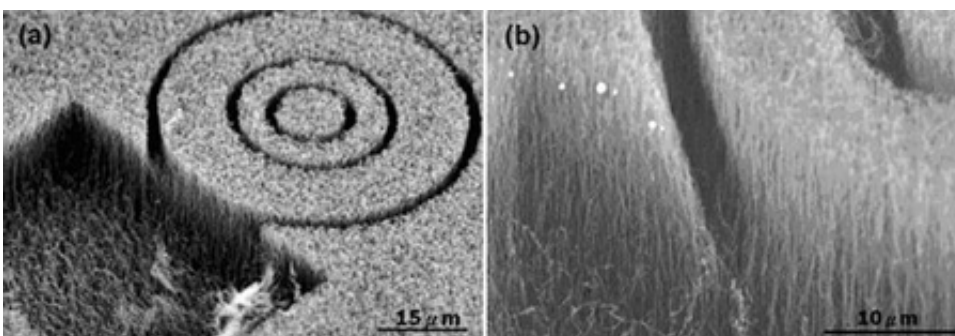


Scientists carve 3D microstructures in carbon nanotube forests

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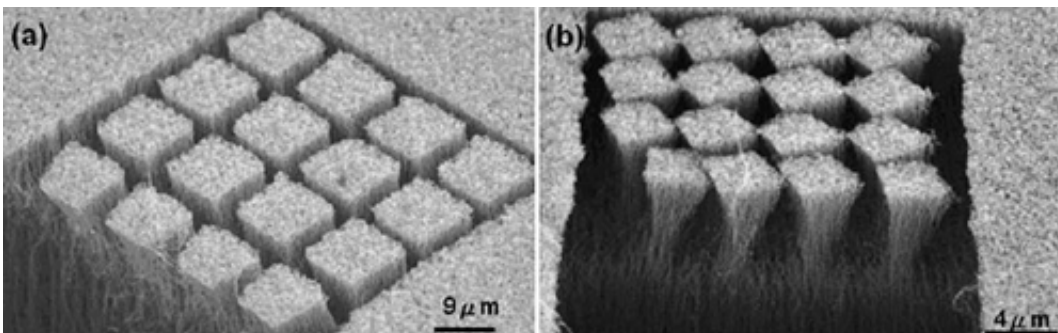
Cylindrical pattern created with the laser burn-out method, with a close-up.
Credit: Wei Hsuan Hung, et al.

Using a focused laser beam to selectively burn regions of a dense forest of multiwalled carbon nanotubes (MWNTs), researchers have demonstrated a method that may enable rapid prototyping of nanotube microstructures.

The researchers, from the University of Southern California and NASA's Jet Propulsion Laboratory, have published their results in a recent issue of *Applied Physics Letters*. They fabricated patterns in the nanotubes such as a staircase structure, cylindrical structures, and square arrays with the laser burning method, which might be used for creating gas and liquid transport channels for various applications.

“While carbon nanotubes possess many exceptional properties which far

exceed most known bulk materials, creating controlled nanotube structures has always been a challenge,” co-author Stephen Cronin told *PhysOrg.com*. “By overcoming this challenge, our technique enables chemically sensitive fields to take advantage of nanotubes’ exceptional properties and expand their possible applications into new areas.”



Square array created with the laser burn-out method, with a close-up. Credit: Wei Hsuan Hung, et al.

The researchers grew the MWNTs in a tube furnace heated to 650 degrees Celsius. Then they focused a high-powered 532-nm laser through a microscope onto the densely packed vertical nanotubes, burning some of the nanotubes to create the desired pattern. Burnout occurred in less than a second at an estimated temperature of around 800 degrees Celsius in air. The researchers found that burnout required a minimum laser power of 244 microwatts, and they tested the method with laser powers up to 9,000 microwatts.

“The initial burnout we observed came as quite a surprise and appeared very striking in our microscope images,” Cronin said. “Typically, carbon nanotubes lying on a silicon wafer are very difficult to heat with a laser.”

Until now, most attempts at patterning microstructures have been done with conventional lithography or other techniques. However, lithography is limited to 2D structures and leaves chemical residues that would be incompatible with biological applications. Other methods don't use nanotubes as the medium, and so cannot take advantage of nanotubes' desirable properties, such as mechanical strength, high surface area, and electrical and thermal conductivities.

Laser burnout seems to offer a good solution, as it's quick, doesn't involve chemicals, and the resolution is limited primarily by the spot size of the objective lens. Using Raman spectroscopy, a non-contact method for measuring the wavelength and intensity of scattered light, the researchers could determine the depth of the burn. This testing revealed that burnout depth increased with laser power, and the minimum burnout depth was 5 micrometers, which could be decreased further with the use of a higher numerical aperture microscope lens.

The researchers also noticed an interesting phenomenon that occurred after laser treatment, which was the development of white spots ranging in size from 100 to 200 nm on the top of the MWNT forests. A scanning electron microscope revealed that the white spots were nanotube bundles that aggregate during the burnout process, providing some insight into the dynamics of the process.

The researchers hope to use the technique to create well-defined gas and liquid transport channels as well as deep trenches for superhydrophobic microfluidic channels. The checker board-like arrays may also be suitable for field emission applications. Further, the researchers suggest that the method may serve as a basis for developing similar patterning methods in other material systems.

“Potential applications are on-chip DNA manipulation, chemical and protein identification, templates for directed stem cell growth, and gas

mixture separation,” said Cronin.

Citation: Hung, Wei Hsuan, Kumar, Rajay, Bushmaker, Adam, Cronin, Stephen B., and Bronikowski, Michael J. “Rapid prototyping of three-dimensional microstructures from multiwalled carbon nanotubes.” *Applied Physics Letters* 91, 093121 (2007).

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