Reliability at PVMC

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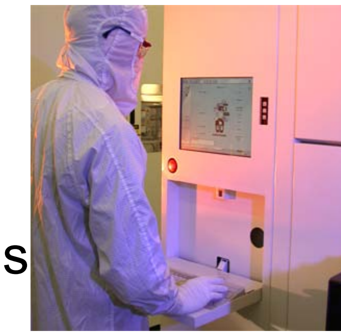
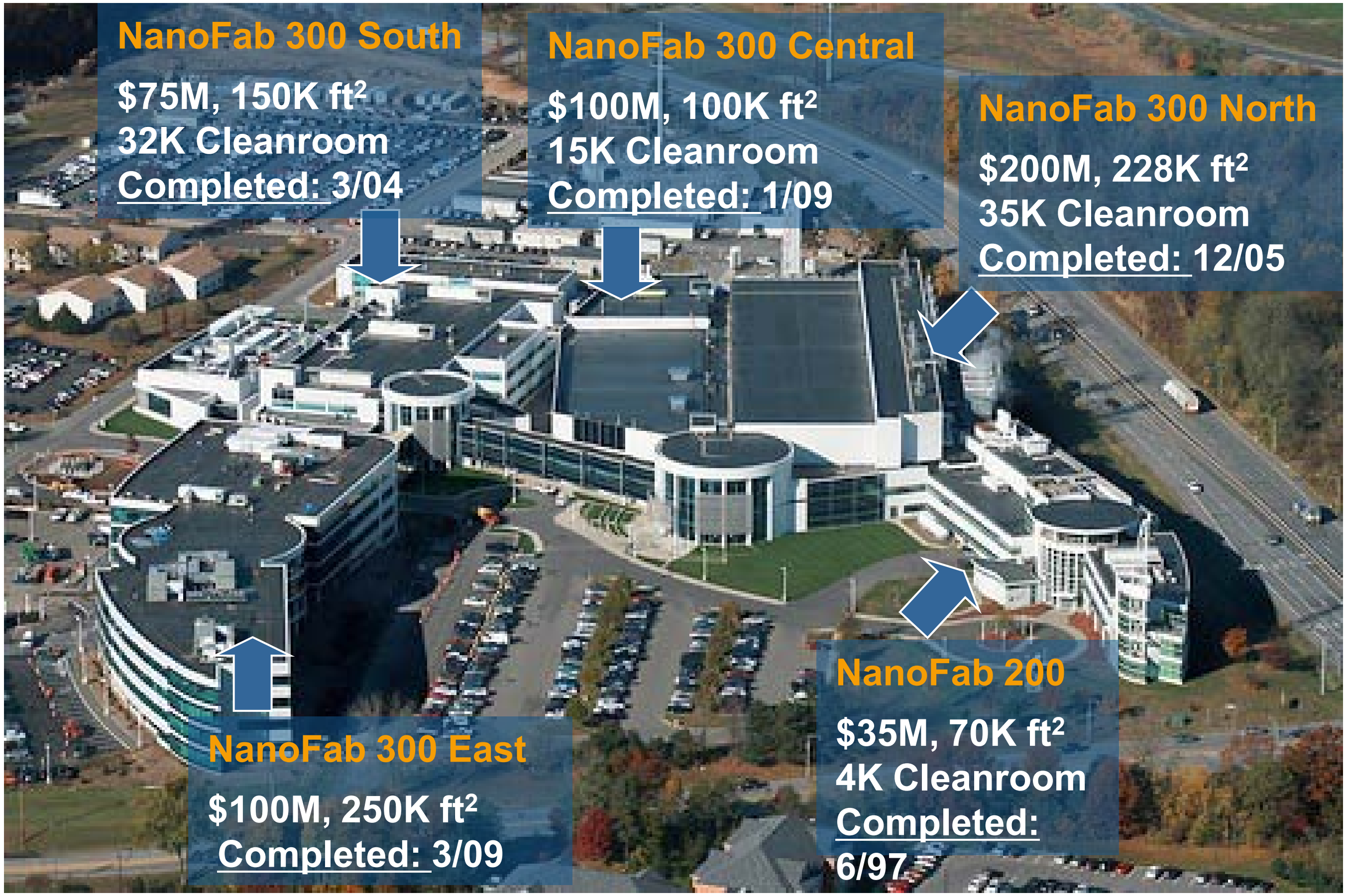
US PVMC program overview

- Hybrid of industry-led consortium and manufacturing development facility (MDF) models with capabilities for collaborative and proprietary activities
- Overall investment of $300M over 5 years from DOE, Industry, New York State.
- Focus on solar PV technology – CuInGaSe (CIGS) thin films – and manufacturing methods
- Expertise of primary partners – SEMATECH, CNSE – in consortium management, technology development, manufacturing productivity, and workforce development
- Breadth of support – partnership with ~60 companies and organizations throughout CIGS industry supply chain



PVMC: Photovoltaics Manufacturing Consortium

Current CNSE Facilities



- 800,000 sq.ft. of cutting-edge facilities, with 85,000 sq. ft. of 300mm clean rooms with a planned expansion to 1,250,000 sq. ft. and 105,000 sq. ft. of 300mm and 450mm cleanrooms
- More than 250 industry partners including electronics, energy, defense & biohealth
- Over $8B investments and over 2,600 R&D jobs currently on site (projected increase to 3500 R&D jobs by 2013)

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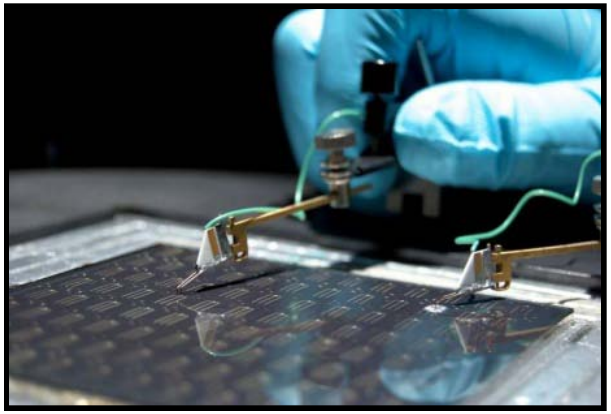
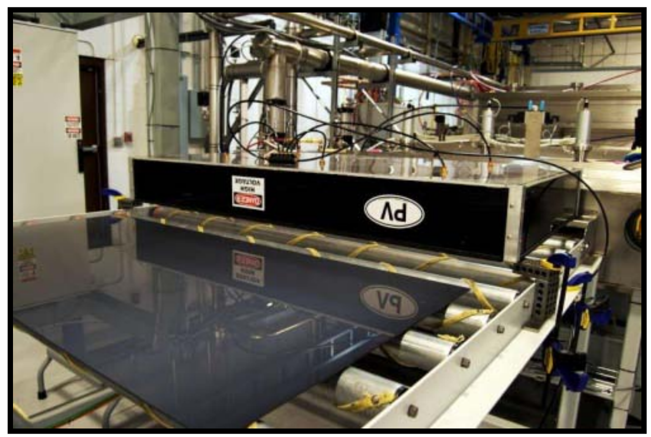
CNSE- Solar Energy Development Center
Pilot Facility for PVMC use (100kW) – Halfmoon, NY








CIGS Cell Test Equipment; Humidity Chamber; Thermal Evaporator for CIGS; Test Chambers; FastLine for Glass; Laminator; Sputtering, Co-Evaporation, Selenization

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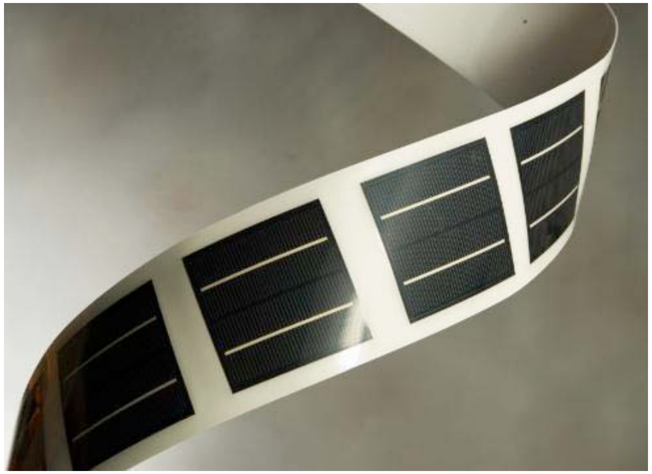
CNSE Process Capabilities - Halfmoon, NY
(Pilot Manufacturing, 100 kW/Year)

- Pilot Line Scale Solar Cell Fabrication
  - 10cm x 10cm substrates
    - Monolithic Interconnect (Laser & Mechanical Scribes)
    - Top Grid (screen printed grids)
    - $1cm^2$ (Evaporated Ni/Al grids)
  - CIGS by thermal evaporation
  - Chemical Bath Deposition: CdS, ZnOS
  - Bottom and Top Contacts by Sputtering
    - Cr/Mo and iZnO/TCO (ITO – AZO)

- Pilot 1.2m X 0.6m CIGS Deposition on Glass



- Metrology
  - UV-VIS
  - XRF
  - ICP
  - SEM w/ EDX
  - SIMS
  - (4) Pt. Probe
  - Adhesion/Pull-Test
  - J-V measurement, AM 1.5

- Module & Environmental Testing
  - Lamination
  - Humidity/Thermal Cycling
  - Mechanical Loading
  - Hail/Impact

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Strategic Objectives of US PVMC

Establish Roadmaps and Standards

Establish CIGS Manufacturing Development Facility

- Access to 100 kW line
- Front End and Back End of 10 MW (Flexible and Rigid Line)

CIGS Manufacturing Scale-up

- Best Practices and Cost Modeling
- Productivity, Effectiveness and Manufacturing Quality

CIGS Commercialization Support

- Licensing, Attraction, Incubation

Develop Highly Trained Workforce

Membership Categories

Collaborative Programs

- **Full Members :** PV manufacturing and supply chain companies
  - May **participate in the full program set** and have **access to all pre-competitive, non-proprietary results and related IP**
  - Have more participation in program and operational direction setting through more broad participation in the various governance, advisory, and management roles

- **Program Members:** PV manufacturing and supply chain companies
  - May **participate in select cell and module development**, materials, metrology, reliability, tool infrastructure, benchmarking, manufacturing productivity, or other consortium programs
  - They have **shared access to IP generated from the programs in which they participate**

Proprietary Programs

- **Proprietary Participants and Users:** PVMC members, industry partners, start-up companies, national labs, and universities (collectively "users")
  - May **access the PVMC facilities** as part of a proprietary program or on an individual, fee-for-service basis
  - IP generated by or on behalf of any company in a proprietary program will be owned by the company and not shared with other participants

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Reliability Focus

- The focus is to aid in manufacturing development
  - Stumbling block is reliability testing
- Everything has to be reliable
  - And therefore pass reliability testing
- To help manufacturing we need fast turn around for valid, believable reliability tests
  - Reduce turn around time for process/material changes

The reliability testing has to be valid

------------No overstressing--------------

Tests must exercise realistic failure mechanisms and reproduce observed failure modes

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Reliability Goal

- To develop reliability tests that can effectively predict 25 years of life in any chosen environment with a test lasting no more than 1,000 hours (6 weeks)
  – To do this we need to know precisely what the physics of failure is.
  – In some cases (for some modes/mechanisms) we already have this in place.
  – For others that we have little confidence in, there needs to be fundamental research
    - Damp Heat

Reliability Effort

- Substantial funding is available to support the needed research
  - Deemed to be one of the most important tasks for the PVMC
  - We do not intend to recreate already available capability
  - Depending on what resources are available across the U.S. the work could be performed in multiple locations
- Precise direction will be determined by members of the consortium
  - TWGs and roadmap effort
- Results will be available to consortium members
  - Proprietary issues will be protected
  - We know how to do this!
    - Both CNSE and Sematech have extensive experience in this area

To Date

- Four broad tasks were identified at the E-Tab meeting
  - Stickies
- Reliability TWG formed and problems identified
  - Over the past few months have met several times
  - Input limited and nothing definitively decided upon
  - Tentative projects follow

Topic 1 Physical modeling of degradation and failure of layers at device and module level (Doug Jungwirth, Boeing)

Objective: Collect failure mechanisms, lifetimes and related parameters that affect the performance of final modules and develop basic models to predict the future performance of the modules in real world situations.

Challenges	Goals	Resources
Inadequate knowledge of failure and degradation mechanisms for CIGS and other thin film cells	Develop list of degradation and failure mechanisms along with parameters that effect these mechanisms	Previous studies of reliability and failure rates for previous CIGS technologies
Inadequate multi-parameter models which describe the working mechanisms of degradation and failure	Develop several multi-parameters models to quantitatively describe the failure and degradation mechanisms	Previous studies of single and multi-parameter degradation sources
Insufficient field data that can be used to validate these models	Generate or collect field or laboratory data to validate proposed models	Previous and recent field test data
Lack of confidence with the existing models for predictive long term (>25 years) reliability estimates	Use collected or test data to predict reliability. Perform ongoing surveying process to verify these models	Monitoring of present and new solar cell fields

Topic 2: Identify basic module failure modes and mechanisms with the goal of producing acceleration models for testing (Mike Mills, Dow Chemicals)

Objective: Reliability of CIGS based photovoltaic (PV) system for bankability, product and system level warranty

Challenges	Goals	Resources
Variety of module and system failure modes for CIGS based products	identify model systems to mimic individual material, component, module and system failure modes	Testing facilities, post mortem analytical capability
Low confidence in CIGS based PV systems (limited field data) and slow new product development cycles	Validate highly accelerated (>50x) testing for single mechanism testing with correlation to field data	Develop new testing procedures and validate correlation with field experience
Lack of unified reliability modeling and understanding specific to CIGS products	Incorporate US National Labs into development and validation of common reliability approach philosophy	Testing facilities, stable source of CIGS in standard packaging, commercial reliability modeling software

Topic 3 Study of performance degradation based on leakage current rates, high voltage stress and electro-chemical corrosion of contacts (David Gower, Intertek)

Objective: Examine data and create protocols to simulate degradation in a lab environment due to failures other than natural degradation of the CIGS material as a result of exposure to leakage current, high voltage stress and corrosion of contacts.

Challenges	Goals	Resources
Deciding variations of testing protocols that should be used for CIGS as opposed to other PV	Examine existing testing methodology and develop adjustments based on knowledge of CIGS material properties	Access and review of existing approaches, material knowledge of CIGS properties, knowledge of testing procedure development
Correlation of real world and lab results	Simultaneous lab and real world data collection with periodic evaluation of in field samples	Indoor and outdoor testing environments. Lab will need environmental chamber, accelerated UV, and wet lab. Collaboration for outdoor results
Using data to create models for accelerated testing in various environmental conditions	Coordinate outdoor data and run parallel testing in lab to simulate environmental conditions	Researchers, technicians, lab equipment, methods for storing, sharing and interpreting data

Topic 4 Quantify requirements for sealing against moisture (Jim Lloyd, CNSE)

Objective: Conduct experiments and provide theoretical guidance towards formulating a viable physical model for moisture ingress to determine the required performance when subjected to accelerated testing.

Challenges	Goals	Resources
Identify relevant failure modes	Study literature and long term test results	Student and staff Test data from members
Develop Accelerated tests	Identify physical failure mechanism and develop theoretical model	Students and staff
Develop test methods and protocols for identified failure modes	Design test structures, test methods sensors for moisture detection	Students and staff Fab to produce test structures and coupons
Test models	Perform tests for 1000 hr equivalence to 25 year EOL	Testing facilities (T&H chambers, outdoor testing facility)

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Contact us

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