Diamond Machining of an Off-Axis Biconic Aspherical Mirror

Complex shapes can be produced at relatively low costs.

Goddard Space Flight Center, Greenbelt, Maryland

Two diamond-machining methods have been developed as part of an effort to design and fabricate an off-axis, biconic ellipsoidal, concave aluminum mirror for an infrared spectrometer at the Kitt Peak National Observatory. Beyond this initial application, the methods can be expected to enable satisfaction of requirements for future instrument mirrors having increasingly complex (including asymmetrical), precise shapes that, heretofore, could not readily be fabricated by diamond machining or, in some cases, could not be fabricated at all.

In the initial application, the mirror is prescribed, in terms of Cartesian coordinates x and y, by aperture dimensions of 94 by 76 mm, placements of –2 mm off axis in x and 227 mm off axis in y, an x radius of curvature of 377 mm, a y radius of curvature of 407 mm, an x conic constant of 0.078, and a y conic constant of 0.127. The aspect ratio of the mirror blank is about 6.

One common, "diamond machining" process uses single-point diamond turning (SPDT). However, it is impossible to generate the required off-axis, biconic ellipsoidal shape by conventional SPDT because (1) rotational symmetry is an essential element of conventional SPDT and (2) the present off-axis biconic mirror shape lacks rotational symmetry. Following conventional practice, it would be necessary to make this mirror from a glass blank by computer-controlled polishing, which costs more than diamond machining and yields a mirror that is more difficult to mount to a metal bench.

One of the two present diamond-machining methods involves the use of an SPDT machine equipped with a fast tool servo (FTS). The SPDT machine is programmed to follow the rotationally symmetric asphere that best fits the desired off-axis, biconic ellipsoidal surface. The FTS is actuated in synchronism with the rotation of the SPDT machine to generate the difference between the desired surface and the best-fit rotationally symmetric asphere. In order to minimize the required stroke of the FTS, the blanks were positioned at a large off-axis distance and angle, and the axis of the FTS was not parallel to the axis of the spindle of the SPDT machine. The spindle was rotated at a speed of 120 rpm, and the maximum FTS speed was 8.2 mm/s.

In the second diamond-machining method, the desired mirror surface is generated by raster fly-cutting on a multiaxis machine, all three Cartesian axes of which are actuated simultaneously. The diamond tool cuts through a mirror blank in a "down milling" mode with toric cutter compensation. In the original application, the fly-cut radius was 63 mm, the tool nose radius was 10 mm, and the finish cut lasted 16 hours.

This work was done by Raymond G. Ohl of Goddard Space Flight Center, Werner Preuss of the University of Bremen, Alex Sohn of North Carolina State University, and John W. MacKenty of Space Telescope Science Institute. Further information is contained in a TSP (see page 1). GSC-14967-1

Laser Ablation Increases PEM/Catalyst Interfacial Area

Increased interfacial area is expected to result in improved fuel-cell performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

An investigational method of improving the performance of a fuel cell that contains a polymer-electrolyte membrane (PEM) is based on the concept of roughening the surface of the PEM, prior to deposition of a thin layer of catalyst, in order to increase the PEM/catalyst interfacial area and thereby increase the degree of utilization of the catalyst. The roughening is done by means of laser ablation under carefully controlled conditions. Next, the roughened membrane surface is coated with the thin layer of catalyst (which is typically platinum), then sandwiched between two electrode/catalyst structures to form a membrane/electrode assembly.

The feasibility of the roughening technique was demonstrated in experiments in which proton-conducting membranes made of a perfluorosulfonic acid-based hydrophilic, proton-conducting polymer were ablated by use

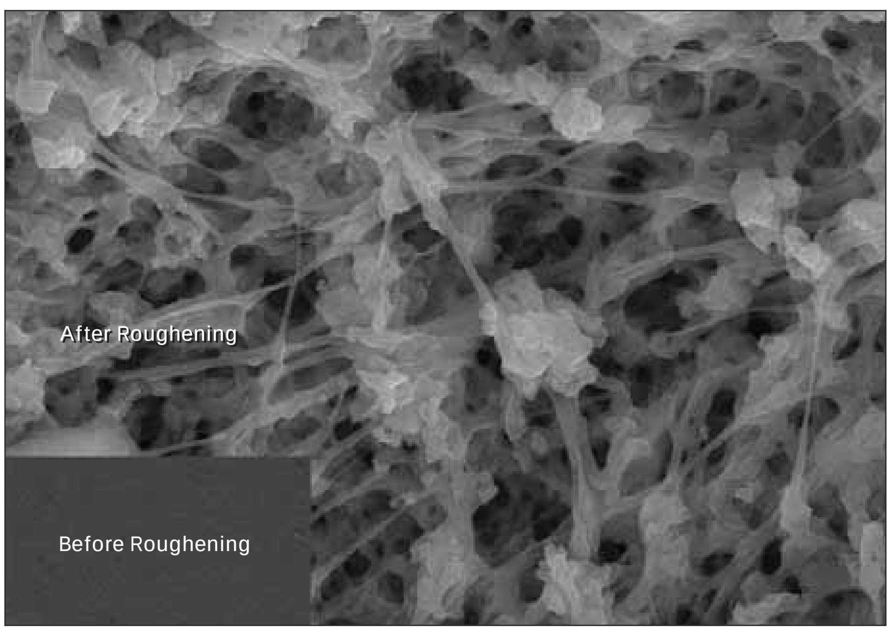

Figure 1. This **Scanning Electron Micrograph** shows portions of a PEM before and after roughening by laser ablation.

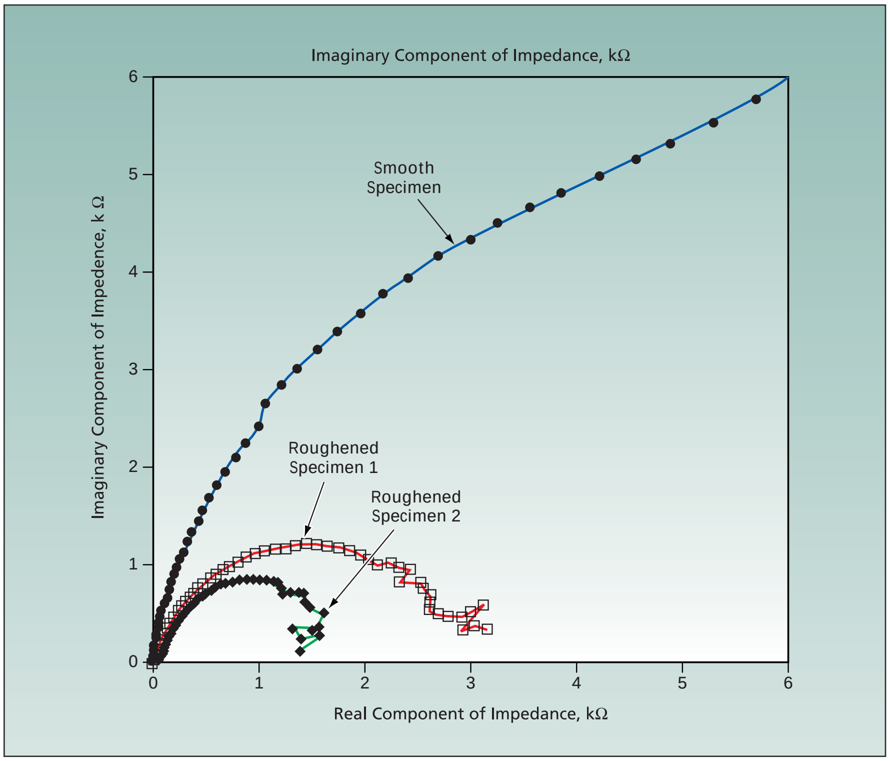

Figure 2. These **EIS Data** were acquired in measurements at frequencies from 100 kHz down to 10 mHz on 0.4-mm-thick smooth and roughened PEMs that had lateral dimensions of 3 by 3 mm, were 0.4 mm thick, and were coated with Pt on both faces. The smaller imaginary components of impedance of the roughened specimens are attributed to greater capacitances, which, in turn, are attributed to greater surface areas. Roughened specimens 1 and 2 were subjected to different laser-ablation conditions.

of femtosecond laser pulses. It was found that when proper combinations of the pulse intensity, pulse-repetition rate, and number of repetitions was chosen, the initially flat, smooth membrane surfaces became roughened to such an extent as to be converted to networks of nodules interconnected by filaments (see Figure 1).

In further experiments, electrochemical impedance spectroscopy (EIS) was performed on a pristine (smooth) membrane and on two laser-roughened membranes after the membranes were coated with platinum on both sides. Some preliminary EIS data were interpreted as showing that notwithstanding the potential for laser-induced damage, the bulk conductivities of the membranes were not diminished in the roughening process. Other preliminary EIS data (see Figure 2) were interpreted as signifying that the surface areas of the laser-roughened membranes were significantly greater than those of the smooth membrane. Moreover, elemental analyses showed that the sulfur-containing molecular groups necessary for proton conduction remained intact, even near the laser-roughened surfaces. These preliminary results can be taken as indications that laser-roughened PEMs should function well in fuel cells and, in particular, should exhibit current and power densities greater than those attainable by use of smooth membranes.

This work was done by Jay Whitacre of Caltech and Steve Yalisove of the University of Michigan for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). *NPO-45075*