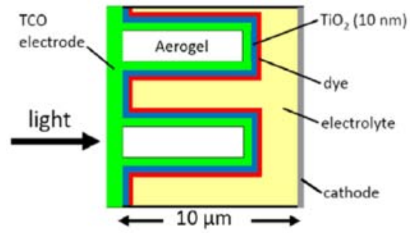
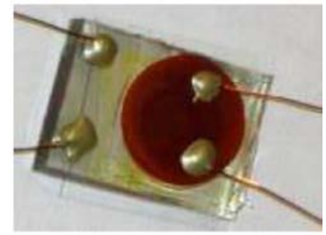
Process Development for Nanostructured Photovoltaics

Low-Cost Nanofabrication Method To Develop Nanostructured, Dye-Sensitized Solar Cells





A schematic illustration of improved nanostructured DSSC photovoltaic device (left). Prototype nanostructured DSSC fabricated using atomic layer processing technology. Active area is 0.5 cm by 0.5 cm (right).

Photos courtesy of Argonne National Laboratory.

Introduction

Photovoltaic (PV) manufacturing is an emerging industry that promises a renewable, carbon-free source of energy for the United States. However, the high temperatures required to manufacture conventional silicon-based crystalline PV cells result in a manufacturing process that is energy-intensive and expensive.

Dye-sensitized solar cells (DSSCs), which use a monolayer of organic dye to absorb sunlight, were developed to reduce the cost and energy intensity required to manufacture traditional PV solar cells. While DSCCs can be cheaper to manufacture than silicon-based PV solar cells, they are also less efficient, currently achieving 11 percent efficiency in research-designed cells, compared to 25 percent for comparable silicon-based cells. The nanostructured solar cells being developed in this project, which are also fabricated using low-energy processes, improve upon the DSSC design and can achieve greater than 11 percent efficiency. However, scale-up and further process improvement is necessary to achieve market readiness.

To address current scale-up and process limitations, the project team is seeking to enhance current low-cost fabrication methods of manufacturing nanostructured photovoltaics. Specifically, researchers are developing and scaling-up the supercritical drying and atomic layer processing steps for producing nanostructured DSSCs. In this project, a porous, high-surface-area silica aerogel is applied to a transparent conductive oxide (TCO) substrate. The aerogel is then coated with a thin layer of TCO material using atomic layer deposition. Successful scale-up and demonstration of the nanostructured solar cell and fabrication process could accelerate the deployment of more cost-effective solar cells.

Benefits for Our Industry and Our Nation

Successful development and market penetration of low-cost nanostructured solar cells will result in direct and indirect energy, environmental, and economic benefits. The direct benefits will arise from market adoption of the low-temperature, less energy-intensive manufacturing process required to produce nanostructured solar cells. The substantial indirect benefits will arise from the implementation of low-cost nanostructured solar power that displaces the dominant fossil fuel-dependent sources of electricity generation.

Utilization of nanostructured solar cells can also reduce the criteria pollutants and other gaseous and solid pollutants that result from burning fossils fuels to generate the comparatively large amount of process energy now needed for manufacturing silicon-based solar cells. Overall, significant energy savings, emission reductions, and cost savings will result from the development of reliable, low-cost nanostructured solar cells.

Applications in Our Nation's Industry

End users of the nanostructured PV technology will primarily be solar cell manufacturing companies and solar cell equipment manufacturing companies. The new materials and methods under development will have many attractive features and benefits for equipment manufacturers and end users, including lower cost, lower manufacturing temperatures, and reduced greenhouse gas and other emissions compared to existing methods. Ultimately, widespread adoption of this technology will allow power generators to incorporate solar into their generation portfolios at a lower cost than current PV options.

Project Description

The goals of this project are to develop nanostructured PV devices and refine and scale-up low-cost, low-energy fabrication methods for these devices. These goals are being targeted by focusing on the supercritical drying and atomic layer processing steps for producing nanostructured DSSCs.

Specifically, researchers are applying silica aerogel to a conducting substrate. The aerogel is then functionalized using atomic layer processing techniques to apply nanometer-thick layers of transparent conducting and semiconducting materials. The resulting nanostructured electrodes are assembled into DSSCs using established methods. Ultimately, the DSSCs will be tested to evaluate their solar conversion efficiency, current voltage characteristics, lifetime, and durability.

Barriers

- Ensuring scalability of low-cost, low-energy nanostructured PV devices while improving conversion efficiency over that achieved by current DSSCs.

Pathways

Researchers first fabricate small area (1 cm x 1 cm) PV devices to evaluate different techniques for aerogel application and different functional coatings. The objective of this task is to arrive at an optimal design. Researchers then scale-up the optimal design to an intermediate size of 5 cm x 5 cm, and then to a larger 10 cm x 10 cm design. Photoelectric cells are fabricated, characterized, and tested to reveal (and ultimately rectify) any deficiencies in fabrication or performance.

The final task entails designing, fabricating, and testing a nine-cell module. This module will be a marketable prototype based on the technology developed in this project.

Milestones

Work on this project commenced in September 2009.

- Complete fabrication of first bench-scale 1 cm x 1 cm DSSC. (Completed)
- Investigate three alternatives to supercritical drying for fabricating nanostructured electrodes and explore alternative scalable routes for casting aerogel thin films. (Completed)
- Complete optimization of 1 cm x 1 cm cell and scale-up to 5 cm x 5 cm device.
- Fabricate and optimize 10 cm x 10 cm cell.
- Characterize and test nine-cell module.

Commercialization

To help realize the commercial potential of nanostructured solar cells, a team of industrial partners has been assembled to develop market strategy and provide commercial viability to the technology. Innosense LLC, the primary industrial partner on the project, currently serves the aerospace, defense, commercial, and industrial markets with cutting-edge nanotechnologies and is providing cost-sharing over the life of the project.

The end product of this project will be the technology and intellectual property for manufacturing nanostructured photovoltaic devices. Following further scale-up to a device suitable for mass production, additional commercial partners will be targeted to accelerate the introduction of nanostructured photovoltaics to the market. These partners may include glass manufacturers, chemical companies, and PV manufacturers. In addition, a specialized technology company such as Innosense may be utilized to fabricate the nanostructured electrodes.

Project Partners

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