Researchers develop new technology for cheaper, more efficient solar cells

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The sun provides more than enough energy for all our needs, if only we could harness it cheaply and efficiently. Solar energy could provide a clean alternative to fossil fuels, but the high cost of solar cells has been a major barrier to their widespread use.

Stanford researchers have found that adding a single layer of organic molecules to a solar cell can increase its efficiency three-fold and could lead to cheaper, more efficient solar panels. Their results were published online in *ACS Nano* on Feb. 7.

Professor of chemical engineering Stacey Bent first became interested in a new kind of solar technology two years ago. These solar cells used tiny particles of semiconductors called "quantum dots." Quantum dot solar cells are cheaper to produce than traditional ones, as they can be made using simple chemical reactions. But despite their promise, they lagged well behind existing solar cells in efficiency.

"I wondered if we could use our knowledge of chemistry to improve their efficiency,"
Bent said. If she could do that, the reduced cost of these solar cells could lead to mass adoption of the technology.

Bent will discuss her research on Sunday, Feb. 20, at the annual meeting of the American Association for the Advancement of Science in Washington, D.C.

In principle, quantum dot cells can reach much higher efficiency, Bent said, because of a fundamental limitation of traditional solar cells.

Solar cells work by using energy from the sun to excite electrons. The excited electrons jump from a lower energy level to a higher one, leaving behind a "hole" where the electron used to be. Solar cells use a semiconductor to pull an electron in one direction, and another material to pull the hole in the other direction. This flow of electron and hole in different directions leads to an electric current.

But it takes a certain minimum energy to fully separate the electron and the hole. The amount of energy required is specific to different materials and affects what color, or wavelength, of light the material best absorbs. Silicon is commonly used to make solar cells because the energy required to excite its electrons corresponds closely to the wavelength of visible light.

But solar cells made of a single material have a maximum efficiency of about 31 percent, a limitation of the fixed energy level they can absorb.

Quantum dot solar cells do not share this limitation and can in theory be far more efficient. The energy levels of electrons in quantum dot semiconductors depends on their size – the smaller the quantum dot, the larger the energy needed to excite electrons to the next level.

So quantum dots can be tuned to absorb a certain wavelength of light just by changing their size. And they can be used to build more complex solar cells that have more than one size of quantum dot, allowing them to absorb multiple wavelengths of light.

Because of these advantages, Bent and her students have been investigating ways to improve the efficiency of quantum dot solar cells, along with associate Professor Michael McGehee of the department of

Materials Science and Engineering.

The researchers coated a titanium dioxide semiconductor in their quantum dot solar cell with a very thin single layer of organic molecules. These molecules were self-assembling, meaning that their interactions caused them to pack together in an ordered way. The quantum dots were present at the interface of this organic layer and the semiconductor. Bent's students tried several different organic molecules in an attempt to learn which ones would most increase the efficiency of the solar cells.

But she found that the exact molecule didn't matter – just having a single organic layer less than a nanometer thick was enough to triple the efficiency of the solar cells. "We were surprised, we thought it would be very sensitive to what we put down," said Bent.

But she said the result made sense in hindsight, and the researchers came up with a new model – it's the length of the molecule, and not its exact nature, that matters. Molecules that are too long don't allow the quantum dots to interact well with the semiconductor.

Bent's theory is that once the sun's energy creates an electron and a hole, the thin organic layer helps keep them apart, preventing them from recombining and being wasted. The group has yet to optimize the solar cells, and they have currently achieved an efficiency of, at most, 0.4 percent. But the group can tune several aspects of the cell, and once they do, the three-fold increase caused by the organic layer would be even more significant.

Bent said the cadmium sulfide quantum dots she is currently using are not ideal for solar cells, and the group will try different materials. She said she would also try other molecules for the organic layer, and could change the design of the solar cell to try to absorb more light and produce more electrical charge. Once Bent has found a way to increase the efficiency of quantum dot solar cells, she said she hopes their lower cost will lead to wider acceptance of solar energy.

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