Industry Partnerships with Florida's c-Si PVMC

Cocoa, FL – Oct 23rd, 2015

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Director, Solar Technologies Research Division

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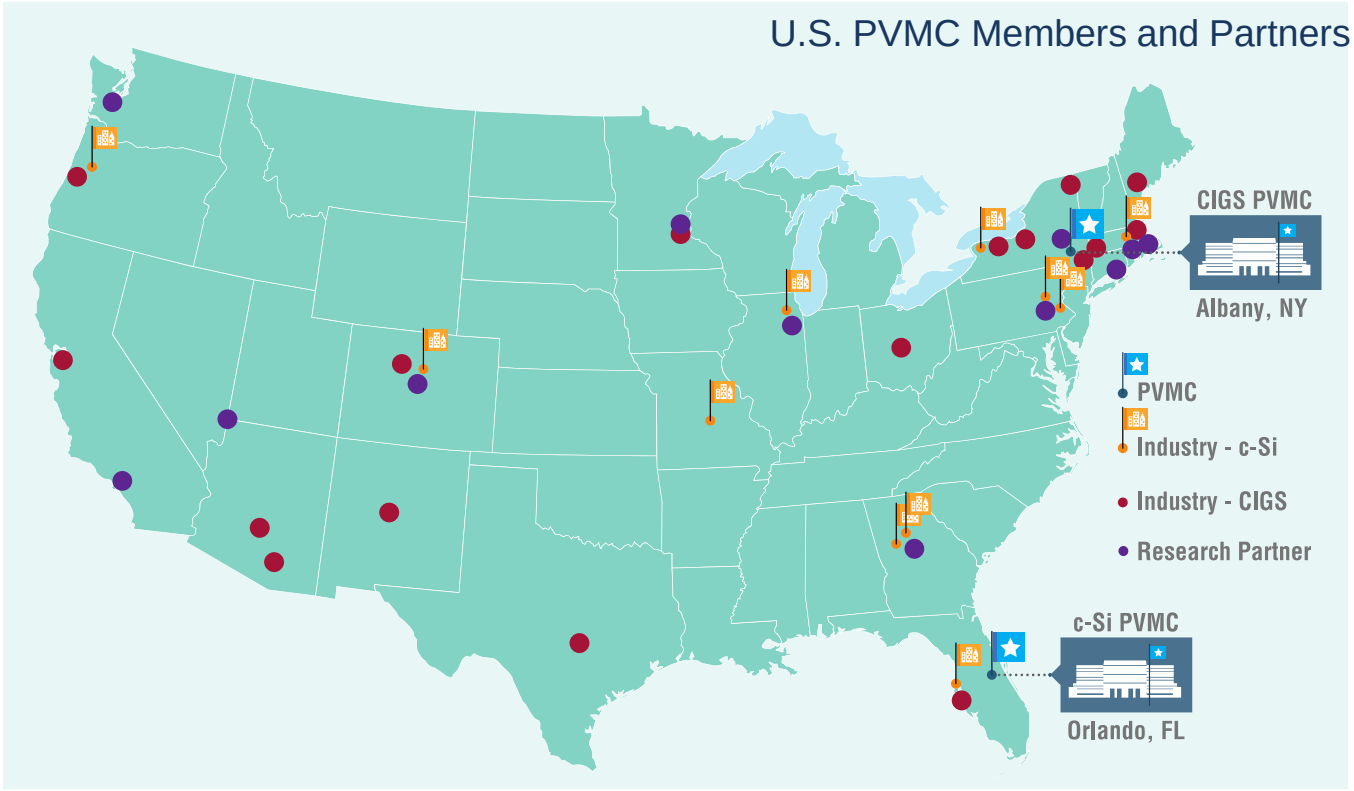
U.S. Photovoltaic Manufacturing Consortium (PVMC)

- Industry-led Consortium, funded by DOE SunShot Initiative
- Two Technology Areas: CIGS/Lightweight PV + c-Si PV
- Broad network of industrial members and partners (60+)



Significant physical infrastructure across Partner sites

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Initial Florida c-Si PVMC Program Areas

Polysilicon | Ingot | Wafer | Cell | Module | System

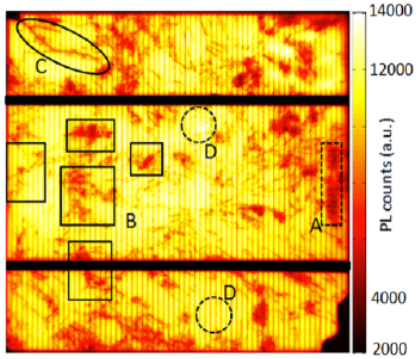





c-Si Feedstock/Wafering

Courtesy of AMAT

Diamond Wire Metrology



c-Si Metrology

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c-Si PVMC Industrial Membership

- Current c-Si PVMC Members

- However, the c-Si PVMC projects involve a much larger network of collaborators…

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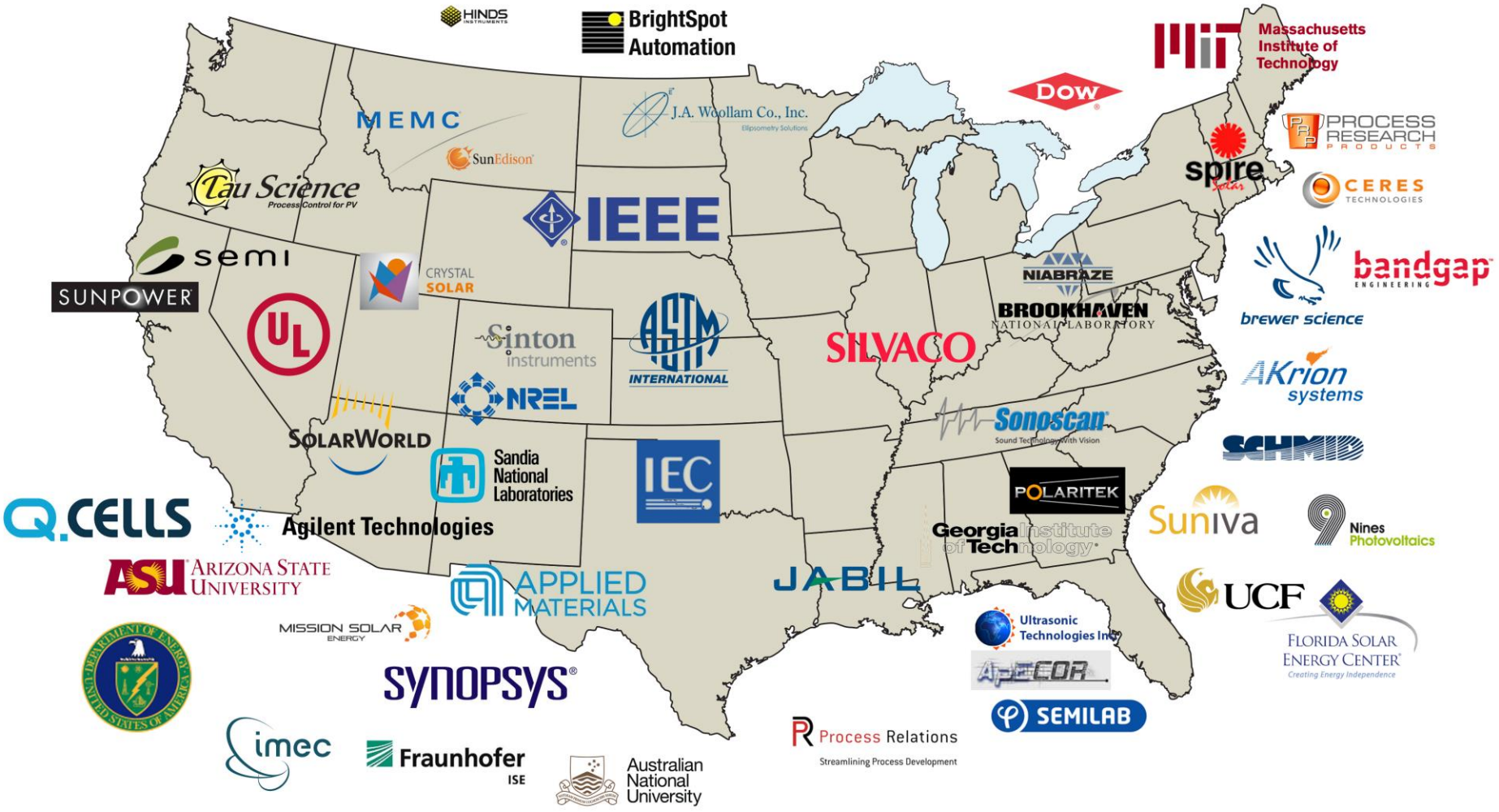
Map of c-Si PVMC Participants (*Members and Collaborators*)



One of the most powerful distributed networks of infrastructure in solar

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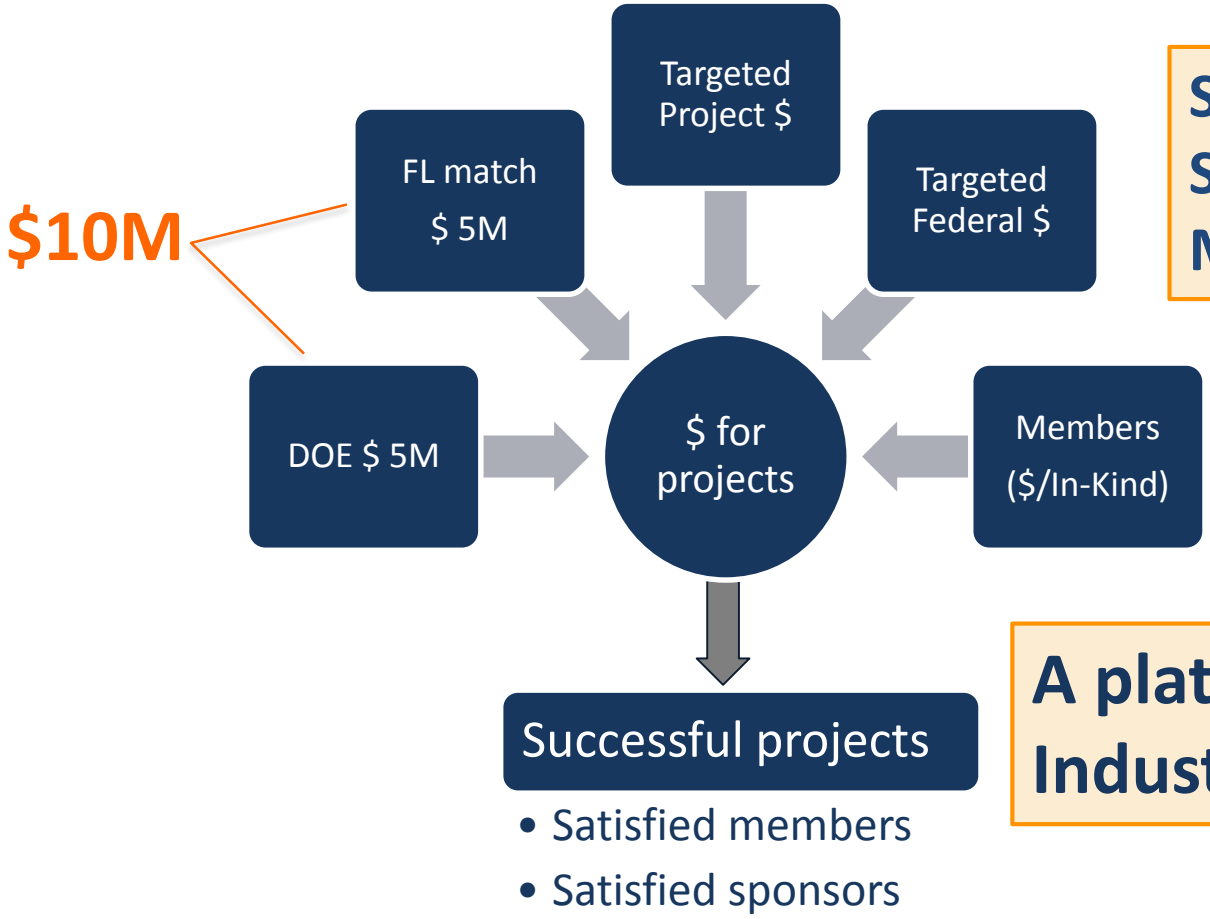
c-Si PVMC Funding

- Current funding to October 2017 (~$2M / Year)

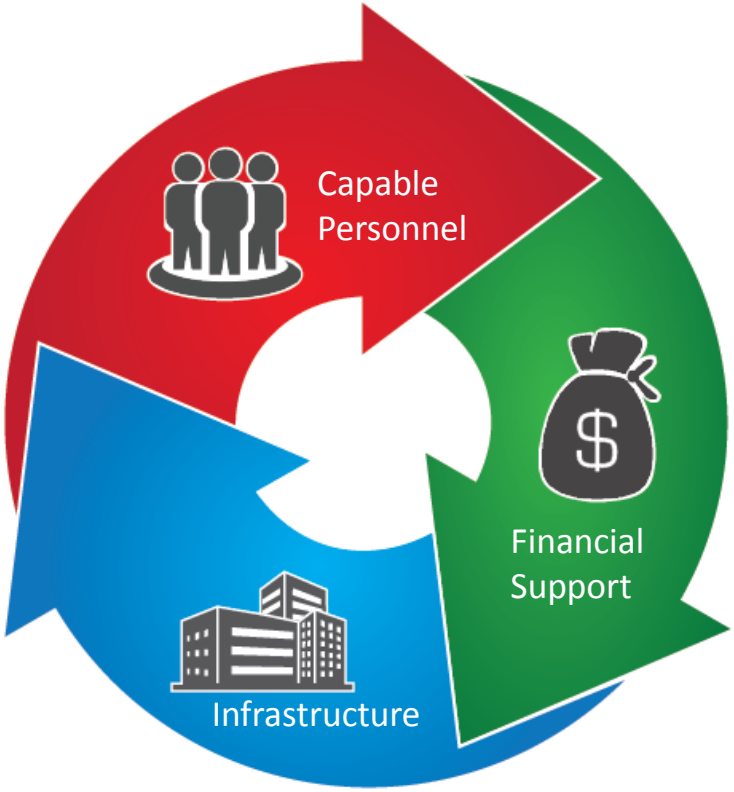


Shared Risk / Shared Resource Model

A platform for Industry Partnership

Direct Impacts of Industry Partnership to FSEC / UCF

- Requirements of Impactful RD&D



- Industry Partnership can provide each of these…particularly infrastructure … but it must be reciprocal.

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PVMC

c-Si PVMC Collaborative Consortium Projects

Some examples of Successful Industry Partnership…

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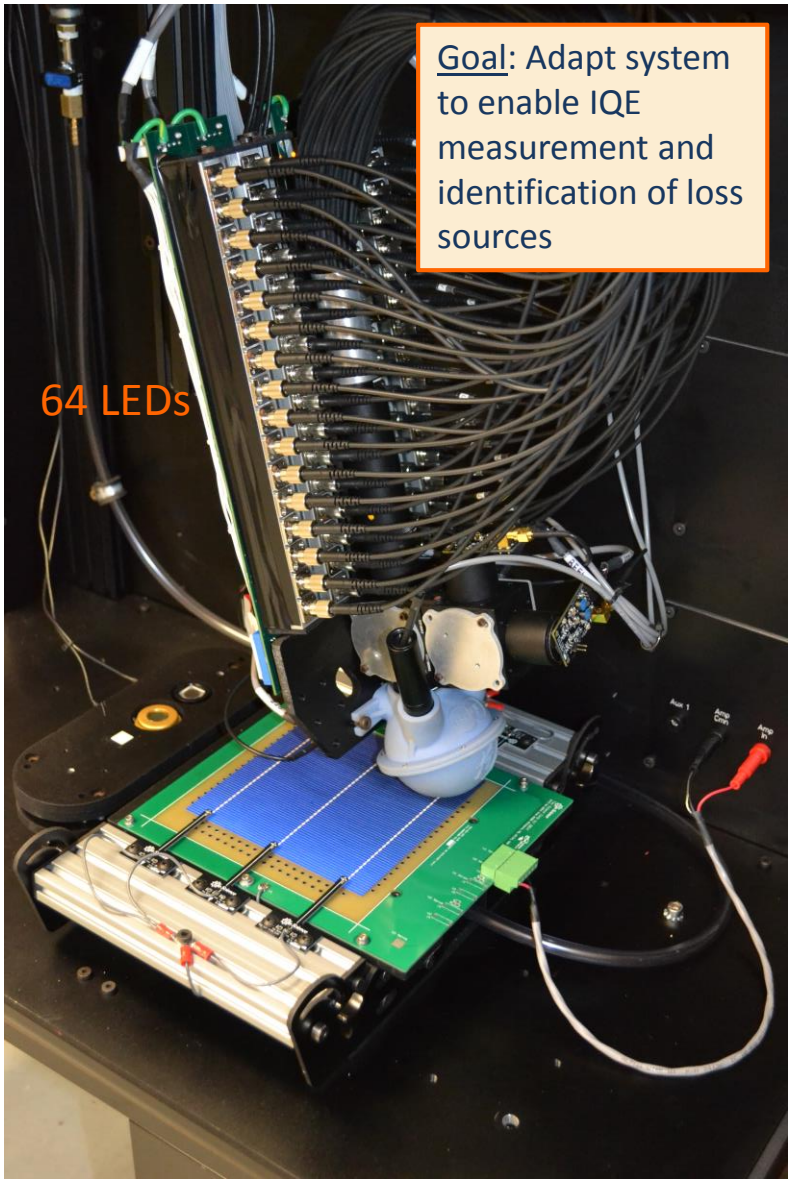
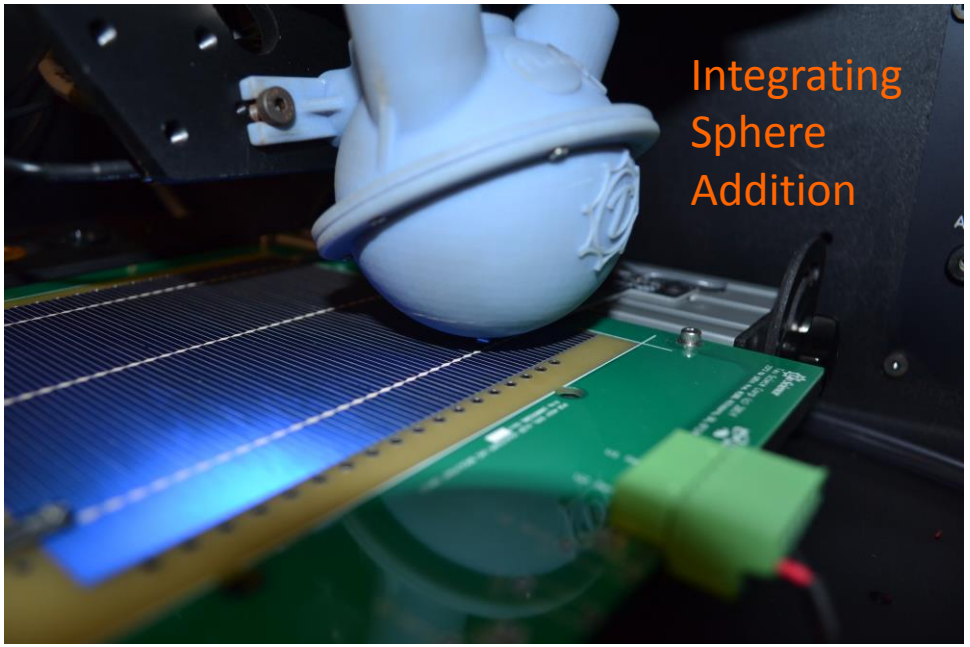
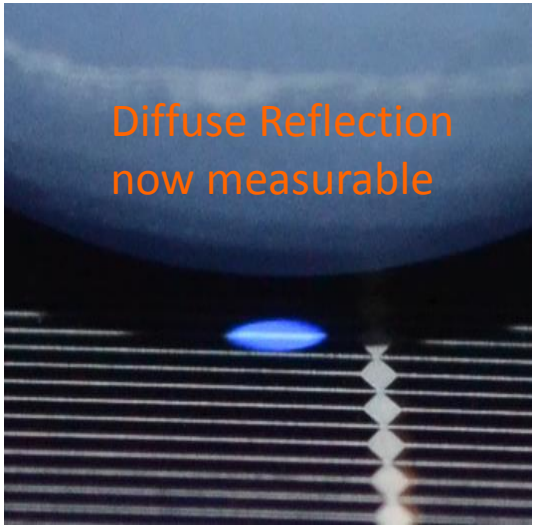
Example #1: Customized FlashQE with Integrating Sphere

Challenge: Existing fast QE system, but limited value to manufacturers



Goal: Adapt system to enable IQE measurement and identification of loss sources





Spot Size: ≈3.5-4.0 mm

Tau Science
Process Control for PV

Impact:
IQE and QE measurement in 1sec rather than 30min

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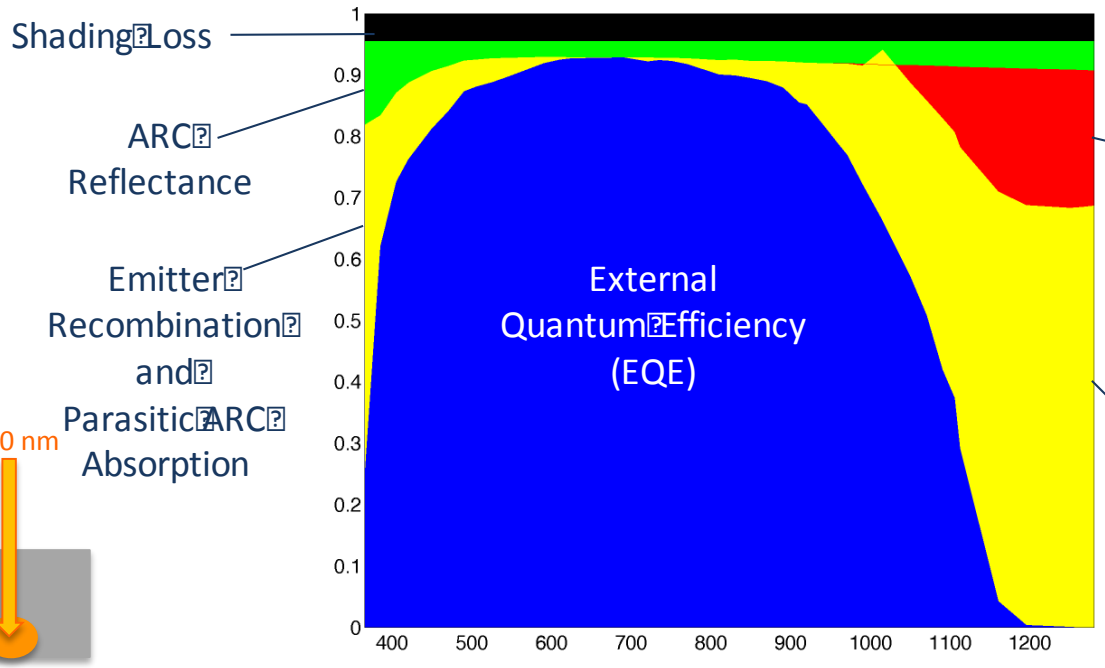
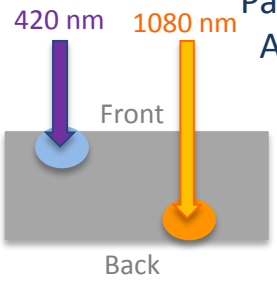
Identifying Where the Problem Occurs in Manufacturing

Front of the Cell

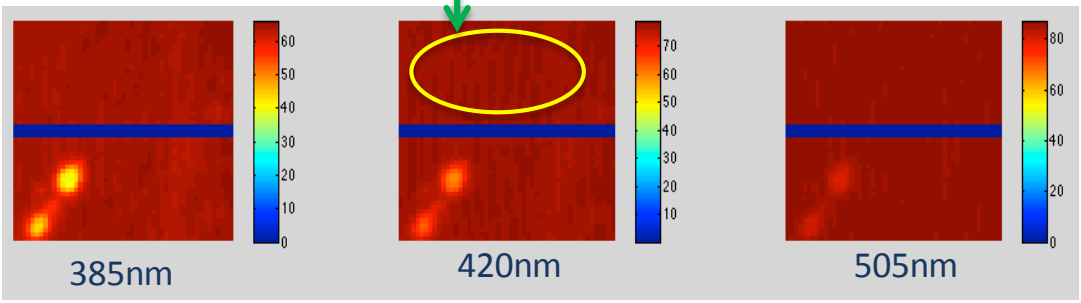
Bulk/Rear of the Cell





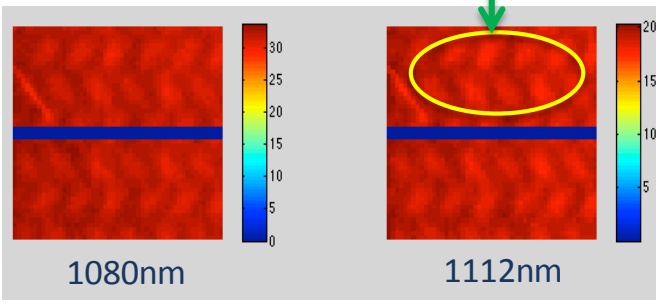
Front of the Cell

Saw Damage



Rear of the Cell

Belt Marks



Impact: First demonstration of correlation between QE and cell location for losses

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Decoupling and Quantifying Current Loss (Why it happened)

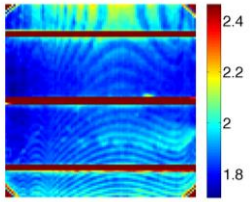
Front of the Cell

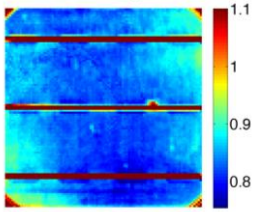
Bulk/Rear of the Cell

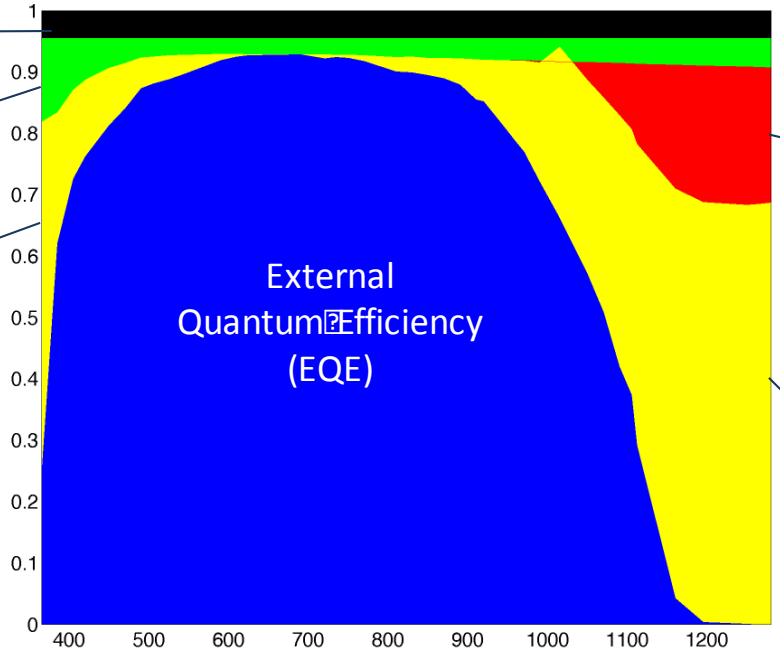
Shading Loss

ARC Reflectance

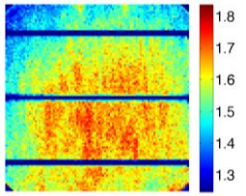
Emitter Recombination and Parasitic ARC Absorption



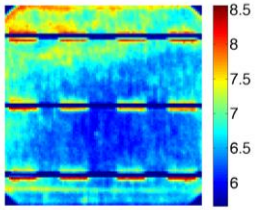




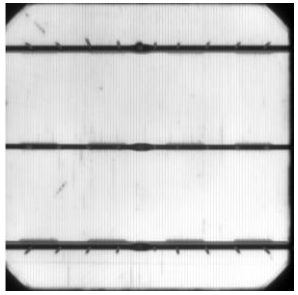
Escape Reflectance



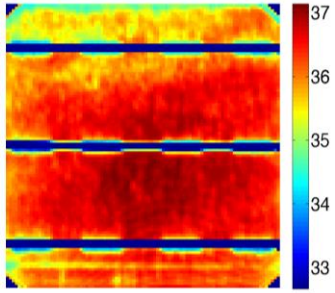
Recombination and Parasitic Absorption at the Bulk and Rear



Current Work:
We (FSEC) developed software that now converts raw data quickly into spatially resolved maps of loss mechanisms



EL Image



J_{sc} from EQE

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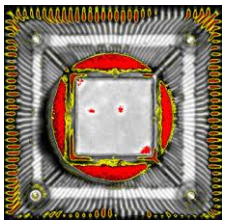
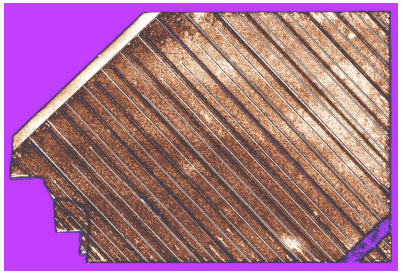
Example #2: Void Detection Using Scanning Acoustic Microscopy (SAM)

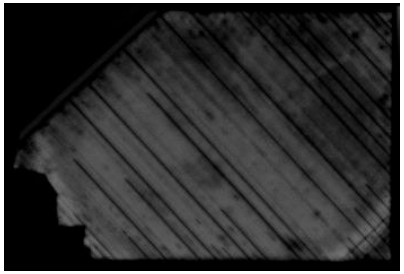
Sonoscan
Sound Technology With Vision



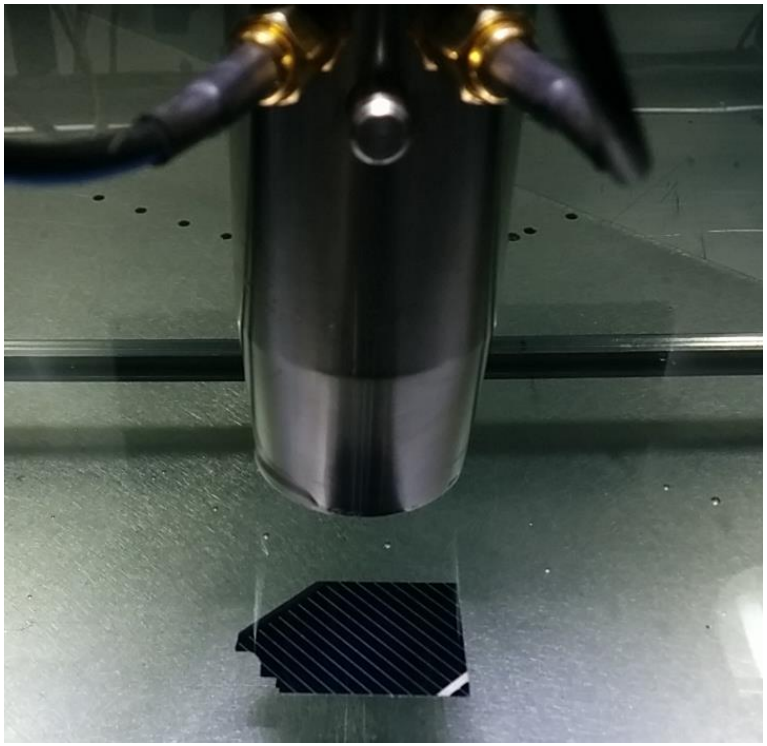
Interface Scan



THRU Scan



Existing SAM Tool at Sonoscan



- Sonoscan, established in semiconductor market, interested in entering Solar market
- Not successful in finding the appropriate application
- We identified void detection and believed SAM might be solution

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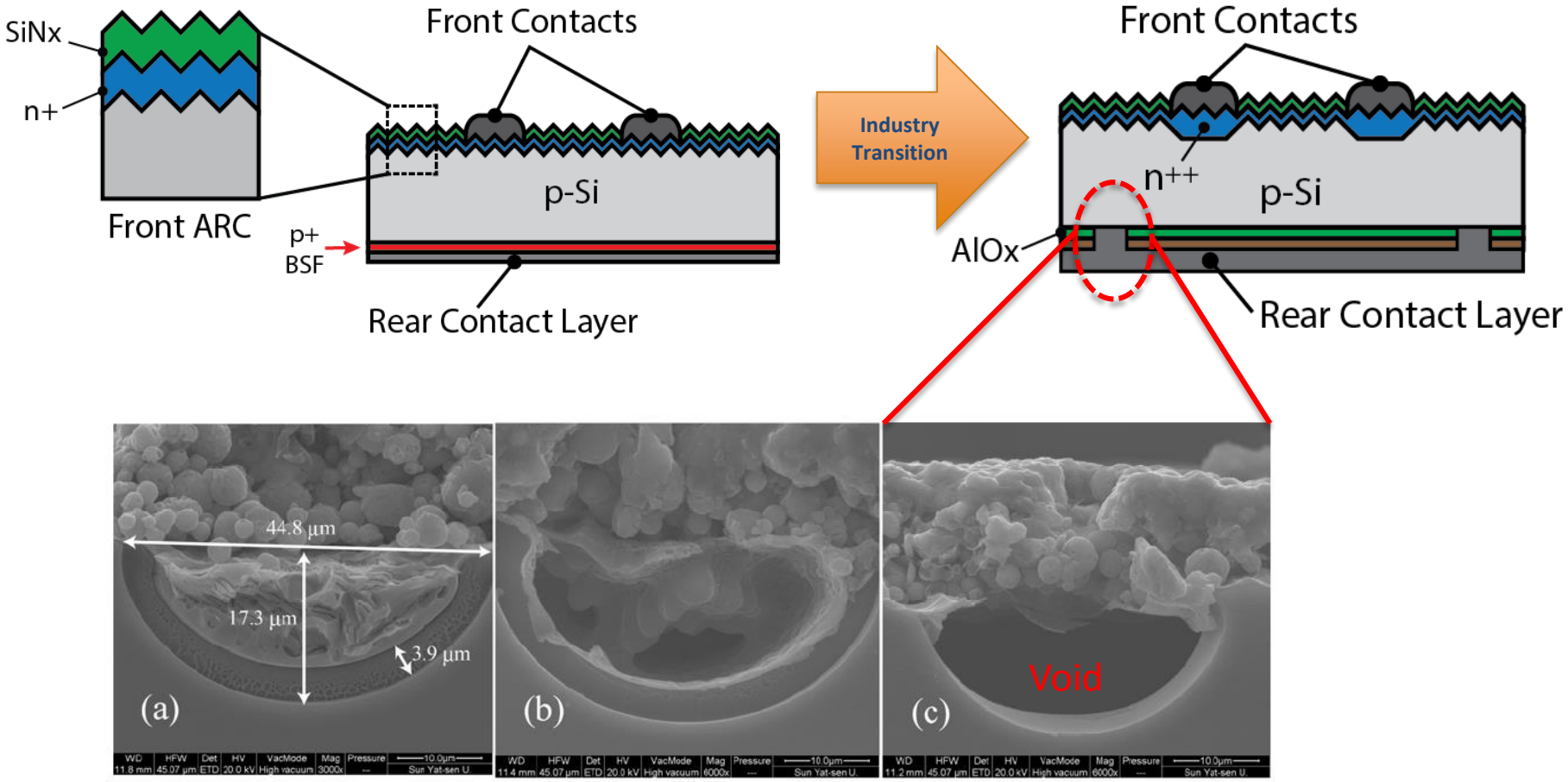
Voids in p-PERC PV Cells - a Major Challenge

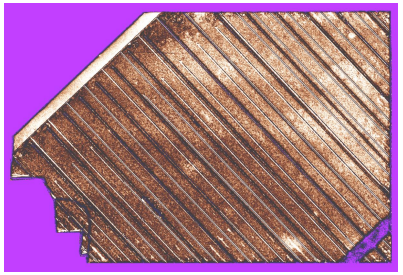
- **Industry Issue**: Voids in PERC cells – How to Detect???



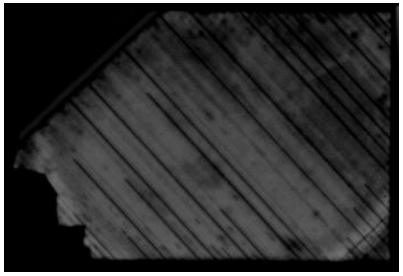
Yifeng C, *et al.*, *40th IEEE PVSC*, Denver, CO, 2014.

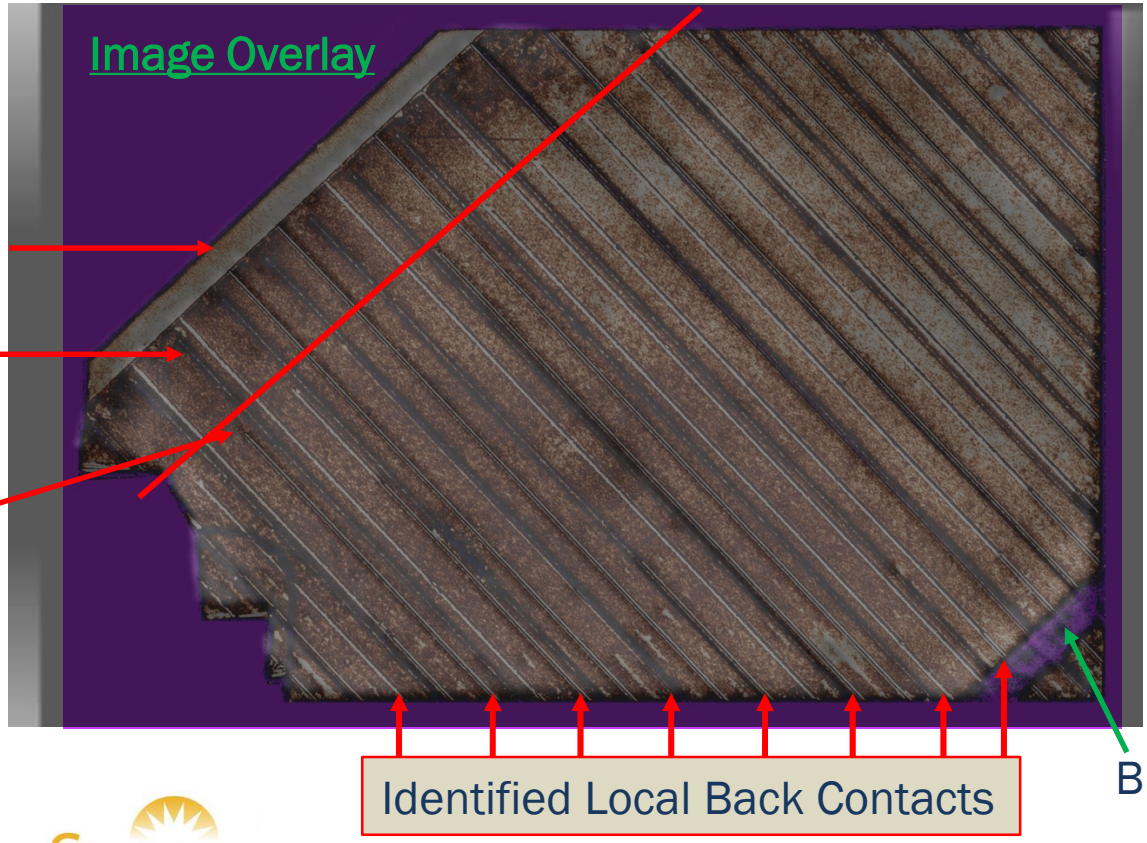
Void Detection Using Scanning Acoustic Microscopy

Interface Scan



THRU Scan





Outcomes:

- Identified potential use for SAM

- Arranged unique p-PERC cell sample set

-Developed high speed method for void detection

- Currently developing an automated process for determining void fraction in manufacturing

Sonoscan Sound Technology With Vision

Suniva

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Example #3: High throughput bonding /debonding process for fabricating thin silicon PV cells

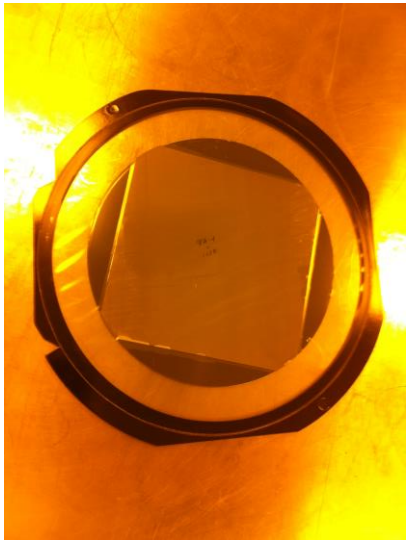
brewer science

Sonoscan
Sound Technology With Vision

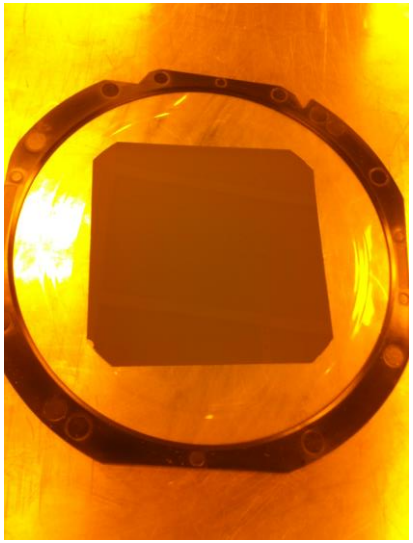
Ultrasonic Technologies, Inc.

Top side after BSI.T13091A coating

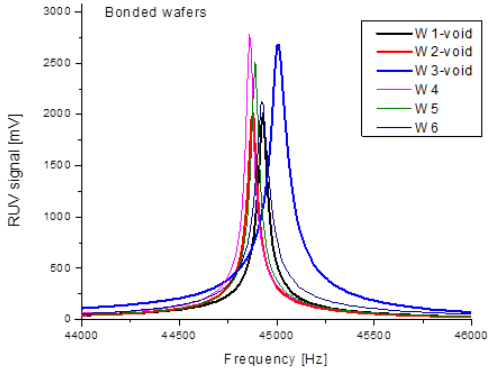
After bonding

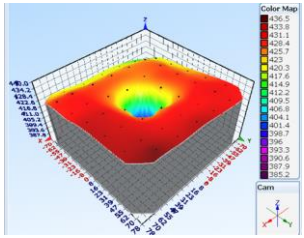


After lamination



After separation





Outcomes:

1. Validation of process compatibility
2. Identified cost requirement and determined it was not feasible

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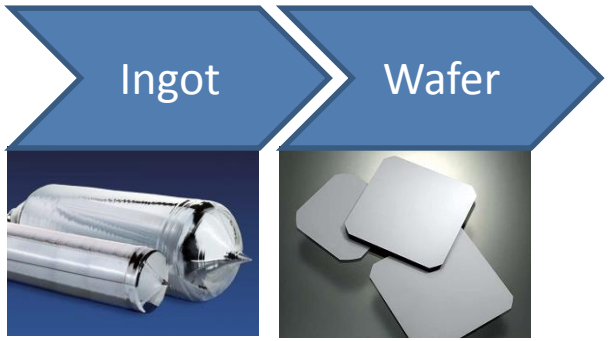
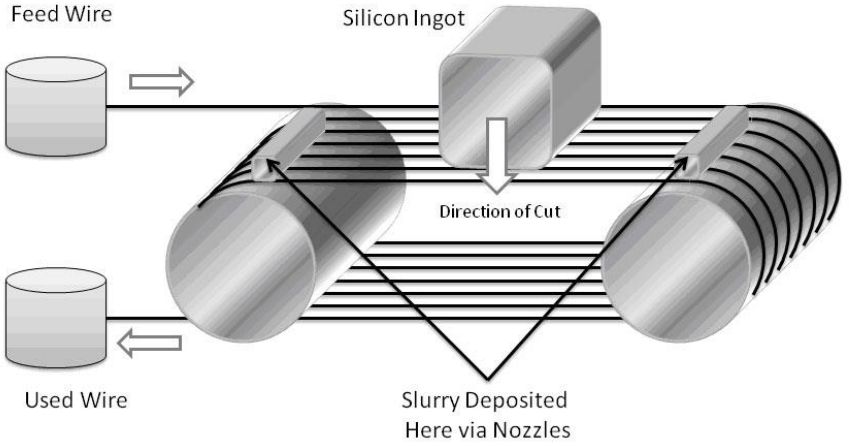
Example 4: In-line Diamond Wire Metrology

- Diamond Wire wafering is growing in market share





- Challenge: There is no robust method to monitor wear, leading to significant yield loss (as high as 30%)

- The value of a consortium…

Question: Can this be applied to diamond wire

Slurry/Lubricant Manufacturer

PROCESS RESEARCH PRODUCTS

Diamond Wire Manufacturer

NIABRAZE

Crack Detection Metrology

Ultrasonic Technologies, Inc.

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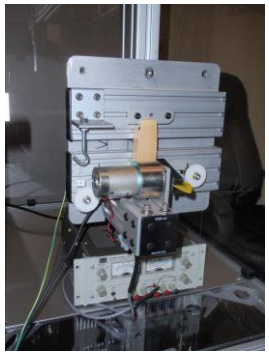
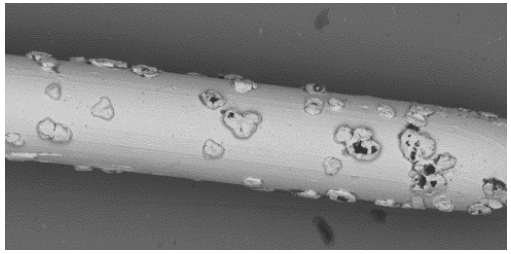
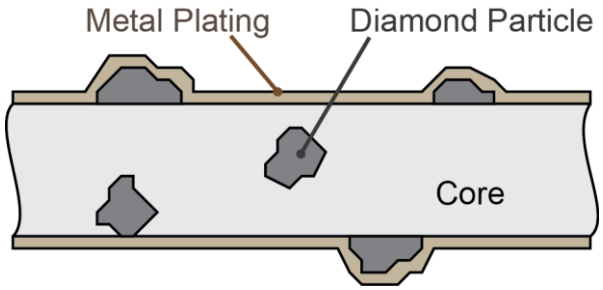
Step 1: Can it detect wire wear?

Gen 1: Static Prototype

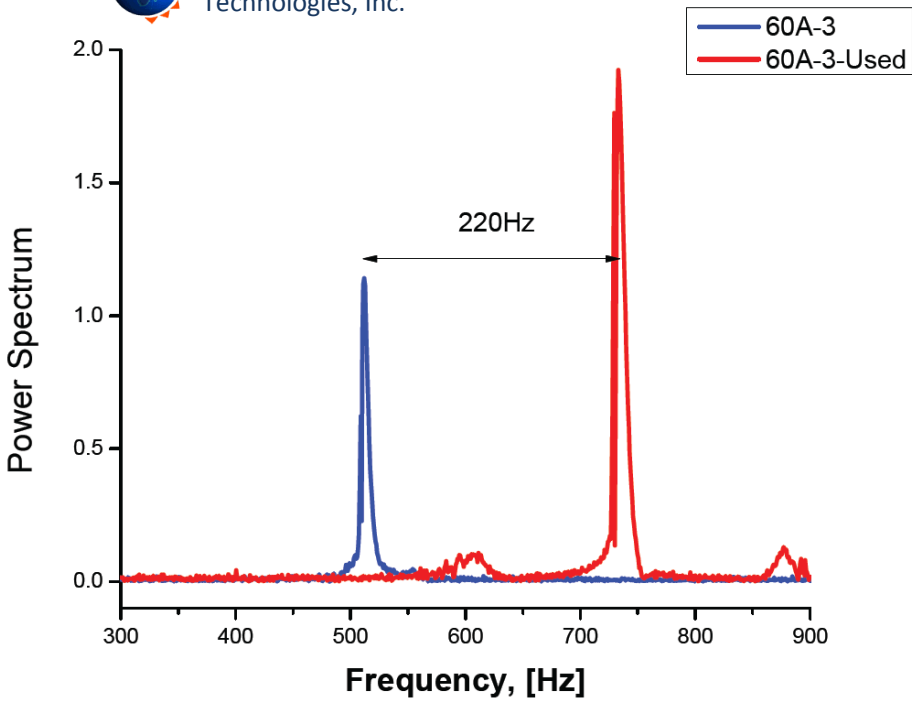




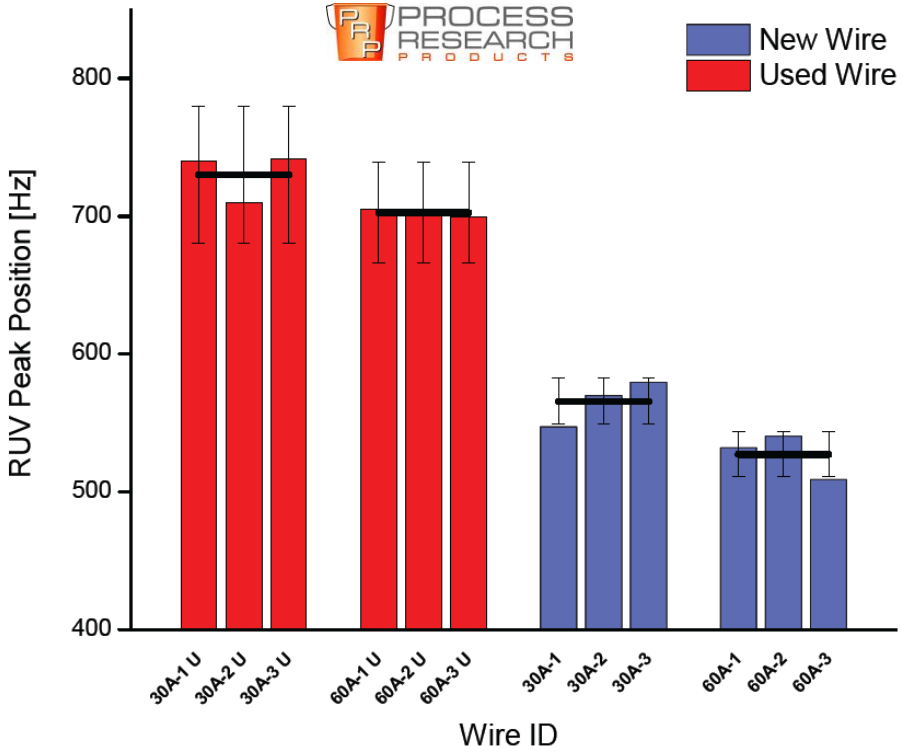
NIABRAZE



Ultrasonic Technologies, Inc.



PROCESS RESEARCH PRODUCTS



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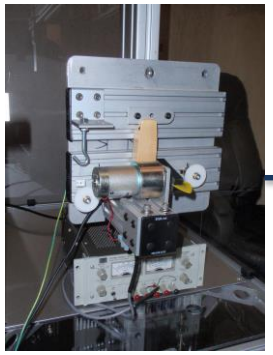
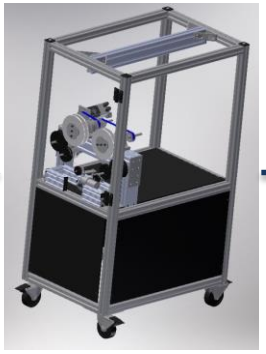
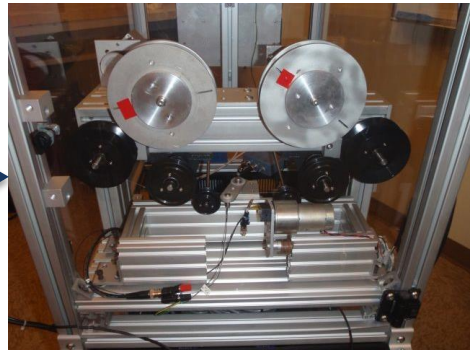
Step 2: Validate with Moving Diamond Wire

Generation 1.0 (Static)





Generation 2.0 (Dynamic)



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NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

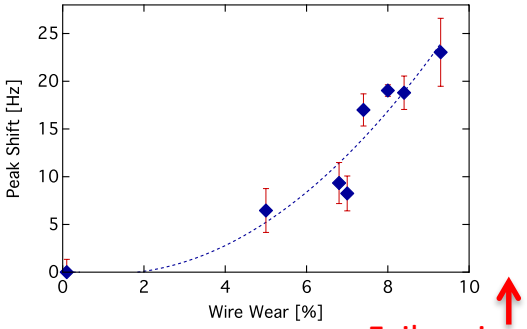
spire Solar

PROCESS RESEARCH PRODUCTS

Suniva

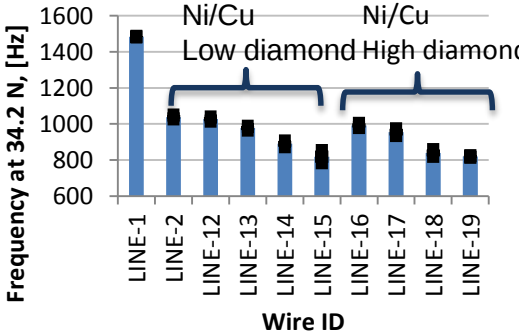
Sinton instruments

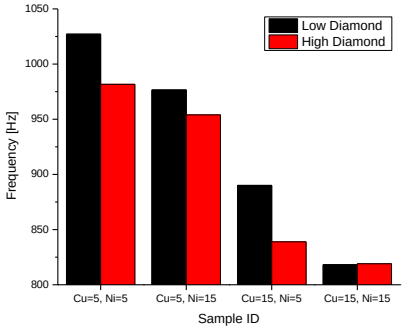
Diamond wire wear monitoring (Sawing)



Failure is at 11%

Quality control (DW manufacturing)





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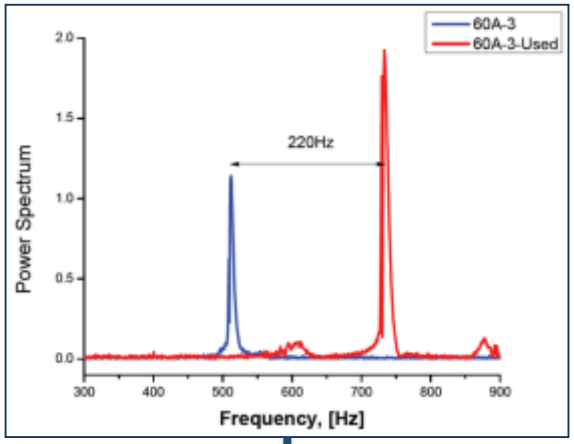
Step 3: Integration into Pilot Line

Proof of Concept (August 2013)



Prototype I: Stationary wire
(November 2013)

Prototype II: Moving wire
(July 2014)

Prototype III: Portable, non-contact sensor (July 2015)

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Suniva

Sinton instruments

Industrial Partnerships allowed us to transition from TRL level 1 to 7

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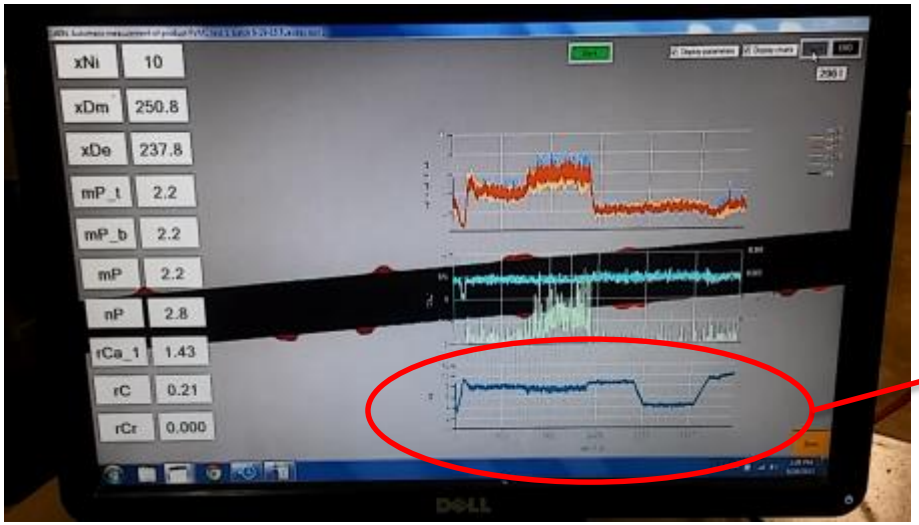
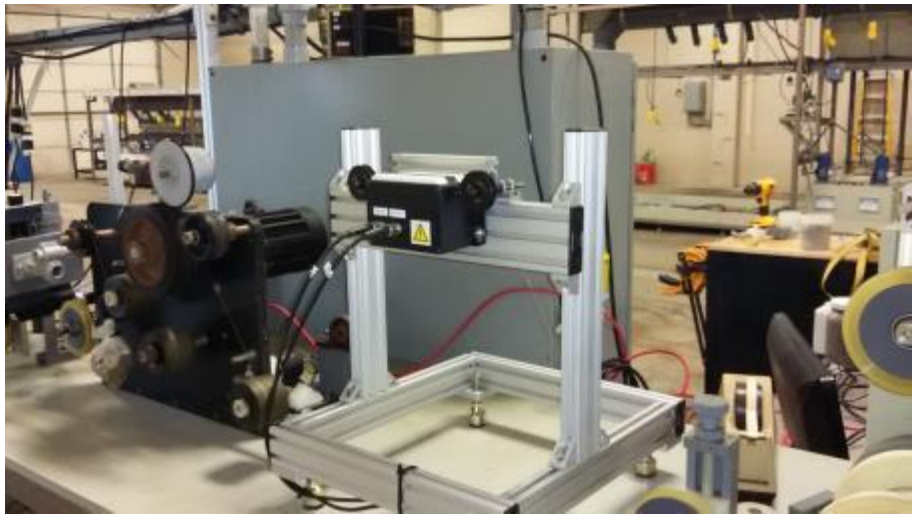
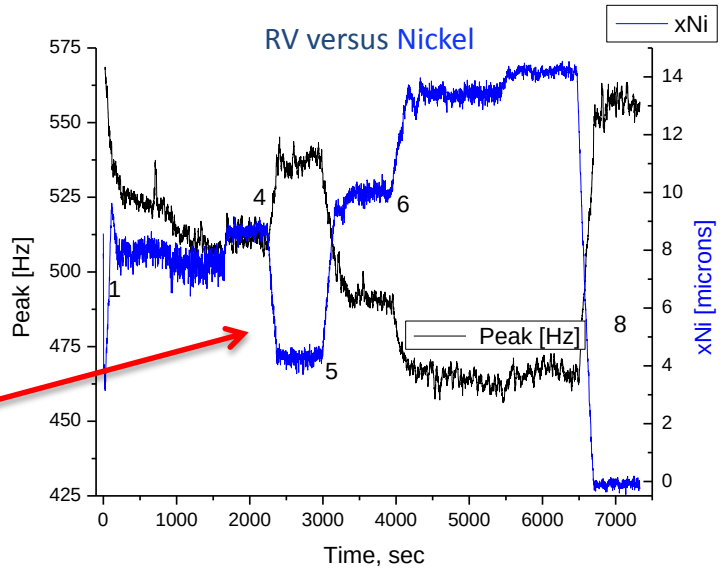
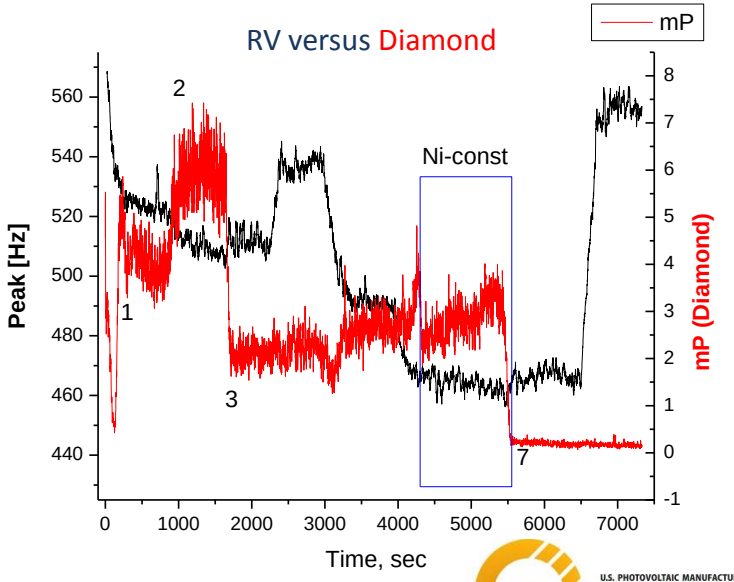
Field validation of inline tool on a DW pilot line









Other Notable FSEC Partnerships

Suniva

BTi LIS-R1

- PL system in their R&D line
- Regular visits to run experiments
- Remote measurement capability
- Considerable joint proposal activity

SCHMID

FSEC Researcher regular multi-week stays in their World class R&D Pilot Line over 2.5 years

Jointly developed APCVD passivation technologies

- 4 peer-reviewed jounal publications
- 3 invited presentations
- 2 patent applications

imec

Plan to have FSEC graduate student working at IMEC on joint project for 6 months starting in January

Fraunhofer ISE

Just began collaboration on passivated contacts.

Submitted joint proposal to DOE in collaboration with Suniva.

U.S. PHOTOVOLTAIC MANUFACTURING CONSORTIUM PVMC

Parting Comments and Thoughts

- Industry Partnership has enabled significant advancement of FSEC/UCF as a recognized leader in PV Research
  Diamond Wire Wafering / Predictive Metrology / Advanced Passivation
- Must identify top needs and challenges of Industry
- c-Si PVMC Projects have allowed FSEC/UCF to engage industry much like dating
- Demonstrating hard work and direct value to industry leads to deeper partnerships and strong trust
- Valuable model to expand into other program areas
- Advisory Board can help FSEC identify areas where model can be applied effectively and perhaps create initial connection to Industry

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