Nano Focus

2D self-assembly of a monolayer film of gold nanoparticles achieved in 10-min synthesis

Uniform thin films composed of closely packed nanoparticles are important for applications such as nanoelectronics, light-emitting diodes, solar cells, and magnetic data storage. While electrostatically stabilized gold nanoparticles (Au-NPs) in water irreversibly aggregate, alkanethiolate-coated Au-NPs are very stable, and can be dried into a powder and subsequently re-dispersed in solvents without size change.

Traditional methods for two-dimensional (2D) self-assembly of NPs coated with hydrophobic organic ligands include Langmuir-Blodgett deposition and spin-coating, although monolayer films prove difficult with the latter. Previously reported, however, were monolayer films prepared with a simple method for 2D self-assembly of dodecanethiol (DDT)-coated Au-NPs at the air-toluene interface of an evaporating toluene droplet. Nevertheless, drawbacks are inherent in the modified Brust methods used to synthesize the Au-NPs, which include the slow Au-NP formation in toluene, and the difficulty in removing from the Au-NPs the surfactant tetraoctylammonium bromide (TOAB), required to transfer gold ions from the aqueous phase to toluene.

Recently, however, S.-K. Eah and co-researchers at Rensselaer Polytechnic Institute have developed a new, 10-min., TOAB-free method for synthesizing DDT-coated Au-NPs. The researchers have uploaded a three-minute demonstration video at http://www.youtube.com/watch?v=nqkwM9o1s-w.

Eah and co-researchers reported in the May 18th issue of *Langmuir* (DOI: 10.1021/la100591h; p. 7410) that they synthesized Au-NPs in water by borohydride reduction. Phase transfer and coating with DDT was then performed by adding acetone to the aqueous Au-NP mixture, and then adding hexane containing DDT. After vigorous shaking for 30 s, the DDT-coated Au-NPs were transferred to the hexane with all reaction byproducts remaining in the aqueous-acetone phase, making a product-cleanup step unnecessary. The researchers found that the lack of the normally used stabilizer molecules was critical for the Au-NP phase transfer. By controlling reaction conditions, the researchers were able to precisely tune the Au-NP diameters in the range of 3.2–5.2 nm. The Au-NPs were indispersible in toluene and therefore self-assembled into a monolayer, closely packed film at the toluene-air interface of a toluene droplet. For Au-NPs with diameter above 4 nm, the Au-NP arrays transferred intact to the substrate as the toluene evaporated. However, droplets containing 3.2 nm and 4.0 nm diameter Au-NPs did not maintain monolayer formation on the substrate as the toluene evaporated, Furthermore, the researchers found that the negative charge on the Au-NPs in nonpolar solvents is an important requirement for such self-assembly. Eah and co-researchers said, "We believe that controlling the charge number of nanoparticles in nonpolar solvents together with precise size-tuning is a new research direction with many open questions, especially for exploiting the 2D self-assembly property in a toluene droplet."

Steven Trohalaki

First operation of a Pr:$YAlO_3$ microchip laser achieved at near-infrared wavelength

Microchip lasers are monolithic solid-state lasers that use a small single crystal as the gain medium. Typically these crystals are composed of a host crystal doped with ions such as neodymium Nd^{3+} or praseodymium (III) Pr^{3+}. In an effort to construct a laser that is both compact in size and operates at infrared laser wavelengths, M. Fibrich, H. Jelínková, and J. Šulcat of Czech Technical University in Prague and K. Nejezchleb and V. Škoda at Crytur Ltd. in Turnov created the first microchip praseodymium (III) yttrium aluminum oxide laser, $YAlO_3$ (YAP), Pr:YAP. These materials are ideal for laser use due to good thermal and mechanical properties and the ability to have high population inversion.

In the August 1st issue of *Optics Letters* (DOI:10.1364/OL.35.002556; p. 2556), the researchers described the fabrication and operation of the Pr:YAP laser microchip system. The system consisted of a GaN laser diode pump operating at 448 nm wavelength (which facilitates the excitation of electrons from lower to higher energy states in the microchip laser crystal), a collimating lens, a focusing lens, the Pr:YAP microchip laser crystal, and a filter all aligned in sequence. The cylindrical Pr:YAP crystal was Czochralski-grown, was 5 mm long and 5 mm in diameter, cut along the *b*-axis, and was free of cracks and twins. The Pr:YAP crystal was coated with dielectric films on both sides. The coating on one side was designed to transmit radiation from the GaN laser diode pump source and to be highly reflective at the microchip laser wavelength. The coating on the opposite side was designed to be 98% reflective for the microchip laser wavelengths generated at 747 nm and partially reflective of the pump laser diode light.

To analyze system performance, up to one watt of power was supplied to the system through the laser diode pump. The light beam generated from the pump laser diode passed through the collimating lens and was focused on the Pr:YAP crystal to a spot size of 60 µm. The pump beam was linearly polarized and oriented with polarization parallel to the *c*-axis of the microchip laser crystal. The spectral line shape of the microchip laser output radiation was measured using a fiber spectrometer to be 0.7 nm full width at half maximum. Laser oscillation threshold was achieved at a pump laser diode

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power of 430 mW. Slope efficiency was 25%. The maximum output power of the crystal was found to be 139 mW at approximately 747 nm with the pump laser diode operating at maximum capacity.

The researchers said that their previous work with the material showed that most of the power was absorbed in the material. The conclusion of the study was that the microchip laser system they designed can operate near wavelengths that produce visible/near-infrared radiation. And with further optimization the technology can be directly applicable to a variety of industries requiring infrared lasers.

Tara Washington

Plasma conditions measured in bubbles imploded by extreme sonoluminescence

High-intensity ultrasound waves traveling through liquid leave bubbles in their wake. Under the right conditions, these bubbles implode spectacularly, emitting light and reaching very high temperatures, a phenomenon called sonoluminescence. Researchers have observed imploding bubble conditions so hot that the gas inside the bubbles ionizes into plasma, but quantifying the temperature and pressure properties has been elusive.

Now University of lllinois professor Kenneth S. Suslick and former student David Flannigan, now at the California Institute of Technology, have experimentally determined the plasma electron density, temperature, and extent of ionization.

Suslick and Flannigan first observed super-bright sonoluminescence in 2005 by sending ultrasound waves through sulfuric acid solutions to create bubbles.

Plasma emission from collapsing bubbles: The imploding bubbles move around after each collapse, tracing out a lit path, like a person flinging their arm around while holding a flashlight. Photo courtesy Hangxun Xu and Ken Suslick.

"The energies of the populated atomic levels suggested a plasma, but at that time there was no estimate of the density of the plasma, a crucial parameter to understanding the conditions created at the core of the collapsing bubble," said Suslick, the Marvin T. Schmidt Professor of Chemistry and a professor of materials science and engineering.

The new work, published in the June 27th online edition of *Nature Physics* (DOI: 10.1038/NPHYS1701), uses the same setup, with a solution of concentrated sulphuric acid (85 wt%) containing Ar at 5% of saturation. The new work contains a detailed analysis of the shape of the observed Ar emission spectrum, which provides information on the conditions of the region around the atoms inside the bubble as it collapses.

"The temperature can be several times that of the surface of the sun and the pressure greater than that at the bottom of the deepest ocean trench," Suslick said.

"What's more," he said, "we were able to determine how these properties are affected by the ferocity with which the bubble collapses, and we found that the plasma conditions generated may indeed be extreme."

The researchers observed temperatures greater than 16,000 K—three times the temperature on the surface of the sun. They also measured electron densities during bubble collapse similar to those generated by laser fusion experiments. However, Suslick said that his group has not observed evidence that fusion takes place during sonoluminescence, as some have theorized possible.

In addition, the researchers found that plasma properties show a strong dependence on the violence of bubble implosion, and that the degree of ionization, or how much of the gas is converted to plasma, increases as the acoustic pressure increases.

"It is evident from these results that the upper bounds of the conditions generated during bubble implosion have yet to be established," Suslick said. "The observable physical conditions suggest the limits of energy focusing during the bubble-forming and imploding process may approach conditions achievable only by much more expensive means."

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