



❏ 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 (nadid 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,

polysilsesquioxane cages decorated with surface amines can be co-reacted with anhydride capped polyimide/polyamic acid.

Cross-linked polyimide aerogels with their high porosity, combined with higher strength, have excellent thermal as well as sound-insulating qualities. In

addition, their high specific surface area (e.g. on the order of 200–1,000 m²/g) should make them well suited for numerous applications, including as adsorbent beds for chemical separations, and as platforms for solid-state sensors.

This work was done by Mary Ann B. Meador of Glenn Research Center. Further

information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18486-1.

❖ Silica/Polymer and Silica/Polymer/Fiber Composite Aerogels

These materials resist compression better than pure silica aerogels do.

Lyndon B. Johnson Space Center, Houston, Texas

Aerogels that consist, variously, of neat silica/polymer alloys and silica/polymer alloy matrices reinforced with fibers have been developed as materials for flexible thermal-insulation blankets. In comparison with prior aerogel blankets, these aerogel blankets are more durable and less dusty. These blankets are also better able to resist and recover from compression — an important advantage in that maintenance of thickness is essential to maintenance of high thermal-insulation performance. These blankets are especially suitable as core materials for vacuum-insulated panels and vacuum-insulated boxes of advanced, nearly seamless design. (Inasmuch as heat leakage at seams is much greater than heat leakage elsewhere through such structures, advanced designs for high insulation performance should provide for minimization of the sizes and numbers of seams.)

A silica/polymer aerogel of the present type could be characterized, somewhat more precisely, as consisting of multiply bonded, linear polymer reinforcements within a silica aerogel matrix. Thus far, several different polymethacrylates (PMAs) have been incorporated into aerogel networks to

increase resistance to crushing and to improve other mechanical properties while minimally affecting thermal conductivity and density.

The polymethacrylate phases are strongly linked into the silica aerogel networks in these materials. Unlike in other organic/inorganic blended aerogels, the inorganic and organic phases are chemically bonded to each other, by both covalent and hydrogen bonds. In the process for making a silica/polymer alloy aerogel, the covalent bonds are introduced by prepolymerization of the methacrylate monomer with trimethoxysilylpropylmethacrylate, which serves as a phase cross-linker in that it contains both organic and inorganic monomer functional groups and hence acts as a connector between the organic and inorganic phases. Hydrogen bonds are formed between the silanol groups of the inorganic phase and the carboxyl groups of the organic phase. The polymerization process has been adapted to create interpenetrating PMA and silica-gel networks from monomers and prevent any phase separations that could otherwise be caused by an overgrowth of either phase.

Typically, the resulting PMA/silica aerogel, without or with fiber reinforcement, has a density and a thermal conductivity similar to those of pure silica aerogels. However, the PMA enhances mechanical properties. Specifically, flexural strength at rupture is increased to 102 psi (≈ 0.7 MPa), about 50 times the flexural strength of typical pure silica aerogels. Resistance to compression is also increased: Applied pressure of 17.5 psi (≈ 0.12 MPa) was found to reduce the thicknesses of several composite PMA/silica aerogels by only about 10 percent.

This work was done by Danny Ou, Christopher J. Stepanian, and Xiangjun Hu of Aspen Aerogels, Inc., for Johnson Space Center. Further information is contained in a TSP (see page 1).

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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Refer to MSC-23736-1, volume and number of this NASA Tech Briefs issue, and the page number.

❖ Alumina Paste Layer as a Sublimation Suppression Barrier for Yb₁₄MnSb₁₁

This material can be applied to any thermoelectric couples requiring sublimation suppression.

NASA's Jet Propulsion Laboratory, Pasadena, California

Sublimation is a major cause of degradation of thermoelectric power generation systems. Most thermoelectric materials tend to have peak values at the temperature where sublimation occurs. A sublimation barrier is needed that is

stable at operating temperatures, inert against thermoelectric materials, and able to withstand thermal cycling stress.

A porous alumina paste layer is suitable as a sublimation barrier for Yb₁₄MnSb₁₁. It can accommodate stress generated by

the thermal expansion discrepancy between the suppression layer and thermoelectric materials. Sublimation suppression is achieved by filling pores naturally with YbO₂, a natural byproduct of sublimation. YbO₂ generated during the subli-