Templates for Fabricating Nanowire/Nanoconduit-Based Devices

Prior templating processes are being extended to finer spatial resolutions.

NASA's Jet Propulsion Laboratory, Pasadena, California

An effort is underway to develop processes for making templates that could be used as deposition molds and etching masks in the fabrication of devices containing arrays of nanowires and/or nanoconduits. Examples of such devices include thermoelectric devices, nerve guidance scaffolds for nerve repair, photonic-band-gap devices, filters for trapping microscopic particles suspended in liquids, microfluidic devices, and size-selective chemical sensors. The technology is an extension of previous work conducted by JPL, UCSD (University of California, San Diego), and Paradigm Optics Inc., which developed a process to fabricate macroporous scaffolds for spinal-cord repair.

Highly-ordered, optical-fiber arrays consisting of dissimilar polymers comprise the template technology. The selective removal of the fiber cores in specific solvents creates the porous templates to be filled with a "top-down" deposition process such as electrochemical deposition, sputter deposition, molecular beam epitaxy, and the like.

Typically, the fiber bundles consist of polystyrene (PS) fiber cores, which are clad with varying thickness poly(methyl methacrylate) (PMMA). When arranged in hexagonal, close-packed configuration and pulled, the fibers form highly-ordered arrays comprised of PS fiber cores surrounded by a continuous matrix of PMMA. The ratio of PMMA cladding thickness to PS core diameter determines the spacing between PS fiber cores and typically ranges from 3:1 to 1:1.

Essentially, the simultaneous heating and drawing or pulling in the longitudinal direction of polymer-fiber arrays fuses the fibers to-gether. Since the fusing process is a constant volume process, a lateral or cross-section reduction is accompanied by a commensurate increase in length. Thus, the degree of pulling determines the final core dimensions.

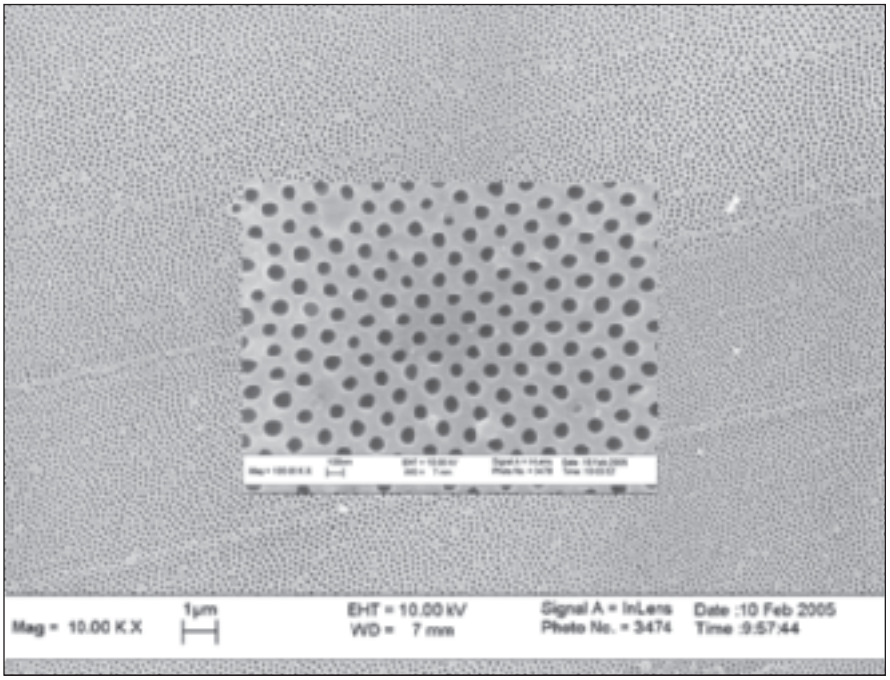

Figure 1. An **Image** from a scanning electron microscope shows the array of 100-nm diameter holes etched in a PMMA matrix.

Compared to previous work, where the fiber cores were in the range of 100 to 200 microns, the extent of pulling was significantly increased, thus resulting in a significant reduction in feature dimensions. The scanning electron microscope (Figure 1) image reveals the close packed array 100-nm diameter holes etched in a PMMA matrix (center image). The background image indicates that the hole monodispersity and order is maintained over relatively large areas. The original template length or fiber length was greater than 1 cm and the cross sectional dimension was 1 cm by 0.4 cm (Figure 2). In principle, the depth of the holes could be far greater than 1 mm, which could result in

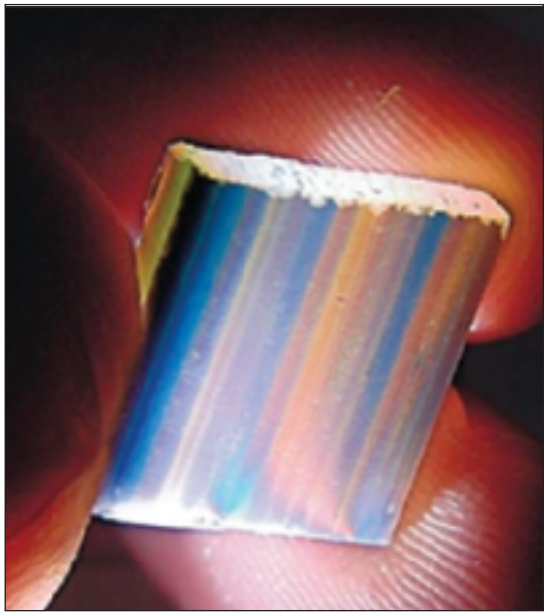

Figure 2. The **Nanotemplate**, approximately 1/2×1/2×1/8 inch (12.7×12.7×3.2 mm), contains about 60 fibers.

features with aspect ratios (length/diameter) in the 1,000 to 10,000 range.

This work was done by Jeffrey Sakamoto of Caltech for **NASA's Jet Propulsion Laboratory**, *and Todd Holt and David Welker of Paradigm Optics, Inc. Further information is contained in a TSP (see page 1).*

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Measuring Vapors To Monitor the State of Cure of a Resin

Excess curing time would no longer be needed as margin against uncertainty.

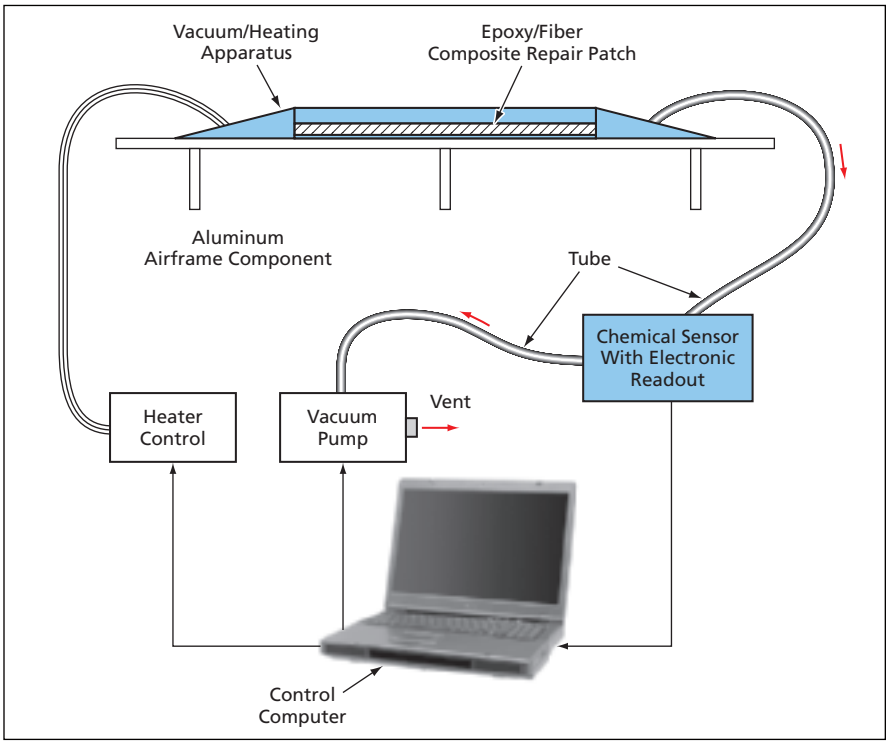
Langley Research Center, Hampton, Virginia

A proposed noninvasive method of monitoring the cure path and the state of cure of an epoxy or other resin involves measurement of the concentration(s) of one or more compound(s) in the vaporous effluent emitted during the curing process. The method is based on the following general ideas:

- The concentrations of the effluent compounds in the vicinity of the curing resin are approximately proportional to the instantaneous rate of curing.
- As curing proceeds at a given temperature, subsequent decreases in the concentrations are indicative of approaching completion of cure; that is, the lower are the concentrations, the more nearly complete is the cure.

The method could be utilized as the basis of a means of controlling the curing process to optimize the properties of the cured resin. It also could be utilized to minimize the cost of the curing process by ensuring a complete cure without the need to provide for excess curing time as margin against uncertainty in a prior estimate of required curing time.

A system to implement the method would include a sensor that produces electronic readouts of the concentrations of effluent compounds of interest. This sensor could be any of a variety of instruments, ranging from general-purpose full-size laboratory instruments capable of rapidly analyzing many compounds to microelectromechanical (MEMS) devices designed to detect effluent compounds specific to one epoxy. Either continuously or at regular intervals, the sensor would sample the effluent. Depending on the specific curing process, the sampling could occur at room temperature, at elevated temperature, under vacuum, or at atmospheric pressure: for example, in a case involving curing in a vacuum/heating apparatus, the sensor could be placed in the unheated tube from the vacuum bag to the vacuum pump.



Curing of Epoxy in a composite patch on an aluminum airframe component would be monitored by measuring concentrations of vaporous effluent compounds. The measurements could serve as feedback for controlling the vacuum pump and the heater.

The concentration(s) of the compound(s) of interest, and, thus, the rate of production of effluent would be monitored electronically and digitized to make a record of the curing process. Once the concentrations of the effluent compounds of interest decreased to predetermined levels, the cure would be considered complete and the operator would be so notified by the sensor circuitry. Alternatively, as depicted schematically in the figure, the sensor could be integrated into a control loop that would turn off the curing apparatus upon completion of the cure. Further, the control loop could be configured for active control to maintain the rate of curing at a predetermined level by monitoring the effluent-production rate and automatically adjusting the temperature and/or the pressure of the partial vacuum.

This work was done by K. Elliott Cramer, Daniel F. Perey, and William T. Yost of **Langley Research Center**. *Further information is contained in a TSP (see page 1).*

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