RESEARCH/RESEARCHERS

Low Voltage Achieves Large Strain in Electroreactive Polymer

Soft polymeric materials that can convert electrical energy into mechanical energy have become an intensive area of study recently, owing to their potential to mimic biological responses. Mohsen Shahinpoor of the Artificial Muscle Research Institute (AMRI) at the University of New Mexico and Kwang Kim from the Active Materials and Processing Laboratory (AMPL) of the University of Nevada have combined lithium-doped poly(ethylene oxide) (PEO) with the plasticizer poly(ethylene glycol) (PEG) to fabricate 320-μm-thick actuators exhibiting large strain (>1% bending strain) at a relatively low applied electric field (<10 V/mm). Actuator motion in these materials arises from the cation attraction to the anode relative to the polymer host, which creates a pressure gradient leading to deformation. This deformation is reversible with the direction of the electric field and also displays stable operation after more than 10 million cycles in air.

As reported in the May 6 issue of *Applied Physics Letters*, the actuation of ionic conductive polymers such as PEO is increased by the use of the plasticizer PEG, which decreases the crystallinity of the medium, leading to increased ion mobility. Load and force measurements indicate that the polymer solid-state actuator produces a useful force density of up to 20 *g*-force/g of PEO-PEG polymer in a cantilevered configuration, under an applied voltage of 1–3 V, while maintaining a constant frequency of 0.5 Hz. Furthermore, the researchers report that strain power-density variations for the PEO-PEG solid-state actuators indicate that the current 2% strain values can lead to power densities of over 50 J/kg, while further improvement of these actuators to enable them to generate 4% strain would lead to power densities of 200 J/kg, comparable to biological muscles.

KYLE BRINKMAN

3D Imaging of Materials Achieved with Differential-Aperture X-Ray Microscopy

X-ray diffraction provides two-dimensional (2D) information on the structure, orientation, and distortion of a crystal. However, information along the path of the incident beam is hidden within the superposition of patterns and cannot be discerned. A group of researchers from Oak Ridge National Laboratory have obtained depth-resolved three-dimensional (3D) images of crystals using a technique they call differential-aperture x-ray microscopy (DAXM).

As reported in the February 21 issue of *Nature*, B.C. Larson and colleagues incorporated an x-ray-absorbing wire as a knife-edge depth profiler. The wire is moved stepwise across the diffraction patterns, selectively blocking out diffracted x-rays from reaching the charge-coupled-device (CCD) detector. Through computer reconstruction, knowledge of the position of the wire can be used in conjunction with the intensity for each pixel located by the CCD detector to obtain the Laue diffraction pattern for that position of the wire. Depth resolution of the order of a tenth of a micrometer is possible, depending on the position of the x-ray-absorbing wire relative to the sample and detector.

This technique allows for a point-by-point detailed determination of structure and 3D mapping. It can be used for extracting detailed information including microstructure and strain from a small, localized volume of a crystal. Particularly on the mesoscopic length scale, it allows for experimental determination of microstructural evolution that was previously only amenable to multiscale modeling and numerical simulations. The researchers provided examples of studies on grain structure in polycrystalline aluminum and orientation and strain measurements in cylindrically bent silicon.

GOPAL RAO

Ordered Arrays of Aluminum Nanoclusters Grown on Silicon

Novel approaches for forming ordered structures of nanoclusters will likely play a role in using these clusters in technological devices. To address this issue, researchers from the Chinese Academy of Sciences, the National Research Council of Canada, Tohoku University, and the National Renewable Energy Laboratory have devised a way to create ordered, two-dimensional arrays of Al_6 clusters on Si(111) surfaces.

They report in the April 29 issue of *Applied Physics Letters* that they formed nanocluster arrays by evaporating Al on a Si(111) 7 × 7 surface. At substrate temperatures above 200°C, an ordered array of uniform Al clusters is formed. The arrays were studied with scanning tunneling microscopy, which showed that the clusters contain six Al atoms, occupying both halves of the Si(111) 7 × 7 unit cell, giving the nanocluster array the same geometry as the underlying 7 × 7 substrate. First-principles total-energy calculations find an optimized structure for the Al_6 clusters, which is in agreement with the experimental images.

"The formation of uniform Al and other metal cluster arrays provides new practical approaches for doping Si with ultrahigh uniformity and atomic precision," said Qi Kun Xue, the lead researcher on the project. "Precision doping also opens the door for fabricating *p-n* junctions across the two halves of each of the Si(111) 7 × 7 unit cells for diode applications. This would probably be among the highest density of integrated solid-state devices that may, one day, reach the commercial market. We are now working in collaboration with the Rowland Institute at Harvard University on proving this very exciting idea," Xue said.

The Al clusters are the most stable metal clusters that the research team has grown. The fact that the Al cluster arrays can sustain temperatures of up to 500°C is an important factor for practical applications, they said. The researchers also believe the Al_6-decorated Si(111) surface could serve as a template for the growth of other types of nanocluster arrays.

CHRISTOPHER MATRANGA

High-Efficiency Solar-Blind GaN Photocathodes Produced for Low-Level UV Detection

Researchers Bruce Wessels, Melville Ulmer, and colleagues at Northwestern University have fabricated a solar-blind UV detector based on a Cs-treated *p*-GaN photocathode. The device achieved a relatively high quantum efficiency (QE) of 30% for detecting radiation in the deep UV (λ = 200 nm), and a UV-visible light-rejection ratio of about 4 orders of magnitude.

Solar blindness is a necessity in several UV detector applications, for example, in UV astronomy, where objects studied are usually 4–8 orders of magnitude brighter in the visible than in the UV range. One of the approaches to making such UV-sensitive photodetectors is by using III–nitride materials as photocathodes by taking advantage of their negative electron affinity (NEA). NEA is obtained when the minimum of the semiconductor conduction band is above the vacuum level. In that case, thermalized electrons can escape the surface of the bulk material. To attain the NEA, the surface of the semiconductor must be treated with impurities.

As reported in the April issue of the *IEEE Journal of Quantum Electronics*, the researchers grew GaN layers 1 μm thick on sapphire substrates by metalorganic chemical vapor deposition. Magnesium was used as the *p*-type dopant, and films were treated with cesium to achieve NEA. In the as-grown materials, carrier concentrations were in the range of 5×10^{16} cm^{-3} to 1×10^{17} cm^{-3} and mobilities were in the range of 3–11.5 cm^2/V s. Subsequently, the films were processed into photocathode tubes.

In the sample with the best material quality, the researchers obtained a QE as high as 30% at 200 nm with a rejection ratio of about 4 orders of magnitude between the UV (200 nm) and visible (500 nm) ranges. They also found that the QE