the CIGS group consists of two scientists.

*We will give priority to support the SAI objectives and those of the TPPs working in CIGS technology. But, support to other industries not participating in the SAI will have to be done under new CRADAs (or other funds-in agreements with NREL) in order to acquire the necessary manpower to handle additional industry requests for collaboration.*