Grand Challenge Area

Energy Conversion and Storage: New Materials and Processes for Energy Needs

Challenge

Inexpensive energy underlies economic prosperity. A nation's ability to develop new energy sources within its own borders can reduce dependency on international energy supplies and finite oil reserves. Novel abilities and improved efficiencies in converting, storing, transmitting, and conserving energy are also critical to the challenge of providing clean, abundant, and secure energy for domestic needs.

Vision

Nanotechnology promises significant improvements in solar energy conversion and storage, thermoelectric converters, high-performance batteries and fuel cells, and efficient electrical power transmission lines. For example, nanoscale control of materials structure and composition has shown promise for novel approaches to photovoltaic systems. A deeper understanding of the physics of phonon and electron transport in nanostructured materials may facilitate production of practical all-solid-state and environmentally clean thermoelectric energy conversion devices. Currently, hard and soft magnets are widely used in electric power production and utilization. Improved nanostructured magnets may yield substantial energy savings by reducing losses incurred in the generation and use of electricity.

Nanostructures may also enhance the controlled release of chemical energy toward specific goals such as more efficient combustion, greater thrust in rocket propulsion, thermobaric destruction of chemical or biological agents, and tailored electromagnetic emission from propulsion systems (lower intensity signatures or better decoys to foil missile seekers). Nanoscale control of the shapes, chemistry, and phases of catalyst particles and supports clearly will impact energy conversion, chemical processing, and related fields.

Opportunities also exist for increasing thermal transport rates in fluids by utilizing nanocrystalline particulate suspensions. These "doped" nanofluids have recently been shown to exhibit substantially increased thermal conductivities and heat transfer rates compared to their "undoped" counterparts.

Agency Participation

(lead in bold)

DOD	Energetic materials for propulsion, decoys, explosives
DOE	All aspects of energy research, including catalysis, fuel cells, hydrogen
IA	Nano-enabled advanced power systems
NASA	Energy conversion and storage for space systems
NSF	Materials science and engineering
NIST	Manufacturing processes and equipment
USDA	Biomass conversion to energy and chemicals, hydrogen production, distributed power production

Research Example: Polymeric Nanostructures for Conversion of Solar Energy (supported by DOE)

Nanotechnology may provide a path to a new generation of solar cells. Presently, low-cost solar cells with power efficiencies of around 12% are readily available, while high-end solar cells with efficiencies of 34% can be made for satellites, but are prohibitively expensive for large-scale terrestrial applications. Researchers at the University of California at Berkeley and Lawrence Berkeley National Laboratory have reported a new type of "paint-on" solar cell that has promise for relatively low fabrication cost and the potential to achieve efficiencies comparable to those of high-end cells.

At the heart of all solar cells are two separate material layers, one with a reservoir of electrons that functions as the "negative pole," and one having vacancies for electrons called electron holes that functions as the "positive pole" of the cell. Absorption of light from the sun or other light source by the cell provides energy to drive the electrons from the negative to the positive pole, creating a voltage difference between the two and thus enabling the cell to serve as a source of electrical energy.

The new devices are based on a combination of a semiconductor polymer (an organic material) and cadmium selenide nanorods (an inorganic material) (Figure 13). In this cell, each microscopic step in the performance of the solar cell is independently optimized. Absorption of light can occur in either the nanorods or the polymer, and charge separation takes place at the interface between them, followed by charge transport to the harvesting electrodes—indium tin oxide (ITO) and aluminum (Al).

Solar cells made with these devices have the potential to provide low-cost, ultra-lightweight, and flexible cells with a wide range of applications. Due to the nanoscale dimensions of the nanorods, quantum-size effects influence their optical properties. By tailoring the size of the rods, they can be made to absorb light within a specific narrow band of colors. By stacking several cells with different sized rods, a broad range of wavelengths across the solar spectrum can be collected and converted to energy. Moreover, the nanoscale volume of the rods leads to a significant reduction in the amount of semiconductor material needed compared to a conventional cell.

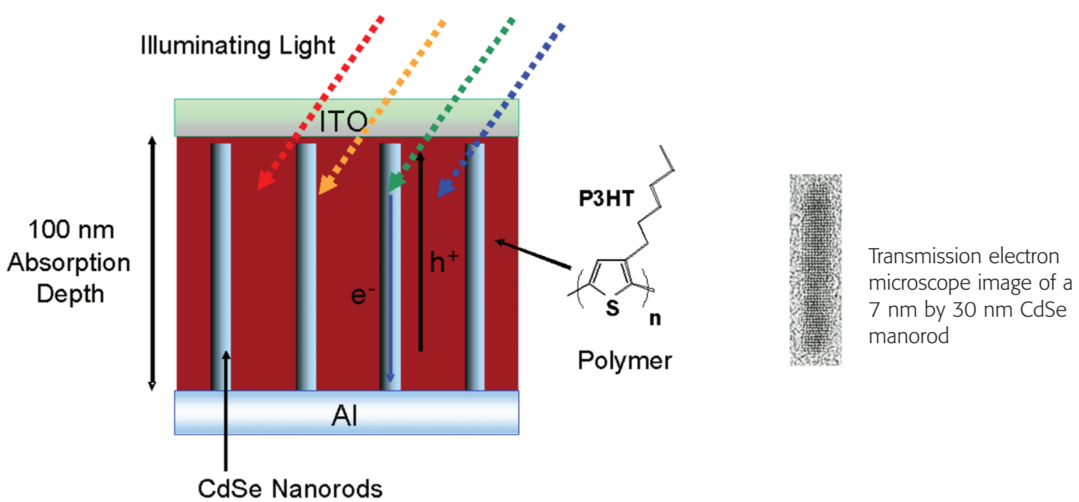

Figure 13. Schematic design of the nanorod-polymer solar cell illustrating how light energy activates the polymer (P3HT) and cadmium selenide (CdSe) components of the cell to drive electrons (e-) and holes (h+) to opposing aluminum (Al) and indium-tin oxide (ITO) electrodes (courtesy P. Alivisatos, University of California, Berkeley, and Lawrence Berkeley National Laboratory).