



# Technology Focus: Nano Materials & Manufacturing

## Nanotip Carpets as Antireflection Surfaces

Reflectance less than  $10^{-3}$  is readily achieved.

NASA's Jet Propulsion Laboratory, Pasadena, California

Carpetlike random arrays of metal-coated silicon nanotips have been shown to be effective as antireflection surfaces. Now undergoing development for incorporation into Sun sensors that would provide guidance for robotic exploratory vehicles on Mars, nanotip carpets of this type could also have many uses on Earth as antireflection surfaces in instruments that handle or detect ultraviolet, visible, or infrared light.

In the original Sun-sensor application, what is required is an array of 50- $\mu\text{m}$ -diameter apertures on what is otherwise an opaque, minimally reflective surface, as needed to implement a miniature multiple-pinhole camera. The process for fabrication of an antireflection nanotip carpet for this application (see Figure 1) includes, and goes somewhat beyond, the process described in "A New Process for Fabricating Random Silicon Nanotips" (NPO-40123), *NASA Tech Briefs*, Vol. 28, No. 1 (November 2004), page 62. In the first step, which is not part of the previously reported process, photolithography is performed to deposit

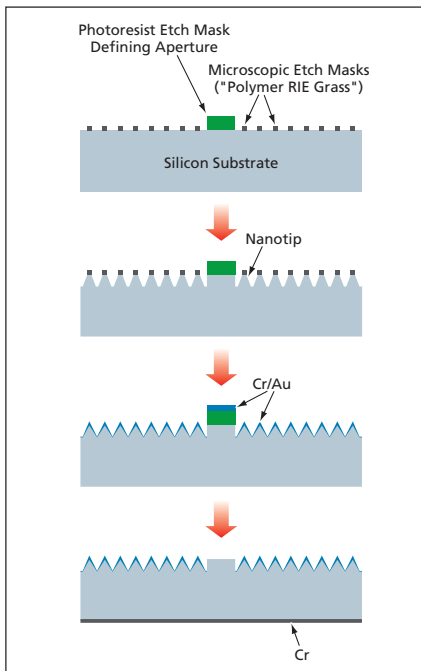
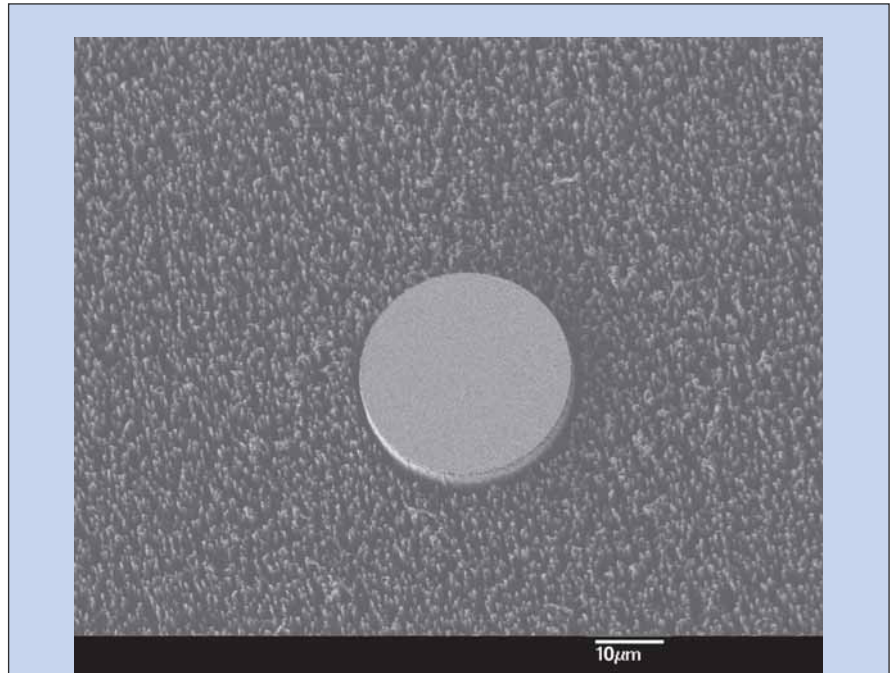
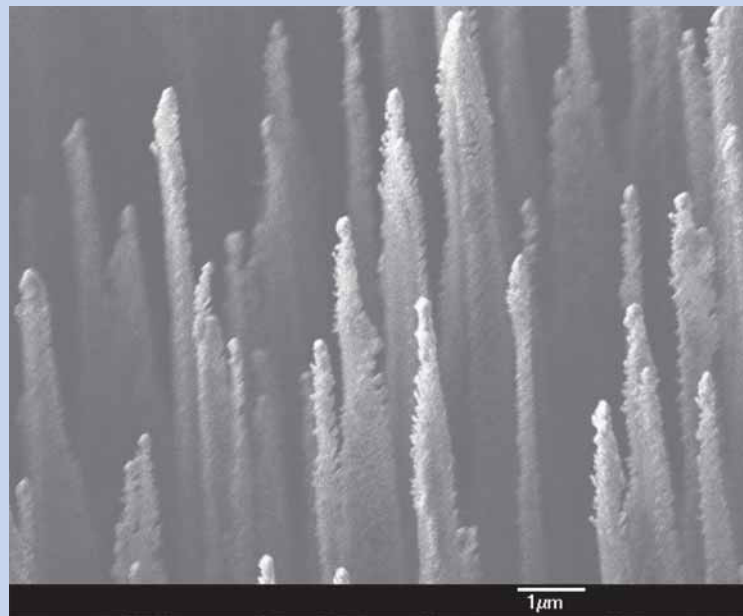


Figure 1. A Random Array of Nanotips is formed on the flat substrate surface surrounding an aperture. The nanotips are coated with Cr/Au to enhance absorption of light. The Cr layer on the rear surface serves as a light attenuator.



Nanotip Carpet Surrounding an Aperture



Enlarged Detail Showing Nanotips

Figure 2. The Antireflection Nanotip Carpet surrounding the aperture absorbs most of the incident light. The reflectance of the carpet at a wavelength of 1  $\mu\text{m}$  was found to be 0.06 percent of that of an aluminum mirror.

etch masks to define the 50- $\mu\text{m}$  apertures on a silicon substrate. In the second step, which is part of the previously reported process, the non-masked silicon area between the apertures is subjected to reactive ion etching (RIE) under a special combination of conditions that results in the growth of fluorine-based compounds in randomly distributed formations, known in the art as "polymer RIE grass," that have dimensions of the order of microns.

The polymer RIE grass formations serve as microscopic etch masks during the next step, in which deep reactive ion etching (DRIE) is performed. What remains after DRIE is the carpet of nano-

tips, which are high-aspect-ratio peaks, the tips of which have radii of the order of nanometers. Next, the nanotip array is evaporatively coated with Cr/Au to enhance the absorption of light (more specifically, infrared light in the Sun-sensor application). The photoresist etch masks protecting the apertures are then removed by dipping the substrate into acetone. Finally, for the Sun-sensor application, the back surface of the substrate is coated with a 57-nm-thick layer of Cr for attenuation of sunlight.

*This work was done by Youngsam Bae, Sohrab Mobasser, Harish Manohara, and Choonsup Lee of Caltech for NASA's Jet*

*Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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*Refer to NPO-42592, volume and number of this NASA Tech Briefs issue, and the page number.*

## Nano-Engineered Catalysts for Direct Methanol Fuel Cells

**Small particle sizes and large surface areas can be produced economically and consistently.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

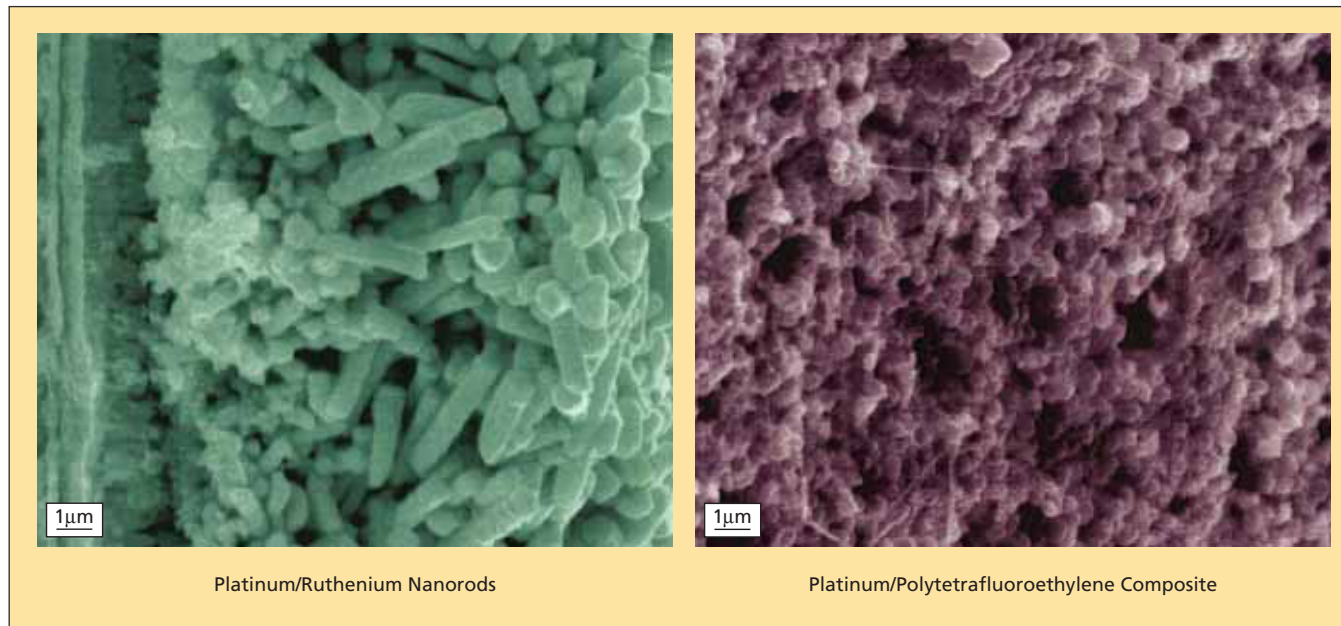
Nano-engineered catalysts, and a method of fabricating them, have been developed in a continuing effort to improve the performances of direct methanol fuel cells as candidate power sources to supplant primary and secondary batteries in a variety of portable electronic products. In order to realize the potential for high energy densities (as much as 1.5 W·h/g) of direct methanol fuel cells, it will be necessary to optimize the chemical compositions and geometric configurations of catalyst layers and electrode structures. High performance

can be achieved when catalyst particles and electrode structures have the necessary small feature sizes (typically of the order of nanometers), large surface areas, optimal metal compositions, high porosity, and hydrophobicity.

The present method involves electrodeposition of one or more catalytic metal(s) or a catalytic-metal/polytetrafluoroethylene nanocomposite on an alumina nanotemplate. The alumina nanotemplate is then dissolved, leaving the desired metal or metal/polytetrafluoroethylene-composite catalyst layer. Unlike some prior methods

of making fine metal catalysts, this method does not involve processing at elevated temperature; all processing can be done at room temperature. In addition, this method involves fewer steps and is more amenable to scaling up for mass production.

Alumina nanotemplates are porous alumina membranes that have been fabricated, variously, by anodizing either pure aluminum or aluminum that has been deposited on silicon by electron-beam evaporation. The diameters of the pores (7 to 300 nm), areal densities of



**These Are Scanning Electron Micrographs** of catalysts fabricated by the method described in the text. The platinum/ruthenium rods, about 0.2  $\mu\text{m}$  wide and 1  $\mu\text{m}$  long, were electrodeposited from a plating bath containing  $\text{H}_2\text{PtCl}_6$ ,  $\text{K}_2\text{RuCl}_5$ , and  $\text{H}_2\text{SO}_4$ . The platinum/polytetrafluoroethylene composite was electrodeposited from a solution containing  $\text{H}_2\text{PtCl}_6$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{CH}_3\text{OH}$ , and suspended polytetrafluoroethylene nanoparticles having sizes from 0.1 to 0.2  $\mu\text{m}$ .