SPIE Newsroom

10.1117/2.1200811.1321

Printing efficient solar cells

Ritesh Tipnis and Darin Laird

Novel photovoltaic inks and materials may enable wide-scale use of renewable solar energy.

As worldwide demand for fossil fuels depletes reserves, scientists are increasingly focused on generating alternative energy—especially if it can be produced cleanly and inexpensively. Hydroelectric, solar, wind, nuclear, and biomass technologies are replacing coal, oil, and natural gas. Many of these new technologies have similar costs. Yet the availability of materials or existing infrastructure can affect how widely they are adopted. With about 125,000TW of solar power hitting the planet, photovoltaic (PV) technologies could satisfy a significant portion of the world's energy demand. In addition, PV cells are economical, renewable, and well suited for large-scale deployment.

First-generation solar panels use silicon technology. Unfortunately, their manufacturing expense prevents them from being cost competitive. Second-generation PV devices, like those using thin films of amorphous silicon, cadmium telluride, or copper-indium-gallium diselenide, are cheaper than silicon. However, they have not been adopted widely because the device materials elicit environmental and manufacturing concerns. Another option, third-generation organic-photovoltaic (OPV) cells based on inherently conductive polymers, may lead to much cheaper solar power. The polymers can be printed just like any other commercially available ink and applied to a substrate using conventional, high-volume, low-cost printing. In addition, the raw materials are ubiquitous and their use has no real impact on the environment.

To further this technology's reach, we have developed an organic photovoltaic-ink system. It may address several issues faced by traditional PV technologies, enabling increased use of printed solar power. Our ink systems are already available for research-scale printed solar-cell development.

Figure 1 shows the architecture of a typical p–n-junction OPV-device stack. The anode, a transparent electrode such as indium-tin oxide (ITO) coated onto plastic or glass, is usually covered with up to 100nm of hole-transport-layer (HTL) ink. The HTL planarizes the ITO surface and facilitates collection of positive-charge carriers (holes) from the light-harvesting layer. The photoactive layer consists of a p-type semiconducting polymer and an n-type material, blended together in a solvent. The cathode is typically made of metals such as calcium or aluminum.

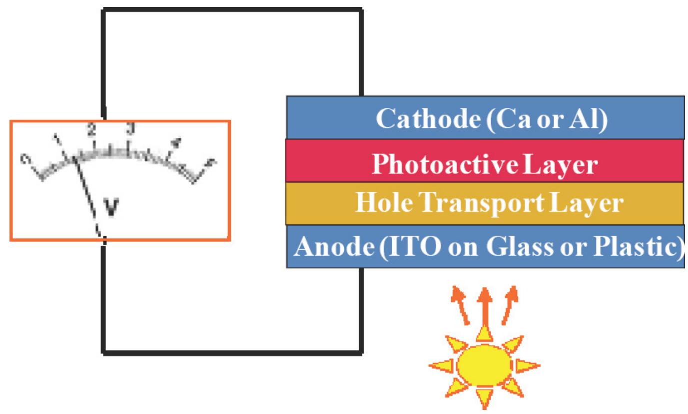

Figure 1. *An organic-photovoltaic (OPV)-device stack. The hole-transport and photoactive layers form the photovoltaic-ink system. ITO: indium-tin oxide, Ca: calcium, Al: aluminum.*

OPV performance depends on a novel family of regioregular poly-3-hexylthiophene (P3HT), part of our active-layer technology. The photoactive ink consists of a blend of P3HT and [6,6]phenyl-C_{61} butyric-acid methyl ester (PCBM). Some of the best-performing organic solar cells are based on the P3HT:PCBM system.[1–4] Combined with a matching hole-transport ink, this type of system typically yields efficiencies of between 3 and 4% in laboratory OPV cells.

We have developed novel p- and n-type materials with electrooptical (highest-occupied molecular-orbital level, band gap, charge mobility) and morphological properties that produce even higher-performing OPV devices. This technology has yielded record-setting efficiencies of 5.98% in laboratory-scale cells and 1.56% in large-area modules (see Figures 2 and 3). We continue to increase device efficiency and lifetime metrics by refining materials synthesis, ink formulation, and device design and fabrication.

As part of the Department of Energy's Solar America Initiative program we are working to improve both ink and process technology. We expect these changes to accelerate the global com-

Continued on next page

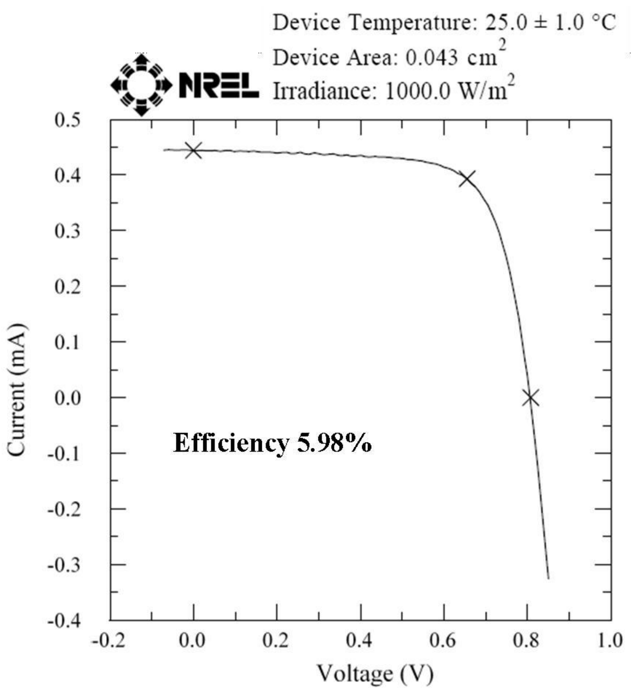

Figure 2. *National Renewable Energy Laboratory (NREL)-certified OPV efficiency for a 50×50mm^2 laboratory cell.*

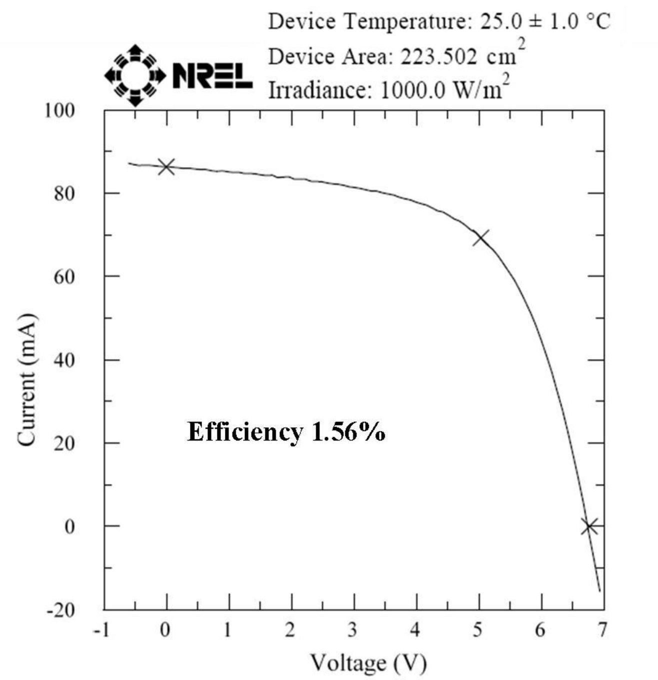

Figure 3. *NREL-certified OPV efficiency for a 15.2×15.2cm^2 module.*

mercialization of PV cells.

This technology may support the nation's need for clean, renewable energy sources by enabling the production of low-cost OPV devices. We have already launched OPV-ink products to support this emerging market. Ongoing work is aimed at improving device efficiency and lifetime.

Plextronics would like to thank Keith Emory's PV performance characterization team at the National Renewable Energy Laboratory for the cell and module measurements shown in Figures 2 and 3.

Author Information

Ritesh Tipnis and Darin Laird
Plextronics Inc.
Pittsburgh, PA

Ritesh Tipnis is technical-marketing manager and therefore responsible for all of the company's writing. He manages several projects, including government accounts. He earned his PhD in polymer science from the University of Connecticut in 2006.

Darin Laird is the director of technology for the power and circuitry teams. He is also one of the company's founders. Prior to joining Plextronics, he was a postdoctoral fellow in Richard D. McCullough's research group at Carnegie Mellon University. He received his PhD in chemistry from the University of Texas at Austin in 2001.

References

1. M. Reyes-Reyes, K. Kim, and D. Carroll, *High-efficiency photovoltaic devices based on annealed poly(3-hexylthiophene) and 1-(3-methoxycarbonyl)-propyl-1-phenyl-(6,6)C_{61} blends*, **Appl. Phys. Lett. 87**, pp. 083506–083508, 2005. doi:10.1063/1.2006986
2. G. Li, V. Shrotriya, J. Huang, Y. Yao, T. Moriarty, K. Emery, and Y. Yang, *High efficiency solution processable polymer photovoltaic cells by self-organization of polymer blends*, **Nat. Mater. 4**, pp. 864–868, 2005. doi:10.1038/nmat1500
3. W. Ma, C. Yang, X. Gong, K. Lee, and A. Heeger, *Thermally stable, efficient polymer solar cells with nanoscale control of the interpenetrating network morphology*, **Adv. Funct. Mater. 15**, pp. 1617–1622, 2005. doi:10.1002/adfm.200500211
4. L. Kazmerski, *Solar photovoltaics R&D at the tipping point: A 2005 technology overview*, **J. Electron. Spectrosc.**, pp. 105–135, 2006. doi:10.1016/j.elspec.2005.09.004