Ultrafast Laser Radiation Generated Silicon Nanocrystals Embedded into a Glass Matrix

The formation of photo-active Si nanocrystals deeply embedded in the bulk is not a trivial matter as most techniques form such nanocrystals only on the surface or shallowly embedded into the bulk. A.H. Nejadmalayeri and coworkers from the University of Toronto, Canada, together with J. Burghoff and coworkers from the Friedrich-Schiller-Universität, Jena and J. Kaspar from the Fraunhofer-Institut für Werkstoff und Strahltechnik in Dresden, Germany, reported in the December 15, 2007 issue of *Optics Letters* (p. 3474) the laser generation of Si nanocrystals within bulk transparent media deep below the surface.

The researchers used linearly polarized mid-infrared ultrafast radiation at a wavelength of 2400 nm to propagate in the transparency window of Si. They focused the beam into Si wafers overcoated with 20-μm thick silicon oxide, and scanned the samples transversely using a motorized translation stage. The laser exposure created damage tracks along the [100] crystallographic direction at the Si/SiO_2 interface, leaving the top oxide surface intact, and generated optical waveguides for 1300 nm and 1550 nm radiation with moderate losses of ~1 dB/cm. Transmission electron micrographs and diffraction patterns showed small crystallites, 5–30 nm in size, without any particular order within the amorphous oxide immediately above the silicon–glass interface.

"Although Si and SiO_2 are transparent to the laser radiation, the interface exhibits relatively low damage threshold due to impact ionization and/or other nonlinear interactions, that cause a rapid heating and melting of a thin Si layer at the interface, followed by the melting of the adjacent oxide. Upon cooling, the molten glass resolidifies, and the silicon droplets recrystallize, forming a heterogeneous mixture of Si nanoparticles randomly oriented in the glass," the researchers said. The Si matrix close to the modified region was disordered and under planar compressive stress, as confirmed by Raman characterization. According to the researchers, this stress caused a density change that can induce an increase of refractive index, responsible for the optical waveguiding observed.

However, the researchers still do not know if this phenomenon is a unique characteristic of the ultrashort pulsed laser interaction with the Si/SiO_2 system or if it can occur in other systems like Si/Si_3N_4. The researchers consider the close proximity of the nanocrystals to the evanescent fields of the guided modes that were observed in these structures "very interesting." They said, "Considering the attractive luminescence properties, their proximity to such guided wave optics in a single step process suggests new opportunities to explore means of making compact Si-based light sources."

JOAN J. CARVAJAL

Boron-Doped Titanium Nitride Nanocomposite Thin Films Exhibit Broadband Photoluminescence

Titanium nitride (TiN) has been used as a template to grow gallium nitride (GaN) thin films due to its high electrical conductivity and small lattice mismatch with GaN. TiN films are usually doped with boron to increase their hardness. However, the photoluminescence (PL) properties of TiN-based thin films have rarely been reported. S.-G. Lu, who is affiliated with City University of Hong Kong and Central South University, China, Z.-K. Xu from City University of Hong Kong, Y.-H. Lu from Beijing University of Science and Technology, and K.-W. Cheah from Hong Kong Baptist University have measured the photoluminescence properties of boron-doped TiN thin films with nanosized grains as a function of B content and temperature.

As reported in the December 2007 issue of the *Journal of the American Ceramic Society* (p. 4002; DOI: 10.111/j.1551-2916.2007.02040.x), the researchers prepared a series of TiBN thin films with different compositions using a reactive close-field unbalanced magnetron sputtering (RCFUMS) system at room temperature. The films were all ~1.5 μm thick and deposited on polished (100) silicon substrates with a 40–50-nm thick Ti buffer layer to improve adhesion and reduce stress.

After the preparation, the researchers characterized the composition and structure of the thin films and investigated their photoluminescence. X-ray diffraction (XRD) results reveal that the grain size in the films decreases and the diffraction peaks of each pattern more or less shift toward low 2θ angles with increasing B content. But all the XRD peaks of TiBN with the highest amount of B studied disappear due to the tiny grain size, although weak diffraction patterns are observed by transmission electron microscopy (TEM). The PL spectra of samples at different temperatures show that at low temperature (12 K), each PL spectrum has two main PL peaks. The strong peak at 3.20 eV is attributed to the recombination between electrons bound to N vacancies and holes in the valence band, and the weaker peak at 1.63 eV is caused by the recombination of electrons in defects at surface states with holes in the valence band. The PL spectra at high temperatures of the sample with the highest B content show that a new peak appears near 2.38 eV and blue shifts slightly with increasing temperature. The researchers attributed this PL peak to deep-trap defect emission. The researchers concluded that the change of color from violet to green with temperature may be useful for applications such as optical display devices.

ZHAOYONG SUN

Inorganic–Organic Composite Scaffolds Offer New Material for Tissue Engineering

Challenges in tissue engineering require the development of materials systems that provide a temporary scaffold mimicking the three-dimensional (3D) natural extracellular matrix. Besides bioactivity, this scaffold must consist of 3D interconnected pore networks with pore size greater than 100 μm (for giant pores), thus promoting cell penetration and growth. Inorganic mesoporous bioactive glasses (MBGs) have been developed to meet these requirements. However, MBGs are too brittle to use alone as bone scaffolds. H.-S. Yun of the Korea Institute of Materials Science, S.-J. Heo of Inje University, and their colleagues overcome this problem by developing an inorganic–organic composite material based on MBGs and poly ε-caprolactone (PCL).

As described in the December 25, 2007 issue of *Chemistry of Materials* (p. 6363; DOI: 10.1021/cm7023923), the researchers fabricated hierarchically a 3D porous MBG–polymer composite using a combination of sol-gel, polymer templating, and rapid prototyping (RP) techniques with a robotic deposition device. A virtual 3D scaffold model was first created by computer-aided design and then used to guide the scaffold fabrication from direct extrusion of a MBG–PCL gel paste onto a cooled substrate. The substrate was maintained at low temperature in order to facilitate the solidification of the PCL. At the same time, the researchers designed a heat-controlled blowing system to accelerate the solvent evaporation and thus maintain the 3D scaffold morphology. The researchers reported that they can also control the ease of 3D scaffold formation by adjusting the MBG content of the paste. By applying these techniques, a scaffold with excellent molding capabilities and mechanical properties was obtained, they said.

The researchers evaluated the bone-forming activity of the MBG–PCL scaffold in simulated body fluid. Field emission scanning electron microscopy (FE-SEM) was used to monitor the apatite formation