

## Diamond Machining of an Off-Axis Biconic Aspherical Mirror

Complex shapes can be produced at relatively low costs.

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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 turn-

ing (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 re-

quired 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 multi-axis 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.

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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

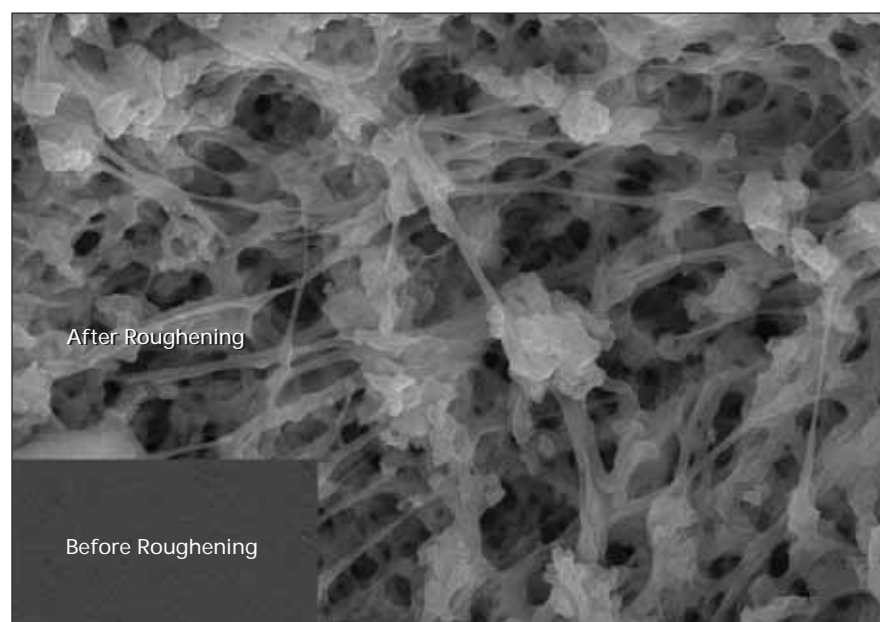


Figure 1. This Scanning Electron Micrograph shows portions of a PEM before and after roughening by laser ablation.