Nano Focus

Nanomechanical mass sensor boasts yoctogram resolution

Diverse fields of study, ranging from surface science to mass spectrometry, benefit from using nanomechanical sensors to weigh ever-smaller masses. In such sensors, the resonance frequency of a nanoscopic cantilever changes when additional mass is adsorbed onto its surface. As reported in the April 1 issue of the online journal *Nature Nanotechnology* (DOI: 10.1038/NNANO.2012.42), J. Chaste and co-workers at the Catalan Institute of Nanotechnology and the Institute of Materials Science of Barcelona have built a sensor that achieves a resolution of 1.7 yg (yg = 10^{-24} g), which is approximately the mass of one proton and is two orders of magnitude lower than anything previously reported.

At the center of their experimental system is a sensitive, suspended carbon nanotube (CNT) resonator, which is fabricated using conventional nanofabrication techniques. The nanotube is suspended over a narrow (~150 nm wide) trench. The operation of the setup relies on monitoring the variation in the resonance frequency of the nanotube when additional mass is adsorbed onto its surface. Annealing the nanotube by passing a large current through it is pivotal to improving the mass sensitivity; this current-induced cleansing removes stray molecules that are posited to diffuse between trapping sites, and dramatically reduces fluctuations in the resonance frequency. The resonator motion is driven and detected through the low-noise frequency modulation mixing technique at liquid He temperatures and at ultrahigh vacuum.

The remarkable sensitivity of the device was used to monitor molecular adsorption onto the carbon nanotube. The expected downward shift in the resonator's natural frequency was observed as naphthalene molecules were introduced into the device, with different shifts being attributed to the location of the adsorption along the nanotube. The scientists could also analyze the temperature-dependence of Xe adsorption onto the CNT, showing that the process is thermally activated and that the binding energy agrees with theoretical values (~130 meV).

It is envisaged that such sensors could be used for investigation of molecular diffusion along nanotubes, high sensitivity magnetometry measurements of magnetic nanoscale objects, and the development of mass spectrometers based on nanotube resonators.

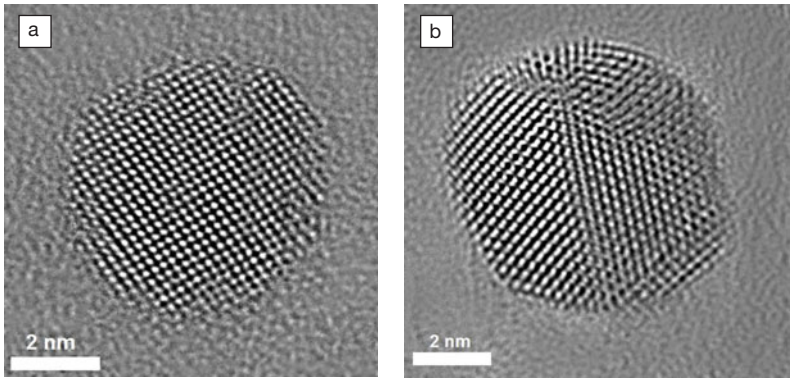
Rich Louie

Nano Focus

Plasmonic behavior of quantum-size metallic nanoparticles as investigated with STEM-EELS

The plasmon resonances of metallic nanoparticles can be exploited in many applications ranging from photovoltaics to the destruction of cancer cells, molecular detection, and solar energy harvesting. While the behavior of larger nanoparticles has been well-studied, research into the behavior of quantum-sized metallic nanoparticles (<10 nm in diameter) has been hindered by weak signals that are considerably broadened with decreasing nanoparticle size.

As reported in the March 22 issue of *Nature* (DOI: 10.1038/nature10904; p. 421), J. Scholl, A.L. Koh, and J. Dionne of Stanford University have adopted a unique approach to investigate the localized surface plasmon resonance (LSPR) properties of nanoparticles in the quantum-size regime. The researchers examined the behavior of individual silver nanospheres with diameters ranging from 2 nm to 20 nm using aberration-corrected transmission electron microscopy (TEM) imaging in conjunction with monochromated scanning TEM electron energy-loss spectroscopy (STEM-EELS). The silver nanospheres were synthesized without ligands to ensure that ligand damping effects did not influence the experiments.



Aberration-corrected transmission electron micrographs of silver nanoparticles synthesized free of stabilizing ligands: (a) 6 nm diameter, (b) 7 nm diameter. Reproduced by permission from *Nature* **483** (2012), DOI: 10.1038/nature10904; p. 421. ©2012 Macmillan Publishers, Ltd.

LSPR spectra were collected by focusing the STEM's electron beam at the edge of each sphere. The LSPR blue-shifted from 3.3 eV to 3.8 eV as the sphere diameter was decreased from 20 nm to 1.7 nm. This compares with a shift of only +0.03 eV predicted by classical Mie Theory over the same size range. The bulk plasmon resonance can also be detected with the STEM-EELS technique and exhibited a blueshift as the particle size decreased, although with a smaller magnitude than the surface plasmon resonance spectra.

To explain the observed behavior, the researchers developed an analytical model rooted in quantum theory that accounts for changes in the metal's electric

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