WHAT'S HOT IN... PHYSICS, May/June 2010

The Future Shines for Efficient Polymer Solar Cells

by Simon Mitton

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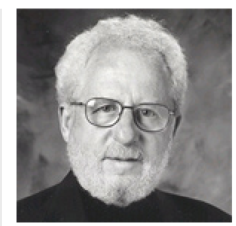
Polymer-based solar cells with a high quantum efficiency have entered the Physics Top Ten at #5. This is the first time a paper on plastic electronics has featured in these physics listings. The results reported in the paper are an important step forward in the development of solar cells with a power conversion rate that would allow a commercial return on the conversion of solar energy to electrical energy.

In 1976, Alan Heeger (University of California, Santa Barbara) and the late Alan MacDiarmid discovered conducting polymers and the techniques to dope those polymers over the full range from insulator to conductor. This opened up an exciting new field at the interface between chemistry and condensed-matter physics, most importantly the promise of a new generation of polymers with the electrical properties of metals and semiconductors as well as the processing advantages of plastics. That breakthrough won the polymer scientists a share of the 2000 Nobel Prize in Chemistry.

The field of plastic optoelectronics took off in 1990 when Richard Friend and his colleagues at the Cavendish Laboratory (Cambridge, U.K.) discovered how to make light-emitting diodes using polymers. In 2000, in his Nobel lecture, Heeger described this result as a major stimulus for the development of a wide variety of applications such as lasers, photodiodes, photovoltaic cells, and integrated circuits made of polymers alone. All these devices share a common architecture: they are thin-films in which the active layers are made from semiconductor or metallic polymers.



View interviews with Alan Heeger (top), and Richard Friend (bottom) from the Special Topic of Conducting Polymers.

In 1992, Heeger and his colleagues made the next step toward the solar cell described in #5 with their discovery of photoinduced electron transfer in composites of polymers (the donors) and C_{60} buckyballs (the acceptors). Years of research followed, while they investigated the fundamental physics of the transfer of photoelectrons. Which brings us to Hot Paper #5.

The paper explains that heterojunction solar cells are based on composites comprised of an electron-donating polymer and an electron-receiving fullerene. Such cells hold great promise for manufacture on an industrial scale because the materials are inexpensive, printable, portable, and flexible. Such characteristics hold the promise that polymer solar cells could become a consumer product (or gadget), following the trajectory of LEDs and solid-state lasers.

But there's a big problem to be solved before solar panels become a product in the home-improvement section of a supermarket: the conversion rate of solar photons to electrical energy is too low.

Newcomer #5 is receiving attention because it describes in some detail the device structure and energy level diagram of a heterojunction that has an internal quantum efficiency approaching 100%. That is to say, essentially every absorbed photon results in a separated pair of charge carriers (an electron and a hole). These released charge carriers are collected at electrodes.

What's new here is the device structure, which perhaps calls to mind a club sandwich. The top layer, the electrode, is an Al film. Sitting immediately below this is an optical spacer and hole blocker made from the sub-oxide TiO_x This layer is the key to understanding the efficiency of the device: it redistributes light inside the heterojunction by avoiding destructive interference from internal reflections. Under the TiO_x optical spacer there is the layer with C_{70} as the acceptor, and this in turn sits on the co-polymer that produces the carriers in response to photons. The outer layer is of course glass, to let the light in.

The conversion rate when illuminated with 532 nm monochromatic light is 17%, and a standard test using a solar simulator gave an overall efficiency of 6%. For *Science Watch*, Prof. Heeger comments on the high citation rate. "The paper provides a scientific basis for confidence that high efficiency will be achieved with the Bulk HeteroJunction (BHJ) solar cell technology. The demonstration of 17% power conversion efficiency for monochromatic light within the absorption band shows that high efficiency can be obtained."

Prof. Kwanghee Lee (Gwangju Institute of Science and Technology, South Korea) adds: "We have set a world record of 6.1% conversion efficiency for BHJ polymer solar cells. Our paper sets a new direction in the pursuit of higher power efficiencies. The results are path-breaking since they lay the foundation for further process related innovations."

Dr. Simon Mitton was awarded a Ph.D. in physics (1972) by the Cavendish Laboratory, University of Cambridge.

Related: View a Research Front Map titled: Thin-Film Organic Solar Cells; selected from the Emerging Research Fronts, April 2008.

Physics Top 10 Papers

Rank	Paper	Citations This Period (Nov-Dec 09)	Rank Last Period (Sep-Oct 09)
1	E. Komatsu, *et al.*, **"Five-year *Wilkinson Microwave Anisotropy Probe* observations: Cosmological interpretation,"** *Astrophys. J. Suppl. Ser.*, 180(2): 330-76, February 2009. [14 institutions worldwide] *406EI	132	1
2	J. Dunkley, *et al.*, **"Five-year *Wilkinson Microwave Anisotropy Probe* observations: Likelihoods and parameters from the *WMAP* data,"** *Astrophys. J. Suppl. Ser.*, 180(2): 306-29, February 2009. [14 U.S. and Canadian institutions] *406EI	55	2
3	J.K. Adelman-McCarthy, *et al.*, **"The Sixth Data Release of the Sloan Digital Sky Survey,"** *Astrophys. J. Suppl. Ser.*, 175(2): 297-313, April 2008. [84 institutions worldwide] *327WN	43	6
4	X.H. Chen, *et al.*, **"Superconductivity at 43K in $SmFeAsO_{1-x}F_x$,"** *Nature*, 453(7196): 761-2, 5 June 2008. [U. Sci. & Tech., Hefei, China] *308UK	37	4
5	S.H. Park, *et al.*, **"Bulk heterojunction solar cells with internal quantum efficiency approaching 100%,"** *Nature Photonics*, 3(5): 297-302, May 2009. [U. Calif., Santa Barbara; Gwangju Inst. Sci. & Tech., S. Korea; U. Laval, Quebec City, Canada] *447UY	36	†
6	M. Kowalski, *et al.*, **"Improved cosmological constraints from new, old, and combined supernova data sets,"** *Astrophys. J.*, 686 (2): 749-78, 20 October 2008. [41 institutions worldwide] *364YB	32	8
7	O. Adriani, *et al.*, **"An anomalous positron abundance in cosmic rays with energies 1.5-100 GeV,"** *Nature*, 458(7238): 607-9, 2 April 2009. [17 institutions worldwide] *427RK	28	3
8	F.-C. Hsu, *et al.*, **"Superconductivity in the PbO-type structure alpha-FeSe,"** *PNAS,* 105(38): 14262-4, 23 September 2008. [Acad. Sinica, Taipei, Taiwan; Natl. Tsing Hua U., Hsinchu, Taiwan; Duke U., Durham, NC] *353TY	25	10
9	W.B. Atwood, *et al.*, **"The Large Area Telescope on the *Fermi Gamma-Ray Space Telescope* mission,"** *Astrophys. J.*, 697(2): 1071-1102, 1 June 2009. [57 institutions worldwide] *446YT	25	†
10	Z.A. Ren, *et al.*, **"Superconductivity at 55 K in iron-based F-doped layered quaternary compound $Sm[O_{1-x}F_x]FeAs$,"** *Chinese Phys. Lett.*, 25(6): 2215-6, June 2008. [Chinese Acad. Sci, Beijing] *306MN	23	5

SOURCE: Thomson Reuters Hot Papers Database. Read the Legend

KEYWORDS: Solar cells, polymer solar cells, plastic electronics, Alan Heeger, solar photons, Kwanghee Lee, internal quantum efficiency.

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