InGaAsN Used in Fabrication of 1.3-μm VCSEL Structure

Researchers at Sandia National Laboratories working with Cielo Communications have developed a 1.3-μm electrically pumped vertical cavity surface emitting laser (VCSEL) grown on gallium arsenide. This VCSEL is made mostly from stacks of layers of semiconductor materials common in shorter-wavelength lasers-aluminum gallium arsenide and gallium arsenide. The research team added to this structure a small amount of the material indium gallium arsenide nitride (InGaAsN), which was initially developed by Hitachi of Japan in the mid-1990s.

The researchers grew the structure by molecular-beam epitaxy in a single growth run. They reported at the Device Research Conference, held June 19–21 in Denver, that the top and bottom *n*-doped distributed Bragg reflector (DBR) mirrors contain 28 and 33 periods, respectively, and are fabricated from alternating quarter-wavelength layers of $Al_{0.94}Ga_{0.06}As$ and GaAs. They said that the relatively low doping in the Si-doped mirrors reduces the free-carrier absorption. They placed a tunnel diode at a node of the optical field in the GaAs layer nearest the cavity in the upper mirror to provide hole injection into the active region, and they oxidized the AlAs low-index layers adjacent to the optical cavity for electrical and optical oxide aperture confinement. They used an rf plasma nitrogen source to grow two 6-nm-thick $In_{0.34}Ga_{0.66}As_{0.99}N_{0.01}$ quantum wells (QW), contained in the optical cavity.

As reported at the conference and in an article to appear in an upcoming issue of *Electronic Letters*, John Klem of Sandia and his colleagues achieved a single-mode output power of 60 μW at 20°C and continuous-wave operation up to 55°C.

Operating at 1.3 μm (a wavelength of low dispersion in single-mode optical fiber) enables the VCSEL to be used for a wide variety of high-speed, medium-distance data-communication applications, including Internet infrastructure, gigabit Ethernet, and fiber to the home. Peter Esherick, manager of the Compound Semiconductor Materials and Processes Department at Sandia, said, "We expect there to be great excitement over the device—fueled by the rapid expansion of Internet use and craving for faster Internet access."

Encapsulation of Ru-Ni Binary Nanoparticles into Dendrimers Enhances Catalytic Activity

A team of researchers at Pohang University of Science and Technology in Korea have obtained Ru-Ni binary nanoparticles by electrodeposition of the metals encapsulated in dendrimers that showed significantly enhanced catalytic activities for the oxidation of ethanol when compared with bulk metal-oxide electrodes. Incorporation of functional groups like amines enables the dendrimers to function as complexing agents of transition metals.

"The dendrimers act as both nanoscale templates and separators between the particles," said Su-Moon Park, professor at Pohang. Therefore, he expected nanoparticles prepared in this way to offer advantages for use as electrocatalysts due to large surface areas, small catalyst loading, and inhibition of aggregation between particles. Having demonstrated before that Ru-Ni mixed oxides are potent electron-transfer mediators for the electro-oxidation of ethanol, his group attempted the synthesis of dendrimer-templated Ru-Ni nanoparticles.

As reported in the August issue of *Electrochemical and Solid-State Letters*, the Ru-Ni binary nanoparticles were prepared by potentiostatic electrodeposition in a mixed solution containing amine-terminated poly(amidoamine) dendrimers (G4(NH_2), where G4 represents the fourth generation) with Ru(III) ions and Ni(0) loaded into G5(OH) dendrimers. The Ni_{21}-G5(OH) was pre-reduced with $NaBH_4$. The particles showed an absorption peak arising from a Mie plasmon resonance in their UV-visible spectra, indicating that the particles were larger than the Mie-onset particle diameter of 5 nm. The blue shift of the plasmon band on progressive deposition suggested that the metal ions were deposited later as nanoparticles. Cyclic voltammograms of pure Ni or pure Ru dendrimers were similar to those for bulk metals and did not show current saturation at ethanol concentrations up to 1.0 M.

"But for the Ni-Ru binary particles, the nucleation current loop appears when the ethanol concentration is greater than 0.05 M," said Jae-Woo Kim, a doctoral student at Pohang. "This suggests that the formation of the passive film is faster than the chemical decomposition reaction subsequent to its formation." Polarization resistances of these electrodes calculated from impedance responses showed a decrease from 460 Ω cm^2 to 31 Ω cm^2 upon addition of ethanol, indicating a significant catalytic activity for ethanol oxidation. Electrochemical experiments revealed a very fast redox reaction of the templated nanoparticles, with exchange currents for ethanol oxidation being improved by a few orders of magnitude when compared with a bulk electrode.

Park and his student agree that "nanoparticles prepared using dendrimer templates are promising candidates for oxidation of organic compounds." In further studies, they plan to investigate the morphology of nanoparticles electrodeposited under experimental conditions.

CORA LIND

Organogelator-Templated Synthesis of Hollow TiO_2 Nanotubes

Nanostructured anatase phases of TiO_2 have potential applications in various photovoltaic and photocatalytic processes. The preparation of hollow TiO_2 nanofibers by sol-gel polymerization of $Ti[OCH(CH_3)_2]_4$ using self-assembled templates of the organogelator compound *trans*-(1R,2R)-1,2-cyclohexanedi(11-aminocarbonylundecylpyridinium) hexafluorophosphate was recently reported by scientists at Shinshu University, Nagano, and the Japan Science and Technology Corporation. Organogelators are low-molecular-weight compounds that act as a template in the sol-gel process and assist sol-gel polymerization at low concentrations. The fibers were ~200 μm long and had inner and outer diameters of 50–300 nm and 150–600 nm, respectively.

As reported in the August issue of *Chemistry of Materials*, the materials were prepared by dropwise addition of an aqueous solution of either NH_4OH or HCl catalyst mixed with ethanol to an ethanol solution of the organogelator and $Ti[OCH(CH_3)_2]_4$ in a 1:10 molar ratio. The solution was then heated to 80°C and slowly cooled to 25°C to form a white precipitate. The precipitate was isolated by allowing the solution to dry at 25°C for 10 days and heating to 50°C in a vacuum for 5 h. The product could also be calcined to remove all organic components by additional heating to 200°C for 2 h, followed by calcining at 450°C for 2 h.

Characterization of dried polymerization products by scanning electron

Recently Announced CRADAs

Argonne National Laboratory (Chicago, Illinois), **Intermagnetics General Corporation** (Latham, New York), and **Los Alamos National Laboratory** (Los Alamos, New Mexico) have signed a three-year, $2.5 million cooperative research and development agreement to focus on coating technologies developed for producing second-generation high-temperature superconducting tape.

microscopy showed that the dried products prepared by both acid and base catalysis consist of aggregates of fibers ~200 μm long and 150–600 nm in diameter. Similar fiber aggregates were observed for the assemblies produced by the organogelator alone, proving its role as the template. The fibers produced by acid-catalyzed polymerization were smooth, while those produced by base-catalyzed polymerization had rough surfaces. This difference was ascribed to the production of TiO_2 particles during base-catalyzed polymerization.

Unlike the dried product, the calcined samples exhibited fiber structures only when the polymerization was base-catalyzed. This result is consistent with the presence of anionic propagation species during base-catalyzed sol-gel polymerization. These negatively charged intermediates adsorb onto the positively charged organogelator template, and the polymerization proceeds along the template. Transmission electron micrographs of the calcined base-catalyzed product show that the nanofibers are hollow and have internal diameters of 50–150 nm. X-ray diffraction studies of the calcined nanofibers show that they have the desired anatase structure.

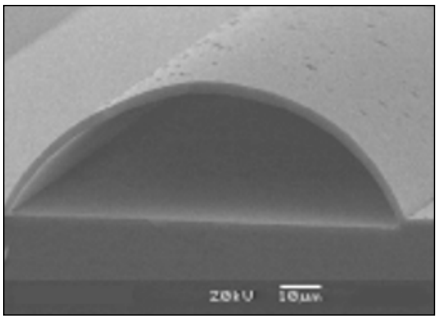
GREGORY KHITROV

Low-Temperature Process Produces Microcanals for Microfluidic Chips

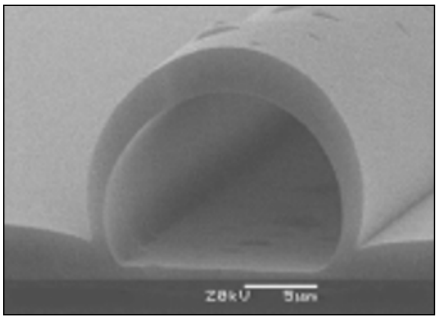
Researchers at Sandia National Laboratories have developed a microchip processing technique that creates raised microscopic canals on chips, through which liquids or gases can flow from one chip feature to another. The raised hemispherical canals, 8–100 μm in diameter, have been created on silicon, glass, and quartz surfaces. Some of the canals have been made with curvatures with radii as small as 8 μm. These canals can be small enough and curvy enough that some liquids or gases pass easily through them and others pass more slowly. This ability to distinguish among fluidic materials is useful for chemical-separation applications, the most common use of microfluidic devices.

To make the canals, the researchers pattern a thin layer of photoresist on the wafer's surface using a conventional photo mask and light, then develop away areas of photoresist exposed to the light, leaving a network of photoresist ridges on the wafer's surface that eventually becomes the canals' interiors.

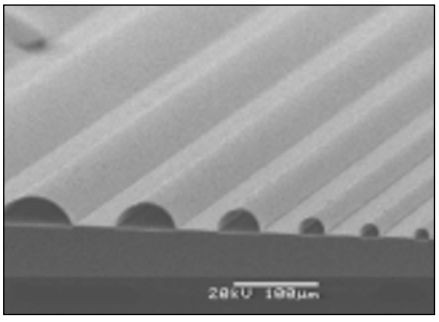
Next, they heat the wafer to a relatively low temperature of 100°C for about 20 s, which causes the square-edged ridges to slump into a hemispherical shape. A 2-μm-thick film of silicon oxynitride is deposited over the rounded photoresist, and the entire wafer is soaked in an acetone bath until the remaining photoresist is dissolved, leaving hollow tunnels on the wafer's surface.



Radius of curvature: 52 μm



Radius of curvature: 8 μm



Microscopic views of raised hemispherical canals 8–100 μm in diameter.

The traditional trench-and-seal method involves the joining of two pre-trenched wafers. But the intense heat required for bonding—up to 1000°C—can damage other chip features, and the care required to remove contaminant particles from the two halves increases the difficulty and cost of manufacturing.

The newly developed and patented technique is 10 to 100 times faster than the trench-and-seal method, said co-developer Carol Ashby. She said that the resulting tunnels are virtually indestructible.

Co-developer Carolyn Matzke of Sandia's Compound Semiconductor Research Laboratory said that the technique's compatibility with standard semiconductor batch-processing tools should allow future microfluidic devices to be made quickly and cheaply in a microchip factory.

Calculations Indicate that 2D Photonic Crystals Based upon Archimedean-Like Tilings Have Nearly Isotropic Properties

Two-dimensional (2D) artificial crystals with photonic-band structures can be used for applications such as microwave or millimeterwave filters for rf photonics or for suppression of spontaneous emission in microcavity resonators. However, 2D photonic crystals based upon real 2D crystals belong to one of the five 2D Bravais lattices. These crystals possess few symmetry elements and are too few to achieve ideal optical isotropy. In calculations performed by S. David, A. Chelnokov, and J.-M. Lourtioz of the Institut d'Electronique Fondamentale at the Université Paris-Sud, three Archimedean-like 2D tiling configurations were considered. Each of these configurations displayed 12-fold symmetry, making the resulting 2D crystal nearly photoisotropic, as they reported in the July 15 issue of *Optics Letters*.

Complete tiling of a plane with a single type of regular polygon can only occur for squares, triangles, and hexagons. However, combinations of squares, triangles, and hexagons can be used to completely tile a plane. The researchers described the Archimedean tilings as "regular convex polygons that are not necessarily identical, but are identically arranged around each vertex." The five 2D Bravais lattices are a subcategory of Archimedean tilings. Three tilings used in this experiment are composed of squares and equilateral triangles. Atoms are then assigned to either square or triangular Bravais lattices, thus allowing definition of Wigner cells. This enabled the team to investigate these theoretical entities with numerical methods, generating information on their band structure and gaps as a function of lattice direction.

Theoretical diffraction patterns of these systems are generated with Fourier transform calculations. The result is a set of points that outlines the vertices of a dodecagon, implying 12-fold symmetry. The plane-wave method was used to construct band diagrams for these crystals. Calculations were performed on main crystallographic directions for both transverse electric (TE) and transverse magnetic (TM) polarizations. These results were