Materials & Coatings

An Integrated, Layered-Spinel Composite Cathode for Energy Storage Applications

The composite cathode can be used in rechargeable Li-ion batteries in hybrid electric vehicles, laptops, medical devices, and military vehicles.

John H. Glenn Research Center, Cleveland, Ohio

At low operating temperatures, commercially available electrode materials for lithium-ion batteries do not fully meet the energy and power requirements for NASA's exploration activities. The composite cathode under development is projected to provide the required energy and power densities at low temperatures and its usage will considerably reduce the overall volume and weight of the battery pack.

The newly developed composite electrode material can provide superior electrochemical performance relative to a commercially available lithium cobalt system. One advantage of using a composite cathode is its higher energy density, which can lead to smaller and lighter battery packs. In the current program, different series of layered-spinel composite materials with at least two different systems in an integrated structure were synthesized, and the volumetric and gravimetric energy densities were evaluated. In an integrated network of a composite electrode, the effect of the combined structures is to enhance the capacity and power capabilities of the material to levels greater than what is possible in current state-of-the-art cathode systems.

The main objective of the current program is to implement a novel cathode material that meets NASA's low temperature energy density requirements. An important feature of the composite cathode is that it has at least two components (e.g., layered and spinel) that are structurally integrated. The layered material by itself is electrochemically inactive; however, upon structural integration with a spinel material, the layered material can be electrochemically activated, thereby delivering a large amount of energy with stable cycling. A key aspect of the innovation has been the development of a scalable process to produce submicron- and micron-scale particles of these composite materials.

An additional advantage of using such a composite electrode material is its low irreversible loss (≈5%), which is primarily due to the unique activation of the composite. High columbic efficiency (>99%) upon cycling may indicate the formation of a stable SEI (solid-electrolyte interface) layer, which can contribute to long cycle life. The innovation in the current program, when further developed, will enable the system to maintain high energy and power densities at low temperatures, improve efficiency, and further stabilize and enhance the safety of the cell.

This work was done by Nader Hagh and Ganesh Skandan of NEI Corporation for 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: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18870-1.

Engineered Multifunctional Surfaces for Fluid Handling

These processes create antibacterial and hydrophilic properties on metallic and polymeric surfaces.

Lyndon B. Johnson Space Center, Houston, Texas

Designs incorporating variations in capillary geometry and hydrophilic and/or antibacterial surface properties have been developed that are capable of passive gas/liquid separation and passive water flow. These designs can incorporate capillary grooves and/or surfaces arranged to create linear and circumferential capillary geometry at the micro and macro scale, radial fin configurations, micro holes and patterns, and combinations of the above.

The antibacterial property of this design inhibits the growth of bacteria or the development of biofilm. The hydrophilic property reduces the water contact angle with a treated substrate such that water spreads into a thin layer atop the treated surface.

These antibacterial and hydrophilic properties applied to a thermally conductive surface, combined with capillary geometry, create a novel heat exchanger capable of condensing water from a humid, two-phase water and gas flow onto the treated heat exchanger surfaces, and passively separating the condensed water from the gas flow in a reduced gravity application.

The overall process to generate the antibacterial and hydrophilic properties includes multiple steps to generate the two different surface properties, and can be divided into two major steps. Step 1 uses a magnetron-based sputtering technique to implant the silver atoms into the base material. A layer of silver is built up on top of the base material. Completion of this step provides the antibacterial property. Step 2 uses a cold-plasma technique to generate the hydrophilic surface property on top of the silver layer generated in Step 1. Completion of this step provides the hydrophilic property in addition to the antibacterial property.

Thermally conductive materials are fabricated and then treated to create the antibacterial and hydrophillic surface properties. The individual parts are assembled to create a condensing heat exchanger with antibacterial and hydrophillic surface properties and capillary geometry, which is capable of passive phase separation in a reduced gravity application.

The plasma processes for creating antibacterial and hydrophilic surface properties are suitable for applications where water is present on an exposed surface for an extended time, such that bacteria or biofilms could form, and where there is a need to manage the water on the surface. The processes are also suitable for applications where only the hydrophilic property is needed. In particular, the processes are applicable to condensing heat exchangers (CHXs), which benefit from the antibacterial properties as well as the hydrophilic properties. Water condensing onto the control surfaces of the CHX will provide the moist conditions necessary for the growth of bacteria and the formation of biofilms. The antibacterial properties of the base layer (silver) will mitigate and prevent the growth of bacteria and formation of biofilms that would otherwise reduce the CHX performance. In addition, the hydrophilic properties reduce the water contact angle and prevent water droplets from bridging between control surfaces. Overall, the hydrophilic properties reduce the pressure drop across the CHX.

This work was done by Chris Thomas and Yonghui Ma of Orbital Technologies Corporation, and Mark Weislogel 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-24496-1/502-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Polyolefin-Based Aerogels

These aerogels can be used for thermal insulation and radiation shielding in apparel, aircraft, race car insulation, and military and recreation tents.

Lyndon B. Johnson Space Center, Houston, Texas

An organic polybutadiene (PB) rubber-based aerogel insulation material was developed that will provide superior thermal insulation and inherent radiation protection, exhibiting the flexibility, resiliency, toughness, and durability typical of the parent polymer, yet with the low density and superior insulation properties associated with the aerogels. The rubbery behaviors of the PB rubber-based aerogels are able to overcome the weak and brittle nature of conventional inorganic and organic aerogel insulation materials. Additionally, with higher content of hydrogen in their structure, the PB rubber aerogels will also provide inherently better radiation protection than those of inorganic and carbon aerogels. Since PB rubber aerogels also exhibit good hydrophobicity due to their hydrocarbon molecular structure, they will provide better performance reliability and durability as well as simpler, more economic, and environmentally friendly production over the conventional silica or other inorganic-based aerogels, which require chemical treatment to make them hydrophobic.

Inorganic aerogels such as silica aerogels demonstrate many unusual and useful properties. There are several strategies to overcoming the drawbacks associated with the weakness and brittleness of silica aerogels. Development of the flexible fiber-reinforced silica aerogel composite blanket has proven one promising approach, providing a conveniently fielded form factor that is relatively robust toward handling in industrial environments compared to silica aerogel monoliths. However, the flexible silica aerogel composites still have a brittle, dusty character that may be undesirable, or even intolerable, in certain applications. Although the cross-linked organic aerogels such as resorcinol-formaldehyde (RF), polyisocyanurate, and cellulose aerogels show very high impact strength, they are also very brittle with little elongation (i.e., less rubbery). Also, silica and carbon aerogels are less efficient radiation shielding materials due to their lower content of hydrogen element.

The present invention relates to maleinized polybutadiene (or polybutadiene adducted with maleic anhydride)-based aerogel monoliths and composites, and the methods for preparation. Hereafter, they are collectively referred to as polybutadiene aerogels. Spelolcifically, the polybutadiene aerogels of the present invention are prepared by mixing a maleinized polybutadiene resin, a hardener containing a maleic anhydride reactive group, and a catalyst in a suitable solvent, and maintaining the mixture in a quiescent state for a sufficient period of time to form a polymeric gel. After aging at elevated temperatures for a period of time to provide uniformly stronger wet gels, the microporous maleinized polybutadiene-based aerogel is then obtained by removing interstitial solvent by supercritical drying. The mesoporous maleinized polybutadiene-based aerogels contain an open-pore structure, which provides inherently hydrophobic, flexible, nearly unbreakable, less dusty aerogels with excellent thermal and physical properties. The materials can be used as thermal and acoustic insulation, radiation shielding, and vibration-damping materials.

The organic PB-based rubber aerogels are very flexible, no-dust, and hydrophobic organics that demonstrated the following ranges of typical properties: densities of 0.08 to 0.255 g/cm^3, shrinkage factor (raerogel/rtarget) = 1.2 to 2.84, and thermal conductivity values of 20.0 to 35.0 mW/m-K.

This work was done by Je Kyun Lee and George Gould 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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