Nanostructured Materials for Renewable Energy

Development of Low-Cost Photovoltaic Solar Cells Utilizing Nanostructured Surfaces and Interfaces

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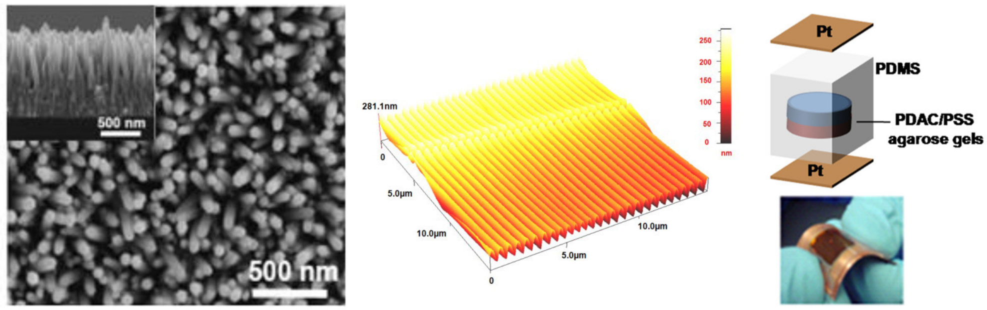

Left: Scanning electron micrograph (SEM) of zinc oxide (ZnO) nanorod growth by a combination of hydrothermal and atomic layer deposition techniques (cross-section SEM inset). Center: Atomic force micrograph of a buckled nanostructured substrate with an indium tin oxide (ITO) coating for use in an organic solar cell device. Right: Prototype of a new flexible gel-based photovoltaic device.

Photovoltaic (PV) solar cells produce renewable electricity by harnessing the power of the sun. PV solar cells represent a particularly promising renewable energy platform because energy from sunlight is abundant and the environmental impact of their use is minimal. At the present time, silicon-based PV solar cells are widely available commercially, but the PV market is limited by the relative high cost and low efficiency of these PV solar cells. Research is on-going to identify alternative PV materials that will combine low production costs with high efficiency cells.

Organic materials that are relatively easy to process and manufacture at high throughput offer one alternative to silicon-based PV cells. An additional advantage of these materials is that they can be patterned on flexible surfaces. However, the organic-based PV solar cells developed thus far are significantly less efficient than conventional silicon PV cells, severely limiting their application.

The project is addressing this issue by developing novel nanoscience techniques, materials, and devices to enable the low-cost production of high-efficiency organic and organic-inorganic hybrid PV solar cells. Project work builds on and expands current expertise in nanoscale materials synthesis techniques, including atomic layer deposition (ALD) and physical vapor nano-evaporation, and couples these techniques with developing fields in electrochemical and solid-state growth. In addition, this project will advance the fundamental state of knowledge in the design, synthesis, assembly, analysis, and modeling of novel molecular (and other nanoscale) systems for other energy-related applications. Future work could expand the use of these nanostructured materials to other heat-scavenging devices, such as thermoelectric and energy storage devices.

Benefits for Our Industry and Our Nation

The organic materials being developed in this project could make PV solar cells more competitive with other sources of electricity generation by drastically decreasing their cost. Integration of photoactive organic materials with inorganic nanostructures could improve the operation of these devices. Reduced cost will support large-scale deployment of PV solar cells, yielding indirect benefits by displacing other fossil fuel–dependent sources of electricity generation.

Much less energy is required to manufacture organic-based devices than conventional PV devices. Organic-based PV devices also are typically less toxic and easier to dispose of at the end of their life cycle.

Applications in Our Nation's Industry

The processes developed in this project will be utilized for improved PV devices that are dependent on nanomaterials. More broadly, this project will advance the fundamental state of knowledge in the design, synthesis, assembly, analysis, and modeling of novel molecular (and other nanoscale) systems for energy-related applications. Results from this work could also eventually help supply renewable electricity for industrial energy systems including motors; pumps; compressed air; and heating, ventilation, and air conditioning (HVAC) systems. Electricity currently accounts for almost one-third of U.S. industrial primary energy use.

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Project Description

The overall objective of this project is to advance the fundamental understanding of novel photoelectronic organic device structures integrated with inorganic nanostructures, while also expanding the general field of nanomaterials for renewable energy devices and systems.

Barriers

- The laboratory-level solutions explored in this project face challenges in scaling-up to industrial-level devices and systems.
- The extremely high surface area of nanostructured photovoltaic (PV) devices will exacerbate challenges for and understanding of energy transduction and charge transfer at organic/ inorganic interfaces.
- Energy consumption for production of nanostructured PV modules need to be competitive with the energy break-even point of conventional technologies.

Pathways

The project is organized into three main tasks that are conducted concurrently. The first task focuses on developing a functional PV device fabrication, testing, and evaluation laboratory at North Carolina State University. This laboratory will house specialized equipment for photovoltaic device fabrication as well as other equipment for materials and optoelectronic device characterization.

The second task focuses on exploring novel inorganic structures for photovoltaics. Researchers will utilize atomic layer deposition (ALD) technology, a technique that enables the precise conformal coatings needed for the fabrication and modification of unique nanostructures. The research team will also utilize other techniques, such as vapor phase nanoevaporation, self-assembly, and imprint lithography to fabricate nanostructured surfaces in a simple, inexpensive, and scalable manner.

The third task involves the development of novel photoactive nanomaterials such as gel-based PV materials and organic PV materials. The organic PV materials will be developed through fabrication and/or patterning via a precursor polymer that converts from an insulator to a metallic conductor directly under patterned radiation.

Milestones

This project started in July 2008. The milestones for year 2 of the project include:

- Months 1-4: Procurement of remaining equipment needed for organic-based PV device fabrication
- Months 1-4: Use of novel oligomer precursors into PV device
- Months 4-8: Fabrication of PV device using inorganic nanostructures developed & modified by ALD and other nanoengineering techniques
- Months 4-8: Integration of bio-derived sensitizers in gel-based PV devices
- Months 8-12: Determination of principles that effect high ionic conduction and current inside aqueous gel layers
- Months 8-12: Develop prototype of other energy-related devices which use nanostructures systems

Commercialization

Project partners will collaborate with local and national research corporations to foster future commercialization opportunities. The project team has initiated discussions with start-up companies such as Alditri Technologies and Protochips (both of Raleigh, NC) and reached out to local renewable energy companies via on-site visits of the PV laboratory at North Carolina State University and promotion through the North Carolina Nanotechnology Commercialization Conference. The project team will identify additional customers for the technology through industrial partnerships, the U.S. defense industry, and other end users.

Project Partners

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