Low-Refractive-Index Nanoporous Silica Improves Reflectivity of Dielectric Mirror

For light-emitting diodes (LEDs) to become practical replacements for incandescent bulbs, the light must be extracted more efficiently than is currently possible. Since the active region emits light in all directions, the efficiency can be improved by adding a mirror to the back of the LED to redirect light out of the device. One such mirror is a triple-layer omnidirectional reflector (ODR), which uses a low-refractive-index (low-*n*), transparent dielectric in a semiconductor–dielectric–metal stack. As reported in the June 15 issue of *Optics Letters* (p. 1518), J.-Q. Xi and co-workers at Rensselaer Polytechnic Institute fabricated an ODR using nanoporous SiO_2 as the low-*n* dielectric.

The researchers used a spin-on sol-gel process to deposit a 105-nm-thick layer of nanoporous SiO_2 (pore size, ~4 nm) on a 300-μm-thick GaP wafer and then evaporated 500 nm of Ag onto the dielectric. They made two similar structures, one with an 89-nm-thick, dense SiO_2 layer, and another without a dielectric layer. Ellipsometry revealed that the nanoporous SiO_2 has a refractive index of only $n = 1.23$, and the dense SiO_2 has a refractive index of $n = 1.457$.

Using a 632.8 nm coherent He-Ne laser, the group measured the angle-dependent reflectivity of the structures with the laser light incident from the GaP-air side and used it to calculate the angle-integrated reflectivity R_{int}, a key figure of merit for an ODR. They coupled light into the device with a high-index fluid and prism, allowing for off-normal measurements up to 25.5° for transverse electric (TE) polarization and 27.3° for transverse magnetic (TM) polarization. Reflectivity measurements for the TE mode in the nanoporous SiO_2 device yielded R_{int} = 99.9%, while the R_{int} of the dense SiO_2 was 99.8%, and the R_{int} of the simple silver mirror was only 97.2%. For TM polarization, which demonstrated more angular variation than the TE mode, the integrated reflectivities followed a similar trend, with R_{int} values of 98.9%, 97.8%, and 94.4% for the nanoporous SiO_2 ODR, dense SiO_2 ODR, and silver mirror, respectively.

The improved reflectivity of the nanoporous dielectric is consistent with its lower refractive index. The researchers said that such small increases in reflectivity translate into considerable reductions in mirror losses, especially when multiple reflections take place, thus suggesting that ODRs with nanoporous SiO_2 could improve LED performance.

AMANDA GIERMANN

3D Defect Structures Embedded in Opal-Based Photonic Crystals

Due to their potential to control light emission, routing, and filtering, photonic crystals can be employed as a tool to manipulate light for optical devices. To fabricate these materials, one route is to utilize the self-assembly of microspheres into colloidal crystals. In order to trap or localize light within these opal-based photonic crystals, researchers want to create controlled microscopic defects inside the lattice structure. As reported in the June 14 issue of *Chemistry of Materials* (p. 3069; DOI: 10.1021/CM050381L), Q. Yan, Z. Zhou, and X.S. Zhao from the National University of Singapore have engineered micrometer-scale defects consisting of polystyrene spheres within silica-based colloidal photonic crystals.

After fabricating the host opal by the assembly of monodisperse 0.39-μm-diameter silica colloidal microspheres using a vertical deposition method, the researchers deposited a thin layer of photoresist on top of the opal by spin-coating and then used conventional photolithography to create linear channels on the surface. Polystyrene microspheres were deposited in these channels either through spin-coating or by the vertical deposition method itself. The researchers then dissolved the photoresist and re-grew the host silica colloidal crystal by vertical deposition. By combining standard lithography with self-assembly, the researchers could embed polystyrene microspheres within the silica colloidal crystal. Another key advantage of this simple process, according to the researchers, is that the thickness of the defect layer (photoresist) can be controlled by merely changing the spinning speed and deposition time.

Besides straight linear channels, other defect structure geometries such as S-bend, Y-branch, X-cross, and rings have been fabricated on the colloidal crystal surface. These configurations are useful for waveguiding and filtering applications. Zhao said that this technique is inexpensive and straightforward to implement, and may be useful for non-photonic devices, such as filtering elements in microfluidic channels.

TUSHAR PRASAD

Molecular-Scale Si Nanowires Enable Coherent Single-Charge Transport

Nanoscale electronics require building blocks that have controllable properties and can easily be arranged into complex, integrated structures. The "bottom-up" approach to creating such structures is advantageous because critical feature sizes are defined during synthesis, allowing for atomic-scale control over size and properties. Although isolated carbon nanotubes exhibit exceptional properties, silicon nanowires show promise for large-scale integration due to the ability to reproducibly control their size and properties. However, fundamental electrical transport properties have not been reported for small-diameter Si nanowires—that is, strong confinement behavior in one dimension. In the May 6 issue of *Nano Letters* (p. 1143; DOI: 10.1021/nl050783s), Z. Zhong, Y. Fang, W. Lu, and C.M. Lieber of Harvard University have now characterized the electrical transport of chemically synthesized, molecular-scale Si nanowires 3–6 nm in diameter.

The study probed the low-temperature (4.2 K) transport properties of such Si nanowires assembled into single-electron transistors (SETs). The SETs were formed from single-crystal Si nanowires on 50-nm-thick thermal oxide on degenerately doped Si substrates with 50-nm-thick Ni source–drain contacts defined by electron-beam lithography. Electrical measurements on single Si nanowires demonstrated regular Coulomb blockade oscillations consistent with phenomena resulting from single-charge tunneling through a single quantum structure, not a series of interconnected quantum dots. Coherent charge transport was further demonstrated through discrete single-particle quantum levels extending across the SET devices over length scales of up to 200 nm, in marked contrast to predictions for the properties of lithographically patterned planar silicon. The researchers said that this molecular-scale Si nanowire system can serve as a potential building block for both conventional and quantum electronics. The researchers also said that the richness of the transport phenomena observed in this initial study suggested that correlation effects beyond the constant interaction model (in which each electron is assumed to be independent) may be important in describing the behavior of these SETs in the few-charge regime, where electron behavior is likely quantized.

ADITI RISBUD

Researchers Elucidate the Structure of the Protein–Mineral Interface in Bone

Bone is a material with remarkable mechanical properties, which have been the focus of numerous investigations. Although bone is relatively lightweight, it is strong, robust, and tough. The reasons for these unusual properties are not yet well understood. In contrast to many synthetic materials, natural bone features a composite-like nanostructure comprising

https://doi.org/10.1557/mrs2005.171 Published online by Cambridge University Press