LLNL Capabilities in Materials Modeling, Characterization, and Synthesis for Module Reliability Improvement and Cost Reduction

Overview

Unique capabilities in computational and experimental materials design, characterization, and synthesis enable accelerated insertion of new, high-performance materials throughout the solar module to improve reliability, extend lifetime, and reduce cost.

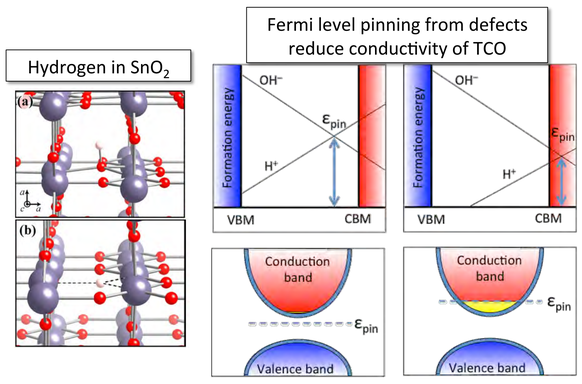
Materials Design and Discovery using High-Performance Computing

- Spanning the atomic-scale, mesoscale, and macro-scales, from first-principles to continuum
- Coupled-scale models allows accurate prediction of device and system response with few parameters

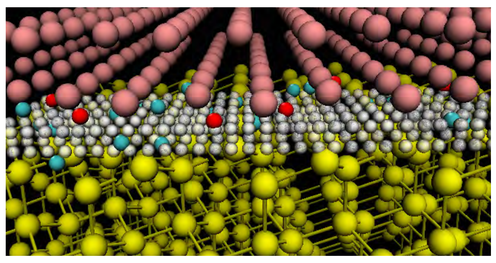
HIGH PERFORMANCE COMPUTING INNOVATION CENTER

HPC4 MANUFACTURING

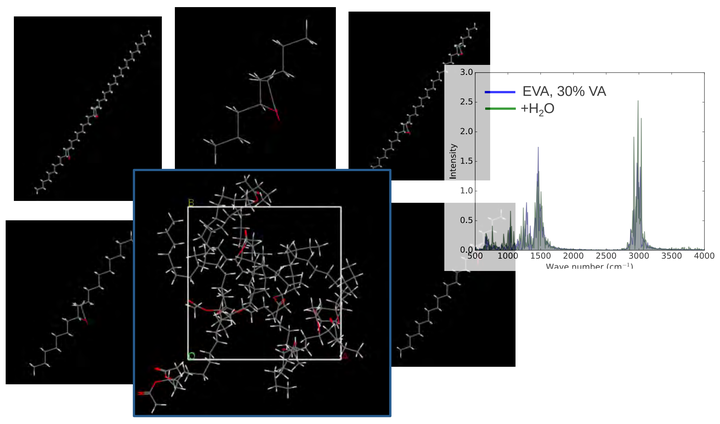
HPC resources, access, and support



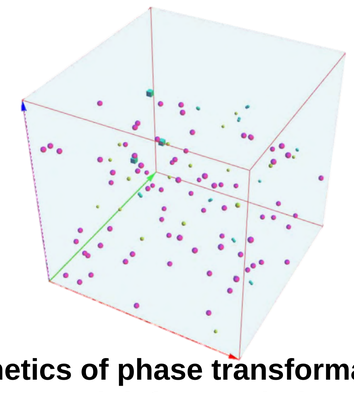
Transparent contact degradation



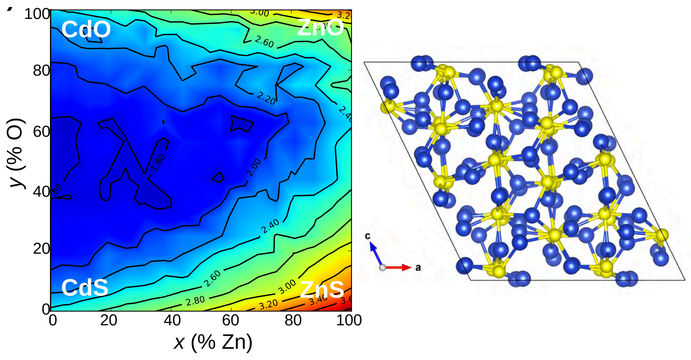
Interfaces and defects



Polymer degradation



Kinetics of phase transformations and defect evolution



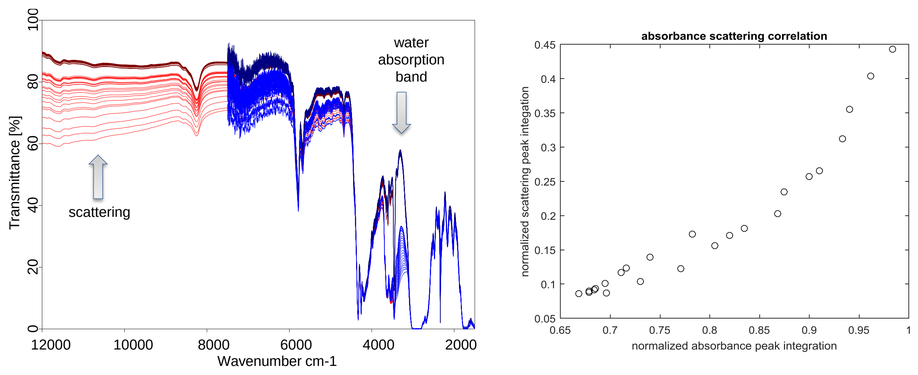
Alloy properties

Structural materials

These computational tools, combined with world-leading HPC, enable the design and search of improved materials for module components for longer lifetimes, higher reliability, and/or reduced cost.

Infrared Spectroscopy of Water Ingress in Solar Modules

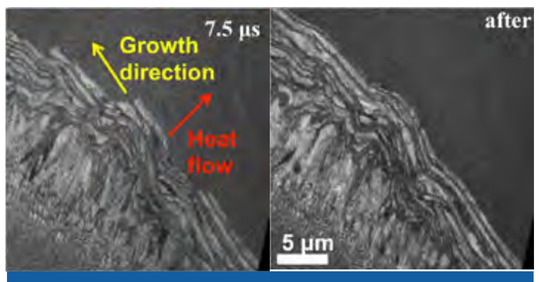
- Non-destructive study and qualification of long-term reliability of (flexible) modules related to water ingress into and through polymer encapsulants



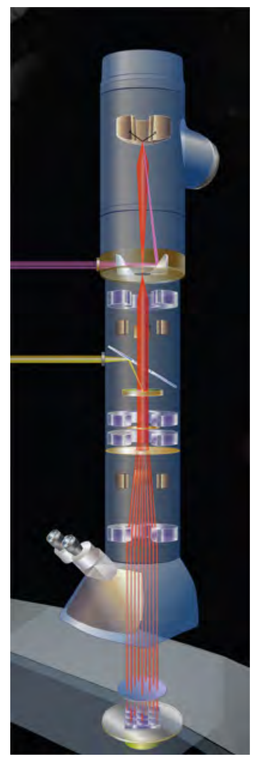
Infrared signatures of water ingress in multiple transparency windows

Dynamic Transmission Electron Microscopy (DTEM)

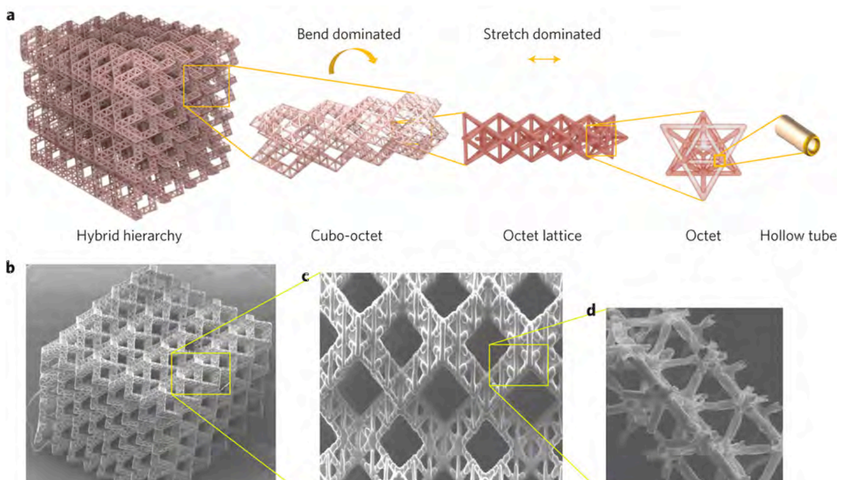
- Unique instrument invented at LLNL for direct imaging of materials transformations at the sub-ns and sub-nm scales
- Enables the study of reactivity, stability, and strength of materials, especially at interfaces, with unprecedented detail



15 nm time resolved images

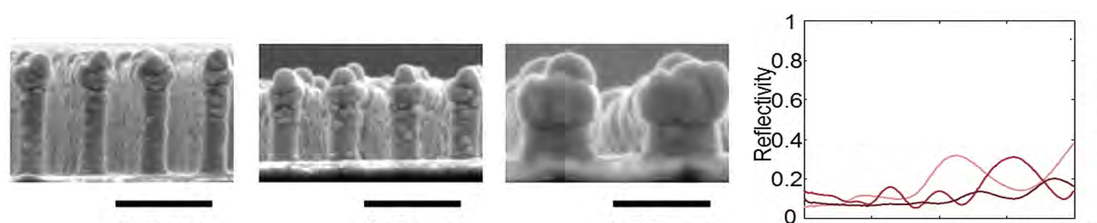


Additive Manufacturing of Hierarchical Metamaterials



Large-area 3D architected metamaterials with features spanning 7 orders of magnitude

- Fabrication of metamaterials with enhanced properties and eschewed tradeoffs compared to traditional bulk materials
- Design of hierarchical materials using HPC
- Integrated monitoring for validation of manufactured parts
  - *Examples:*
    - *Ultra wide-angle, broadband anti-reflective coatings*
    - *Highly absorptive coatings*
    - *Negative and zero thermal expansion materials*
    - *High-stiffness, high-strength, ultra-lightweight materials*



Hierarchically structured broadband absorptive coating

Lawrence Livermore National Laboratory

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