High-throughput experimental (HTE) combinatorial capabilities for inorganic durable module materials

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Abstract

The High-Throughput Experimental (HTE) capabilities are proposed for development of new inorganic materials that would increase durability of photovoltaic modules. In general the HTE combinatorial capabilities consist of combinatorial synthesis, spatially-resolved characterization, and semi-automated data analysis. The current combinatorial synthesis capabilities at NREL feature multi-element thin film deposition chambers with intentional and well-controlled composition-, and temperature gradients using sputtering. The existing spatially-resolved characterization techniques include chemical composition (XRF), crystallographic structure (XRD), microstructure (AFM), surface properties (PES, KP), electrical transport (4-point probe), optical properties (transmittance/reflectance), all as a function of position on the thin film, and hence as a function of the graded composition or temperature. The data analysis tools include custom-written processing and visualization routines for user-assisted data analysis, and data warehouse connections and project-specific databases. The HTE combinatorial capabilities established at NREL for semiconductors, are proposed here to be extended to handle metals (e.g. electrical connections such as solder bonds) and insulators (e.g. multifunctional coatings for anti-soiling, antireflection etc).

Material Synthesis

HTE Synthesis:
- Physical Vapor Deposition: co-sputtering, co-PLD
- Multiple deposition chambers to avoid cross-contamination
- Gradients: composition, temperature, thickness
- Multi-layer stacks: orthogonal gradients, interfaces
- Uniform depositions: substrate rotation, scale-up chambers
- Substrate size: typically 2x2” or 3” diameter

Future Ideas

Extend HTE approach to inorganic module materials
- New durable coatings to avoid soiling, heating etc
- New durable metal alloy formulations

Sample Characterization

Spatially-resolved characterization (mapping) capabilities:
- Composition (X-ray fluorescence, Rutherford backscattering)
- Crystal structure (X-ray diffraction, Raman spectroscopy)
- Thickness (step edge profilometry, X-ray fluorescence)
- Optical properties (UV-VIS-NIR, FTIR, ellipsometry)
- Photo response (photoluminescence, photoconductivity)
- Transport properties (4-point probe, Hall, Seebeck effects)
- Morphology/microstructure (atomic force microscopy)
- Surface and interface properties (photoemission spectroscopy, Kelvin prove, atmospheric photoemission)
- Device performance (J-V measurement under solar simulator)
- Mechanical properties (nanoindentation)
- Electrical properties (dielectric function, impedance spectra)

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