SAND2012-0391P

Microsystems Enabled Photovoltaics (MEPV) Grand Challenge

(Science-Enabled Next Generation PV for Disruptive Advances in Solar Power and Global Energy Safety and Security)

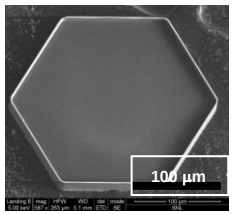
PI: Gregory N. Nielson **PM: Jeffrey S. Nelson**

External Advisory Board Meeting

December 15th, 2011

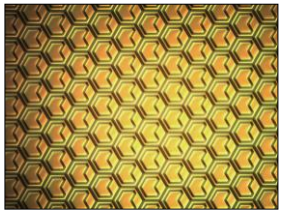
History of MEPV Research Efforts

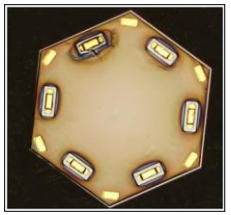
2005-2006



2007

2009





2011

Research Process:

Can we make them, Si and III-V?

Do they have good performance?

What are the advantages of small cells?

Can we assembly them?

Can we integrate Si and III-Vs?

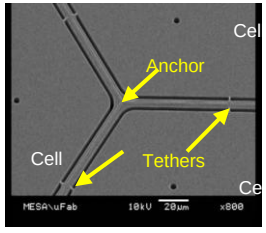
Can we interconnect them? Advantages?

Is it possible to integrate micro-optics?

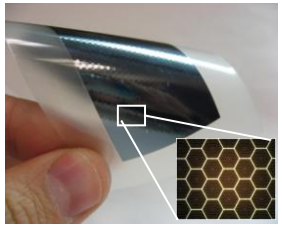
Are the cost models compelling?

Do we see significant opportunities for performance and cost improvements?

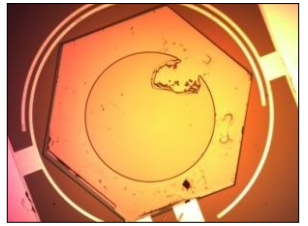
Is there a new systems concept that will benefit the US solar industry?



2009

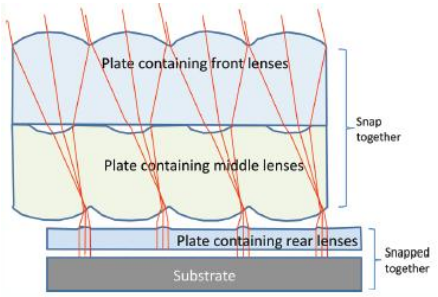


2010



2011

2010



2010-2011

Grand Challenge!

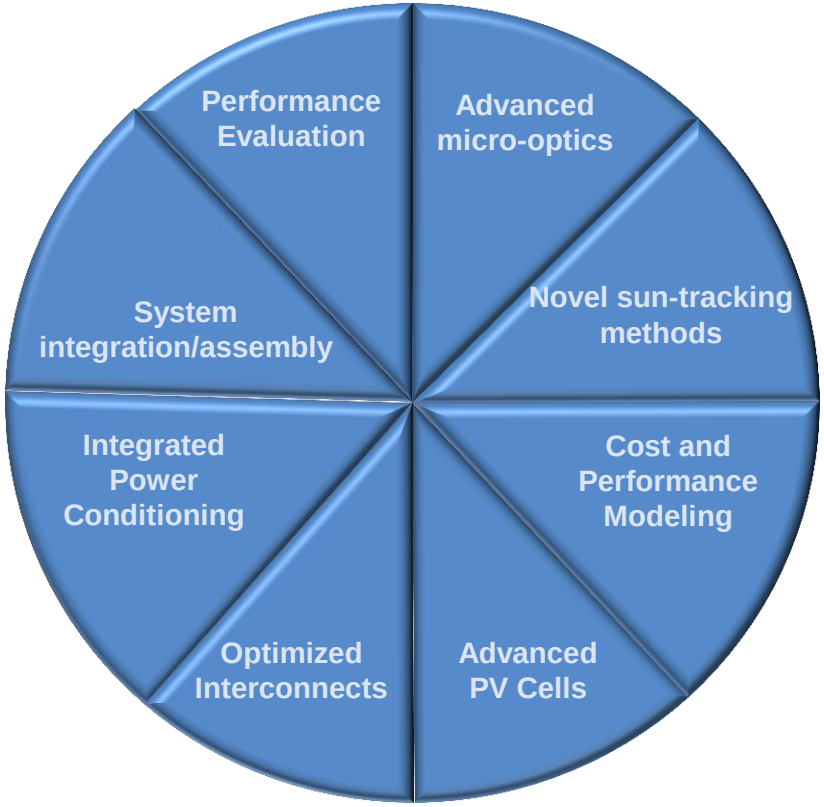
MEPV Grand Challenge: R&D Goals and Task Areas

System Performance Goals:

- **Develop a next-generation PV module and system based on Microsystems-Enabled PV (MEPV) technology with 40% conversion efficiency.**
- **Achieve a solar power system that provides power that is cost-competitive with grid power (less than $0.10/kWh).**

National Energy Security
DOE SunShot Initiative

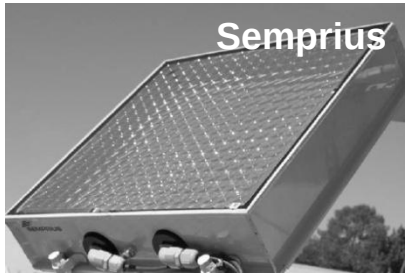
Scientific and Engineering Advances:



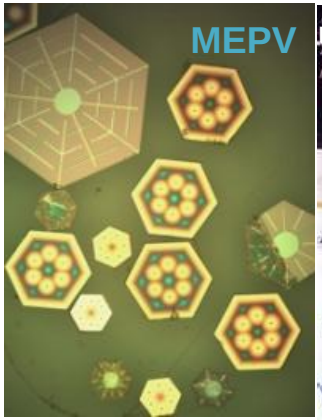
High-Risk, Multi-Disciplinary Solution, Requiring Broad Technical Capabilities

The MEPV Team has a Big Challenge Ahead

CPV Industry



But the reward will be Great!



PV Industry

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

MEPV Team

MEPV GC Leads

Greg Nielson(PI) Jeff Nelson(PM)
Murat Okandan Vipin Gupta

PV Cells and Materials (Greg Nielson):

- Bob Biefeld, New PV Materials Development (**Lead**)
  * Jonathan Wierer, InGaN Device Fab and Processing
  * Jeff Cederberg, InGaAsP Growth (AlInGaP & AlGaAs)
  * Anna Tauke-Pedretti, Device Modeling & Fabrication
  * Gerry Girard, InGaAsP Device Testing
  * Dan Koleske, InGaN Growth

- Igal Brenner, Photonics for low Eg PV cells/Light Trapping
- Willie Luk, Photonics for low Eg PV cells/Light Trapping

- Murat Okandan, Si Cell & Process Design
- Jose Luis Cruz-Campa, Si & GaAs Processing
- Paul Resnick, Si Processing
- Carlos Sanchez, GaAs Processing

Performance (Jose Luis Cruz-Campa):

- Jennifer Granata, Reliability
- Craig Carmignani, Outdoor Testing
- Bongsang Kim, Cell testing

System Design, Integration, and Assembly (Murat Okandan):

- Jose Luis Cruz-Campa, Stack Integration
- Tony Lentine, Integrated Electronics
- Judy Lavin, Directed Self Assembly
- Jeff Koplow, Systems Engineering

Cost Modeling (Vipin Gupta):

- Scott Paap, System Models
- Jose Luis Cruz-Campa, BOS Models
- Murat Okandan, Process Models

Optics (Bill Sweatt):

- Bradley Jared, Micro-Optics Fabrication and Design
- Ben Anderson, Optical Materials
- Vipin Gupta, Coatings
- Jose Luis Cruz-Campa, Optical System Design
- Mike Haney (University of Delaware), Micro-optics

High Concentration CPV Systems

General Characteristics:

- High Efficiency Cells (~ 37-42%)
- High Concentration (~500-1000x)
- Large, Stiff, Accurate Tracking Structures
- Promising System Efficiencies (~ 24-30%)
- Improving Costs (CPV → PV → TF)
- Demonstrating Field Reliability
- Increasing Manufacturing Capacity

Low Concentration CPV Systems

General Characteristics:

- More Efficient use of Cell Manufacturing Capacity
- Small Increase in Efficiency (1-2%)
- Low Concentration (3x-15x)
- Mechanically Simple Single-Axis Tracking
- Use in a Wider Range of DNI Environments

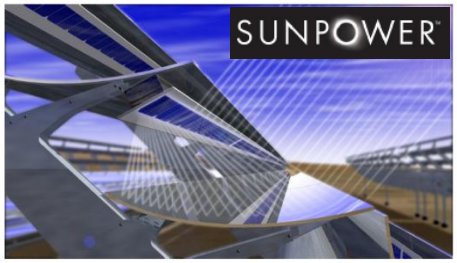
TBD

- Future Upgradeability?
- Decreased Cost?
- System Reliability more “Bankable”?

3x

7x

Simple optical system uses glass mirrors to focus 7 suns onto a SunPower high efficiency solar cell



14x

Skyline X14 System

- Silicon, reflector, 1-axis tracker

Sandia MEPV Systems Vision

General Characteristics:

- Moderate Concentration (50-100x)
- Inexpensive Trackers (Flat-plate, 2-axis), Large Acceptance Angle, Refractive Micro-Lens Arrays (±4-8°)
- Non-Monolithic, Vertically Stacked, 1J-4J, High-Efficiency Cells
- Thin Cells (Si and III-V) with Back contacts
- Wafer Bonding, Layer Release and Transfer Approaches
- Integrated Power Conditioning
- 3D Integration and Optoelectronic Packaging
- IC/MEMS Processing Technologies

Synergistic Benefit to US Industry

External Partners

Organization (POC)	Work Description/Need
NREL (Mark Wanlass)	Growth and development of novel AlGaAs/AlInGaP dual junction cells (WBS 3.3).
Emcore (Paul Sharps)	Growth of inverted dual junction GaAs/InGaP cells (WBS 3.3).
University of Delaware (Mike Haney)	Optical design of novel large acceptance angle optics for moderate concentration level MEPV systems, system analysis, and defense application studies (WBS 2.1).
International Micro Industries	Electroplating of high accuracy stud and solder bumps for high performance die to die and die to substrate interconnects (WBS 4.1).
Universal Instruments	Development of pick-and-place and surface mount technology for proposed systems (WBS 4.3).
Endicott Interconnect	Development of metalized substrates providing electrical leads for electrical connections to cells (WBS 4.2).
IC Knowledge	Cost modeling expertise for modeling specific cost-of-ownership values for different cell processing techniques (WBS 6.1).
Deposition Sciences	Advanced anti-reflection coating design, modeling, deposition, and testing (WBS 2.4).
Georgia Tech	Provides unique high indium content InGaN deposition method (WBS 3.2).

Communications and IP

Meetings:

- Principals meet every week
- Team Leads meet with Principals every other week
- Team Leads meet with their team and PI each week
- Project Team meets Quarterly (1/26/2012, 5/3/2012, 8/23/2012)
- Project kickoff meeting Oct. 27th, 2011
- First EAB meeting Dec. 15th, 2011

Sharepoint Site:

- MEPV site: https://sharepoint.sandia.gov/sites/mepv/default.aspx
- Post all significant results, publications, internal events
- Serve as a communication portal for external advances and events
- Project communication tool
- Expectation for team members to participate on the site

Intellectual Property:

- PM, PI, and IP lead (Vipin Gupta) notified on all TA's and Patent Apps

Project Funding

	FY12	FY13	FY14
Requested	$5.6M	$5.4M	$5.4M
Granted	$3.4M	$4.5M	$4.5M

	Labor	Purchases	Subcontracts	Travel	Total
	Yr 1	Yr 1	Yr 1	Yr 1	Yr 1
1.0 System	470	10	0	4	484
2.0 Optics	395	15	175	17	602
3.0 PV Cells and Materials	875	80	65	24	1044
4.0 Integration, Assembly, and Packaging	326	36	115	10	487
5.0 Performance Evaluation	65	5	0	0	55
6.0 Cost and Performance Modeling	125	0	15	8	148
7.0 Project Adminstration	435	0	55	40	530
Totals	**2691**	**146**	**425**	**103**	**3350**

What You Should Expect

Today :

- **Well motivated project with targeted project deliverables**
- **Focused integration of individual project areas**
- **Main technical challenges and our solutions**

Challenges

Fabrication Costs, Materials Lifetime, Optical Interfaces

In Incorporatation

Interfaces

Wafer Bonding

Liftoff Processes

Optical Interfaces

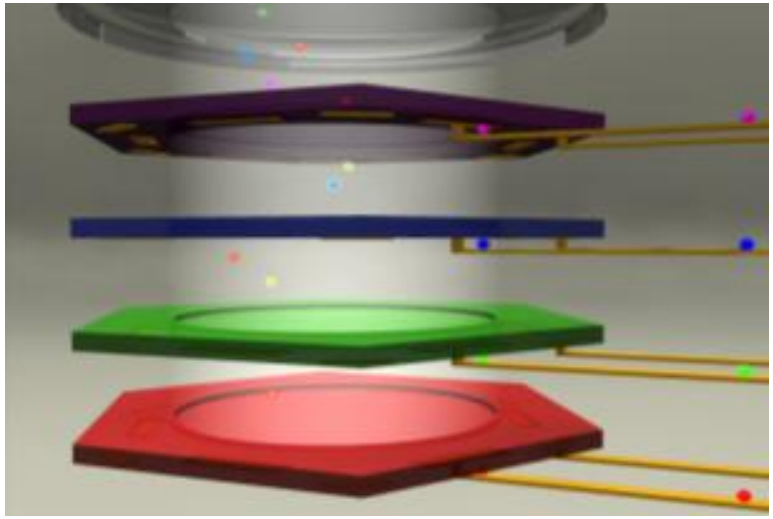
Process Integration

New Interconnect Paradigm Optimization for Efficiency and Reliability

Vipin Gupta
(Cost Model)

Greg Nielson

Murat Okandan
(Integration, Assembly)



Jose Luis
(Synergistic Applications: Flexible Formats)

Solutions

Bill Sweatt
(Micro-optics Design)

Jonathan Wierer
(III-N Cell)

Bob Biefeld
(III-V Cells)

Tony Lentine
(Interconnection/ Power Conditioning)

What You Should Expect

Next September:

- **On-Sun results from our first prototype**
- **Significant progress on our technical challenges**
- **Clear path to the second generation prototype integrating Si and III-V cells.**
- **A comprehensive cost model.**

3-Year Project:

- **Demonstrate a new system architecture that allows for performance improvements, dramatic initial price reductions, and continued price reductions over time and with volume manufacturing**
- **Firmly establish the role of microsystem technologies within solar power and establish Sandia as the lead national laboratory for microsystem-enabled photovoltaic work**
- **Develop an IP portfolio designed to allow rapid commercialization of technologies**

Agenda

9:00AM-9:40AM	Charles Barbour Hank Westrich Jeff Nelson	Introductions and "Charge" to the EAB LDRD Programs Grand Challenge Overview
9:40AM-10:20AM	Greg Nielson	"Utility-Scale Photovoltaic Systems: Grand Challenge Vision, S&T, Project Roadmap"
10:20AM-10:35AM	Break and Refreshments	
Team Lead Presentations		
10:35AM-11:20AM	Murat Okandan	"System Design, Integration, and Assembly"
11:20AM-11:40AM	Bill Sweatt	"Optical Materials and Design"
11:40AM-11:55AM	Bob Biefeld	"III-V PV Materials and Device"
11:55PM-12:15PM	Vipin Gupta	"Cost Modeling"
12:15PM-1:00PM	Working Lunch- Discussion/Clarification of Project with EAB	
Selected Detailed Topics		
1:00PM-1:25PM 1:25PM-1:50PM 1:50PM-2:15PM	Tony Lentine Jonathan Wierer Jose Luis	"Cell Interconnections and Power Conditioning" "High-Bandgap Nitride Materials and Devices" "Flexible MEPV Formats"
2:15PM-2:20PM	Richard Macklin	"Charge to the EAB: Final Review"
2:20PM-2:30PM	Break	
2:30PM -3:45PM	EAB Closed Meeting	
3:45PM-4:30PM	EAB Report-Out to Grand Challenge Team and Sandia Management	
4:30PM	Meeting Adjourned	

Microsystems Enabled Photovoltaics (MEPV) Grand Challenge

(Science-Enabled Next Generation PV for Disruptive Advances in Solar Power and Global Energy Safety and Security)

Charles Barbour, Director

Physical, Chemical, and Nano Sciences Center

External Advisory Board Meeting

December 15th, 2011

EAB Team

Professor Joe Simmons	(Chair)	Professor of Materials Science and Engineering Professor of Optical Sciences Director, Arizona Research Institute for Solar Energy University of Arizona
Dr. Hong Hou		Chief Executive Officer Emcore Corporation
Dr. Dan Friedman		Manager, CPV R&D Group, National Renewable Energy Lab
Professor Stephen Fonash		Director, Center for Nanotechnology Education & Utilization Pennsylvania State University
Jon Hawkins		Manager, Advanced Technology and Strategy, Public Service Company of New Mexico
TBD		IC Manufacturing Executive
TBD		DOD R&D Representative

Questions for the External Advisory Board

Purpose and Vision

- Are the technical and program goals for the MEPV Grand Challenge clear, important, and timely? Have we focused our R&D activities on matters that are well suited to Sandia's strengths and role as a National Laboratory?
- Does the project have the potential to solve many of the outstanding technical challenges associated with utility-scale concentrating photovoltaics? Have we identified the most important technical challenges?

Proposed R&D

- In your opinion, is the proposed R&D leading-edge and does the proposed R&D demonstrate innovative thinking?
- Do the proposed project plan, R&D approach, milestones and metrics put the team in a position to achieve the MEPV Grand Challenge goals?
- Do we have the right team for the proposed R&D? Have we set up the right collaborations to fill the science or engineering gaps we have identified? Are there other potential collaborators that could contribute significantly to our R&D effort?
- Going forward, are there other technical directions we should consider in our project plan?

Impact

- Overall Project: if successful, is this project likely to demonstrate significant technical achievement and provide timely impact on solar energy adoption?
- Individual Technical Achievements: are individual project components likely to provide significant, meaningful impact to the solar community, and lead to other synergistic long-term research efforts?

Outreach:

- What can we do to raise the visibility of MEPV within the broader Photovoltaics community?
- How and to whom should we communicate our technical results?