



Materials

▣ Oxide Fiber Cathode Materials for Rechargeable Lithium Cells

Lyndon B. Johnson Space Center, Houston, Texas

LiCoO₂ and LiNiO₂ fibers have been investigated as alternatives to LiCoO₂ and LiNiO₂ powders used as lithium-intercalation compounds in cathodes of rechargeable lithium-ion electrochemical cells. In making such a cathode, LiCoO₂ or LiNiO₂ powder is mixed with a binder [e.g., poly(vinylidene fluoride)] and an electrically conductive additive (usually carbon) and the mixture is pressed to form a disk. The binder and conductive additive contribute weight and volume, reducing the specific energy and energy density, respectively.

In contrast, LiCoO₂ or LiNiO₂ fibers can be pressed and sintered to form a

cathode, without need for a binder or a conductive additive. The inter-grain contacts of the fibers are stronger and have fewer defects than do those of powder particles. These characteristics translate to increased flexibility and greater resilience on cycling and, consequently, to reduced loss of capacity from cycle to cycle. Moreover, in comparison with a powder-based cathode, a fiber-based cathode is expected to exhibit significantly greater ionic and electronic conduction along the axes of the fibers. Results of preliminary charge/discharge-cycling tests suggest that energy densities of LiCoO₂- and

LiNiO₂-fiber cathodes are approximately double those of the corresponding powder-based cathodes.

This work was done by Catherine E. Rice and Mark F. Welker of TPL, Inc., for Johnson Space Center.

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-22892-1, volume and number of this NASA Tech Briefs issue, and the page number.

▣ Electrocatalytic Reduction of Carbon Dioxide to Methane

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A room-temperature electrocatalytic process that effects the overall chemical reaction $\text{CO}_2 + 2\text{H}_2\text{O} \rightarrow \text{CH}_4 + 2\text{O}_2$ has been investigated as a means of removing carbon dioxide from air and restoring oxygen to the air. The process was originally intended for use in a spacecraft life-support system, in which the methane would be vented to outer space. The process may also have potential utility in terrestrial applications in which either or both of the

methane and oxygen produced might be utilized or vented to the atmosphere.

A typical cell used to implement the process includes a polymer solid-electrolyte membrane, onto which are deposited cathode and anode films. The cathode film is catalytic for electrolytic reduction of CO₂ at low overpotential. The anode film is typically made of platinum. When CO₂ is circulated past the cathode, water is circulated past the

anode, and a suitable potential is applied, the anode half-cell reaction is $4\text{H}_2\text{O} \rightarrow 2\text{O}_2 + 8\text{H}^+ + 8\text{e}^-$. The H⁺ ions travel through the membrane to the cathode, where they participate in the half-cell reaction $\text{CO}_2 + 8\text{H}^+ + 8\text{e}^- \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$.

This work was done by Anthony F. Sammells and Ella F. Spiegel of Eltron Research, Inc. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23097-1

▣ Heterogeneous Superconducting Low-Noise Sensing Coils

Electrically superconductive outer layers are supported by highly thermally conductive skeletons.

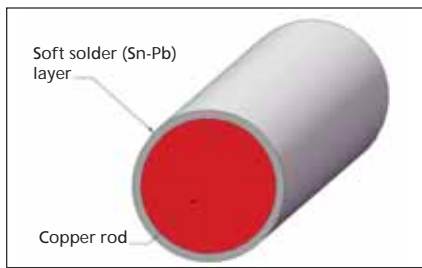
NASA's Jet Propulsion Laboratory, Pasadena, California

A heterogeneous material construction has been devised for sensing coils of superconducting quantum interference device (SQUID) magnetometers that are subject to a combination of requirements peculiar to some advanced applications, notably including low-field magnetic resonance imaging for medical diagnosis. The requirements in question are the following:

- The sensing coils must be large enough (in some cases having dimensions of as much as tens of centimeters) to afford adequate sensitivity;
- The sensing coils must be made electrically superconductive to eliminate Johnson noise (thermally induced noise proportional to electrical resistance); and
- Although the sensing coils must be cooled to below their superconduct-

ing-transition temperatures with sufficient cooling power to overcome moderate ambient radiative heat leakage, they must not be immersed in cryogenic liquid baths.

For a given superconducting sensing coil, this combination of requirements can be satisfied by providing a sufficiently thermally conductive link between the coil and a cold source. How-



A Solder-Covered Copper Rod or Wire affords the benefit of high thermal conductivity of the copper and, when sufficiently cold, electrical superconductivity of the solder.

ever, the superconducting coil material is not suitable as such a link because electrically superconductive materials are typically poor thermal conductors.

The heterogeneous material construction makes it possible to solve both the electrical- and thermal-conductivity problems. The basic idea is to construct the coil as a skeleton made of a highly thermally conductive material (typically, annealed copper), then coat the skeleton with an electrically superconductive alloy (typically, a lead-tin solder) [see figure]. In operation, the copper skeleton provides the required thermally conductive connection to the cold source, while the electrically superconductive coating material shields against Johnson noise that originates in the copper skeleton.

This work was done by Inseob Hahn, Konstantin I. Penanen, and Byeong Ho Eom of

Caltech for NASA's Jet Propulsion Laboratory. 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 NPO-45929, volume and number of this NASA Tech Briefs issue, and the page number.

Progress Toward Making Epoxy/Carbon-Nanotube Composites

Lyndon B. Johnson Space Center, Houston, Texas

A modicum of progress has been made in an effort to exploit single-walled carbon nanotubes as fibers in epoxy-matrix/fiber composite materials. Two main obstacles to such use of carbon nanotubes are the following: (1) bare nanotubes are not soluble in epoxy resins and so they tend to agglomerate instead of becoming dispersed as desired; and (2) because of lack of affinity between nanotubes and epoxy matrices, there is insufficient transfer of mechanical loads between the nanotubes and the matrices.

Part of the effort reported here was oriented toward (1) functionalization of single-walled carbon nanotubes with methyl methacrylate (MMA) to increase their dispersability in epoxy resins and increase transfer of mechanical loads and (2) ultrasonic dispersion of the functionalized nanotubes in tetrahydrofuran, which was used as an auxiliary solvent to aid in dispersing the functionalized nanotubes into a epoxy resin. In another part of this effort, poly(styrene sulfonic acid) was used as the dispersant

and water as the auxiliary solvent. In one experiment, the strength of composite of epoxy with MMA-functionalized-nanotubes was found to be 29 percent greater than that of a similar composite of epoxy with the same proportion of untreated nanotubes.

This work was done by Thomas Tiano, Margaret Roylance, and John Gassner of Foster-Miller, Inc. and William Kyle (consultant) for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23278-1

Predicting Properties of Unidirectional-Nanofiber Composites

John H. Glenn Research Center, Cleveland, Ohio

A theory for predicting mechanical, thermal, electrical, and other properties of unidirectional-nanofiber/matrix composite materials is based on the prior theory of micromechanics of composite materials. In the development of the present theory, the prior theory of micromechanics was extended, through progressive substructuring, to the level of detail of a nanoscale slice of a nanofiber. All the governing equations were then formulated at this level.

The substructuring and the equations have been programmed in the

ICAN/JAVA computer code, which was reported in "ICAN/JAVA: Integrated Composite Analyzer Recoded in Java" (LEW-17247), *NASA Tech Briefs*, Vol. 26, No. 12 (December 2002), page 36. In a demonstration, the theory as embodied in the computer code was applied to a graphite-nanofiber/epoxy laminate and used to predict 25 properties. Most of the properties were found to be distributed along the through-the-thickness direction. Matrix-dependent properties were found to have bimodal through-the-thickness distributions with discon-

tinuous changes from mode to mode.

This work was done by Christos C. Chamis, Louis M. Handler, and Jane Manderscheid 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-18366-1.