SAND2020-2366C

Discover, Develop, and De-Risk module materials, architectures, accelerated testing protocols, data analytics, and financial models to reduce the LCOE of solar energy

Instrumented Modules for Environmental Characterization and Simulation Model Validation (SPARK Project)

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DuraMAT Capabilities

1. **Data Management & Analytics, DuraMAT Data Hub**
2. **Predictive Simulation**
3. **Advanced Characterization & Forensics**
4. **Module Testing**
5. **Field Deployment**
6. **Techno-Economic Analysis**

Project Goals

- Design, build, and test full-sized modules with embedded instrumentation to better characterize the internal states of modules in deployment environments
- This project provides model validation data to support the **Predictive Simulation** capability area. If highly successful, instrumentation concepts could be applied in **Field Deployment** and **Module Testing** capability areas.

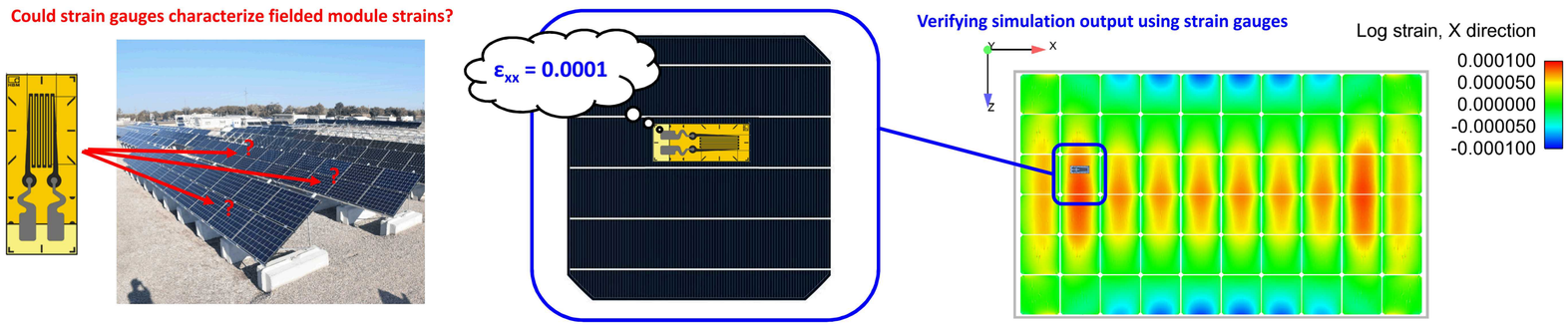
Accomplishments

- Selected strain gauges and data acquisition hardware, and post-processed existing simulation results to identify module locations of greatest interest for measurements.
- Designed and built 3 instrumented modules and a control module to capture specific data objectives.
- Completed EL imaging of modules to assess impact of gauges and wires on cells

Outcomes and Impact

- This project provides module scale mechanical test data to support computational model validation
- If successful, instrumentation concepts may be applied to field deployed modules to quantify the stresses imposed by outdoor exposures, or to supplement data acquired in modules undergoing accelerated testing

Project Summary and Motivation



Can we verify that simulations predict the correct internal strain in a full PV module? Can gauges report fielded module strain?

Computational Finite Element Models (FEM) are a useful tool enabling assessment and optimization of PV module designs. However, to be applied with full confidence, models must be validated against experimental data in controlled test cases. Currently, validation for full module mechanical FEM consists of comparing external deflection vs. load measurements, which is qualitatively adequate but could be improved upon when attempting to validate more complex quantities of interest.

This project seeks to design, build, and test a set of custom modules containing internal strain gauge instrumentation, to collect internal measurements for detailed model validation. If the embedded instrumentation concept is successful, instrumented models could be deployed in the field to collect mechanical exposure histories, or subjected to accelerated testing to improve confidence in test representativeness.

Timeline

Quarter 1

Develop instrumented module designs

- FEM post processing for quantities and locations of interest
- Gauge selection
- Gauge placements
- Material choices
- Data routing and acquisition requirements

Module manufacturing lead time

Quarter 2

Conduct testing

- Simultaneous internal and external data acquisition
- Loads up to 2400 Pa to be tested

Quarter 3

Analyze data and report on correlations and lessons learned

- Is gauge output reliable?
- Can a deformation magnitude and shape be inferred?
- How do simulations compare?
- Is the implementation suitable for outdoor use?

Project will design, build, test, and report on lessons learned

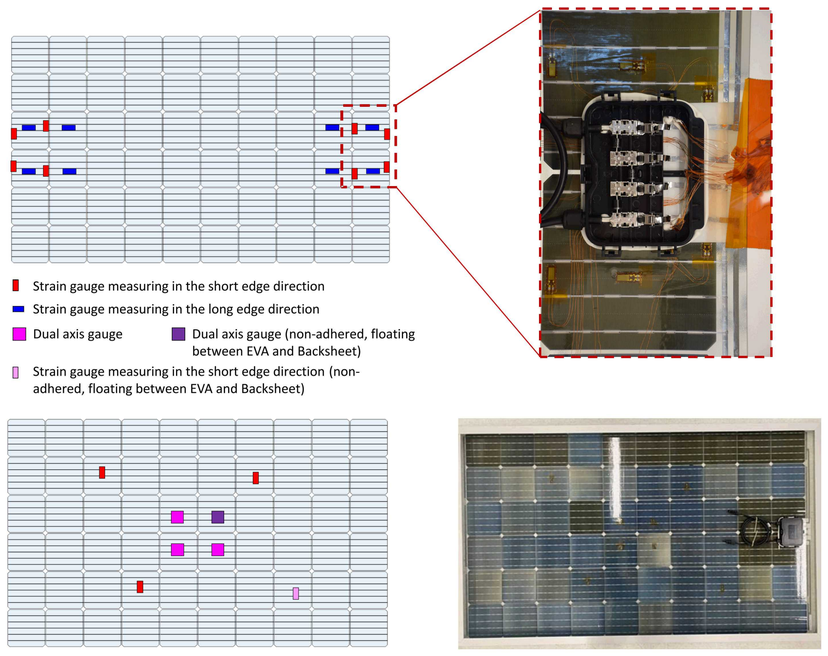
Instrumented Module Design and Fabrication

Three unique, instrumented modules plus one control module were manufactured with the following data objectives:

- Assess J-box effect on nearby cell strain
- Probe cells with maximum or minimum strain along module short edge
- Probe cells with maximum or minimum strain along module long edge
- Confirm symmetry across module quadrants
- Assess module-to-module variability

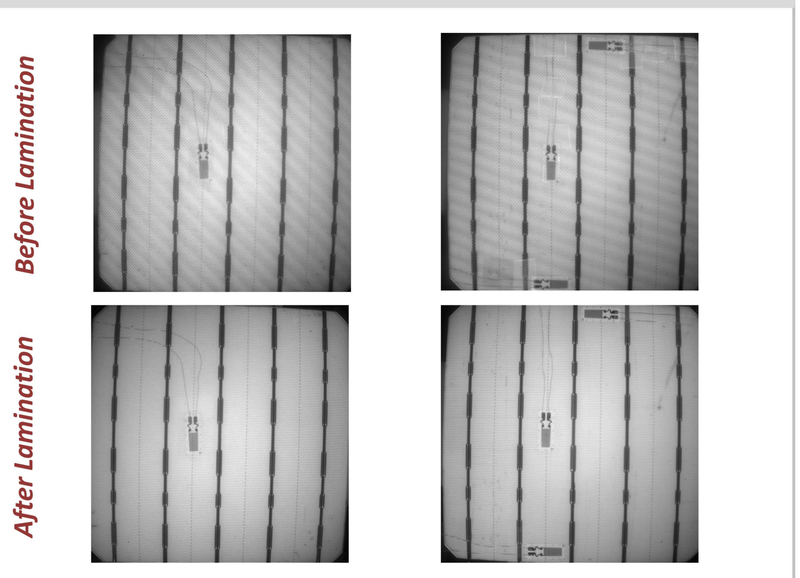
BOM includes EVA and a clear backsheet so gauges and wires can be visually inspected.

Module fabrication and design considerations accomplished in collaboration with D2 Solar.



Modules have been received at Sandia with gauges mounted at locations of interest

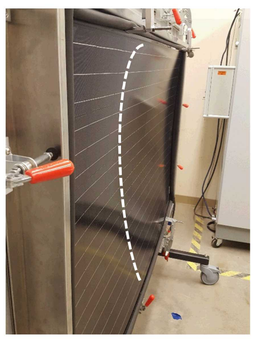
Single Cell Prototype Coupons



Photoluminescence images of two example gauge/wire placements

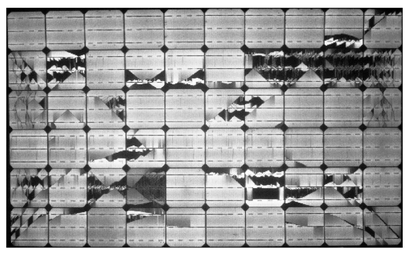
- Single cell coupons were fabricated to match each desired gauge layout and the module BOMs. This allowed for practice and improvement of:
  - Strain gauge application with 2-part adhesive
  - Strain gauge soldering method
  - Wire management with alignment tape
  - Lamination conditions for selected BOM
- Photoluminescence (PL) imaging before and after lamination step confirmed that gauge and wire placement did not lead to cell cracking

Load Spot Module Mechanical Tester



Module under test, -5400 Pa

BrightSpot Automation



Simultaneous EL @ -5400 Pa loading

Load Spot mechanical tester enables controlled module loading with simultaneous internal & external measurements

- Air pressure based mechanical tester enables repeatable, controlled loads with simultaneous internal and external data collection
- Experimental Load Spot test scenario can be simulated and compared against strain gauge output as well as electroluminescence images and external optical deflection measurements to validate outputs

Module Imaging

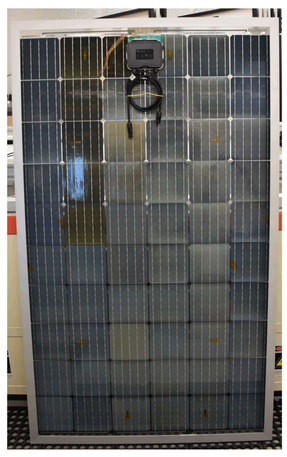
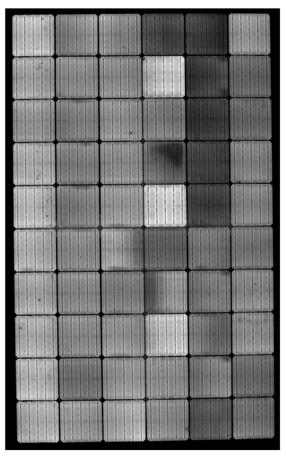


Photo of backside w/ gauges



EL image of frontside

- EL images collected for all modules to check for cell damage after lamination and shipping
- Although cell mismatch observed (project not focused on cell performance), no issues with cell cracking over gauges or wires

Project Status and Next Steps

- Visit to D2Solar conducted in December 2019 to monitor and troubleshoot the fabrication of the first instrumented module
- Preliminary EL imaging and strain gauge connectivity tests confirm gauges and cells survived the lamination process
- Loads up to 2400 Pa will be applied to each module with a Load Spot mechanical tester while collecting strain data and EL images
- Cell strain at each load condition will be compared to expected behavior and lessons learned will be shared at PVSC 2020

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