IN FOCUS

Directed Self-Assembly of Materials Workshop
September 28, 2011 - October 1, 2011
Nashville, Tennessee
Location: Opryland Hotel

Preregistration is now open!

This workshop will review the current state-of-the-art in the directed self assembly of materials, and then seek to identify breakthrough strategies and enabling technologies (both theoretical and experimental) that will facilitate the design and massive self assembly of multi-component 3D structures with precisely engineered electronic and optical properties.

Aldrich® Materials Science/Materials Research Society Mid-Career Award Nominations are Open through October 1, 2011

The Materials Research Society, with a generous, permanent endowment from Aldrich® Materials Science, a strategic growth initiative of Sigma-Aldrich (NASDAQ:SIAL), has recently established a Mid-Career Award that will honor individuals who have made outstanding mid-career advances in the scientific materials industry.

Nominations for the inaugural award are open through October 1, 2011, with the inaugural presentation to take place at the 2012 MRS Spring Meeting and Exhibit in San Francisco, April 9-13. Open to researchers, scientists and engineers in all areas of
materials research between the ages of 40 and 52 at the time of nomination, the award is fully funded by Aldrich® Materials Science and managed by the Materials Research Society. In addition to the prestige of being recognized by their peers within the materials research community, the winner will receive a $5,000 cash award.

More information on the award, eligibility and the nomination process will be available soon. Look for details in future issues of *MRS Bulletin* and *Materials 360*, or on the MRS Web site at [www.mrs.org/awards](http://www.mrs.org/awards).

### NEWS FROM THE WORLD OF MATERIALS

Keep up with materials research news through MRS!

[Materials News Web Page](http://www.mrs.org/news) | [RSS feed](http://www.mrs.org/news/rss) | [Twitter feed](http://twitter.com/MRS_Programs)

#### Materials in Focus

**Researchers control chemical functionalization along carbon nanotubes**

(University of Maryland. See also the press release by Rebecca E. Copeland, UMD Newsdesk. Image credit: Nature Communications.) Click image to enlarge.

Image caption: The Billups-Birch alkylcarboxylation reaction allows functional groups to propagate down the carbon nanotube from points of pre-existing defects.

Attempts to add functional groups to single-walled carbon nanotubes (SWCNTs) to improve, for example, their solubility, have generally also led to the loss of the optical and electronic properties that make SWCNTs desirable materials. This was largely due to the positional randomness of the functional groups along the nanotube and their uncontrolled growth. But now scientists led by YuHuang Wang of the University of Maryland have developed a more fundamental understanding of the process that could lead to functionalization with retention of the optical and electronic properties of SWCNTs.

As reported in *Nature Communications*, Wang and coworkers used a reductive alkylation reaction with a variety of organic functional groups to show that functionalization can occur by activation of sp\(^3 \) defect sites, followed by propagation in the tubular direction exclusively from these defect sites. Furthermore, the rate of propagation is constant (at 18±6 nm per reaction cycle under the reported conditions), which allows the researchers to control the spatial pattern of functional groups on the nanometer scale. “This is a fundamental discovery about how chemistry occurs on a graphene lattice,” Wang says. “The most surprising result is that this chemistry occurs starting from an initial defect and grows by propagation, much like crystal growth after the initial nucleation, which confines the chemistry to the vicinity of the initial defect.”

The resulting functionalized SWCNTs are highly soluble in water and can largely retain the optical absorption and fluorescence properties of the initial SWCNTs, the researchers report. Wang is confident that the degree of retention can be further improved upon by developing the ability to choose precisely the location of activated sp\(^3 \) defects. “This is the first wet chemistry that demonstrates control of the covalent addition of functional groups on a graphene lattice,” Wang says. “It’s a new concept that provides a powerful tool to chemically tailor carbon materials for many intended applications.” [Nature Communications](http://www.nature.com/articles/ncomms12728)

**Nano Focus**
**Watching a dynamic, real-time phase transition**

(Lawrence Berkeley National Laboratory. See also the feature story by Lynn Yarris, Berkeley Lab News Center. Image credit: Alivisatos/Zheng.) Click image to enlarge.

Image caption: Micrographs showing the low-chalco-cite (left) and high-chalco-cite atomic structures of a copper sulfide nanorod.

By taking advantage of the advances in TEM technology that allow rapid imaging with single-atom selectivity and greater electron collection efficiency, researchers at the Lawrence Berkeley National Laboratory (LBNL), the University of California-Berkeley, and Stanford University have observed a real-time, dynamic phase transition in a Cu$_2$S single nanocrystal. While previously researchers could observe phase transitions in an ensemble of nanocrystals and extract average properties, this work demonstrates the ability to directly observe the structural fluctuations a crystal undergoes during a phase transition.

As reported recently in Science, LBNL lab director Paul Alivisatos and his team used the heat generated by the TEM’s electron beam to help enable the phase transformation, which occurs near room temperature, from the low-chalco-cite phase to the high-chalco-cite phase of Cu$_2$S. The hexagonal sulfur lattice frame is unchanged during this transition, but copper atoms change positions. They used high resolution TEM and digital masks in Fourier space to filter the image and distinguish between the two phases in a single nanorod of Cu$_2$S. A movie of the trajectory of the structural transformation shows high-chalco-cite forming on the outer surface of the nanorod and then propagating inward concentrically until the whole nanorod is transformed to high-chalco-cite. Soon low-chalco-cite begins to nucleate at the center of the nanorod and propagates along its x axis. After a period of fluctuations, the nanorod ultimately stabilizes into a high-chalco-cite phase. The researchers concluded in their paper that this work provides “crucial insight for the understanding of microscopic pathways of phase transitions.” [Science]

**Bio Focus**

**Single cell “biopsies” made possible by fractal dimensionality of cancer cells**

(Clarkson University, Potsdam, New York. Image credit: Igor Sokolov.) Click image to enlarge.

Image caption: A collage demonstrating examples of (Mandelbrot Set) fractals in cells (top left) and a scanning electron microscopy (SEM) image of a cervical epithelial cell (top right); atomic force microscopy (AFM) images of cell surfaces are shown at the bottom.

Researchers at Clarkson University in Potsdam, New York, have developed an atomic force microscopy (AFM) based method of detecting cancer cells on the single cell level, which may make it possible to pre-screen some forms of cancer without doing tissue biopsies. Biopsies involve removing a sample of tissue containing many cells from the suspect area for analysis. Now, as reported in Physical Review Letters, Igor Sokolov and his group, including M.E. Dokukin, N.V. Guz, R.M. Gaikwad, and C.D. Woodworth, have used the fractal nature of cancer cells to separate cancerous cervical cells from healthy ones using the degree of adhesion of the AFM tip to the cell as the metric. “Doctors do not have problems separating normal cells from those that look like cancer, but unfortunately those cells that look like cancer can be caused by irritation, inflammation, infection, and so on,” Sokolov says. "Our method clearly distinguishes between normal cells in enhanced growth conditions (which occur during irritation or inflammation) and cancer cells. Most of the normal cells we studied looked cancerous using optical microscopy.”

Traditionally, biochemical labeling of cells and examination by optical microscopy have been used for cancer diagnoses. Because of intrinsic constant mutations of cancerous cells,
biochemical labeling cannot identify all cancer cells, Sokolov says. His AFM-based method uses the physical parameter of adhesion to the AFM tip to replace chemical parameters, with what seems to be more reliable results. Because the contact area between an AFM tip and a cell is extremely small just before they pull apart, the technique has high spatial resolution.

The emergence of fractal behavior when a cell becomes cancerous has been expected but not shown before, Sokolov says, noting that a fractal is an object that repeats its pattern when you zoom in or out. The researchers found that cancer cells can indeed be described as fractal, whereas normal cells can only be approximately described as fractal on a small scale; the “fractal dimensionality” (FD) differs substantially between normal cells and cancerous cells. The FD used by the researchers is a value between 2.0 and 3.0 that approximately correlates to the roughness of a cell’s surface. “Say you have a perfectly smooth 2D surface fractal, then its FD is 2.0,” Sokolov explains. “Now if you have an extremely rough surface fractal that almost covers the 3D space, the FD would be 3.0.”

In this study of more than 300 cervical cells taken from six patients with cancer and six healthy patients, the cancerous cells had FD values that clustered around 2.5, while the healthy cells clustered around 2.1. What’s more, Sokolov says, is that there was not one case of overlap between the FDs of cancerous and healthy cells in the entire sample of more than 300 cells. “We found that even on the single cell level, physical characterization of the surface of the cell gives better results than the existing biochemical methods,” Sokolov concludes. “That’s why we think and hope that our results might lead to highly accurate cancer prescreening methods.” [Physical Review Letters]

**Energy Focus**

Flexible, paper-based photovoltaics can deliver high watts per kilogram (Massachusetts Institute of Technology. See also the press release by David L. Chandler, MIT News Office. Photo credit: Patrick Gillooly.) Click image to enlarge.

Photo caption: Graduate student Miles Barr holds a flexible and foldable array of solar cells that have been printed on a sheet of paper.

Vladimir Bulović and his colleagues at MIT are trying to move away from the paradigm of large, heavy, rigid solar cells that must cover large areas of land to generate enough electricity to be of value. “What if we could make solar cells flap in the wind?” he asks. “What if we could make them the way trees are made? Trees do not have rigid leaves, they have leaves that are connected by stems, that are able to withstand the wind by simply twisting the leaf in the stem. Well, what if we could make a paper-like solar cell that is able to conform to the environment and hence, in the long run, reduce the deployment costs?”

Bulović answers his own questions in a recent paper in Advanced Materials, which describes his team’s successful efforts to create working, organic photovoltaic circuits on ordinary, untreated paper. Using a chemical process developed and implemented by his colleague Prof. Karen Gleason, also of MIT, they deposited the conductive polymer poly(3,4-ethylenedioxythiphene) on uncoated paper substrates using the dry technique of oxidative chemical vapor deposition (oCVD) combined with in situ shadow masking. They succeeded with uncoated paper where others have failed by ensuring that their polymer actually formed a chemical bond with the paper. “Other techniques typically do not have a thin film that is strongly covalently bonded to the substrate,” he says. “A film that just sits on top of the paper flakes off when you twist and bend the substrate. This is not the case with our thin film electrodes, which after hundreds of bending cycles still strongly adhere to the paper, showing the same electrical characteristics.”
In a video available on YouTube, they demonstrate the flexibility of a paper-based solar cell by folding it into a paper airplane and measuring its current output under illumination. Similarly, the paper solar cell has survived 1,000 compressive folding cycles with little loss in performance. The researchers can even coat the paper cell with a moisture barrier and show that it works under water, or feed it through the heating cycle of a laser printer without damaging the solar cell.

Bulović believes that presently the most pertinent use for this type of solar cell would be in developing countries, where cell phones and other devices are catching on by the millions, but where some people may have to walk miles to another village to recharge their phones. Solar recharging stations could possibly be established more locally due to the ruggedness of this technology. Paper solar cells could survive the journey over bumpy, unpaved roads that would destroy glass-based solar cells.

And while their paper solar cells currently have a relatively low efficiency, Bulović believes that perhaps a new figure of merit might be useful: the number of watts produced per kilogram of solar cell, or even watts per kilogram per dollar. Adding in the cost factor, he says, “It appears that if you’re expecting a useful lifetime of a few years for your device, and if you require a power source that doesn’t weigh very much and can easily deliver a large number of watts per kilogram, our cells might be able to meet that need quite elegantly.”

**Image in Focus**

**Cubist Microflower**

A scanning electron micrograph of a copper oxide microflower which was electrochemically deposited on a titanium dioxide layer. The length of the central petal in the flower is about 12 µm. (Click image to enlarge.)

*Credit: Talia Gershon, University of Cambridge*

(One of three Science as Art competition second place winners at the 2011 MRS Spring Meeting)

*[We invite you to submit your images to the Editor for possible inclusion in this feature]*