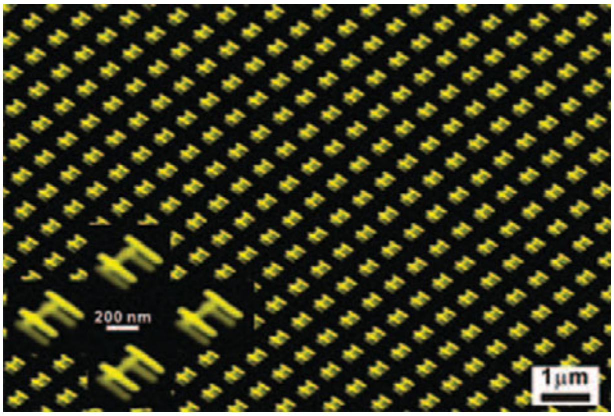


Scanning electron micrograph of a three-dimensional plasmon ruler fabricated from gold nanorods by electron beam lithography.

rod structure also enabled the research team to distinguish the direction as well as the magnitude of structural changes.

"As a proof of concept, we fabricated a series of samples using high-precision electron-beam lithography and layer-by-layer stacking nanotechniques, then embedded them with our 3D plasmon rulers in a dielectric medium on a glass substrate," Liu said. "Experimental results were in excellent agreement with the calculated spectra."

The researchers envision a future in which 3D plasmon rulers would, through biochemical linkers, be attached at different positions to a sample macromolecule, such as a strand of DNA or RNA, or a protein or peptide. The sample macromolecule would then be exposed to light and the optical responses of the 3D plasmon rulers would be measured through dark-field microspectroscopy.

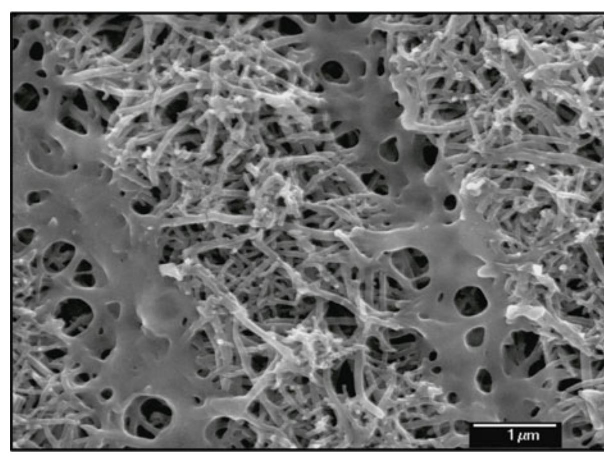
"The realization of 3D plasmon rulers using nanoparticles and biochemical linkers is challenging, but 3D nanoparticle assemblies with the requisite symmetries and configurations have already been demonstrated," Liu said. "We believe that these exciting experimental achievements and the introduction of our new concept will pave the road toward the realization of 3D plasmon rulers in biological and other soft-matter systems."

Nano Focus

IR lasers enable direct patterning on conjugated polymers

A versatile and simple new technique for patterning submicrometer features in a conjugated polymer using an infrared laser is described in the August 10 issue of *Nano Letters* (DOI: 10.1021/nl2011593; p. 3128). While the potential for low-cost processing is a key advantage of using organic semiconductor materials in the place of conventional silicon electronics, many patterning techniques used at present such as contact printing and dip-pen lithography are either time-consuming or expensive. In their recent article, R. Kaner from the University of California–Los Angeles, G. Wallace of the University of Wollongong, Australia, and co-workers demonstrate how a laser in a commercial disk drive can be used to write features with tunable conductivity onto polyaniline-coated discs.

The team made use of a commercially available program normally used to create images on a compact disc, by activating a dye coating with a 788 nm laser. By replacing this coating with the well-known conductive polymer polyaniline, features could instead be written into the polymer by thermally inducing cross-linking at the irradiated regions. The high photothermal conversion efficiency and poor thermal conductivity of polyaniline allows the laser to induce highly localized melting of the polymer fibers into visibly welded regions as thin as 1 μm. Chemical cross-linking between neighboring fibers is proposed to occur through the formation of heterocycles containing two nitrogen atoms from adjacent chains, and the accompanying rearrangement of carbon double bonds can be clearly observed by the change in infrared spectra.



A scanning electron micrograph of a polyaniline film with lines of cross-linked polymer formed by an infrared laser. Reproduced with permission from *Nano Lett.* (DOI: 10.1021/nl2011593; p. 3128). © 2011 American Chemical Society.

The program's facility for creating grayscale images by varying the intensity of the laser could also be neatly translated into controlling the conductivity of the polyaniline features. At maximum laser intensity, the irradiated regions were rendered electrically insulating by the cross-linking, but as the intensity was lowered, a range of intermediate resistances from insulating to metallic could be achieved. Corresponding changes in the emission spectrum and reflectivity of the polymer film also allowed the team to create high-resolution color images, which could be varied in a myriad of ways by altering the polymer's oxidation state or through the addition of chemical substituents.

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The ability to produce thin, uniform dielectric regions within a conductive polymer film makes this maskless lithographic technique a particularly attractive route to flexible batteries, supercapacitors, or interdigitated electrodes. As a one-step process performed entirely in the solid state, it serves as a promising demonstration of the potentially low-cost large-scale methods available to organic electronics, said the researchers.

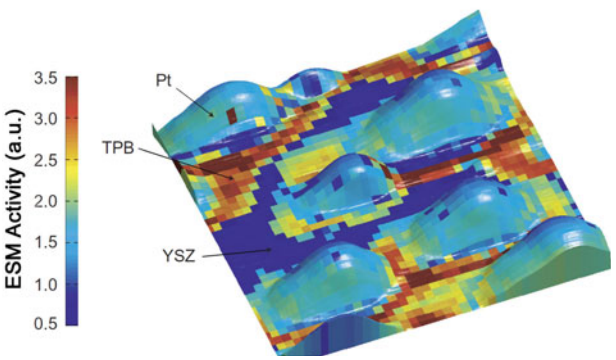
Tobias Lockwood

Energy Focus

SPM reveals nanoscale understanding of oxygen reactions in fuel cells and batteries

Researchers are currently exploring the use of atmospheric oxygen as an oxidizer in fuel cells and lithium-air batteries to improve energy-storage densities. However, its implementation is currently limited by a poor understanding of surface reaction kinetics. In the September issue of *Nature Chemistry* (DOI: 10.1038/NCHEM.1112; p. 707), a research team reports on the use of a novel scanning probe electrochemical strain mapping (ESM) technique that makes it possible to study volumes of material 10^6–10^8 times smaller than current microcontact methods.

As described by the research team—A. Kumar of Oak Ridge National Laboratory, F. Ciucci of Ruprecht-Karls-University in Heidelberg, A.N. Morozovska of the National Academy of Science of Ukraine, and their colleagues—a scanning probe tip is first brought into contact with a surface, and an electric-field bias is then applied across the tip-surface junction. When a strong enough field is applied, the oxygen atoms react through the generation and annihilation of vacancies. This results in a local structural distortion that can be measured down to 2–5 pm resolution. Additional sensitivity is attained by slowly varying field pulses and using differential detection to remove topographic cross-talk and tip-induced mechanical effects on the substrate.



Map of electrochemical activity is overlaid onto the topography of Pt catalyst dots deposited on a YSZ surface. TPB indicates a triple-phase boundary where the catalyst electrode is in contact with both the reactants and electrolyte. Reproduced with permission from *Nature Chem.* (DOI: 10.1038/NCHEM.1112; p. 707). © 2011 Macmillan Publishers Ltd.

The researchers have demonstrated several applications of this technique, including measurements of oxygen vacancy kinetics and spatially resolved mapping of local electrochemical activity in yttria-stabilized zirconia (YSZ). They also show that it is possible to study more complicated systems, such as a YSZ substrate coated with an array of Pt catalyst dots. As shown in the figure, the researchers are able to map the surface of the material and measure an enhanced ESM response near the edges of the dots.

The research team predicts that this technique can be applied to studies of many other air-based fuel-cell systems and metal-air batteries. The high resolution and sensitivity of the technique will make it possible to bridge models across different length scales and optimize the design of energy-storage systems.

Steven Spurgeon

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