

which are then bonded or fastened to an optical bench. When the part is exposed to extreme cold, the epoxy holding the mirror can crack and the fasteners holding the mirror mount can shrink, shifting the position of the mirror. In the gradient alloy, the glass mirror can be bonded to Invar, which has a near-zero thermal expansion coefficient that matches glass. However, the whole part does not need to be made from Invar, but rather it can be graded to stainless steel and then welded to the optical bench, eliminating thermal expansion mismatch from dissimilar metals. The gradient technique has also been used in an optics application to fabricate an Invar mirror with a high-stiffness isogrid backing. Isogrids are extremely costly

and complicated to fabricate, but the AM technique allows gradient compositions to be built up right on the backside of the mirror. Other gradients have been developed, including a stainless steel to Inconel (a high-temperature Ni alloy) gradient to be fabricated into a valve stem for automotive applications. Invar-containing metal inserts have been developed to eliminate low-temperature pull-out in carbon fiber panels and low-density titanium alloys have been graded to refractory metals (e.g. Nb and V) for high-temperature applications (such as rocket nozzles and engine components). Ongoing work has focused on developing new types of gradient armor for defense applications as well as a wide assortment of commercial applications.

This work was done by Douglas C. Hofmann, John Paul C. Borgonia, Robert P. Dillon, Eric J. Suh, Jerry L. Mulder, and Paul B. Gardner of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

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:

*Innovative Technology Assets Management
JPL*

Mail Stop 321-123

4800 Oak Grove Drive

Pasadena, CA 91109-8099

E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-48419, volume and number of this NASA Tech Briefs issue, and the page number.

Passivation of Flexible YBCO Superconducting Current Lead With Amorphous SiO₂ Layer

The aim of this project is to design and construct leads from YBCO composite conductors to reduce the heat load to adiabatic demagnetization refrigerators.

Goddard Space Flight Center, Greenbelt, Maryland

Adiabatic demagnetization refrigerators (ADR) are operated in space to cool detectors of cosmic radiation to a few 10s of mK. A key element of the ADR is a superconducting magnet operating at about 0.3 K that is continually energized and de-energized in synchronism with a thermal switch, such that a piece of paramagnetic salt is alternately warm in a high magnetic field and cold in zero magnetic field. This causes the salt pill or refrigerant to cool, and it is able to suck heat from an object, e.g., the sensor, to be cooled. Current has to be fed into and out of the magnets from a dissipative power supply at the ambient temperature of the spacecraft. The current leads that link the magnets to the power supply inevitably conduct a significant amount of heat into the colder regions of the supporting cryostat, resulting in the need for larger, heavier, and more powerful supporting refrigerators. The aim of this project was to design and construct high-temperature superconductor (HTS) leads from YBCO (yttrium barium copper oxide) composite conductors to reduce the heat load significantly in the tem-

perature regime below the critical temperature of YBCO.

The magnet lead does not have to support current in the event that the YBCO ceases to be superconducting. Customarily, a normal metal conductor in parallel with the YBCO is a necessary part of the lead structure to allow for this upset condition; however, for this application, the normal metal can be dispensed with.

Amorphous silicon dioxide is deposited directly onto the surface of YBCO, which resides on a flexible substrate. The silicon dioxide protects the YBCO from chemically reacting with atmospheric water and carbon dioxide, thus preserving the superconducting properties of the YBCO. The customary protective coating for flexible YBCO conductors is silver or a silver/gold alloy, which conducts heat many orders of magnitude better than SiO₂ and so limits the use of such a composite conductor for passing current across a thermal gradient with as little flow of heat as possible to make an efficient current lead. By protecting YBCO on a flexible substrate of low thermal conductivity with

SiO₂, a thermally efficient and flexible current lead can be fabricated. The technology is also applicable to current leads for 4 K superconducting electronics current biasing.

A commercially available thin-film YBCO composite tape conductor is first stripped of its protective silver coating. It is then mounted on a jig that holds the sample flat and acts as a heat sink. Silicon dioxide is then deposited onto the YBCO to a thickness of about 1 micron using PECVD (plasma-enhanced chemical vapor deposition), without heating the YBCO to the point where degradation occurs.

Since SiO₂ can have good high-frequency electrical properties, it can be used to coat YBCO cable structures used to feed RF signals across temperature gradients. The prime embodiment concerns the conduction of DC current across the cryogenic temperature gradient. The coating is hard and electrically insulating, but flexible.

This work was done by Daniel Johannes and Robert Webber of Hypes for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16732-1