Microreactor-Assisted Nanomaterial Deposition for Photovoltaic Thin-Film Production

Improved Energy and Material Efficiency in Production of Nanoscale Materials

Among renewable energy sources, the conversion of sunlight directly into electricity using the photovoltaic (PV) properties of suitable materials is an increasingly attractive option. However, current PV manufacturing practices suffer from high costs and large carbon footprints associated with poor energy efficiency, poor material utilization, high processing temperatures, and/or high solvent usage. The development of more energy- and material-efficient manufacturing processes for greener, low-cost production of solar cells will be the key enabler for moving PV technology forward.

This project, led by the Pacific Northwest National Laboratory, and based at the Microproducts Breakthrough Institute, is addressing this challenge by developing improved processes for the production of nanoscale materials relevant to PV devices and by integrating these nanomaterials into composite devices.

To achieve this goal, the project is using Microreactor-Assisted Nanomaterial Deposition (MAND™) and supercritical fluid (SCF) technologies. MAND represents a new platform for solution-phase synthesis, purification, functionalization, and deposition of nanomaterials, while SCF is a promising technology for the replacement of traditional solvents with a benign alternative.

Successful demonstration and commercialization of these technologies could significantly reduce the environmental discharge, manufacturing energy, and production costs associated with current nanoscale thin-film PV manufacturing approaches.

Benefits for Our Industry and Our Nation

Implementation of MAND and SCF technologies will have both direct and indirect energy, environmental, and economic benefits. The direct benefits will arise from the cleaner, more efficient production of PV systems. The very large indirect benefits will arise from the implementation of PV projects that displace other fossil fuel–dependent sources of electricity generation.

Use of MAND and SCF technologies will also reduce chemical waste due to increased material yield, increased productivity due to reduced labor costs and reduced processing time for PV device production, and improved material and energy efficiency during the PV device manufacturing process.

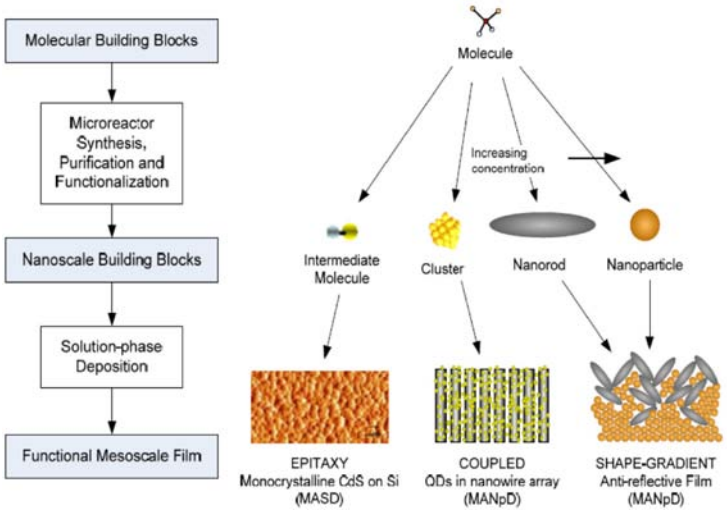

Figure 1. Left: Microreactor-Assisted Nanomaterial Deposition (MAND™) architecture. The microreactor technology generates nanoscale building blocks for precise, economical solution-phase deposition. Right: Microreactor-Assisted Solution Deposition (MASD) and Microreactor-Assisted Nanoparticle Deposition (MANpD) routes to PV-relevant films.

Illustration courtesy of Oregon State University.

Applications in Our Nation's Industry

Initial application of the proposed processes will be for improved PV devices that are enabled by nanoscale materials. More broadly, the manufacturing technology (and associated energy savings and waste reduction) developed in this project will be adaptable/applicable to the production of other nanoscale materials (and devices that use them).

Project Description

The goal of this project is to develop and demonstrate a scalable microreactor-assisted nanomaterial deposition pilot platform for the production, purification, functionalization, and solution deposition of nanomaterials for PV applications. Phase I of the project focuses on improving process unit operations and devices for PV material production. Efforts will target scale-up of the microreactor-assisted deposition of PV nanofilms and the synthesis and purification of PV quantum dot nanoparticles. Phase II of the project will integrate the modular efforts in Phase I to scale up the microreactor-assisted deposition of PV nanoparticles.

Barriers

- Improving energy and material efficiency of nanomaterial manufacturing for PV production while reducing associated cost
- Development of a demonstration pilot plant incorporating MAND and SCF technologies

Pathways

The project will focus on the scalability and viability of the MAND and SCF technologies.

Two MAND processes will be used within this project. Microreactor-Assisted Solution Deposition (MASD) uses microreactor technology to produce reactive fluxes of short-life, intermediate molecules for heterogeneous growth on a temperature-controlled substrate. Microreactor-Assisted Nanoparticle Deposition (MANpD) uses microreactor technology to implement real-time nucleation, growth, purification, and functionalization of nanoparticles for deposition and assembly of nanoparticle films and structures.

Milestones

This project started in September 2008.

1. Develop and scale-up an integrated platform for depositing nanoscale films via MASD for thin-film PVs. (Completed)
2. Develop and scale-up a MANpD system capable of generating near-monodisperse distributions of functionalized nanocrystals. This will involve scale-up of individual process components and integration of multiple unit operations.
3. Further system integration and demonstration of the MANpD technology with the MASD tool previously developed.

Commercialization

Technology commercialization will be coordinated by project partner CH2M HILL's Electronics and Advanced Technology Group. CH2M HILL is one of the world's largest environmental and facilities engineering firms.

The commercialization strategy will be executed in three phases:

1. Construction of a development production line that, once completed, will be operated as a demonstration production line
2. Construction of a full-scale "replication line" and the establishment of a business entity responsible for ownership of the technology
3. Mass deployment of manufacturing capacity

The business entity will form agreements with international manufacturing organizations to meet the extensive capital requirements necessary for rapid deployment.

Project Partners

Pacific Northwest National Laboratory (PNNL)*
Richland, WA
Principal Investigator: Daniel Palo
E-mail: dpalo@pnl.gov

Oregon State University (OSU)*
Corvallis, OR
*Collaborating though The Microproducts Breakthrough Institute.

CH2M HILL (Electronics and Advanced Technology Group)
Portland, OR

Voxtel, Inc.
Beaverton, OR

Oregon Nanoscience and Microtechnologies Institute
Corvallis, OR

For additional information, please contact

Gideon Varga
Technology Manager
U.S. Department of Energy
Industrial Technologies Program
Phone: (202) 586-0082
E-mail: Gideon.Varga@ee.doe.gov

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