

microscopy (TEM), selected-area electron diffraction (SAED), and photoluminescence spectroscopy to probe the correlation of the size, morphology, and structure of these nano-objects with their photoluminescent characteristics.

The researchers used 2H wurtzite single-crystal ZnS nanoribbons synthesized by hydrogen-assisted thermal evaporation. This method produces nanoribbons that have nearly perfectly rectangular cross sections, with lengths of tens of micrometers,

widths of several micrometers, and an average thickness of approximately 80–100 nm. The nanoribbons were dispersed onto a TEM grid, and TEM measurements were performed on a single nanoribbon, confirming the 2H wurtzite structure and the orientation of the crystal. The nanoribbon was then illuminated with the 266 nm output of a frequency-quadrupled Nd:YAG laser to study the nanoribbon photoluminescence. Light emission was observed near 338 nm, just below the band edge of the ZnS nanoribbon. At high optical pump intensity, the spectral width of the photoluminescence peak narrowed, and the optical emission increased superlinearly, indicating the stimulation of lasing action in the nanoribbon. An optical fiber was used to collect the photoluminescence, thus permitting study of the lasing characteristics of individual nanoribbons at a variety of angles. Room-temperature lasing was observed in at least 20 of the single-crystal ZnS nanoribbons and also in a macroscopic amount of the ribbons. The researchers believe that the study of lasing phenomena in ZnS nanoribbons can be extended to nanoribbons of other semiconductor materials with direct bandgaps.

LARKEN E. EULISS

### Review Articles and Special Issues

*Review of Scientific Instruments* 75 (3) (2004) contains L. Eldada, "Optical Communication Components," p. 575.

*Low Temperature Physics* 30 (2) (2004) contains A.M. Kosevich, "Topology and Solid-State Physics," p. 97.

*Physics of the Solid State* 46 (2) (2004) contains S.M. Dunaevski, "Magnetic Phase Diagrams of Manganites in the Electron Doping Region," p. 193.

*Technical Physics* (February 2004) contains A.L. Stepanov, "Optical Properties of Metal Nanoparticles Synthesized in a Polymer by Ion Implantation: A Review," p. 143.

*Applied Mechanics Reviews* 57 (1) (2004) contains V. Raizer, "Theory of Reliability in Structural Design," p. 1; S. Seelecke and I. Muller, "Shape Memory Alloy Actuators in Smart Structures: Modeling and Simulation," p. 23; G.W. Brodland, "Computational Modeling of Cell Sorting, Tissue Engulfment, and Related Phenomena: A Review," p. 47; and A. Gyr and W. Kinzelbach, "Bed Forms in Turbulent Channel Flow," p. 77.

*Reviews of Modern Physics* 76 (1) (2004) contains M. Dine and A. Kusenko, "Origin of the Matter–Antimatter Asymmetry," p. 1; R.G. Endres, D.L. Cox, and R.R.P. Singh, "Colloquium: The Quest for High-Conductance DNA," p. 195; A.S. Jensen, K. Riisager, D.V. Federov, and E. Garrido, "Structure and Reactions of Quantum Halos," p. 215; and R. Casalbuoni and G. Nardulli, "Inhomogeneous Superconductivity in Condensed Matter and QCD," p. 263.

*Journal of Environmental Engineering* 130 (3) (2004) is a special issue on Air Quality—Capture and Recovery or Destruction of Trace Vapors from Gas Streams.

*IEEE Transactions on Instrumentation and Measurement* 53 (1) (February 2004) is a special issue on Lightwave Technology in Instrumentation and Measurement.

*Powder Diffraction* 19 (1) (March 2004) contains a special section on X-Ray Studies of Art and Archaeological Objects.

*Journal of Biomedical Optics* 9 (1) (2004) contains a special section on Ophthalmic Diagnostics.

*Journal of Computing in Civil Engineering* 18 (1) (2004) is a special issue on Applications of Imaging Technologies in Civil Engineering Materials.

*Journal of Microlithography, Microfabrication, and Microsystems* 3 (1) (2004) contains a special section on Immersion Lithography.

*IEEE Transactions on Device and Material Reliability* 3 (4) (December 2003) is a special issue on Interface Reliability.

*Journal of Computing and Information Science in Engineering* 3 (4) (December 2003) is a special issue on Solid Modeling Theory and Engineering Applications.

*IEEE Journal of Selected Topics in Quantum Electronics* 9 (6) (November/December 2003) is a special issue on Quantum Internet Technologies.

*Journal of Physics and Chemistry of Solids* 65 (4) (2004) is a special issue containing the Proceedings of Symposium K on Design, Characterization, and Modeling of Molecule-Based Magnetic Materials, from the E-MRS Spring Meeting, held in Strasbourg, France, in June 2003.

*Optical Materials* 25 (2) (March 2004) is a special issue containing selected papers on Photonic Glasses presented at ICO XIX, the 19th Congress of the International Commission for Optics in Firenze, Italy, August 25–30, 2002.

*Thin Solid Films* 451–452 (March 22, 2004) is a special issue containing papers from the Proceedings of Symposium D on Thin Film and Nanostructured Materials for Photovoltaics, from the E-MRS Spring Meeting (Strasbourg, June 2003).

*Vacuum* 73 (2) (March 19, 2004) is a special issue containing papers from the Proceedings of the European Vacuum Congress Berlin 2003, June 23–26, 2003, featuring the 8th European Vacuum Conference, 2nd Annual Conference of the German Vacuum Society, held in Berlin, Germany, June 23–26, 2003.

*Vacuum* 73 (1) (March 8, 2004) is a special issue containing papers from the 16th Ion–Surface Interactions Conference held in Zvenigorod, Russia, August 25–29, 2003.

*Journal of Lightwave Technology* 22 (1) (2004) is a special issue containing papers from the Optical Fiber Communications Conference, 2003.

### Replica-Molded, Polymeric Microresonators Demonstrate High Quality Factors

Micrometer-scale dielectric resonators are able to store and confine optical energy for long periods of time and are characterized by a quality factor ( $Q$  factor), which is essentially the number of oscillations of light that takes place during the storage time of the device. Applications include biosensing, photonics, and telecommunications. Using lithography and etching techniques, ultrahigh- $Q$ , toroid-shaped, silica microresonators (termed "whispering gallery" resonators because optical trajectories occur near the surface of the interior periphery of the microcavity) were recently fabricated on a silicon chip. Employing these resonators as a master, a team of researchers at the Department of Applied Physics, California Institute of Technology, has developed a fast, effective, and novel micromolding method that produces high- $Q$  polymeric microresonators, with  $Q$  factors as high as  $5 \times 10^6$ , which is nearly 40× greater than previous polymeric microresonators.

As reported in the March 15 issue of *Optics Letters*, A.L. Martin, D.K. Armani, L. Yang, and K.J. Vahala used poly(dimethylsiloxane) (PDMS) and Vicast (a polymer used in domestic consumer applications) to demonstrate their replica-

molding process. The elastomeric PDMS was chosen as the material from which to make the mold because mechanical flexibility is required. The process consists of three main steps. First, and as previously published, an array of ultrahigh- $Q$  silica microtoroids on a chip (the master) is prepared. Second, a PDMS mold is then made of the master, and third, either a PDMS or Vicast replica is cast from the mold. To prevent the mold from adhering to either the silica resonators or the silicon chip, the master was silanized with trichloromethylsilane. After de-airing, the mold-master assembly is cured at 80°C

for 60 min. After release from the master, the mold is cured for an additional 12 h.

Although both PDMS and Vicast are optically transparent, Vicast is rigid and its optical properties have not been previously characterized. After casting and de-airing, the liquid PDMS is cured for 1 h at 80°C, after which it is released from the mold. In contrast, the Vicast requires curing for 12 h at 75°C and must remain in the mold for an additional 48 h at room temperature before release.

The  $Q$  factors were measured with a single-frequency, tunable, extended-cavity laser coupled to a single-mode optical

fiber containing a short, tapered section that acts as a waveguide and couples power into the whispering gallery modes of the microtoroids. Maximum  $Q$  factors of  $2 \times 10^6$  and  $5 \times 10^6$  were measured for PDMS and Vicast, respectively. Both the modal structure and the frequency spectral range of the PDMS and Vicast microtoroids are similar to those of the silica masters because the indices of refraction for all three materials are similar.

No degradation in  $Q$  factor of the resulting microresonators was observed, even after repeated use of the masters and molds. The surfaces of the PDMS and

### New Form of Matter Created: A Fermionic Condensate

Scientists at JILA, a joint laboratory of the National Institute of Standards and Technology (NIST) and the University of Colorado at Boulder (CU—Boulder), have observed a “fermionic condensate” formed from pairs of atoms in a gas, a long-sought, novel form of matter. Physicists hope that further research with such condensates will eventually help unlock the mysteries of high-temperature superconductivity, a phenomenon with the potential to dramatically improve energy efficiency across a broad range of applications.

D.S. Jin of NIST and CU—Boulder and M. Greiner and C. Regal of CU—Boulder reported their findings in the January 28 issue of *Physical Review Letters*. A gas of 500,000 potassium atoms was cooled to temperatures of  $<5 \times 10^{-8}$  K, and then a magnetic field was applied near a special resonance strength. This magnetic field coaxed the fermion atoms to match into pairs, akin to the pairs of electrons that produce superconductivity.

The temperature at which metals or alloys become superconductors depends on the strength of the pairing interaction between their electrons. The highest-known temperature at which superconductivity occurs in any material is about -135°C.

Jin said, “We expect that the fermionic condensates that we observed will exhibit superfluid behavior. They represent a novel phase that lies in the crossover between superconductors and BECs [Bose–Einstein condensates].”

Last November, Jin’s team, as well as a separate research group in Innsbruck, Austria, reported that they produced a Bose–Einstein condensate of molecules. In those experiments, a time-varying magnetic field was applied to fermionic atoms that forced them to combine into bosonic molecules. Fermions have half-integer “spins” (i.e., 1/2, 3/2, 5/2), while bosons have integer “spins” (i.e., 1, 2, 3). Spins are additive, so that a

molecule containing two fermionic atoms is a boson. However, even if two fermions are not bound into one molecule, but merely move together in a correlated fashion, then as a pair they can act like a boson, and undergo condensation. It is this second, more subtle form of condensation that has been observed in the current experiments.

The current work was performed by applying a particular magnetic field at values where individual fermionic atoms cannot bind together to form bosonic molecules. Instead, the pairing of fermions is caused by the collective behavior of many atoms, similar to what causes Cooper pairs of electrons to form in a superconductor.

Paradoxically, in order to detect that the experiment produced a condensate from paired fermions (and not molecules), the researchers first converted the pairs into molecules. A magnetic field at the right strength for molecular bonding was rapidly applied to the fermionic condensate, and simultaneously the optical “trap” holding the gas was opened. This magnetic-field change can create molecules, but is too fast to create a molecular BEC, as shown in previous research. Nonetheless, a “picture” of the molecules’ motion showed the characteristic shape of a condensate cloud (see Figure).

“It happens too fast for anything to move around,” said Jin. “The condensate that appears in our ‘snapshot’ of the gas has to have existed before the molecules were formed.”

In other words, the “snapshot” showed bound molecules, but the arrangement of those molecules was determined earlier when the pairs first matched up.

“Even in this first observation, we were able to see the fermionic atom condensates in a much more direct way than anyone had anticipated,” said Jin. “This opens up the very exciting potential to study superconductivity and superfluid phenomena under extreme conditions that have never existed before.”

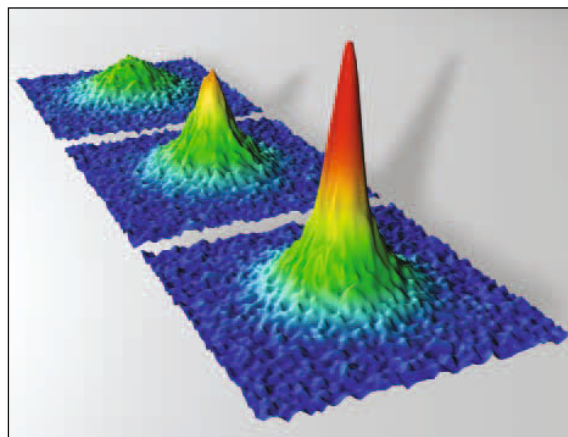


Figure. False-color images of a condensate formed from pairs of fermion potassium atoms. Higher areas indicate a greater density of atoms. Images from left to right correspond to the increasing strength of attraction between the atoms that form fermion pairs as the magnetic-field strength is varied. (Image credit: NIST/University of Colorado.)

Vicast microresonators are exceptionally smooth, and the scattering component of optical loss is therefore very low (such microresonators are said to be material-loss-limited). Because of these properties, Vahala and co-workers believe that their method "has a secondary application for rapid evaluation of optical loss in previously untested polymers." The researchers reported that with the use of other polymers such as poly(methyl methacrylate), which is known to exhibit even lower material losses than PDMS or Vicast, "replicated devices with  $Q$  factors in excess of 100 million, that is, comparable with their masters, could be molded and used to probe nonlinear optical and thermo-optic tuning effects."

STEVEN TROHALAKI

### Tunable Superhydrophobic Surfaces Fabricated by Nanosphere Lithography

Superhydrophobic materials received much attention after the discovery of water-repellent behavior in micro- and nanostructured plant surfaces. In examining the influence of nanostructure on surface water-repellent behavior, J.-Y. Shiu, C.-W. Kuo, and P. Chen of Academia Sinica and C.-Y. Mou of National Taiwan University have fabricated well-ordered, tunable superhydrophobic surfaces with a variable water-contact angle (tuned from  $132^\circ$  to  $170^\circ$ ) using nanosphere lithography and oxygen plasma. They accomplished this by creating rough surfaces covered with low-surface-energy molecules and by roughening the surface of hydrophobic materials.

As reported in the February 24 issue of *Chemistry of Materials*, the scientists obtained single- and double-layer close-packed polystyrene (PS) arrays by spin-coating monodisperse PS bead solutions onto substrates. This approach to nanosphere lithography achieves arrays of self-ordered, close-packed nanostructures. In a first approach, they used 440-nm-diameter PS beads to form single-layer arrays and later reduced the beads to 360 nm, 330 nm, and finally 190 nm by oxygen plasma treatment. The nanosphere separation remained constant during the oxygen plasma treatment. After the oxygen plasma treatment, the arrays were coated with a 20-nm-thick gold film and modified with octadecanethiol (ODT). The apparent water-contact angle of the single-layer surfaces changed monotonically from  $132^\circ$  (for 440-nm-diameter arrays) to  $168^\circ$  (for 190-nm-diameter size-reduced arrays).

The water-contact angles on the nanostructured surfaces were much larger than that of an ODT-modified gold surface on a flat substrate ( $114^\circ$ ). The researchers said that this is an indication that the surface nanostructure governs the superhydrophobic behavior of surfaces.

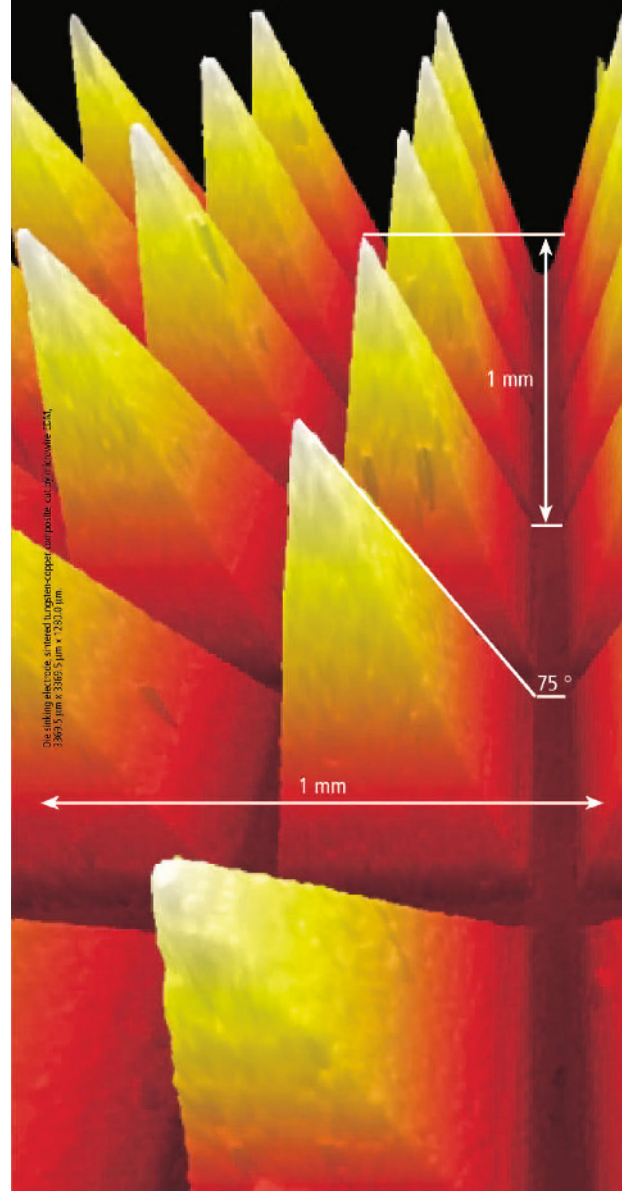
Two well-established models, one developed by R.N. Wenzel and one by A.B.D. Cassie and S. Baxter, are typically used to describe the water dewetting behavior on a rough surface. The researchers believe that their results are more consistent with the second model, which predicts a decrease in contact angle with bead diameter for the size-reduced beads in agreement with their results, whereas the first model predicts an increase in contact angle with bead diameter. The researchers also measured water-contact angles for several close-packed arrays formed with bead diameters from 270 nm to 690 nm. The measured contact angle was  $131^\circ \pm 2^\circ$ , compared with a prediction of  $141^\circ$  degrees for the Wenzel model and  $133^\circ$  for the Cassie and Baxter model. The researchers said that for such nanostructured surfaces, the Cassie and Baxter model works better, with the exception of a few discrepancies. One is the difference in water-contact angle between single- and double-layer arrays. In contrast to the assumption that only the top layer affects contact angle, double-layer PS arrays have even higher contact angles than single-layer arrays, which can be explained by the defects formed during the nanosphere lithography process. Two more discrepancies are the surface fine structures caused by inhomogeneous oxygen etching and the imperfect spherical shape of the etched PS beads.

Furthermore, the measured water-contact angle hysteresis is rela-

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