# University PV Processes and Products Development Support

DOE Solar Energy Technologies Program

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# University Product and Process Development Objectives

## Leverage universities' fundamental understanding of materials and photovoltaic (PV) devices

- Accelerate transition of PV technology from laboratory to marketplace.
- Help industry efficiently develop and optimize manufacturing processes.

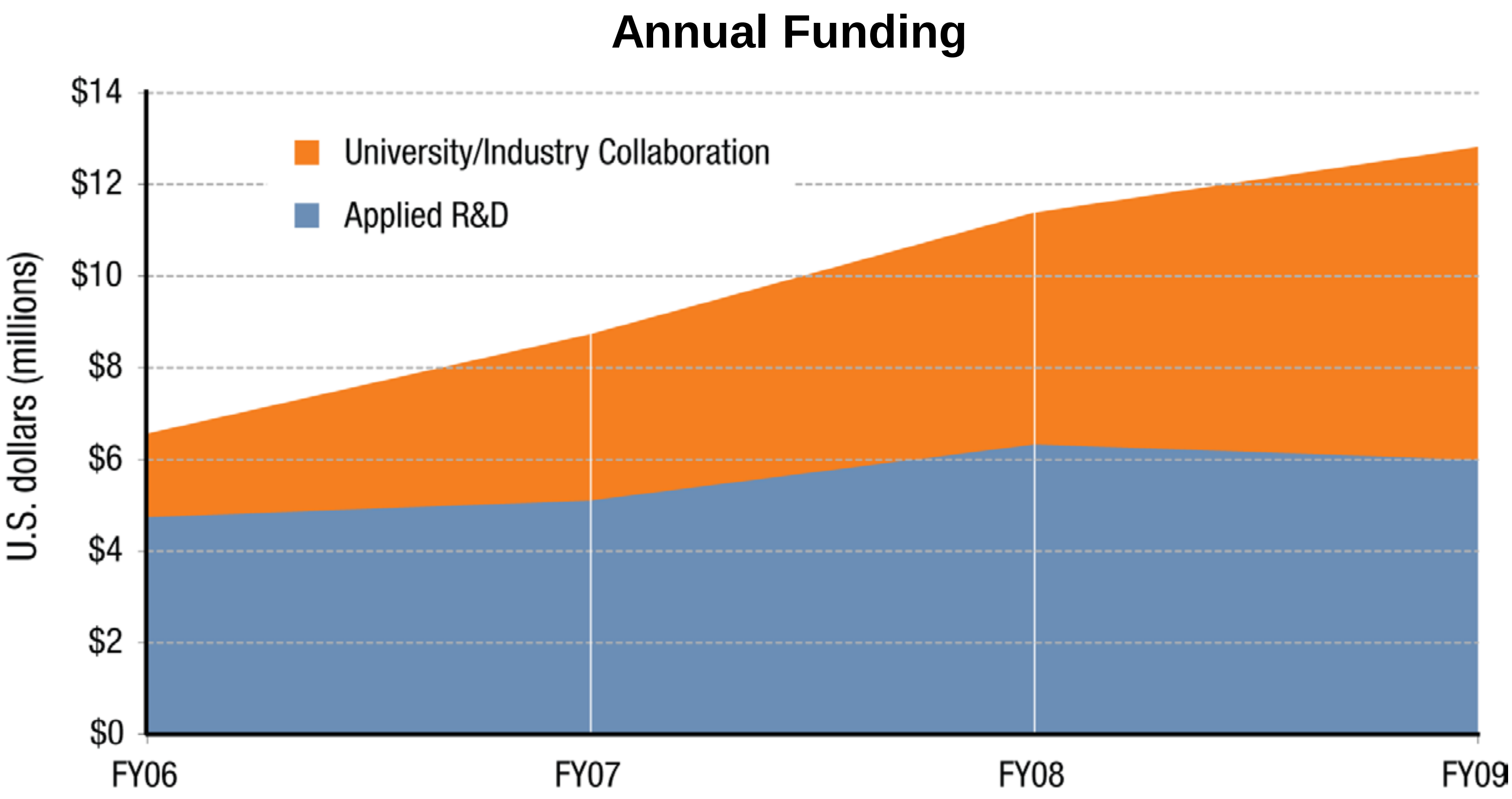
## Strengthen university involvement in rapidly expanding PV industry

- Form direct project partnerships between leading U.S. companies and proven university research groups.
- Provide clear strategies to move products and processes into commercial production.

## Expand the domestic PV R&D workforce

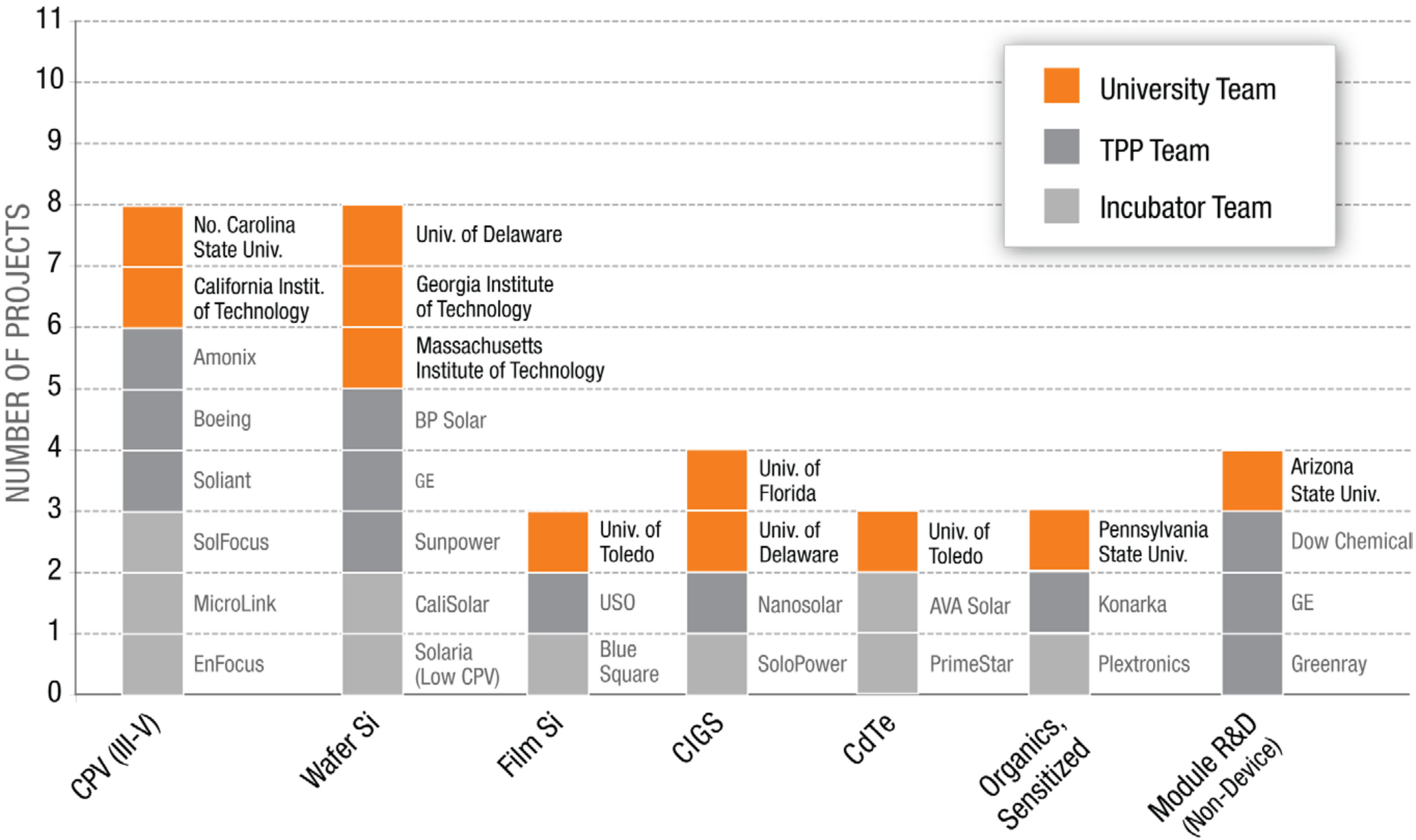
- Expose students to growing PV-related commercialization efforts.
- Supply industry with a stream of qualified scientists.

# Since 2006, DOE has increased university collaboration with industry while maintaining commitment to longer term R&D projects.

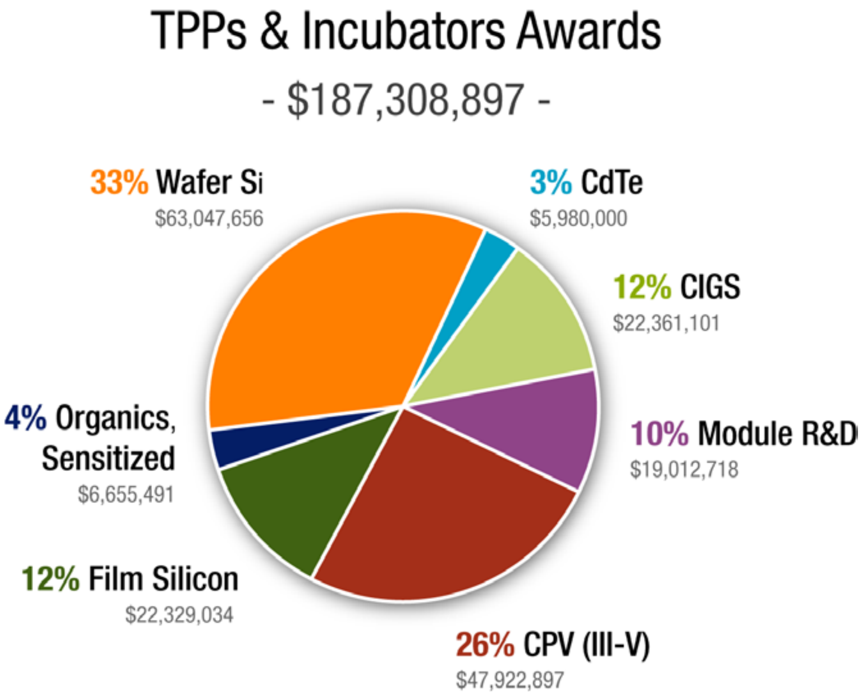


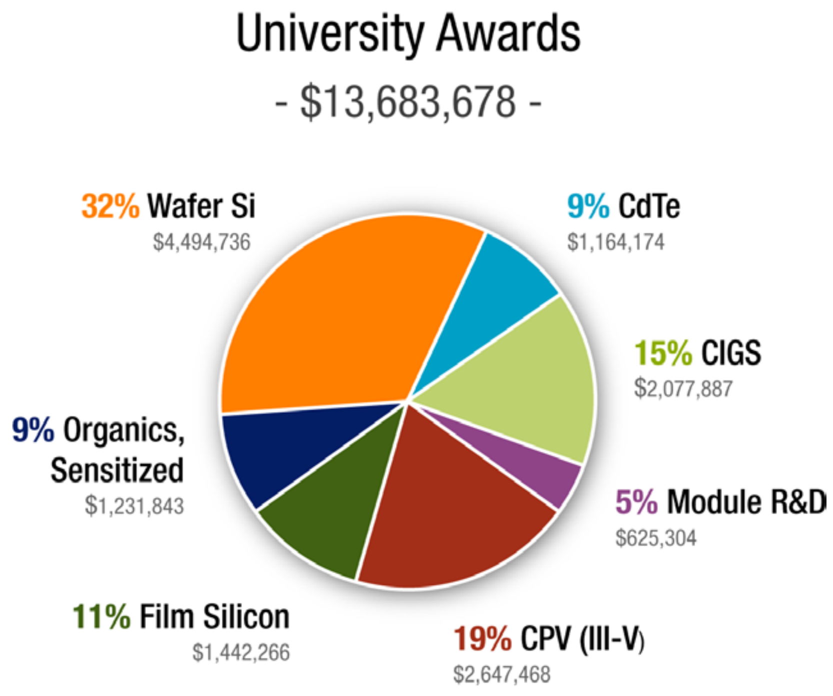

**University funding increases commensurate with PV budget increase**

# Distribution of projects across technology types.



# University Product and Process Development funding remains aligned with current industry targeted programs.

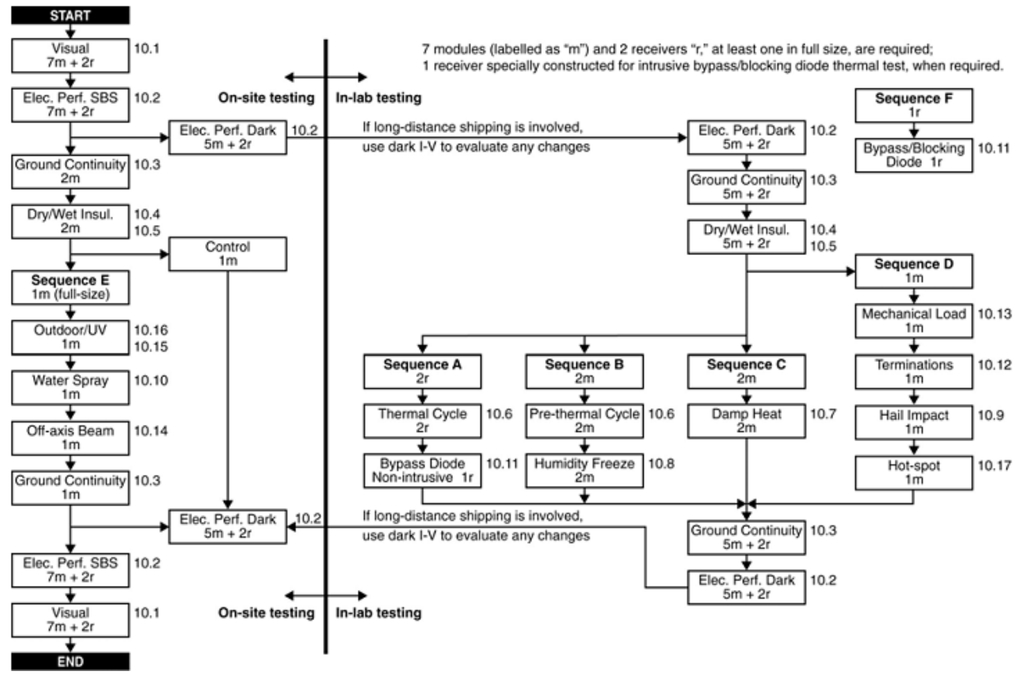


# Selected Projects:
# University PV Processes and Products Development Support

# Arizona State University
## with SolFocus, Inc. and Soliant Energy, Inc.

## Reliability Evaluation of Concentrator Photovoltaics per IEC Qualification Specifications




| Technologies Addressed |
|---|
| Product qualification process for concentrating PV modules |

| Description |
|---|
| Reduce qualification bottlenecks such as environmental chamber testing while enhancing scheduling and coordination with industry to significantly increase testing throughput and efficiency. |

| | |
|---|---|
| **Project Target** | **IEC testing costs and time reduced by as high as 65%** |

| Resources ($) | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$785,304** | **$625,304** | **$160,000** |

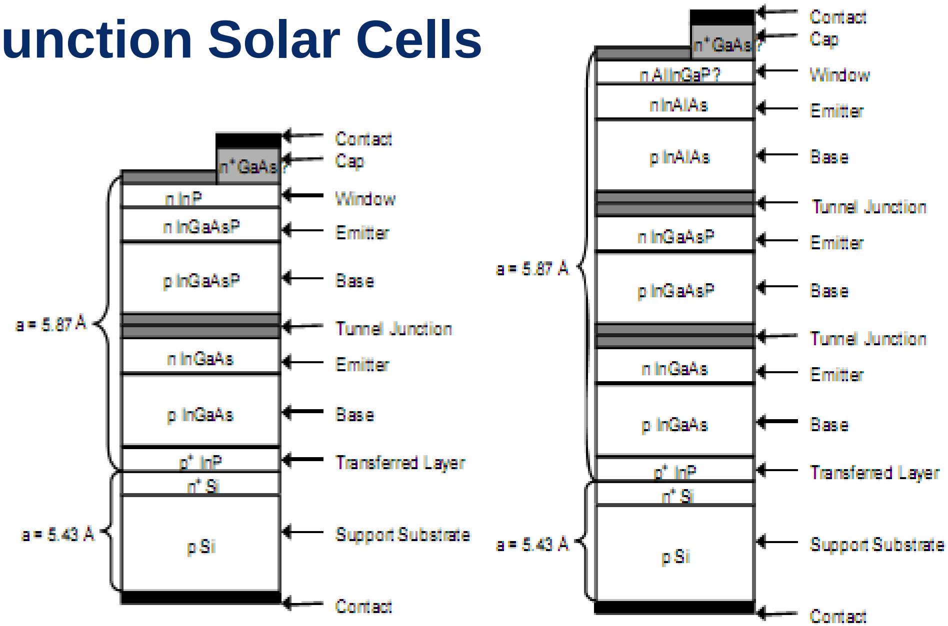
**Dr. Govindasamy TamizhMani**

# California Institute of Technology
## with Spectrolab, Inc.

## 100mm Engineered InP on Si Laminate Substrates for InP based Multijunction Solar Cells

| Technologies Addressed |
|---|
| Thin InP on inexpensive Si substrate for low cost multijunction cells |
| **Description** |
| Development 100 mm diameter InP/Si laminate substrates to enable development of a cost-effective, scaleable fabrication of InP based multijunction cell process, opening up a new design space for high-efficiency multijunction solar cells. |

| Target Efficiency | >40% |
|---|---|




a) Bottom Cell for Mechanically Stacked Multijunction Cell

b) Lattice-matched InP-based Triple Junction Cell

| Resources ($) | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,065,799** | **$837,000** | **$228,799** |

**Dr. Harry Atwater**

# Georgia Institute of Technology
## with SiXtron Advanced Materials, Inc.

## Rear Contact Technologies for Next Generation High-Efficiency Commercial Silicon Solar Cells

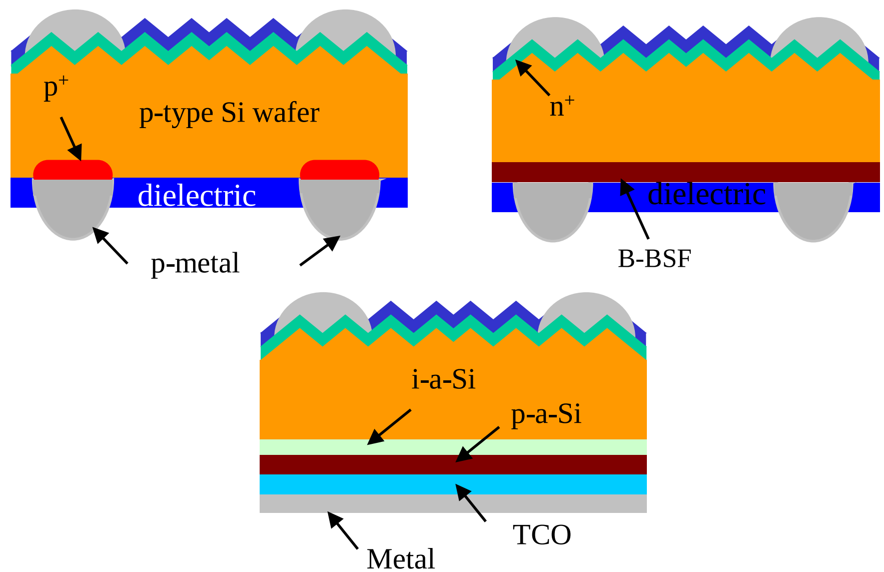
**Technologies Addressed**

Low cost monocrystalline and multicrystalline silicon solar cells

**Description**

Develop enhanced, cost-effective back surface passivation, light trapping, and inkjet printed back contacts, to yield a complete, low-cost, cell process which is ready for commercialization.

| **Target Efficiency** | **17-20%** |
|---|---|



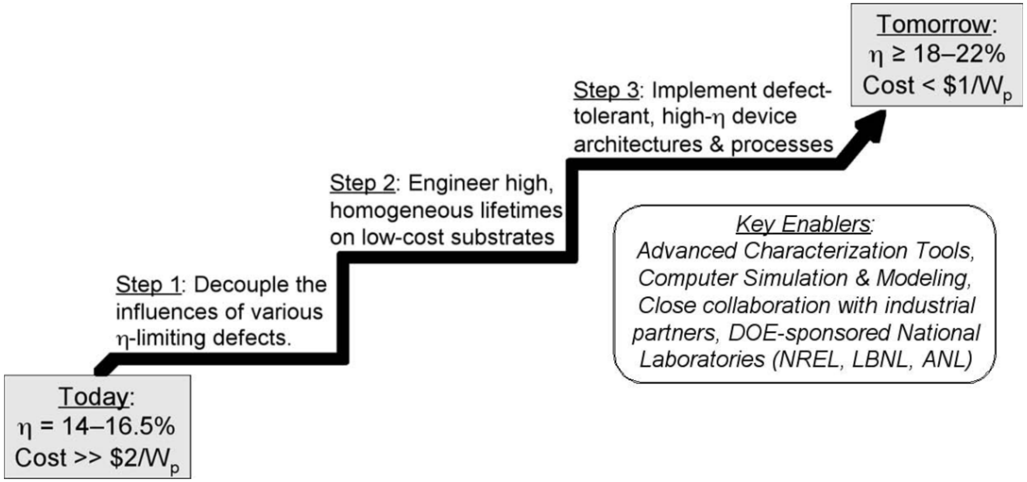

**Resources ($)**

| Total Project | DOE Funds | Cost Share |
|---|---|---|
| **$1,875,000** | **$1,500,000** | **$375,000** |


Dr. Ajeet Rohatgi

# Massachusetts Institute of Technology
with CaliSolar, Inc. and BP Solar International, Inc.

## Defect Engineering, Cell Processing, and Modeling for High-Performance, Low-Cost Crystalline Silicon Photovoltaics




| Technologies Addressed | |
|---|---|
| Low-cost monocrystalline and multicrystalline silicon solar cells | |
| **Description** | |
| Close the efficiency gap between industrial multicrystalline and high-efficiency monocrystalline silicon cells, while preserving the cost advantage of low-cost, high-volume substrates. | |
| **Target Efficiency** | **18-22%, <$1/W$_p$** |

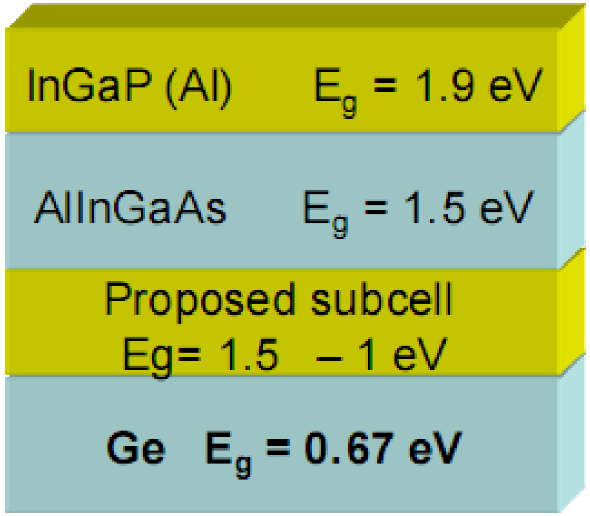
| Resources ($) | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,886,327** | **$1,500,000** | **$386,327** |

Dr. Tonio Buonassisi

# North Carolina State University
## with Spectrolab, Inc.

## Tunable Narrow Bandgap Absorbers for Ultra-High-Efficiency Multijunction Solar Cells

| **Technologies Addressed** | |
|---|---|
| High-efficiency 4-junction cells for CPV systems | |
| **Description** | |
| Develop and optimize a 1-1.5 eV, graded strain subcell and then integrate this layer into Spectrolab's triple junction device to produce a higher efficiency four junction solar cell. | |
| **Target Efficiency** | **45%** |



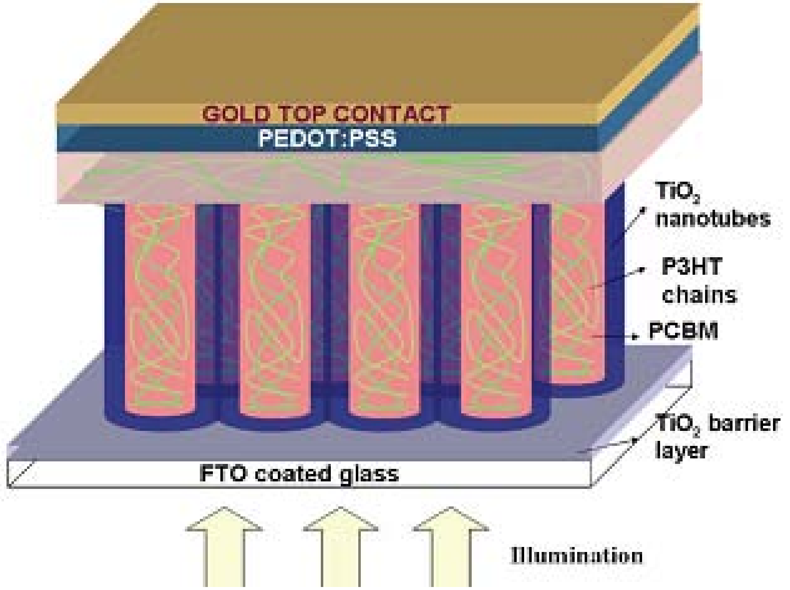

| **Resources ($)** | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,434,420** | **$1,147,468** | **$ 286,952** |


**Dr. Salah M. Bedair**

# Pennsylvania State University
## with Honeywell International, Inc.

## Organic Semiconductor Heterojunction Solar Cells for Efficient, Low-Cost, Large-Area Scalable Solar Energy Conversion

| Technologies Addressed | |
|---|---|
| Organic cell with ordered $TiO_2$ nanotube arrays | |
| **Description** | |
| Use high surface area $TiO_2$ nanotube arrays in combination with electron and hole transporting organic semiconductors to fabricate inorganic-organic hybrid hetrojunction solar cells. | |
| **Target Efficiency** | >7% |

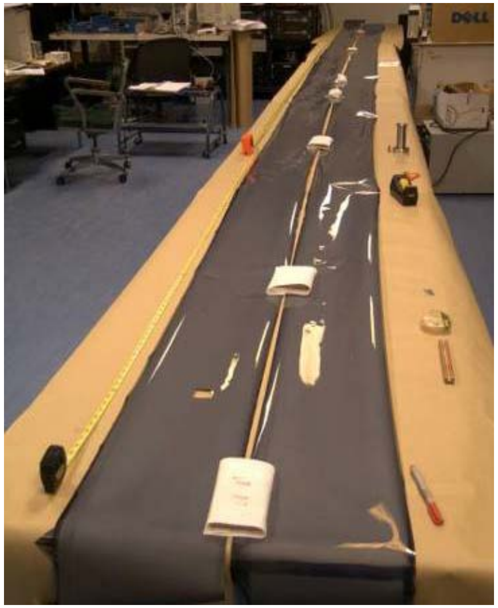



| Resources ($) | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,539,803** | **$1,231,843** | **$307,960** |

Dr. Craig Grimes

# Development of a Low-Cost Insulated Foil Substrate for CIGS Photovoltaics

| Technologies Addressed | |
|---|---|
| Insulating substrate for high-temperature CIGS deposition | |
| **Description** | |
| Develop a low-cost stainless steel flexible substrate coated with silicone-based resin dielectric and monolithic integration technology applicable across a variety of roll-to-roll (R2R) CIGS manufacturing techniques. | |
| **Target Efficiency** | **R2R devices ≥ 12%** |



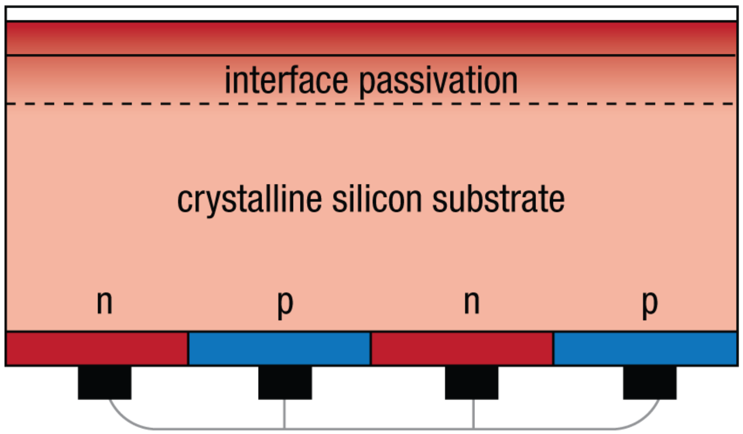
| Resources ($) | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,848,024** | **$1,478,331** | **$369,693** |

Dr. Erten Eser

## **University of Delaware** Institute of Energy Conversion with SunPower Corporation

# High-Efficiency Back Contact Silicon Heterojunction Solar Cells

| **Technologies Addressed** | |
|---|---|
| High-efficiency back contact silicon solar cells | |
| **Description** | |
| Develop low-temperature passivation, low-cost metallization and low-cost cell structures to fabricate rear interdigitated back contact hetrojunction solar cells. | |
| **Target Efficiency** | **>26%** |



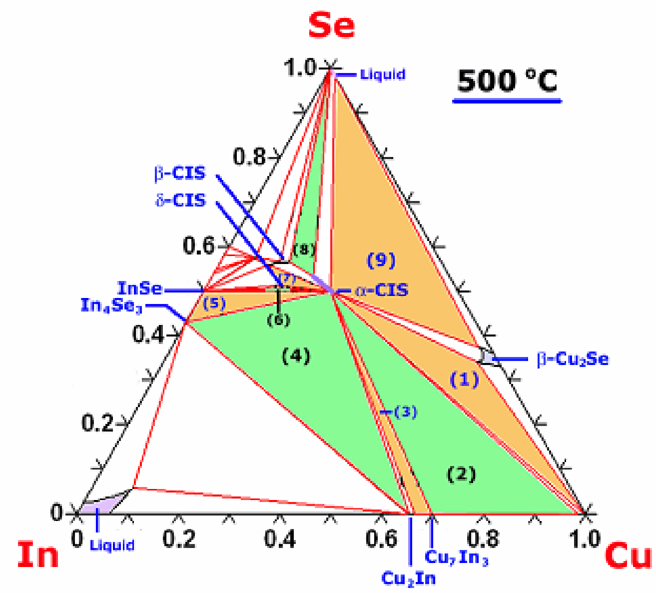

| **Resources ($)** | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,870,903** | **$1,494,736** | **$376,167** |

**Dr. Stuart Bowden**

# **University of Florida** with Global Solar Energy Inc., International Solar Electric Technology Inc., Nanosolar Inc., Solyndra Inc.

## Routes for Rapid Synthesis of CIGS Absorbers

| **Technologies Addressed** | |
|---|---|
| High-rate deposition CIGS | |
| **Description** | |
| Develop predictive models that quantitatively describe reaction pathways to synthesize CIGS which will reduce synthesis processing time and identify scaling issues for commercial manufacturing. | |
| **Project Target** | **CIGS synthesis ≤ 2 min** |




| **Resources ($)** | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$760,863** | **$599,556** | **$161,307** |

**Dr. Tim Anderson**

# **University of Toledo** with Calyxo USA, Inc.

## Improved Atmospheric Vapor Pressure Deposition to Produce Thin CdTe Absorber Layers

| **Technologies Addressed** | |
|---|---|
| Commercial CdTe modules | |
| **Description** | |
| Develop 10% efficient modules which utilize CdTe absorber layers approximately 1µm thick. Improvements to contacts, uniformity, and monolithic integration will also be achieved. | |
| **Target Efficiency** | **10%** |

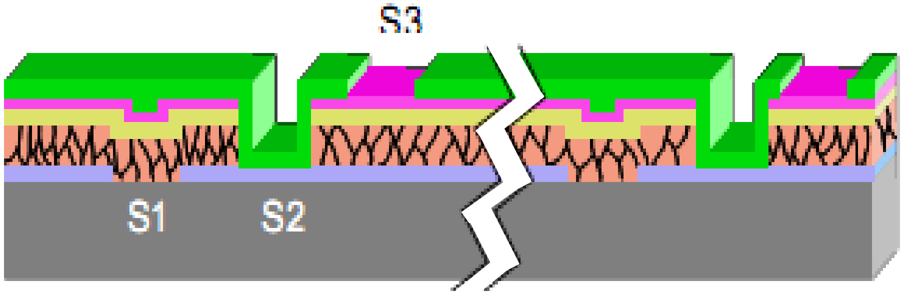



**Figure 1:** Three Scribe sequence shown for Calyxo USA monolithically integrated CdTe module.

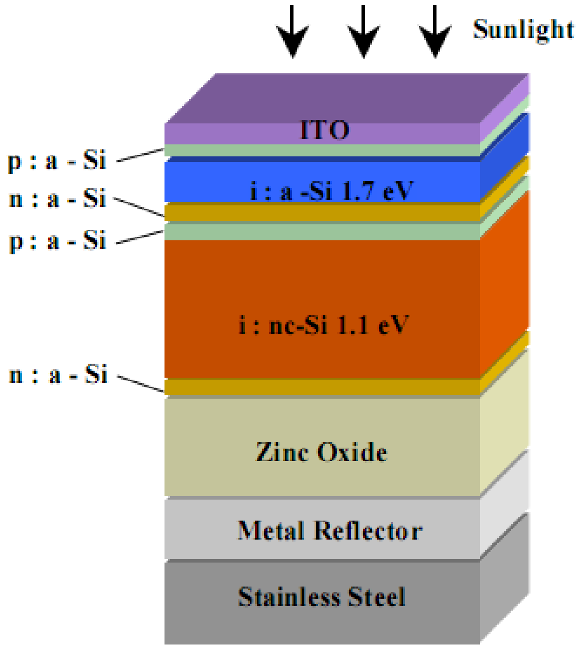
| **Resources ($)** | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,657,358** | **$1,164,174** | **$493,184** |

Dr. Robert W. Collins

# University of Toledo with Xunlight Corporation

## High Rate Fabrication of a-Si-Based Thin-Film Solar Cells Using Large Area VHF PECVD

| Technologies Addressed | |
|---|---|
| Amorphous silicon thin-film modules | |
| **Description** | |
| Develop uniform large-area (3 ft x 3 ft) VHF PECVD processes for fabrication of high-efficiency amorphous silicon and nanocrystalline silicon (nc-Si) solar cells at high rates. | |
| **Target Efficiency** | **10%** |




| Resources ($) | | |
|---|---|---|
| Total Project | DOE Funds | Cost Share |
| **$1,895,798** | **$1,442,266** | **$453,532** |

Dr. Xunming Deng