A Polymer Solar Cell with Near-Perfect Internal Efficiency

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An international group of scientists has developed a polymer-based solar cell with an ability not yet seen in similar cells: almost every single photon it absorbs is converted into a pair of electric-charge carriers, and every one of those pairs is collected at the cell's electrodes.

The overall efficiency of the cell is six percent, meaning a total of six percent of the absorbed energy is converted into usable electricity when illuminated in the lab with similated solar light. This may seem low, but polymer solar cells to date have not yielded efficiencies better than five percent.

“These characteristics make our polymer solar cell the best of its kind produced so far,” said the study's corresponding scientist, Alan Heeger of the University of California at Santa Barbara and the Heeger Center for Advanced Materials at the Gwangju Institute of Science and Technology, in South Korea.

Heeger collaborated with colleagues from UC Santa Barbara, the Heeger Center, and the University of Laval in Quebec, Canada.

The group's work is a good sign that it is possible to produce polymer solar cells with efficiencies good enough for commercial production. As alternative-energy media, polymer solar cells are already promising because they would be much cheaper to produce and far more lightweight than conventional solar cells or cells made using other materials. They would also be highly portable and physically flexible,

making it possible to place them in locations that standard solar cells cannot go.

The solar cell is made of a “copolymer,” a polymer consisting of two different alternating polymer chains. Its role is to release electrons when hit by sunlight; the electrons are accepted by a fullerene derivative, a material based on a form of carbon that tends to form large spherical molecules known as fullerenes. When the two materials are combined into a composite “active layer,” regions form that separating the positive and negative charge - the positively charged “holes” left by electrons as they leave the copolymer and, of course, the electrons themselves. The regions are known as bulk heterojunctions, or BHJs.

Historically, increasing the photocurrent produced in BHJ solar cells has proven difficult. Simply increasing the thickness of the copolymer-fullerene layer so that it absorbs more light and thus releases more charge carriers doesn't work because charge carriers don't travel far within the material.

Heeger and his colleagues tried an approach that would retain a typical active layer thickness, about 80 nanometers, yet maximize the photocurrent. They added another layer to the cell, a sheet of titanium-oxide sandwiched between the copolymer and the top electrode, which has two roles. First, it redirects the intensity of the light such that it is maximized in the active layer. With higher intensity light reaching the active layer, the photocurrent increases. Second, it acts as a “hole blocker,” helping to keep the photo-generated electrons from recombining with holes.

The group discovered that at a copolymer-to-fullerene ratio of 1:4, the internal quantum efficiency, the number of electrons produced per absorbed photon, is remarkably high - close to 100 percent for light with a wavelength of 450 nanometers (violet-blue light) and above 90 percent

for all other wavelengths in the absorbed spectrum.

When illuminated by monochromatic green light, a wavelength of 532 nanometers, the group measured an overall efficiency - the efficiency that measures how much usable current is produced - of 17 percent. This is very high for a solar cell.

“Although, in practice, a solar cell would never be used under a light source that emitted only green light, this shows that it should be possible to achieve efficiencies of 10 to 15 percent in bulk heterojunction solar cells,” says Heeger.

More information: Sung Heum Park, Anshuman Roy, Serge Beaupre, Shinuk Cho, Nelson Coates, Ji Sun Moon, Daniel Moses, Mario Leclerc, Kwanghee Lee and Alan J. Heeger, *Nature Photonics*, advance online publication, DOI: 10.1038/nphoton.2009.69