Manufacturing & Prototyping

Graphite Composite Panel Polishing Fixture

Composite fixture eliminates problems that may be caused by those made from aluminum.

Goddard Space Flight Center, Greenbelt, Maryland

The use of high-strength, lightweight composites for the fixture is the novel feature of this innovation. The main advantage is the light weight and high stiffness-to-mass ratio relative to aluminum.

Meter-class optics require support during the grinding/polishing process with large tools. The use of aluminum as a polishing fixture is standard, with pitch providing a compliant layer to allow support without deformation. Unfortunately, with meter-scale optics, a meter-scale fixture weighs over 120 lb (≈55 kg) and may distort the optics being fabricated by loading the mirror and/or tool used in fabrication. The use of composite structures that are lightweight yet stiff allows standard techniques to be used while providing for a decrease in fixture weight by almost 70 percent.

Mounts classically used to support large mirrors during fabrication are especially heavy and difficult to handle. The mount must be especially stiff to avoid deformation during the optical fabrication process, where a very large and heavy lap often can distort the mount and optic being fabricated. If the optic is placed on top of the lapping tool, the weight of the optic and the fixture can distort the lap. Fixtures to support the mirror during fabrication are often very large plates of aluminum, often 2 in. (≈5 cm) or more in thickness and weight upwards of 150 lb (≈68 kg). With the addition of a backing material such as pitch and the mirror itself, the assembly can often weigh over 250 lb (≈113 kg) for a meter-class optic.

This innovation is the use of a lightweight graphite panel with an aluminum honeycomb core for use as the polishing fixture. These materials have been used in the aerospace industry as structural members due to their light weight and high stiffness. The grinding polishing fixture consists of the graphite composite panel, fittings, and fixtures to allow interface to the polishing machine, and introduction of pitch buttons to support the optic under fabrication. In its operation, the grinding polishing fixture acts as a reaction structure to the polishing tool. It must be stiff enough to avoid imparting a distorted shape to the optic under fabrication and light enough to avoid self-deflection. The fixture must also withstand significant tangential loads from the polishing machine during operations.

This work was done by John Hagopian, Carl Strojny, and Jason Budinoff of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15911-1

Material Gradients in Oxygen System Components Improve Safety

Lyndon B. Johnson Space Center, Houston, Texas

Oxygen system components fabricated by Laser Engineered Net Shaping™ (LENS™) could result in improved safety and performance. LENS™ is a near-net shape manufacturing process fusing powdered materials injected into a laser beam. Parts can be fabricated with a variety of elemental metals, alloys, and nonmetallic materials without the use of a mold. The LENS™ process allows the injected materials to be varied throughout a single workpiece. Hence, surfaces exposed to oxygen could be constructed of an oxygen-compatible material while the remainder of the part could be one chosen for strength or reduced weight. Unlike conventional coating applications, a compositional gradient would exist between the two materials, so no abrupt material boundary exists. Without an interface between dissimilar materials, there is less tendency for chipping or cracking associated with thermal-expansion mismatches.

This work was done by Bradley S. Forsyth of Honeywell Technology Solutions, Inc., for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-23166-1

Ridge Waveguide Structures in Magnesium-Doped Lithium Niobate

Goddard Space Flight Center, Greenbelt, Maryland

This work proposes to establish the feasibility of fabricating isolated ridge waveguides in 5% MgO:LN. Ridge waveguides in MgO:LN will significantly improve power handling and conversion efficiency, increase photonic component integration, and be well suited to space-based applications. The key innovation in this effort is to combine recently available large, high-photorefractive-damage-threshold, z-cut 5% MgO:LN with novel ridge fabrication techniques to achieve high-optical power, low-cost, high-volume manufacturing of frequency conversion structures. The proposed ridge waveguide structure should maintain the characteristics of the periodically poled bulk substrate, allowing for the efficient frequency conversion typical of waveguides and the high optical damage threshold and long lifetimes typical of the 5% doped bulk substrate. The low cost and large area of 5% MgO:LN wafers, and the improved performance of the proposed ridge waveguide structure, will enhance existing measurement capabilities as well as reduce the resources required to achieve high-performance specifications.

The purpose of the ridge waveguides in MgO:LN is to provide platform technology that will improve optical power handling and conversion efficiency compared to existing waveguide technology. The proposed ridge waveguide is produced using standard microfabrication techniques. The approach is enabled by recent advances in inductively coupled plasma etchers and chemical mechanical planarization techniques. In conjunction with wafer bonding, this fabrication methodology can be used to create arbitrarily shaped waveguides allowing complex optical circuits to be engineered in nonlinear optical materials such as magnesium doped lithium niobate. Researchers here have identified NLO (nonlinear optical) ridge waveguide structures as having suitable value to be the leading frequency conversion structures. Its value is based on having the low-cost fabrication necessary to satisfy the challenging pricing requirements as well as achieve the power handling and other specifications in a suitably compact package.

This work was done by Phillip Himmer of Montana State University and Philip Battle, William Suckow, and Greg Switzer of AdvR Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16031-1

Modifying Matrix Materials to Increase Wetting and Adhesion

Improvements are achieved at lower cost and without degradation of fibers.

Marshall Space Flight Center, Alabama

In an alternative approach to increasing the degrees of wetting and adhesion between the fiber and matrix components of organic-fiber/polymer matrix composite materials, the matrix resins are modified. Heretofore, it has been common practice to modify the fibers rather than the matrices: The fibers are modified by chemical and/or physical surface treatments prior to combining the fibers with matrix resins — an approach that entails considerable expense and usually results in degradation (typically, weakening) of fibers.

The alternative approach of modifying the matrix resins does not entail degradation of fibers, and affords opportunities for improving the mechanical properties of the fiber composites. The alternative approach is more cost-effective, not only because it eliminates expensive fiber-surface treatments but also because it does not entail changes in procedures for manufacturing conventional composite-material structures.

The alternative approach is best described by citing an example of its application to a composite of ultra-high-molecular-weight polyethylene (UHMWPE) fibers in an epoxy matrix. The epoxy matrix was modified to a chemically reactive, polarized epoxy nano-matrix to increase the degrees of wetting and adhesion between the fibers and the matrix. The modification was effected by incorporating a small proportion (0.3 weight percent) of reactive graphitic nanofibers produced from functionalized nanofibers into the epoxy matrix resin prior to combining the resin with the UHMWPE fibers. The resulting increase in fiber/matrix adhesion manifested itself in several test results, notably including an increase of 25 percent in the maximum fiber pullout force and an increase of 60–65 percent in fiber pullout energy. In addition, it was conjectured that the functionalized nanofibers became involved in the cross linking reaction of the epoxy resin, with resultant enhancement of the mechanical properties and lower viscosity of the matrix.

This work was done by Katie Zhong of North Dakota State University for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32665-1