Composite Aerogel Multifoil Protective Shielding

These composites are also suitable for environments containing an atmosphere.

NASA's Jet Propulsion Laboratory, Pasadena, California

New technologies are needed to survive the temperatures, radiation, and hypervelocity particles that exploration spacecraft encounter. Multilayer insulations (MLIs) have been used on many spacecraft as thermal insulation. Other materials and composites have been used as micrometeorite shielding or radiation shielding. However, no material composite has been developed and employed as a combined thermal insulation, micrometeorite, and radiation shielding.

By replacing the scrims that have been used to separate the foil layers in MLIs with various aerogels, and by using a variety of different metal foils, the overall protective performance of MLIs can be greatly expanded to act as thermal insulation, radiation shielding, and hypervelocity particle shielding. Aerogels are highly porous, low-density solids that are produced by the gelation of metal alkoxides and supercritical drying. Aerogels have been flown in NASA missions as a hypervelocity particle capture medium (Stardust) and as thermal insulation (2003 MER).

Composite aerogel multifoil protective shielding would be used to provide thermal insulation, while also shielding spacecraft or components from radiation and hypervelocity particle impacts. Multiple layers of foil separated by aerogel would act as a thermal barrier by preventing the transport of heat energy through the composite. The silica aerogel would act as a convective and conductive thermal barrier, while the titania powder and metal foils would absorb and reflect the radiative heat. It would also capture small hypervelocity particles, such as micrometeorites, since it would be a stuffed, multi-shock Whipple shield. The metal foil layers would slow and break up the impacting particles, while the aerogel layers would convert the kinetic energy of the particles to thermal and mechanical energy and stop the particles.

Thermal insulation, micrometeorite shielding, and radiation shielding on spacecraft are usually produced by using two, or even three, different materials. By using an aerogel multifoil composite, all three of these functionalities can be achieved with a single material. The thermal insulation needed for a given application can be produced by using the number of layers required to provide a given level of thermal protection, and by using either plain silica aerogel or an aerogel composite. By varying the types of foils or aerogel used in a given composite, the effectiveness for different impactor environments can be achieved. By changing the types of foils used, the effectiveness against certain types of radiation can be increased, since the types of foils used to shield against electrons would be different from those used to shield against protons.

Since aerogels are excellent convective and conductive thermal insulators, aerogel multifoil composites can also be used in environments that include an atmosphere. Traditional MLIs are only effective in vacuum environments, since the presence of an atmosphere renders it ineffective as thermal insulation.

This work was done by Steven M. Jones of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48883

Li-Ion Electrolytes With Improved Safety and Tolerance to High-Voltage Systems

Promising electrolytes are identified.

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Given that lithium-ion (Li-ion) technology is the most viable rechargeable energy storage device for near-term applications, effort has been devoted to improving the safety characteristics of this system. Therefore, extensive effort has been devoted to developing nonflammable electrolytes to reduce the flammability of the cells/battery. A number of promising electrolytes have been developed incorporating flame-retardant additives, and have been shown to have good performance in a number of systems. However, these electrolyte formulations did not perform well when utilizing carbonaceous anodes with the high-voltage materials. Thus, further development was required to improve the compatibility.

A number of Li-ion battery electrolyte formulations containing a flame-retardant additive [i.e., triphenyl phosphate (TPP)] were developed and demonstrated in high-voltage systems. These electrolytes include: (1) formulations that incorporate varying concentrations of the flame-retardant additive (from 5 to 15%), (2) the use of mono-fluoroethylene carbonate (FEC) as a co-solvent, and (3) the use of LiBOB as an electrolyte additive intended to improve the compatibility with high-voltage systems. One of the promising electrolytes identified of the group investigated is 1.0M $LiPF_6$ in EC+EMC+TPP (20:70:10 vol %) + 0.15M LiBOB, which was demonstrated to have comparable performance to that of the baseline ternary electrolyte in MPG-111/Toda ($LiNiMnCoO_2$) coin cells, in terms of reversible capacity and discharge rate capability at room temperature. Thus, improved safety has been provided without loss of performance in the high-voltage, high-energy system.

The use of higher concentrations of the flame-retardant additive is known to reduce the flammability of the electrolyte solution, with 15% concentration resulting in solutions of substantially reduced flammability. Thus, the desired concentration of the flame-retardant additive is the greatest amount tolerable without adversely affecting the performance in terms of reversibility, ability to operate over a wide temperature range, and the discharge rate capability. The use of FEC was used to reduce the inherent flammability of mixtures and improve the compatibility at the interfacial regions, due to desirable surface reactions.

This work was done by Marshall C. Smart and Ratnakumar V. Bugga of Caltech, and G.K. Surya Prakash and Frederick C. Krause of the University of Southern California for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Refer to NPO-47980, volume and number of this NASA Tech Briefs *issue, and the page number.*

Polymer-Reinforced, Non-Brittle, Lightweight Cryogenic Insulation

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The primary application for cryogenic insulating foams will be fuel tank applications for fueling systems. It is crucial for this insulation to be incorporated into systems that survive vacuum and terrestrial environments. It is hypothesized that by forming an open-cell silica-reinforced polymer structure, the foam structures will exhibit the necessary strength to maintain shape. This will, in turn, maintain the insulating capabilities of the foam insulation. Besides mechanical stability in the form of crush resistance, it is important for these insulating materials to exhibit water penetration resistance. Hydrocarbon-terminated foam surfaces were implemented to impart hydrophobic functionality that apparently limits moisture penetration through the foam. During the freezing process, water accumulates on the surfaces of the foams. However, when hydrocarbon-terminated surfaces are present, water apparently beads and forms crystals, leading to less apparent accumulation.

The object of this work is to develop inexpensive structural cryogenic insulation foam that has increased impact resistance for launch and ground-based cryogenic systems. Two parallel approaches will be pursued: a silica-polymer co-foaming technique and a post foam coating technique.

Insulation characteristics, flexibility, and water uptake can be fine-tuned through the manipulation of the polyurethane foam scaffold. Silicate coatings for polyurethane foams and aerogel-impregnated polyurethane foams have been developed and tested. A highly porous aerogel-like material may be fabricated using a co-foam and coated foam techniques, and can insulate at liquid temperatures using the composite foam.

NASA is currently involved with varying space and terrestrial projects that would greatly benefit from more efficient cryogenic insulation to reduce fuel boil-off. Hydrogen quality testing methods require terrestrial sampling lines that would benefit from this insulation by reducing line losses for more accurate representation of tank holdings. Moreover, rockets and orbital depot systems require insulation that will maintain liquid fuel during liftoff, and during the initiation of orbit.

This work was done by David M. Hess of InnoSense LLC for Kennedy Space Center. For more information, contact the Kennedy Space Center Innovative Partnerships Office at (321) 867-5033. KSC-13569

Controlled, Site-Specific Functionalization of Carbon Nanotubes With Diazonium Salts

Possible applications include molecular switches and molecular wires.

Lyndon B. Johnson Space Center, Houston, Texas

This work uses existing technologies to prepare a crossbar architecture of nanotubes, wherein one nanotube is fixed to a substrate, and a second nanotube is suspended a finite distance above. Both nanotubes can be individually addressed electrically. Application of opposite potentials to the two tubes causes the top tube to deform and to essentially come into contact with the lower tube. Contact here refers not to actual, physical contact, but rather within an infinitesimally small distance referred to as van der Walls contact, in which the entities may influence each other on a molecular and electronic scale.

First, the top tube is physically deformed, leading to a potentially higher chemical reactivity at the point of deformation, based on current understanding of the effects of curvature strain on reactivity. This feature would allow selective functionalization at the junction via reaction with diazonium salts. Secondly, higher potential is achieved at the point of "cross" between the tubes. In a pending patent application, a method is claimed for directed self-assembly of molecular components onto the surface of metal or conductive materials by application of potential to the metal or conductive surface. In another pending