Engineers Devise New Method of Chemical Vapor Deposition for Smaller Nanostructures

October 18 2006

Engineers at the California Institute of Technology have invented an ingenious new method for depositing tiny amounts of materials on surfaces. The researchers say that the technique, known as plasmon-assisted chemical vapor deposition, will add a powerful new tool to the existing battery of techniques used to construct microdevices.

In the current issue of the journal *Nano Letters*, research scientist David Boyd and his colleagues at Caltech, Stanford University, and New York University report that the new vapor deposition process can be used with a variety of materials by focusing a low-powered laser beam onto a substrate coated with gold nanoparticles. The laser wavelength is chosen to match a natural resonance in the gold particles, and those particles in the small spot illuminated by the laser (about one micron in diameter, or less than a hundredth the diameter of a human hair) absorb energy from the laser and quickly heat up, rising in temperature several hundred degrees.

The gold particles become hot enough to decompose precursor molecules in the gas that strike them, forming microscopic deposits on the nanoparticles. Since this only happens for the hot gold particles in the laser spot, and not for the nearby cool ones outside the laser spot, structures form only where the laser shines, allowing deposition in patterns "drawn" by moving the laser spot on the substrate.

The key to the process is the surprisingly low thermal conductivity at the tiny scales involved, explains Boyd. The nanoparticles absorb energy from the laser very efficiently, but are much worse than bigger particles would be at getting rid of this energy by conducting heat away to the surroundings. As a result, the nanoparticles can be heated to temperatures much higher than expected based on classical concepts of heat conduction.

The process is simple to implement and requires only a small laser, about as powerful as a green laser pointer, says David Goodwin, a professor of mechanical engineering and applied physics at Caltech and a coauthor of the paper. The ability to write micron-scale or smaller structures directly, without need for lithographic patterning and etching, while also keeping the substrate cool outside the small laser spot, opens up new possibilities for the types of structures that may be easily fabricated, explains Goodwin.

To demonstrate the technique, the researchers grew nanowires of lead oxide on a glass substrate that were as small as a few tens of nanometers in diameter. Their results show promise that microdevices can be constructed at even smaller scales in the future.

So far, the team has worked with depositing titanium oxide, lead oxide, and cerium oxide in lab experiments, but says that many other materials should work just as well.

"Anything that can be deposited as a film by conventional means can probably be deposited with this technique," Boyd says.

The other authors of the paper are Leslie Greengard, of New York University's Courant Institute of Mathematical Sciences; Mark Brongersma, of Stanford University's department of materials science and engineering (and a former Caltech postdoc in applied physics); and Mohamed Y. El-Naggar, a former graduate student in mechanical engineering at Caltech, now doing postdoctoral work at USC.

The article is available online at dx.doi.org/10.1021/nl062061m

Source: Caltech