

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 MgB₂ Enhances Critical Current Density by Means of Refined Grain Structure

Researchers Y. Zhao and colleagues at ISTEK, Japan, and the University of New South Wales, Australia, studied the effect of Ti doping on the critical current density (J_c) of MgB₂, 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 MgB₂ crystal structure, but forms a thin TiB₂ layer in the grain boundaries of the MgB₂. The researchers said that refined MgB₂ 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 MgB₂ samples with an atomic ratio of Mg:Ti:B = (1 - x):x:2 (0 ≤ x ≤ 1.0) by solid-state reaction at ambient pressure. At a doping level of 10% Ti in MgB₂, the superconducting properties of the MgB₂ bulk superconductor were significantly improved, and a J_c of 1 MA/cm² 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 MgB₂ 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 MgB₂ 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 MgB₂ 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 MgB₂ grains.

According to the researchers, because of the tight bonding between MgB₂ nanoparticles and the ultrathin TiB₂ grain boundaries, very little weak-link effect exists in the Ti-doped MgB₂. The researchers observed high J_c values at high magnetic field, for example, 5 × 10⁴ A/cm² 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 MgB₂ bulk sample, and it is close to the pinning force of the established technological superconductors NbTi and Nb₃Sn.

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 O₂ 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 O₂-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'-phenanthroline)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 O₂-responsive PPCSAs. The dual-analyte PPCSAs were prepared by printing alternating columns of O₂- 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 O₂- 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 O₂ sensor responded only to changes in the O₂ 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