

QUANTUM DOTS

ENHANCING OPTICAL ABSORPTION IN SOLAR CELLS

FOR THE LAST TWO YEARS, Professor Anand Kulkarni and graduate student Jaspreet Nayyar have been trying to understand the behavior of a nanoscale semiconductor called the quantum dot.



Anand Kulkarni

A solar cell company in the United Kingdom, Quanta Sol Ltd., recently announced an improvement in solar cell efficiency using quantum well structures, citing the enhancement of optical absorption. In addition, in a recent paper Kulkarni and Nayyar used quantum mechanical calculations to clearly show the enhancement

of optical absorption coefficient. "This recent development provides some experimental credibility to our theoretical work," says Kulkarni.

Previous research has shown quantum dots to be particularly effective at converting sunlight into electrical energy. Used in photovoltaic solar cells, they can greatly enhance optical absorption—and hence efficiency.

Electrons on their own are free to move in all three dimensions. When confined in a quantum well, however, they are restricted to one dimension and allowed free propagation in two dimensions. In a quantum dot, electrons are confined in all three directions. The confinement causes the band gap energy to vary according to size. Different-sized quantum dots will absorb different color light more efficiently. "In other words, varying the sizes of quantum dots, it is possible to absorb all the wavelengths of solar radiation equally well," Kulkarni explains. "Present-day solar cells only absorb part of the solar radiation based on the band gap of the material. The use of multiple band gaps (called a Tandem cell) makes it possible to absorb different parts of solar radiation more effectively—but the cost of these materials and the fabrication process is very high."

Lowering the cost and enhancing the efficiency of solar

cells remains a challenge. "Right now, solar cells have a 40 percent efficiency rate for sophisticated cells in the lab. But in actual use, the rate drops to only about 15 percent in solar cell panels made of silicon," notes Kulkarni. In the lab, solar cells created with quantum dots have been shown to have a potential efficiency of 63.2 percent – far more than any other photovoltaic technology.

"Scientists have studied quantum dots and quantum mechanics for more than 100 years," he adds. "They began making quantum devices in the 1950s and early 1960s. But only now are we incorporating that knowledge into solar cells."

Kulkarni describes four kinds of photovoltaic technology. The first is thin-film silicon, which is commonly used today. The second is the concentrating and focusing of solar power (CSP). The third is organic photovoltaic, which studies the way plants generate energy from sunlight. Last but not least are quantum dots. "It's the newest approach."

Kulkarni, along with Associate Professor Paul Bergstrom (electrical engineering) and Professor Stephen Hackney (materials science and engineering) are attempting to use quantum principles to determine optical absorption in nanoscaled silicon and silica. "It has been shown that energy absorption is enhanced—but can it be controlled? That's more important," adds Kulkarni. "Our goal is to use theoretical work in order to make that important connection to the practical use, the ability to control energy absorption."

Solar power remains an expensive form of energy. Kulkarni and his team also hope to reduce material costs. "With quantum dots, solar panels would require much less silicon and other materials, because quantum dots are very small," he says.

"A quantum dot can be thought of as a cluster of molecules or atoms. Cluster size could run somewhere between 10nm to 100nm. One of the challenges is determining how to best distribute quantum dots of different sizes on the solar cell."

Even after success is achieved in the lab, Kulkarni predicts it will take about ten years for the method to become commercialized and profitable.

"Recently on a trip to southern India, it struck me—there is so much sun! The potential for solar power is very great in India. The need is great, as well," he notes. "There are random power outages every day for an hour or more in many parts of the country." Solar panels are mostly manufactured in Japan, Europe, and China. "Not yet in India, but that will come," he says.

"I'm really excited about this research—it has the potential to help society a great deal," he adds. "We have a global energy crisis, and we desperately need sources of renewable energy."