



## Fiber-Reinforced Reactive Nano-Epoxy Composites

*Marshall Space Flight Center, Alabama*

An ultra-high-molecular-weight polyethylene/matrix interface based on the fabrication of a reactive nano-epoxy matrix with lower surface energy has been improved. Enhanced mechanical properties versus pure epoxy on a three-point bend test include: strength (25 percent), modulus (20 percent), and toughness (30 percent). Increased thermal properties include higher T<sub>g</sub> (glass transition temperature) and stable CTE (coefficient of thermal expansion). Improved processability for manufacturing

composites includes faster wetting rates on macro-fiber surfaces, lower viscosity, better resin infusion rates, and improved rheological properties. Improved interfacial adhesion properties with Spectra fibers by pullout tests include initial debonding force of 35 percent, a maximum pullout force of 25 percent, and energy to debond at 65 percent. Improved mechanical properties of Spectra fiber composites (tensile) aging resistance properties include hygrothermal effects.

With this innovation, high-performance composites have been created, including carbon fibers/nano-epoxy, glass fibers/nano-epoxy, aramid fibers/nano-epoxy, and ultra-high-molecular-weight polyethylene fiber (UHMWPE).

*This work was done by Wei-Hong (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](mailto:sammy.a.nabors@nasa.gov). Refer to MFS-32666-1.*

## Polymerization Initiated at the Sidewalls of Carbon Nanotubes

*Lyndon B. Johnson Space Center, Houston, Texas*

A process has been developed for growing polymer chains via anionic, cationic, or radical polymerization from the side walls of functionalized carbon nanotubes, which will facilitate greater dispersion in polymer matrices, and will greatly enhance reinforcement ability in polymeric material.

Aryl bromide functionalized carbon nanotubes are dispersed in 5-mL tetrahydrofuran (THF), and a solution of n-butyllithium (5 mL, 2.19 M in hexane) was added at 23 °C, and the solution stirred for 10 min. The stirring was then turned off, and the nanotubes were allowed to settle out of solution. After settling, the excess n-butyllithium solution was removed from the reaction vessel via cannula, and the nanotubes were washed three times with dry THF (10 mL) to remove traces of n-butyllithium.

The flask was then charged with dry THF (10 mL), and the tubes were dispersed in solution with rapid stirring. Styrene (1.7 mL, 15 mmol) was added to the reaction vessel, and the mixture was stirred for 180 min before adding ethanol (1 mL) or a function terminator of choice such as trimethylsilyl chloride. The mixture was then diluted with 100 mL dichloromethane, and filtered through Fisherbrand P8 filter paper to remove any large particulates. The filtrate was concentrated under reduced pressure and precipitated into methanol. The resulting gray powder was then collected by filtration, using Whatman 451 filter paper and dried under vacuum (0.1 mm) to a constant weight (typically 0.100–1.00 g, depending on the precise amount of styrene added). This material can then be

blended with other polymers, or can be molded and used by itself as a specialty material.

*This work was done by James M. Tour and Jared L. Hudson of Rice University for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.*

*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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## Metal-Matrix/Hollow-Ceramic-Sphere Composites

**These materials are relatively inexpensive, lightweight, stiff, tailorable, and machinable.**

*Goddard Space Flight Center, Greenbelt, Maryland*

A family of metal/ceramic composite materials has been developed that are relatively inexpensive, lightweight alternatives to structural materials that are typified by beryllium, aluminum,

and graphite/epoxy composites. These metal/ceramic composites were originally intended to replace beryllium (which is toxic and expensive) as a structural material for lightweight

mirrors for aerospace applications. These materials also have potential utility in automotive and many other terrestrial applications in which there are requirements for lightweight mate-