Using Nanomaterials for Solar Cells

TONY HEINZ
ELECTRICAL ENGINEERING

The amount of energy from the sun that falls to Earth far, far exceeds our demand for energy. Sunlight would surely be of broad use in today’s world if we could capture and convert it into electricity sufficiently efficiently and economically. The conversion of light to electricity is carried out in photovoltaic devices or, as they are known more commonly, solar cells. These devices are typically made from silicon. Silicon, the basis of electronic circuits, is in many ways an excellent material. However, the basic properties of electrons in silicon imply that more than two-thirds of the incident energy will necessarily end up as heat rather than as electricity. Is there a way to avoid this energy loss and increase the efficiency of photovoltaic devices?

Tony Heinz, David M. Rickey Professor of Optical Communications in the Department of Electrical Engineering, and professor of physics in the Graduate School of Arts and Sciences, is working with an interdisciplinary team of colleagues on a project that may revolutionize both our understanding of energy-conversion processes and the practical production of electricity from sunlight. He and his group are exploring a fundamentally new type of energy-conversion process, one in which a single absorbed photon creates two or more electronic excitations in a suitable nanostructured material. While this process, known as Multiple Exciton Generation (MEG), is intrinsically weak in conventional semiconductor materials, Heinz is convinced that it will work if the right materials—novel nanoscale materials—are found.

Heinz and his collaborators are making such structures—individual nanoscale photovoltaic devices based on carbon nanotubes and other tailored nanoscale materials—in which these ideas can be rigorously tested. He says that both the electrical and optical measurements require experimental advances. The program builds on recent progress by his group and collaborators in extracting photogenerated charges from individual carbon nanotubes on the one hand and, on the other hand, in directly measuring the amount of light absorbed by such tiny structures through the use of new laser-based techniques.

“This is very an exciting fundamental scientific issue that goes to the core of understanding how light interacts with electrons in solids. At the same time, it is a problem with the potential to have an important impact on addressing the world’s needs for sustainable energy,” says Heinz. “As part of the Energy Frontier Research Center recently established at Columbia University with the support of the U.S. Department of Energy, we have the good fortune of being able to pursue these fascinating questions. At Columbia, we also benefit from an excellent collaborative research environment. This allows us to bring together the diverse expertise in science and engineering disciplines that is indispensable for progress in attacking these demanding problems.”

Making a Smarter Power Grid

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The advancements ushered in by the digital age have touched nearly every area of human existence in the world, from how people shop and navigate their vehicles to how they work and consume news and entertainment. However, complex power grids—which connect us with many of these relatively new technologies—are still mostly stuck in the analog age.

One man who wants to change that is senior research scientist Roger Anderson, the Con Edison Senior Scholar at Columbia Engineering’s Center for Computational Learning Systems. He and colleague Albert Boulanger have developed a patented Adaptive Stochastic Controller (ASC) technology that will be part of Con Edison’s Smart Grid Demonstration Project.

“We are trying to make the electric grid smarter, much more like the Internet, so that control systems can route power to where people need it, when they need it, and from green sources as much as possible,” says Anderson.

The ASC is an algorithm-based, machine learning system that will allow the Smart Grid to calculate, on a minute-by-minute basis, the cheapest, most efficient and most reliable ways of delivering electricity to consumers. It also will allow the Smart Grid to anticipate and respond automatically to problem events, such as weather changes and equipment failures, in order to prevent power outages.

Columbia’s role is to produce the ASC for the New York City Smart Grid Demonstration Project, funded by the federal Department of Energy (DOE), to help build a smarter, more efficient, more resilient national electric grid.

Last November, the DOE awarded Con Edison $45 million for its Secure Interoperable Open Smart Grid Demonstration Project—one of sixteen projects selected nationwide. The New York Public Service Commission will provide additional matching funds to make it the largest Smart Grid Demonstration Project in America.

Once the Smart Grid is implemented, Anderson says, “Things will happen too fast for optimal decision making by humans—even from the highly skilled operators at Con Edison.”

The Smart Grid will use Columbia-designed ASC computer control to respond more quickly to power surges and emergency outages so that power can be redirected to where it’s needed, using photovoltaics, wind, battery storage, and other green sources from areas with less demand.

“The whole idea of the Smart Grid is to have enough computer intelligence so you can control (the grid) better and make it more stable,” Anderson says.

Such technology is also being developed in Europe and China, he says, and an international utility working group has been established to share best-practice ideas and technologies across the globe.