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).

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

Polymer-Reinforced, Non-Brittle, Lightweight Cryogenic Insulation

John F. Kennedy Space Center, Florida

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 patent application, a method is claimed for attaching molecules to the surface of nanotubes via the use of reactive diazonium salts. In the present invention, the directed functionalization of the crossed-nanotube junctions by applying a potential to the ends of the nanotubes in the presence of reactive diazonium slats, or other reactive molecular species is claimed.

The diazonium salts are directed by the potential existing at the junction to react with the surface of the nanotube, thus placing functional molecular components at the junctions. The crossed nanotubes therefore provide a method of directly addressing the functionalized molecules, which have been shown to function as molecular switches, molecular wires, and in other capacities and uses. Site-specific functionalization may enable the use of nanotubes in molecular electronic applications because device functionality is critical at the cross points.

This work was done by James M. Tour of Rice University for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

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-24050-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Regenerable Sorbent for CO_2 Removal

Marshall Space Flight Center, Alabama

A durable, high-capacity regenerable sorbent can remove CO_2 from the breathing loop under a Martian atmosphere. The system design allows near-ambient temperature operation, needs only a small temperature swing, and sorbent regeneration takes place at or above 8 torr, eliminating the potential for Martian atmosphere to leak into the regeneration bed and into the breathing loop. The physical adsorbent can be used in a metabolic, heat-driven TSA system to remove CO_2 from the breathing loop of the astronaut and reject it to the Martian atmosphere. Two (or more) alternating sorbent beds continuously scrub and reject CO_2 from the spacesuit ventilation loop. The sorbent beds are cycled, alternately absorbing CO_2 from the vent loop and rejecting the adsorbed material into the environment at a high CO_2 partial pressure (above 8 torr). The system does not need to run the adsorber at cryogenic temperatures, and uses a much smaller temperature swing.

The sorbent removes CO_2 via a weak chemical interaction. The interaction is strong enough to enable CO_2 adsorption even at 3 to 7.6 torr. However, because the interaction between the surface adsorption sites and the CO_2 is relatively weak, the heat input needed to regenerate the sorbent is much lower than that for chemical absorbents.

The sorbent developed in this project could potentially find use in a large commercial market in the removal of CO_2 emissions from coal-fired power plants, if regulations are put in place to curb carbon emissions from power plants.

This work was done by Gokhan Alptekin and Ambal Jayaraman of TDA Research for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32902-1

Sprayable Aerogel Bead Compositions With High Shear Flow Resistance and High Thermal Insulation Value

This aerogel insulation could be used in fuel cell systems, oil and gas pipelines, and in building and construction applications.

Marshall Space Flight Center, Alabama

A sprayable aerogel insulation has been developed that has good mechanical integrity and lower thermal conductivity than incumbent polyurethane spray-on foam insulation, at similar or lower areal densities, to prevent insulation cracking and debonding in an effort to eliminate the generation of inflight debris.

This new, lightweight aerogel under bead form can be used as insulation in various thermal management systems that require low mass and volume, such as cryogenic storage tanks, pipelines, space platforms, and launch vehicles. These aerogel beads, with a packing density of 0.03 to 0.05 g/cm^3, can be used as pour-in, formable, or sprayable insulation, showing versatility in a variety of applications.

Silica and organically modified silica aerogel beads in a mixture with binders or foams can be formed into complex shapes, or sprayed onto panels. The aerogel composites have a fast cure, and have good mechanical strength at densities of 0.05 to 0.15 g/cm^3. Compression modulus for the aerogel bead/foam composite was 60 percent higher than the one from the foam without aerogel dopant.

Lightweight aerogel beads can be used in sprayable form together with a carrier for on-site applications. The sprayable thermal insulator has several advantages, such as a large temperature range of operation (from cryogenic temperatures to +300 °C), facile on-site installation, can be cured at room temperature, is mechanically robust and durable, and has excellent thermal performance insulation capability. This innovation is also water repellent, but does