Advanced Process Technology: Combi Materials Science and Atmospheric Processing

High-throughput combinatorial ("combi") material science and atmospheric processing are two key focus areas of the Advanced Process Technology Group. The third major focus, organic solar cells, is discussed in another capabilities sheet.

High-Throughput Combinatorial Material Science

Scope. Combi approaches, based on thin-film composition-spread sample libraries, accelerate the development and optimization of new materials for photovoltaic (PV) and other energy technology applications. The NREL Combi team has developed state-of-the-art deposition, characterization, data handling, data analysis, and modeling tools to enable these high-throughput parallel approaches. Using these tools, we work closely with application experts, both internal and external, to rapidly develop application-specific optimized materials. Work has been done in solar absorbers, transparent conductors and interfacial contact layers demonstrating new high performance materials in general and device specific.

Core Competencies and Capabilities. The Combi team specializes in thin-film deposition by both sputtering and pulsed-laser deposition (PLD), property characterization and analysis, and development of new mapping characterization and data analysis tools as needed for new projects. Current experimental capabilities include:

- Multi-source sputtering (up to 4 sources)
- RF, DC, RF+DC sputtering
- Pulsed-laser deposition (up to 6 sources)
- Composition mapping (XRF, LIBS, EPMA, RBS)
- X-ray diffraction (XRD) mapping
- XRD with in-situ annealing (T < 800°C)
- Materials we can grow: metals, oxides, sulfides, nitrides
- Optical R, T mapping (200 nm – 25 µm)
- Spectroscopic ellipsometry mapping (190–2000 nm)
- Conductivity mapping
- Work-function mapping
- Seebeck Coefficient mapping

Atmospheric Processing

Scope. Atmospheric processing, especially based on solution-derived inks, can reduce overall cost and scalability issues of PV production. Our research focuses on developing these "inks" and "ink" conversion processes to acquire desired opto-electronic materials with targeted properties. Research is performed across all PV technologies, i.e., silicon, thin-film, and organic PV. Atmospherically processable materials developed include:

- Metals: Ag, Ni, Cu, Al
- Semiconductors: Cu-In-Ga-(S,Se), Cu-Zn-Sn-(S,Se), CdTe
- Oxides: ZnO, In_2O_3, SiO_x, $Ba_xSr_{1-x}TiO_3$, TiO_2
- Silicon contact burn-through, dopants
- Organic absorbers materials and encapsulants

Core Competencies and Capabilities. The atmospheric processing capabilities consist of the following:

Stand-alone:

- Tabletop inkjet printer for testing inks
- Two commercial-style inkjet printers
- Three ultrasonic spray stations (one in inert environment)
- Slot coater
- Three controlled-environment Rapid Thermal Processing (RTP) systems
- Laser scribing and annealing system

Process Development and Integration Laboratory (PDIL): Atmospheric Processing Platform

- Integrated system for atmospheric processing
- Multi-color inkjet printing resolution to < 50 microns
- Multi color ultrasonic spraying
- Aerosol jet spraying resolution to < 20 microns
- Controlled environment Rapid Thermal Processing
- X-ray fluorescence and X-ray diffraction analysis
- Integrated vacuum deposition capability

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Web (Advanced Concepts): http://www.nrel.gov/pv/advanced_concepts.html
Web (Atmospheric Processing): http://www.nrel.gov/pv/pdil/ap_capabilities.html

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