Industry Partnerships with Florida’s c-Si PVMC

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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+)

U.S. PVMC Members and Partners

Significant physical infrastructure across Partner sites
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**
c-Si PVMC Industrial Membership

• Current c-Si PVMC Members

• However, the c-Si PVMC projects involve a much larger network of collaborators...
Map of c-Si PVMC Participants (Members and Collaborators)

One of the most powerful distributed networks of infrastructure in solar
c-Si PVMC Funding

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

$10M

DOE $5M

FL match $5M

Targeted Project $

Targeted Federal $

$ for projects

Members ($/In-Kind)

Successful projects
- Satisfied members
- Satisfied sponsors

Shared Risk / Shared Resource Model

A platform for Industry Partnership

$500k/yr
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.
c-Si PVMC Collaborative Consortium Projects

Some examples of Successful Industry Partnership...
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

Diffuse Reflection now measurable

Impact: IQE and QE measurement in 1sec rather than 30min
Identifying **Where** the Problem Occurs in Manufacturing

**Front of the Cell**
- Shading Loss
- ARC Reflectance
- Emitter Recombination and Parasitic ARC Absorption

**Bulk/Rear of the Cell**
- Escape Reflectance
- Recombination and Parasitic Absorption at the Bulk and Rear

**Impact:** First demonstration of correlation between QE and cell location for losses
Decoupling and Quantifying Current Loss (Why it happened)

Front of the Cell
- Shading Loss
- ARC Reflectance
- Emitter Recombination and Parasitic ARC Absorption

Bulk/Rear of the Cell
- 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
**Example #2**: Void Detection Using Scanning Acoustic Microscopy (SAM)

- 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
Voids in p-PERC PV Cells - a Major Challenge

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

Void Detection Using Scanning Acoustic Microscopy

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

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

[Diagram showing the process of ingot to wafer conversion with labels and images]

- Slurry/Lubricant Manufacturer
- Diamond Wire Manufacturer
- Crack Detection Metrology
- Ultrasonic Technologies, Inc.
**Step 1:** Can it detect wire wear?

Gen 1: Static Prototype

Ultrasonic Technologies, Inc.

- **Power Spectrum**
  - Frequency, [Hz]
  - Power Spectrum
  - 220 Hz

- **RUV Peak Position** [Hz]
  - Wire ID
  - New Wire: Blue
  - Used Wire: Red
Step 2: Validate with Moving Diamond Wire

Generation 1.0 (Static)

Generation 2.0 (Dynamic)

Diamond wire wear monitoring (Sawing)

Quality control (DW manufacturing)

Failure is at 11%
Proof of Concept (August 2013)

Step 3: Integration into Pilot Line

Prototype I: Stationary wire (November 2013)

Prototype II: Moving wire (July 2014)

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

Industrial Partnerships allowed us to transition from TRL level 1 to 7
Field validation of inline tool on a DW pilot line

RV versus Nickel

RV versus Diamond

Peak [Hz]

Time, sec

Peak [Hz]
Other Notable FSEC Partnerships

- BTi LIS-R1
  - PL system in their R&D line
  - Regular visits to run experiments
  - Remote measurement capability
  - Considerable joint proposal activity

- 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 journal 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.
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