

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 tech-

nology 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*

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## **Modifying Matrix Materials to Increase Wetting and Adhesion**

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

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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 functional-

ized 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.

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