



## Adjustable Membrane Mirrors Incorporating G-Elastomers

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

Lightweight, flexible, large-aperture mirrors of a type being developed for use in outer space have unimorph structures that enable precise adjustment of their surface figures. A mirror of this type includes a reflective membrane layer bonded with an electrostrictive grafted elastomer (G-elastomer) layer, plus electrodes suitably positioned with respect to these layers. By virtue of the electrostrictive effect, an electric field applied to the G-elastomer membrane induces a strain along the membrane and thus causes a deflection

of the mirror surface. Utilizing this effect, the mirror surface figure can be adjusted locally by individually addressing pairs of electrodes.

G-elastomers, which were developed at NASA Langley Research Center, were chosen for this development in preference to other electroactive polymers partly because they offer superior electro-mechanical performance. Whereas other electroactive polymers offer, variously, large strains with low moduli of elasticity or small strains with high moduli of elasticity, G-elastomers offer both large strains

(as large as 4 percent) and high moduli of elasticity (about 580 MPa). In addition, G-elastomer layers can be made by standard melt pressing or room-temperature solution casting.

*This work was done by Zensheu Chang and Rhonda M. Morgan of Caltech, Eui-Hyeok Yang of Stevens Institute of Technology, Yoshikazu Hishinuma of Fuji Film Corp., and Ji Su and Tian-Bing Xu of NASA Langley Research Center for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-45616*

## Hall-Effect Thruster Utilizing Bismuth as Propellant

*Marshall Space Flight Center, Alabama*

A laboratory-model Hall-effect spacecraft thruster was developed that utilizes bismuth as the propellant. Xenon was used in most prior Hall-effect thrusters. Bismuth is an attractive alternative because it has a larger atomic mass, a larger electron-impact-ionization cross-section, and is cheaper and more plentiful.

The design of this thruster includes multiple temperature-control zones and other features that reduce parasitic power losses. Liquid bismuth (which

melts at a temperature of 271°C) is supplied by a temperature-controlled reservoir to a vaporizer. The vaporizer exhausts to an anode/gas distributor inside a discharge channel that consists of a metal chamber upstream of ceramic exit rings. In the channel, bismuth ions are produced through an electron impact ionization process and accelerated as in other Hall-effect thrusters. The discharge region is heated by the discharge and an auxiliary anode heater, which is required to prevent bismuth condensa-

tion at low power levels and at thruster start-up. A xenon discharge is also used for preheating the discharge channel, but an anode heater could provide enough power to start the bismuth discharge directly.

*This work was done by James Szabo, Charles Gasdaska, Vlad Hruby, and Mike Robin of Busek Co., Inc. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at [sammy.a.nabors@nasa.gov](mailto:sammy.a.nabors@nasa.gov). Refer to MFS-32440-1.*

## High-Temperature Crystal-Growth Cartridge Tubes Made by VPS

**Mechanical properties and maximum useful temperature exceed those of tungsten-alloy tubes.**

*Marshall Space Flight Center, Alabama*

Cartridge tubes for use in a crystal-growth furnace at temperatures as high as 1,600°C have been fabricated by vacuum plasma spraying (VPS). These cartridges consist mainly of an alloy of 60 weight percent molybdenum with 40 weight percent rhenium, made from molybdenum powder coated with rhenium. This alloy was selected because of its high melting temperature

(≈2,550°C) and because of its excellent ductility at room temperature. These cartridges are intended to supplant tungsten/nickel-alloy cartridges, which cannot be used at temperatures above ≈1,300°C.

Graphite mandrels were used as substrates for VPS to form the cartridge tubes to the desired size and shape. A mandrel was placed in the

VPS chamber, oriented vertically. Before spraying, the plasma gun was used to heat the mandrel to a temperature of about 1,093°C. Then, the Mo/Re alloy precursor powder was deposited by VPS on the mandrel to a thickness between 0.51 and 0.64 mm. The deposition was done in one pass, spraying from the top to the bottom of the mandrel.