Materials

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 electromechanical 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. 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 condensation 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. 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.

Then a tantalum coat was deposited in a similar manner onto the Mo/Re deposit to a thickness between 0.13 and 0.18 mm. The tantalum coat serves as a sealing layer, increasing the protection of the Mo/Re alloy against the formation of such volatile oxides as MoO_3.

Next, the pressure in the chamber was reduced to <100 mtorr (less than about 13 Pa) and the cartridge allowed to cool. Once the cartridge had cooled to room temperature, the chamber was opened to the atmosphere and the cartridge was removed from the mandrel.

A cross section of a representative cartridge tube fabricated in this process showed a good bond between the tantalum coat and the main body of Mo/Re alloy. Both the Mo/Re and the Ta were dense. Because this tube was not heat treated, the Mo/Re-alloy layer still contained two phases — one Mo-rich and one Re-rich. Tests of the mechanical properties of tubes like this one in the as-sprayed condition have revealed a vast improvement over similar tungsten-alloy tubes in the as-sprayed condition.

This work was done by Richard Holmes of Marshall Space Flight Center and Scott O'Dell, Timothy McKechnie, and Christopher Power of Plasma Processes, Inc. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. MFS-31540-1

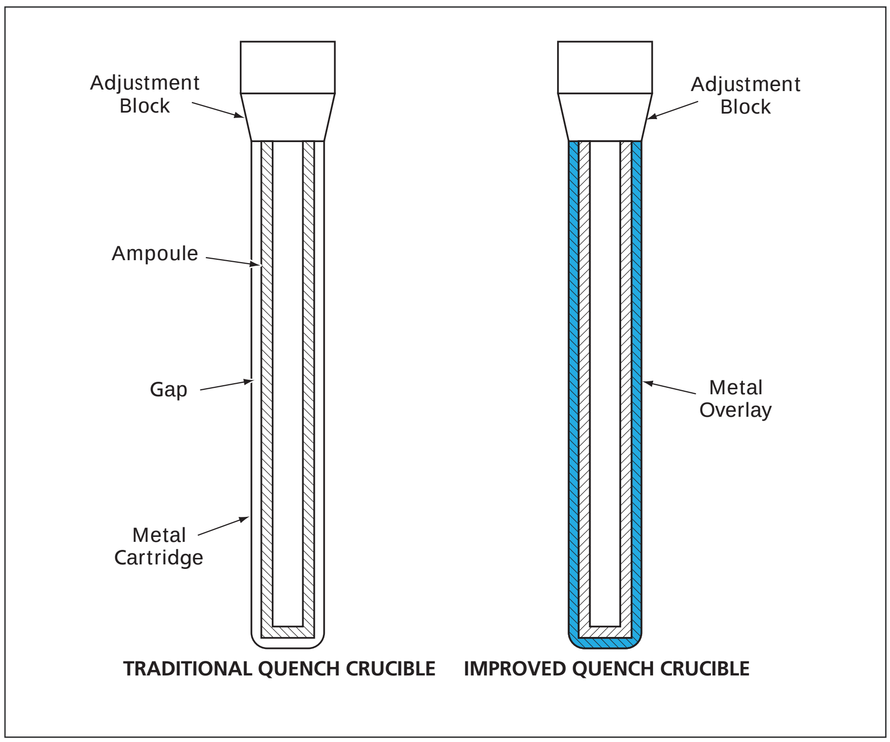
Quench Crucibles Reinforced With Metal

Specimens can be quenched rapidly, without cracking ampules.

Marshall Space Flight Center, Alabama

Improved crucibles consisting mainly of metal-reinforced ceramic ampules have been developed for use in experiments in which material specimens are heated in the crucibles to various high temperatures, then quenched by, for example, plunging the crucibles into water at room temperature. A quench crucible of the traditional type intended to be supplanted by the improved crucibles consists mainly of a ceramic or graphite ampule inside a metal cartridge, with a gap between the metal and the cartridge, as shown on the left side of the figure.

The need for the improved quench crucibles arises as follows: In a traditional quench crucible, the gap between the ampule and the metal cartridge impedes the transfer of heat to such a degree that the quench rate (the rate of cooling of the specimen) can be too low to produce the desired effect in the specimen. One can increase the quench rate by eliminating the metal cartridge to enable direct quenching of the ampule, but then the thermal shock of direct quenching causes cracking of the ampule.



The **Metal Cartridge and Gap** surrounding the ampule are replaced with an overlay of metal in intimate contact with the ampule.

In a quench crucible of the present improved type, there is no gap and no metal cartridge in the traditional sense. Instead, there is an overlay of metal in direct contact with the ampule, as shown on the right side of the figure. Because there is no gap between the metal overlay and the ampule, the heat-transfer rate can be much greater than it is in a traditional quench crucible. The metal overlay also reinforces the ampule against cracking.

The choice of ampule material and metal depends on the specific application. In general, the ampule material should be chemically compatible with the specimen material. The overlay metal should be chosen to have a coefficient of thermal expansion (CTE) as close as possible to that of the ampule material. Examples of suitable ampule/metal-overlay material pairs include the following:

- graphite (CTE = 8.0×10^{-6} K^{-1}) and stainless steel (CTE = 9.9×10^{-6} K^{-1})
- aluminum nitride (CTE = 5.2×10^{-6} K^{-1}) and tungsten heavy alloy (CTE = 5.0×10^{-6} K^{-1}) and
- silicon carbide (CTE = 4.5×10^{-6} K^{-1}) and tungsten heavy alloy (CTE = 5.0×10^{-6} K^{-1}).

Several thermal-spray processes for applying metal overlays to ampules were investigated. Of these processes, vacuum plasma spraying was found to yield the best results.

This work was done by Richard R. Holmes and Edgar Carrasquillo of Marshall Space Flight Center and J. Scott O'Dell and Timothy N. McKechnie of Plasma Processes Inc. For further information, contact Sammy Nabors, MSFC Commercialization Lead, at sammy.a.nabors@nasa.gov. MFS-31598-1