WHAT'S HOT IN... CHEMISTRY , January/February 2009

A Neat Little Trick Doubles Plastic Solar-Cell Efficiency

by John Emsley

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Superconductors continue to head the top of the chemistry Hot Ten: witness papers #1 and #3, both of which were reported on in the previous issue, and #5, which is from the same stable. Also high in the list is paper #4, which is at the other end of electron mobility, i.e., semiconductors. The new entrant, however, paper #2—which is also about electricity—offers practical applications in the form of more efficient solar panels.

If in 50 years time the world wishes to enjoy the lifestyle we are used to, but without our dependence on fossil fuels, then it will have to find ways of harvesting energy from the sun. Turning its bounteous supply of photons into moving electrons will be a vital part of making the world independent of polluting forms of power. A major step in making this possible will be plastic solar cells, and making these more efficient is the essence of paper #2.

This comes from the Center for Polymers and Organic Solids at the University of California at Santa Barbara and reports the remarkable findings of a group led by Nobel Laureate Alan Heeger and Guillermo Bazan. They have discovered that adding 1,8-octanedithiol to the solution from which plastic solar cells are made almost doubles their power-conversion efficiency from 2.8% to 5.5%. (Other dithiols also increased the efficiency but not quite so markedly.) The method is operationally very simple, and once the film has formed then the additive disappears, and it seems that there is no need either to optimize materials or to change the way the cells

Chemistry Top Ten Papers

Rank	Papers	Cites Jul-Aug 08	Rank May-Jun 08
1	Y. Kamihara, *et al.*, "Iron-based layered superconductor La[$O_{1-x}F_x$]FeAs (x = 0.05-0.12) with T_c = 26 K," *J. Am. Chem. Soc.*, 130 (11): 3296-7, 19 March 2008. [Tokyo Inst. Technol., Yokohama, Japan] *273SL	62	2
2	J. Peet, *et al.*, "Efficiency enhancement in low-bandgap polymer solar cells by processing with alkane dithiols," *Nature Mater.*, 6(7): 497-500, July 2007. [U. Calif., Santa Barbara] *184NH	27	†
3	Y. Kamihara, *et al.*, "Iron-based layered superconductor: LaOFeP," *J. Am. Chem. Soc.*, 128(31): 10012-3, 9 August 2006. [Tokyo Inst. Technol., Yokohama, Japan] *069NI	26	†
4	X.L. Lie, *et al.*, "Chemically derived, ultrasmooth graphene nanoribbon semiconductors," *Science*, 319(5867): 1229-32, 29 February 2008. [Stanford U., CA] *267SX	21	†
5	T. Watanabe, *et al.*, "Nickel-based oxyphosphide superconductor with a layered crystal structure, LaNiOP," *Inorganic Chem.*, 46(19): 7719-21, 17 September 2007. [Tokyo Inst. Technol., Yokohama, Japan] *209EJ	20	†

are fabricated.

Polymer solar cells combine fullerenes with polymer semiconductors, the former releasing electrons and the latter providing the "holes." The electrons and holes then migrate to their respective electrodes and produce the current. Of course electrons and holes near the interface simply move towards each other and combine to no net effect, but this is inherent in the morphology that results from the spin-casting method of manufacture.

Improving this morphology has been achieved by Heeger and Bazan, and the method requires only small concentrations of 1,8-octanedithiol to be added to the solutions from which the heterojunctions films are cast. These were fabricated from the photo-donor organic polymer poly(3-hexylthiophene) (a.k.a. P3HT) with the acceptor being the fullerene derivative [6,6]-phenylC_{61}- butyric acid methyl ester (C_{61}-PCBM). The drawback from solar cells produced from these components is that they do not respond to thermal annealing or to slow solvent evaporation after the film has been cast.

The answer which Heeger and Bazan provide is both a simple and versatile method for tailoring the heterojunction morphology in systems where thermal annealing is not effective. They also point out that their approach even works on a system in which polymer crystallinity is not observed.

6	M. Dinca, *et al.*, "Hydrogen storage in a microporous metal-organic framework with exposed Mn^{2+} coordination sites," *J. Am. Chem. Soc.*, 128 (51): 16876-83, 27 December 2007. [6 U.S. institutions] *118KQ	17	6
7	D. Enders, *et al.*, "Organocatalytic one-pot asymmetric synthesis of functionalized tricyclic carbon frameworks from a triple-cascade/Diels-Alder sequence," *Angew. Chem. Int. Ed.*, 46(3): 467-9, 2007. [RWTH Aachen, Germany] *125PJ	17	†
8	Y. Hayashi, *et al.*, "Diphenylprolinol silyl ether as a catalyst in an enantioselective, catalytic, tandem Michael/Henry reaction for the control of four stereocenters," *Angew. Chem. Int. Ed.*, 46(26): 4922-5, 2007. [Tokyo U. Sci., Japan] *186IV	17	†
9	J.E. Green, *et al.*, "A 160-kilobit molecular electronic memory patterned at 1011bits per square centimetre," *Nature*, 445 (7126): 414-7, 25 January 2007. [Caltech, Pasadena; U. Calif., Los Angeles; Ohio St. U., Columbus] *128WD	15	5
10	C. Soci, *et al.*, "ZnO nanowire UV photodetectors with high internal gain," *Nano Lett.*, 7(4): 1003-9, April 2007. [U. Calif., San Diego] *155TG	15	†

SOURCE: Thomson Reuter's Hot Papers Database. Read the Legend.

The addition of a mere 24 mg per liter of 1,8-octanedithiol to the chlorobenzene solution from which the films were cast had a remarkable effect. Moreover, after these had been dried in vacuum they were examined by FTIR and Raman spectroscopy, and these showed no thiol residues to be present. More than 250 samples of the plastic solar films were made and more than 1,000 devices were constructed for testing. The most efficient of these had a polymer/fullerene ratio of between 1:2 and 1:3 and attained a power-conversion efficiency of 5.5% under illumination of 100 $mWcm^{-2}$ generating a current of 16.2 $mAcm^{-2}$ and a voltage of 0.62V.

Currently Bazan is researching how the different environments brought about by the additive influence the way the internal components of the photovoltaic film assemble.

As he tells *Science Watch*: "We have found that the nano-scale arrangement of the molecular components is critical for effective charge generation and collection. However, very little known is known about what the optimal spatial organization of the components is, and even if we knew that, we still don't know how to get there!"

Nevertheless, paper #2 predicts that significant improvements are likely to be forthcoming and to lead to even more efficient solar-energy conversion.

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Keywords: solar cells, polymer solar cells, plastic solar cells, Alan Heeger, Guillermo Bazan, solar panels.

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