biasing tends to be overwhelming for device practicality. In an article published in the March 18 issue of *Applied Physics Letters*, Lee and Steckl proposed lateral color integration (different dopant species found on side-by-side regions of a single layer). They have found with their technique that fine-tuning within the visual spectrum is not only possible, but also improves the emission intensity.

The researchers grew GaN films on Si(111) substrates by means of molecular-beam epitaxy (MBE), doping with Er and Eu *in situ*. Indium tin oxide (ITO) electrodes were deposited after GaN growth, for electroluminescence (EL) characterization. ELDs were fabricated by two methods: by a shadow mask at 400°C and by photoresist (PR) lift-off at temperatures of <100°C. To obtain multiple colors within the visible spectrum, GaN layers doped with the appropriate rare-earth element were deposited and patterned serially, either by repeating the PR lift-off process or by translating the shadow mask. The integrated ELDs fabricated at 400°C were bright, while those made at <100°C were significantly less bright but still visible under normal ambient lighting. From the EL experiments, GaN:Er has green peaks at 537 nm and 558 nm, while GaN:Eu has a single red peak at 621 nm. Atomic force microscopy measurements show surface roughness of 5 nm RMS for the 400°C sample and 10 nm RMS for the <100°C sample.

In previous research, rare-earth dopants were incorporated in II–VI hosts. This research shows that GaN serves as a much better host than the II–VI elements because of charge neutrality with 3^+ rare-earth ions; GaN also possesses superior chemical and thermal stability.

June Lau

Doping Ti in Superconducting MgB_2 Enhances Critical Current Density by Means of Refined Grain Structure

Researchers Y. Zhao and colleagues at ISTEC, Japan, and the University of New South Wales, Australia, studied the effect of Ti doping on the critical current density (J_c) of MgB_2, the newly discovered superconducting compound with $T_c = 39$ K. This was done to refine grain size and to create a fine and well-bonded structure of the superconducting phase for practical applications. The researchers observed a significantly improved J_c in Ti-doped bulk samples. By studying the microstructure of the samples, they found that Ti does not occupy atomic sites in the MgB_2 crystal structure, but forms a thin TiB_2 layer in the grain boundaries of the MgB_2. The researchers said that refined MgB_2 grains, forming a strongly coupled nanoparticle structure, may be responsible for the enhanced J_c.

As reported in the March 4 issue of *Applied Physics Letters*, the researchers prepared a series of Ti-doped MgB_2 samples with an atomic ratio of Mg:Ti:B = $(1 - x)$:x:2 ($0 \leq x \leq 1.0$) by solid-state reaction at ambient pressure. At a doping level of 10% Ti in MgB_2, the superconducting properties of the MgB_2 bulk superconductor were significantly improved, and a J_c of 1 MA/cm^2 at 20 K in zero applied field was achieved. In order to understand the underlying mechanism for the effect of Ti doping on J_c, the researchers investigated the crystal structure of the bulk samples by powder x-ray diffraction and performed microstructural and compositional analysis by a field-emission high-resolution transmission electron microscope equipped with an energy-dispersive x-ray spectroscopy system.

The researchers reported that the lattice constants of the MgB_2 remain unchanged, and T_c decreases only slightly with the increasing Ti doping level from $x = 0$ to $x = 0.4$. With $x = 0.1$, the average size of the MgB_2 grains is about 8 nm. The connection between the nanoparticles is very tight because of the thinness of the grain boundaries (<1 nm). Ti was found in the grain boundaries, but could not be detected inside the MgB_2 grains. Therefore, the researchers believe that Ti does not occupy the atomic sites in the lattice, but merely forms impurity phases, remaining outside of the MgB_2 grains.

According to the researchers, because of the tight bonding between MgB_2 nanoparticles and the ultrathin TiB_2 grain boundaries, very little weak-link effect exists in the Ti-doped MgB_2. The researchers observed high J_c values at high magnetic field, for example, 5×10^4 A/cm^2 in 5 T at 5 K. The bulk pinning force of the Ti-doped samples is an order of magnitude higher than the best result of the pure MgB_2 bulk sample, and it is close to the pinning force of the established technological superconductors NbTi and Nb_3Sn.

Shiming Wu

Pin Printing of Xerogels Allows Rapid Formation of Chemical-Sensor Arrays

As reported in the March 1 issue of *Analytical Chemistry*, Frank V. Bright and Eun Jeong Cho from the State University of New York at Buffalo have developed a method to rapidly fabricate reusable chemical-sensor elements into arrays. In order to provide a simple method for simultaneous multianalyte quantification to allow for simultaneous determination of O_2 and pH in aqueous samples, the researchers fabricated micrometer-scale xerogel-based sensor elements on a planar substrate by combining pin printing and sol-gel processing techniques.

Two sol-gel stock solutions were prepared by hydrolyzing solution A, which contained tetraethylorthosilane, distilled deionized water, EtOH, and HCl, for 2 h; and solution B, which contained *n*-propyltrimethoxysilane, tetramethoxysilane, EtOH, and HCl, for 1 h. By doping and printing the stock solutions onto clean glass microscope slides, the gas-phase O_2-responsive sensor elements and the solution-phase pH-sensitive sensor elements making up the pin-printed chemical-sensor array (PPCSA) were formed, based on tris(4,7′-diphenyl-1,10′-phenanathroline)ruthenium(II) [$Ru(dpp)_3$] and fluorescein-labeled dextran, respectively. The center-to-center spacing from one sensor element to another is ~200 μm on the pH- and O_2-responsive PPCSAs. The dual-analyte PPCSAs were prepared by printing alternating columns of O_2- and pH-responsive sensor elements with column-to-column center spacing adjusted to 300 μm and row-to-row center spacing set at 200 μm. The xerogel sensor elements were 1–2-μm thick, as observed by scanning electron microscopy.

After the xerogel was fully formed, the PPCSAs were characterized by using a CW argon-ion laser, an epifluorescence microscope, and a CCD camera. The behavior of O_2- and pH-responsive PPCSAs was tested, and the results showed the response reproducibility and stability—in another words, PPCSA methodology is suitable for performing reproducible measurements in the gas or solution phase. From the tests of the dual-analyte PPCSAs, the pH sensors responded only to changes in the pH of the solution, and the O_2 sensor responded only to changes in the O_2 level. There was no significant cross talk among sensor elements nor interference in the response profiles.

According to the researchers, the combination of pin printing and sol-gel processing techniques not only provided a simple method to rapidly fabricate reusable chemical-sensor elements into arrays (<1 s/sensor element) that exhibit good analytical figures of merit, but also provided a straightforward means to fabricate reusable multianalyte sensor arrays. The researchers predicted the potential of the PPCSA strategy for simultaneous multianalyte quantification. More recently, Cho and Bright showed that they could extend this methodology to pin-print sensor elements directly onto the face of a light-emitting diode to form a pin-printed optical-sensor array and integrated light source (PPOSAILS). Work on true distributed sensor arrays and biosensor arrays is now investigation in their laboratory.

YUE HU

Organic-Based Magnet Mn(TCNE)$_x \cdot y$(CH$_2$Cl$_2$) Shows Photoinduced Magnetization

D.A. Pejakovic and colleagues at the Ohio State University and the University of Utah have reported reversible photoinduced magnetization (PIM) in an organic-based magnet, Mn(tetracyanoethylene)$_x \cdot y$(CH$_2$Cl$_2$) ($x \sim 2$, $y \sim 0.8$). At low temperatures, the PIM lasts for several days after illumination.

As described in the February 4 issue of *Physical Review Letters*, for dc magnetization (M) measurements, the polycrystalline material was dispersed in mineral oil and sealed in a quartz capsule. At 5 K, illumination with 2.54-eV argon laser light in a 10-Oe magnetic field increased M. After illumination, M initially increased due to sample cooling and then decreased by about 0.5% in 60 h, suggesting a PIM lifetime of $>10^6$ s.

The ac susceptibility (χ_{ac}) of about 0.05 mg of the material applied in a thin layer on adhesive tape increased substantially below $T_c = 75$ K after illumination with 2.7-eV argon laser light for 60 h at 90 K. In the range of 13–18 K, χ' increased more than 50%, and χ'' increased by more than a factor of 4. The researchers suggest that the increase originates in altered spin organization and/or spin-spin coupling. After heating to 200 K and cooling to 5 K, about 5% of the increase in χ' remained. However, heating to above 250 K returned the material to the original state.

After illumination with 2.54-eV light for 10 min, the UV–vis–NIR absorption spectrum shows photoinduced absorption in the 1.5–2.4-eV and 3.1–3.8-eV regions. After illumination, 2.41-eV line excitation can reduce the effects. The researchers suggest that PIM results from a photoinduced electronic transition into a metastable state that enhances charge transfer.

The change in the IR absorption spectrum was also measured after 10 min of illumination at 2.54 eV. Again, the photoinduced effect is partially reduced after illumination with the 2.41-eV line. The changes in the IR spectrum suggest the presence of a lattice distortion occurring when a fraction of electrons relax from the π^* level. The researchers speculate that the lattice distortion plays a key role in stabilizing the state with enhanced magnetization.

ELIZABETH SHACK

X-Ray Microdiffraction Allows Direct Study of Antiferromagnetic Domain Evolution in Chromium

The evolution of antiferromagnetic domains in chromium during a "spin-flip" transition has been observed by x-ray microdiffraction imaging. A team of researchers from Lucent Technologies, NEC Research Institute, and Argonne National Laboratory report in the February 8 issue of *Science* that the transition begins at the walls between domains with orthogonal modulation vectors and progresses inward during cooling.

In contrast to ferromagnets, in which the spin polarization alone characterizes the magnetic domains, the description of antiferromagnetic chromium requires two parameters: the spin polarization and the modulation wave vector. Despite its structural and compositional simplicity, chromium displays complex magnetic behavior: During cooling, it not only undergoes a transition between a disordered paramagnetic state and an ordered Néel state, but also a spin-flip (SF) transition between two Néel states with perpendicular spin polarizations at T_{SF}.

"It is important to understand the domain evolution during this spin-flip transition," said Paul Evans, a postdoctoral researcher at Lucent. "However, we needed a technique that allowed us to image the domains by following the spin polarization and the modulation wave vector with good spatial resolution."

The researchers observed the spin-density wave and charge-density wave (SDW and CDW) under magnetic x-ray microscopy. They focused the x-ray microprobe beam to a spot size of 0.5 μm using a Fresnel plate followed by an order-sorting aperture. SDW Bragg reflections resulting from the ordered antiferromagnetic state were observed close to reciprocal space points (h,k,l) with $h + k + l$ odd, where no Bragg peaks resulting from atomic cores were observed from the bcc structure. CDW reflections due to the coupling of spin and charge had half the period of the SDW. For the measurement of $(0,0,1 - \delta)$ SDW reflections and $(0,0,2 - 2\delta)$ CDW reflections, the research team used 5.8-keV and 11.6-keV x-rays, respectively.

E.D. Isaacs, director of semiconductor physics research at Lucent, said, "If we mount the crystal in the right orientation, any transverse spin polarization gives us Bragg intensity, while longitudinal spin polarization does not fulfill the Bragg law."

Using this technique, the researchers followed the SDW and CDW during cooling through the spin-flip transition at ~123 K. While the CDW remained unchanged above and below the transition, the scattering intensity due to the SDW decreased with temperature, which was due to the reorientation of spins from transverse to longitudinal below T_{SF}. Additionally, it could be shown that different points of the same SDW domain converted at temperatures that differed by up to 7 K. The researchers attributed this to an inward progression of the spin-flip transition that started at antiferromagnetic domain walls. According to the researchers, possible explanations for this phenomenon are local strain fields, Heisenberg exchange interactions, and the quantum mixing of states with different Fermi surfaces across the domain walls.

CORA LIND

Magnetic Resonant Mode Discovered in Single-Layer HTS Tl$_2$Ba$_2$CuO$_{6+\delta}$

High-temperature superconductors (HTSs) with crystal structures consisting of copper oxide bilayers exhibit a resonant spin excitation mode. The observation of this unusual mode in the bilayer materials has prompted numerous theoretical studies of the interaction between charged quasiparticles and collective spin excitations in these superconductors. Previous experiments on single-layer La$_{2-x}$Sr$_x$CuO$_{4+\delta}$ did not show this magnetic resonant mode. Researcher H. He and colleagues from the Max-Planck-Institut für Festkörperforschung, CEA-CNRS, CEA-Grenoble, and the Russian Academy of Sciences have performed neutron-scattering experiments that show the presence of this mode in Tl$_2$Ba$_2$CuO$_{6+\delta}$, a single-layer copper oxide material with a superconducting transition temperature T_c of ~90 K. Based on these results, the researchers suggest that the mode is a general feature of all copper oxide superconductors, regardless of the sequence of layers.

At currently available neutron sources, inelastic neutron scattering requires a minimum single-crystal volume of 1 mm^3. The only known single-layer copper oxide superconductors, with $T_c \sim 90$ K, are Tl- and Hg-based and have typical crystal volumes well below 1 mm^3. As reported in the February 8 issue of *Science*, the researchers synthesized ~300 single crystals of Tl$_2$Ba$_2$CuO$_{6+\delta}$, each with volumes of up to 3 mm^3, using a CuO-rich flux technique. The relatively large crystals were then aligned into a larger mosaic of 0.11 cm^3 (total volume) by using Laue x-ray diffraction to measure the alignment of their crystallographic axes to an accuracy of 1.5°.

The researchers reported that inelastic neutron-scattering measurements of optimally doped Tl$_2$Ba$_2$CuO$_{6+\delta}$ show a sharp