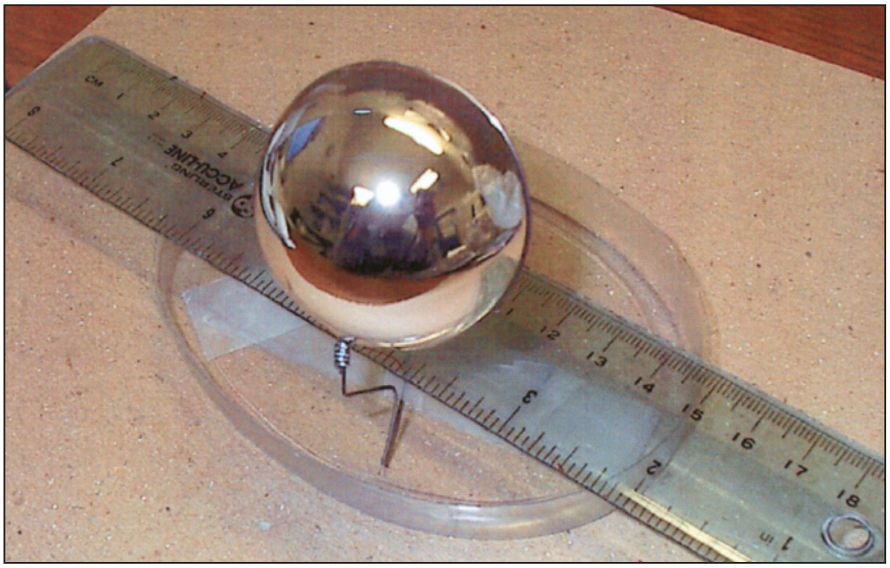
Manufacturing

Fabrication of Spherical Reflectors in Outer Space

Process takes advantage of vacuum.

NASA's Jet Propulsion Laboratory, Pasadena, California

A process is proposed for fabrication of lightweight spherical reflectors in outer space for telescopes, radio antennas, and light collectors that would be operated there. The process would obviate the relatively massive substrates and frames needed to support such reflectors in normal Earth gravitation. According to the proposal, fabrication of a reflector would begin with blowing of a bubble to the specified reflector radius. Taking advantage of the outer-space vacuum as a suitable environment for evaporative deposition of metal, a metal-evaporation source would be turned on and moved around the bubble to deposit a reflective metal film over the specified reflector area to a thickness of several microns. Then the source would be moved and aimed to deposit more metal around the edge of the reflector area, increasing the thickness there to ≈100 µm to form a frame. Then the bubble would be deflated and peeled off the metal, leaving a thin-film spherical mirror having an integral frame. The mirror would then be mounted for use.



A **Prototype Reflector** was successfully produced, showing that the proposed fabrication is practicable.

The feasibility of this technology has been proved by fabricating a prototype at JPL. As shown in the figure, a 2-in. (≈5-cm) diameter hemispherical prototype reflector was made from a polymer bubble coated with silver, forming a very smooth surface.

This work was done by Yu Wang, Jennifer Dooley, and Mark Dragovan of Caltech and Wally Serivens of the University of South Carolina for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1). NPO-30649*

Automated Rapid Prototyping of 3D Ceramic Parts

Unlike in prior rapid-prototyping processes, there is no manual stacking of sheets.

Marshall Space Flight Center, Alabama

An automated system of manufacturing equipment produces three-dimensional (3D) ceramic parts specified by computational models of the parts. The system implements an advanced, automated version of a generic rapid-prototyping process in which the fabrication of an object having a possibly complex 3D shape includes stacking of thin sheets, the outlines of which closely approximate the horizontal cross sections of the object at their respective heights. In this process, the thin sheets are made of a ceramic precursor material, and the stack is subsequently heated to transform it into a unitary ceramic object.

In addition to the computer used to generate the computational model of the part to be fabricated, the equipment used in this process includes:

- A commercially available laminated-object-manufacturing machine that was originally designed for building woodlike 3D objects from paper and was modified to accept sheets of ceramic precursor material, and
- A machine designed specifically to feed single sheets of ceramic precursor material to the laminated-object-manufacturing machine.

Like other rapid-prototyping processes that utilize stacking of thin sheets, this process begins with generation of the computational model of the part to be fabricated, followed by computational sectioning of the part into layers of predetermined thickness that collectively define the shape of the part. Information about each layer is transmitted to rapid-prototyping equipment, where the part is built layer by layer.

What distinguishes this process from other rapid-prototyping processes that utilize stacking of thin sheets are the details of the machines and the actions that they perform. In this process, flexible sheets of ceramic precursor material (called "green" ceramic sheets) suitable for lamination are produced by tape casting. The binder used in the tape casting is specially formulated to enable lamination of layers with little or no applied heat or pressure. The tape is cut into individual sheets, which are stacked in the sheet-feeding machine until used. The sheet-feeding machine can hold enough sheets for about 8 hours of continuous operation.

A vacuum chuck in the sheet-feeding machine picks up a single green ceramic sheet. The sheet is then coated with a lamination-aiding material. The coated sheet is wrapped around a roller, on which it is transported into the laminated-object-manufacturing machine. There, the roller is actuated in such a manner as to laminate the coated sheet onto the stack of previously laminated and cut sheets.

Once the sheet has been thus incorporated as the top layer of the stack, control of the operation is passed back to the laminated-object-manufacturing machine. A carbon dioxide laser that is part of the laminated-object-manufacturing machine cuts the desired cross-sectional outline out of the top layer. (To make this possible, the laser operating parameters are adjusted, in accordance with the composition and thickness of the layers, so that only the top layer is cut.) The motion of the laser and thus the cutting path are determined by the computational specification of the cross-section represented by the just-added top layer.

The excess layer material lying outside the cross section is temporarily left in place to provide support as the 3D object is built. In addition to cutting the outline of the cross section, the laser cuts the excess layer material into tiles to facilitate removal of supporting material from around the 3D object after completion of the stack. After the cutting is finished, control is passed back to the sheet-feeding machine, which then laminates the next sheet onto the stack. The laminating and cutting steps are repeated until the stack is complete. The supporting material is then removed. Finally, the green ceramic stack is heat-treated in a furnace to remove the binder and sinter the ceramic to high density. This process has been used to make objects from diverse engineered ceramics, including alumina, zirconia, silicon carbide, aluminum nitride, silicon nitride, aluminum silicates, hydroxyapatite, and various titanates.

This work was done by Scott G. McMillin, Eugene A. Griffin, and Curtis W. Griffin of Lone Peak Engineering, Inc.; and Peter W. H. Coles and James D. Engle, Jr., of Automation Engineering, LLC for **Marshall Space Flight Center**. *For further information, contact the company at www.javelin3d.com.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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