



## ❏ Magnesium Diboride Current Leads

**The superconductor can be applied to cryogenic wiring.**

*Goddard Space Flight Center, Greenbelt, Maryland*

A recently discovered superconductor, magnesium diboride ( $MgB_2$ ), can be used to fabricate conducting leads used in cryogenic applications. Discovered to be superconducting in 2001,  $MgB_2$  has the advantage of remaining superconducting at higher temperatures than the previously used material, NbTi. The purpose of these leads is to provide 2 A of electricity to motors located in a 1.3 K environment. The providing environment is a relatively warm 17 K. Requirements for these leads are to survive temperature fluctuations in the 5 K and 11 K heat sinks, and not conduct excessive heat into the 1.3 K environment. Test data showed that each lead in the assembly could conduct 5 A at 4 K, which, when scaled to 17 K, still provided more than the required 2 A.

The lead assembly consists of 12 steel-clad  $MgB_2$  wires, a tensioned Kevlar support, a thermal heat sink interface at 4 K, and base plates. The wires are soldered to heavy copper leads at the 17 K end, and to thin copper-clad NbTi leads at the 1.3 K end. The leads were designed, fabricated, and tested at the Forschungszentrum Karlsruhe - Institut für Technische Physik before inclusion in Goddard's XRS (X-Ray Spectrometer) instrument onboard the Astro-E2 spacecraft.

A key factor is that  $MgB_2$  remains superconducting up to 30 K, which means that it does not introduce joule heating as a resistive wire would. Because the required temperature ranges are 1.3–17 K, this provides a large margin of safety.

Previous designs lost superconductivity at around 8 K. The disadvantage to  $MgB_2$  is that it is a brittle ceramic, and making thin wires from it is challenging. The solution was to encase the leads in thin steel tubes for strength. Previous designs were so brittle as to risk instrument survival.

$MgB_2$  leads can be used in any cryogenic application where small currents need to be conducted at below 30 K. Because previous designs would superconduct only at up to 8 K, this new design would be ideal for the 8–30 K range.

*This work was done by John Panek of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15657-1*

## ❏ Polyimide Aerogels With Three-Dimensional Cross-Linked Structure

**These aerogels are suited for use as insulation as well as adsorbent beds for chemical separators, and as platforms for solid-state sensors.**

*John H. Glenn Research Center, Cleveland, Ohio*

Polyimide aerogels with three-dimensional cross-linked structure are made using linear oligomeric segments of polyimide, and linked with one of the following into a 3D structure: trifunctional aliphatic or aromatic amines, latent reactive end caps such as nadic anhydride or phenylethynylphenyl amine, and silica or silsesquioxane cage structures decorated with amine. Drying the gels supercritically maintains the solid structure of the gel, creating a polyimide aerogel with improved mechanical properties over linear polyimide aerogels.

Lightweight, low-density structures are desired for acoustic and thermal insulation for aerospace structures, habitats, astronaut equipment, and aeronautic applications. Aerogels are a unique material for providing such properties because of their extremely low density and small pore sizes. How-

ever, plain silica aerogels are brittle. Reinforcing the aerogel structure with a polymer (X-Aerogel) provides vast improvements in strength while maintaining low density and pore structure. However, degradation of polymers used in cross-linking tends to limit use temperatures to below 150 °C. Organic aerogels made from linear polyimide have been demonstrated, but gels shrink substantially during supercritical fluid extraction and may have lower use temperature due to lower glass transition temperatures.

The purpose of this innovation is to raise the glass transition temperature of all organic polyimide aerogel by use of tri-, tetra-, or poly-functional units in the structure to create a 3D covalently bonded network. Such cross-linked polyimides typically have higher glass transition temperatures in excess of

300–400 °C. In addition, the reinforcement provided by a 3D network should improve mechanical stability, and prevent shrinkage on supercritical fluid extraction. The use of tri-functional aromatic or aliphatic amine groups in the polyimide backbone will provide such a 3D structure.

Alternatively, cross-linking of the polyimide can be carried out by capping long-chain oligomers with latent reactive end caps (nadec anhydride or phenylethynylphenylamine, for example). After supercritical fluid extraction, the cross-linking is carried out on a post-cure of the dried gels. In another embodiment, polyimide or polyamic acid can be capped with trialkoxy silanes, which can be co-reacted with small amounts of tetraalkoxy silanes to form regions of covalently bonded silica crosslinks. Alternately,