U.S. DEPARTMENT OF ENERGY   Office of Science

Novel Synthesis and Processing Methods
Enable Flexible, Transparent and Cheaper Solar Cells
University of Illinois-Urbana Champaign Team's Research Funded by Office of Basic Energy Sciences in U.S. Department of Energy's Office of Science

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Mention "solar cells," and it conjures up the image of large, bulky modules on a roof top. The relatively low efficiencies of solar cells coupled with their high-cost have largely been responsible for their very limited use in power generation.

Now imagine solar cells made of silicon that use one-tenth the amount of material but with the potential to produce comparable amount of power as conventional modules, and also are thin, semitransparent, lightweight, and flexible. These capabilities will not only make solar power more cost effective but will also expand its use in applications not hitherto possible – in, for example, fabrics, windows of buildings, and sunroofs of automobiles.

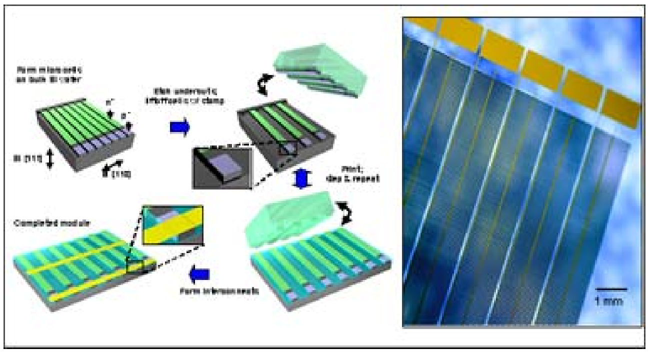
This is precisely what an interdisciplinary team of researchers from the Frederick Seitz Materials Research Laboratory at the University of Illinois-Urbana Champaign has accomplished. Semiconductor materials that are normally brittle are rendered flexible and rugged by their approach. The team's work, supported by the Office of Basic Energy Sciences in the U.S. Department of Energy's Office of Science, establishes new design rules and fundamentally new approaches for photovoltaic devices that will open up unprecedented applications.

"This research illustrates how advances in synthesizing materials in new forms can open up entirely new opportunities in harnessing solar energy," said Dr. Harriet Kung, Associate Director of the Office of Science for Basic Energy Sciences.

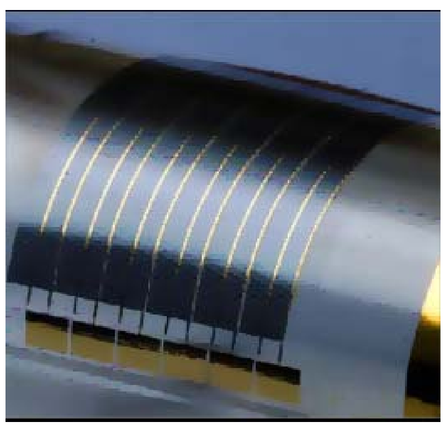
The research team reports their findings in the October 5 issue of Nature Materials (Advance Online Publication, doi:10.1038/nmat2287). Their strategy involves two parts: (i) the synthesis of large-scale collections of solar cells that are much thinner (down to ~100 nanometers) and smaller (down to a few micrometers or microns) than those possible with conventional technologies and (ii) the integration of these microcells in modules with unusual designs. Even more importantly, this work also suggests that purity requirements of silicon, an abundant semiconductor material with high public acceptance, are not as stringent as in conventional cells.

"This research demonstrates new ways to use silicon in photovoltaics," said Professor John A. Rogers, who led this multi-investigator effort. "These methods enable solar cell modules with unprecedented capabilities – flexibility, bendability, lightweight, and partial transparency – that are just inconceivable with monocrystalline silicon implemented in the usual manner."

In the first step of the approach, individual micro scale cells are generated by etching a silicon wafer. A rubber stamp then places, in a solid printing-like process, large-area arrays of these individual cells into desired configurations, for integration into working modules. The resulting systems are capable of being produced on a large scale and offer high efficiency solar energy conversion using less than one-tenth of the amount of silicon typically needed in current-generation solar panels. Even with simple designs, efficiencies of ~12% are achieved at thicknesses of 15 microns, more than ten times thinner than wafers used in conventional photovoltaic devices.



Furthermore, these concepts offer many design opportunities that lie beyond the current capabilities of established mono-crystalline silicon technologies. For example, the use of thin, lightweight plastic substrates provides modules that can be rolled-up for easy transport or storage, and then unfurled onto flat or curved surfaces for installation. Demonstration devices show bendability to an extent that allows the modules to be wrapped around a pencil.



Controlling the spacing of the microcells enables 'see-through' designs with user-definable levels of transparency, for use as energy-producing window tinting in automobiles or buildings. Transmission anywhere between 10% and 90% across the entire visible range is possible. Finally, by adding molded micro-lens arrays to these systems, light is tightly focused onto the microcells to further improve their energy efficiency.

Fundamental theoretical and experimental studies of the electrical, mechanical and optical characteristics of several types of modules that incorporate cells of this type illuminate the basic materials science aspects. Current experimental investigations focus on exploring theoretical predictions of the ability to use low purity silicon in these ultrathin cells without reducing their performance. Engineering implementation of low cost printing, doping and etching techniques for producing similar types of modules on a massive scale is being explored by a start-up company that has licensed the intellectual property associated with the basic science.