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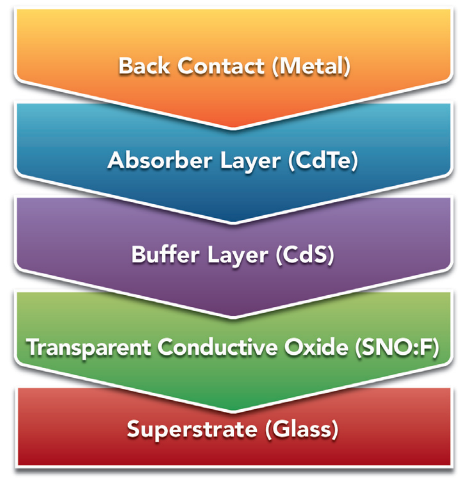
Assembly and Production of Nanomaterials for Solar Energy

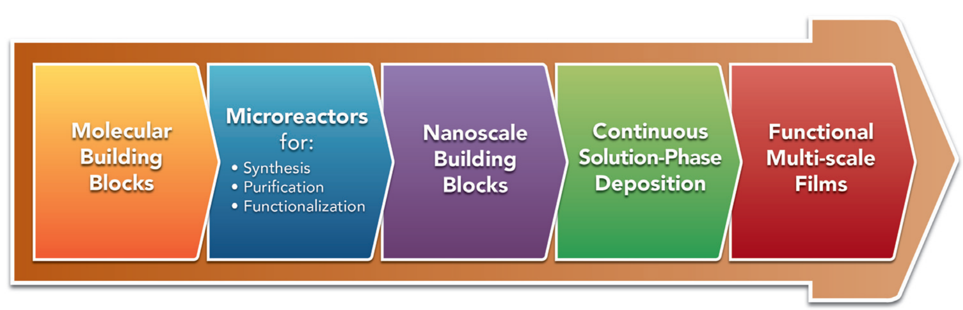


2nd Generation PV requires the precise deposition of nano-thin film layers on large format glass substrates. Control of layer growth, higher material utilization, and process scale-up are needed in making this approach more cost effective. Shown here are the layers of a CdTe solar cell, which are, from bottom up: Glass Superstrate, Transparent Conductive Oxide Layer, Cadmium Sulfide Buffer Layer, Cadmium Telluride Absorbing Layer, and Metal Back Contact.

Conversion of sunlight directly into electricity using photovoltaic (PV) devices is a very attractive source of renewable energy. However, current (PV) technology has challenges with efficient capture and conversion of solar energy and the high price of solar modules. The cost per watt for PV solar cells must be competitive with conventional energy sources if PV is to become widely utilized. The key enabler for moving PV technology forward is to develop more energy efficient, more material efficient, greener, low-cost manufacturing processes for both existing and future versions of high efficiency solar cells. A PNNL-led team that includes development partners Oregon State University, CH2M HILL, and Voxtel, Inc. is addressing these issues by developing improved processes for the production and integration of nanoscale materials relevant to the next generation of PV devices. The approach is twofold, involving both thin-film (2nd Generation) and hierarchically ordered (3rd Generation) solar cell technology. 2nd Generation PV technology utilizes thin film layers built on glass superstrates—eliminating the silicon wafer constraint of present PV technology and making PV potentially more efficient and cost effective if viable manufacturing methods can be developed. Hierarchically ordered (3rd Generation) solar cell technology is based on integrated micro and nanostructured materials that provide improved solar energy capture and transport. *Cost effective production and assembly of these nanostructured materials at the industrial scale will determine the viability of using them for advanced solar energy technology.*

IMPROVING THIN FILM PV

The various layers required in constructing 2nd Generation PV cells are most often deposited by vacuum-based and/or high-temperature processes that result in much material waste. What is needed for of 2nd Generation PV to improve performance and reduce



Microreactor Assisted Nanomaterial Deposition™ (MAND) techniques work according to the process illustrated here. Molecular building blocks (starting materials) are fed to microreactors for synthesis, purification, and functionalization steps, resulting in nanoscale building blocks (nanomaterials). These materials are then deposited through solution phase processes to produce functional multi-scale films.

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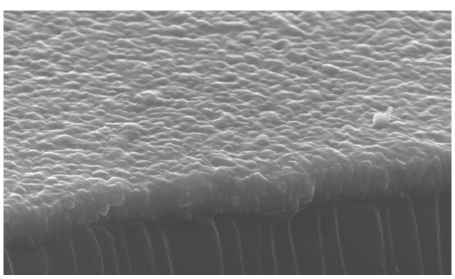
cost is efficient production and precise deposition techniques for nano-scale thin films in a continuous process that is amenable to scale-up (much like the increasingly larger formats found in the flat panel display industry). We have demonstrated the deposition of one of these key layers, the CdS buffer layer. Our novel approach utilizes a form of chemical bath deposition, but operates in continuous mode, allowing the material to be produced at the point of deposition, at the exact rate required, resulting in much less waste production and energy consumption. The process is enabled by in-line micromixer and microchannel heat exchange that allow easy production scale-up and result in precise control of a complex reaction mixture. The result is a film with excellent consistency. Presently we are depositing CdS films over a 150-mm^2 substrate, having achieved uniform CdS deposition (± 5% thickness deviation), and we are currently working to maximize material utilization and reduce waste. Flow synthesis of films like this offers control over reactant residence time, reactant concentration, and material utilization that is not achievable in batch processes such as chemical bath depostion.



CdS film deposited by continuous solution deposition on FTO-coated glass.

NANOMATERIALS FOR STRUCTURED SOLAR CELLS

Hierarchically ordered (3rd Generation) solar cell technology is based on integrated micro and nanostructured materials that provide improved solar energy capture and transport. A range of nanomaterials are being considered for advanced solar cell configuration including titania, graphene, carbon nanotubes, and quantum dot emitters. Cost effective production, purification and efficient rational assembly of these nanostructured materials at the industrial scale will determine the viability of using them for advanced solar energy technology. We are exploring microchannel technology, supercritical fluids, advanced membranes, and novel chemical processes to improve industrial scale production, purification, and assembly of nanomaterials that may be utilized in advanced solar cells.

SPONSORS

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ABOUT PNNL

Pacific Northwest National Laboratory, a U.S. Department of Energy Office of Science laboratory, solves complex problems in energy, the environment, and national security by advancing the understanding of science. PNNL employs more than 4,900 staff, has a business volume exceeding $1.1 billion, and has been managed by Ohio-based Battelle since the Lab's inception in 1965.

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