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Thermal-mechanical-electrical model for PV module-level mechanical failure mechanisms

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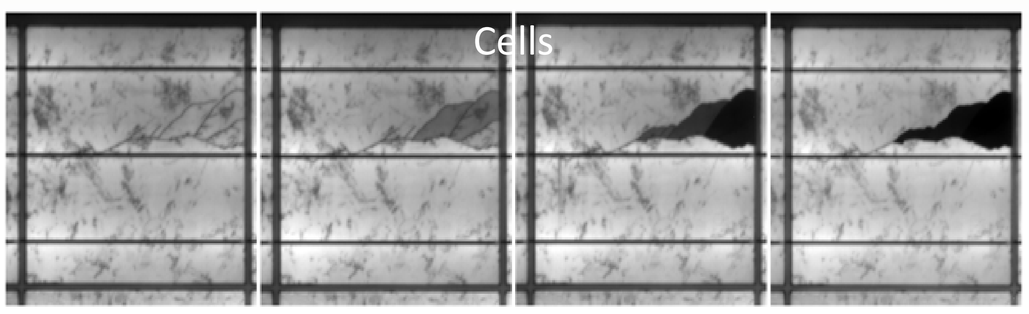
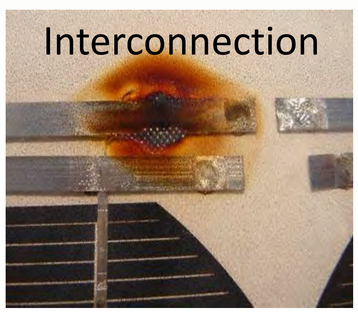
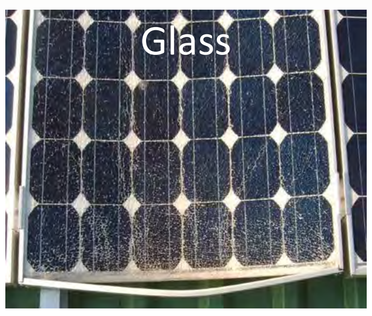
PV module mechanical failure modes







Capability proposal

Thermomechanical stress induced in a PV module is a leading driving force of module failure. These failures include delamination, cell fracture, and solder bond fatigue, among others. Each of these failure modes depend on the specific deployment environment (temperature, humidity, etc) and electrical characteristics (e.g. temperature non-uniformity) of the module.

A predictive thermal-mechanical-electrical simulation capability is desired to quantify loads on PV module interfaces and materials as the result of the environment and stressors. The model will be three-dimensional in order to capture details of the module configuration. As a part of the Predictive Simulation Capability, this model framework should integrate predictive simulation with capabilities in materials discovery and module durability testing. Thermal loads (from environmental cycling or from electrically-generated temperature non-uniformities) will drive mechanical deformation, and the mechanical component of the model will predict generated stresses, interface and material failures. A major part of this effort will include the development of appropriate constitutive models for the complex thermo-visco-elastic/plastic behavior of many materials. Model validation is also critical, both at the materials and module scales.

This capability will be a computational code (model), documented workflow, and a community of practice for industry and academia to characterize environmental thermomechanical loads on PV modules. This model will enrich PV degradation databases to expose the origins and magnitudes of thermal and structural stressors on modules, materials, and materials interfaces.

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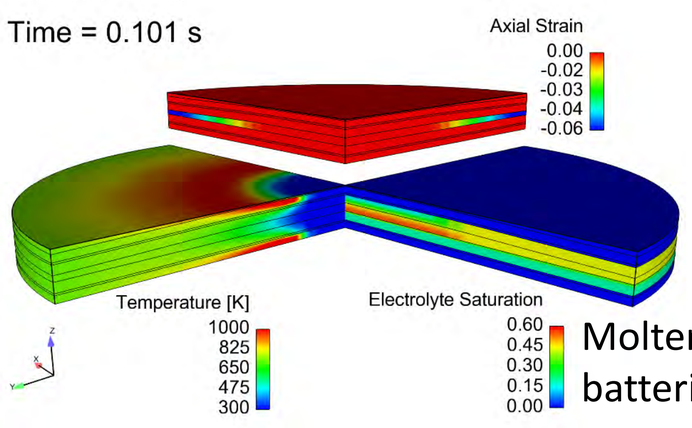
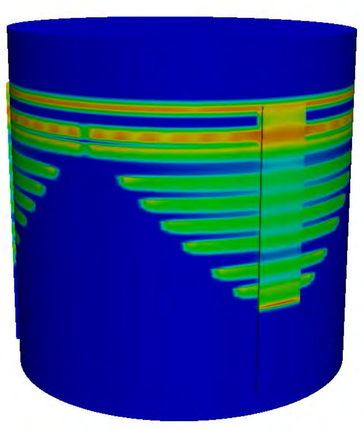
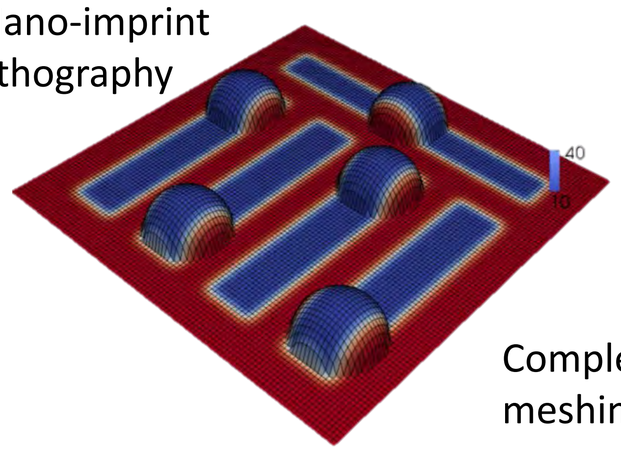
3D thermal, mechanical, electrical finite element modeling



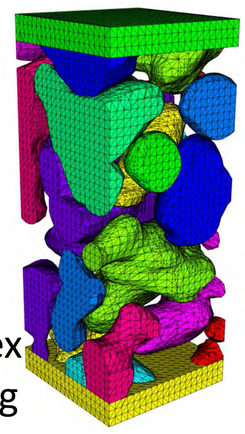
Molten salt batteries



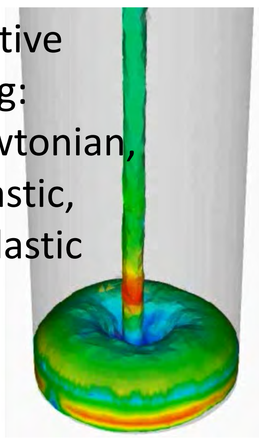
Nano-imprint lithography



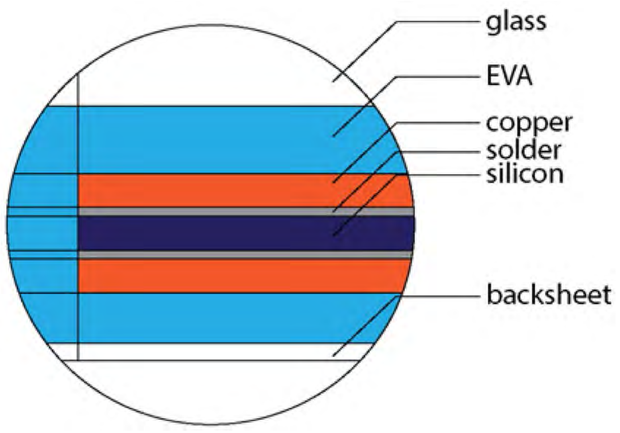
Complex meshing

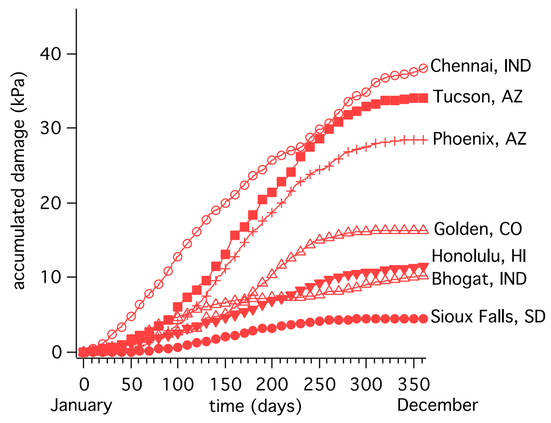


Constitutive modeling: non-Newtonian, visco-plastic, elasto-plastic



Previous 2D PV models





Component-scale validation

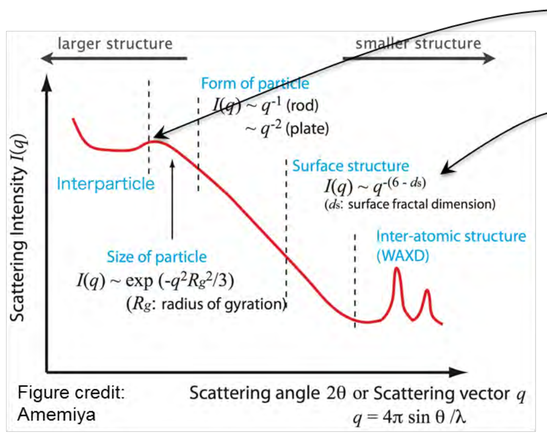
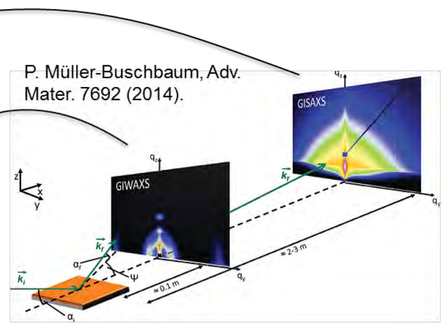


Figure credit: Amemiya



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National Nuclear Security Administration

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