

The novel feature is that fabrics do not inherently possess good thermal conductivity. In fact, fabrics are used for thermal insulation, not heat removal. The technology represents the first material that is a wearable fabric, based on company textiles and materials that will significantly conduct heat.

*This work was done by L. P. Felipe Chibante of NanoTex Corporation for Johnson Space Center. Further information is contained in a TSP (see page 1).*

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## Imidazolium-Based Polymeric Materials as Alkaline Anion-Exchange Fuel Cell Membranes

**Polymer electrolyte membrane fuel cells can be used for portable power sources.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Polymer electrolyte membranes that conduct hydroxide ions have potential use in fuel cells. A variety of polystyrene-based quaternary ammonium hydroxides have been reported as anion exchange fuel cell membranes. However, the hydrolytic stability and conductivity of the commercially available membranes are not adequate to meet the requirements of fuel cell applications. When compared with commercially available membranes, polystyrene-imidazolium alkaline membrane electrolytes are more stable and more highly conducting. At the time of this reporting, this has been the first such usage for imidazolium-based polymeric materials for fuel cells.

Imidazolium salts are known to be electrochemically stable over wide po-

tential ranges. By controlling the relative ratio of imidazolium groups in polystyrene-imidazolium salts, their physiochemical properties could be modulated.

Alkaline anion exchange membranes based on polystyrene-imidazolium hydroxide materials have been developed. The first step was to synthesize the poly(styrene-co-(1-((4-vinyl)methyl)-3-methylimidazolium) chloride through a free-radical polymerization. Casting of this material followed by *in situ* treatment of the membranes with sodium hydroxide solutions provided the corresponding hydroxide salts. Various ratios of the monomers 4-chloromethylvinylbenzene (CMVB) and vinylbenzene (VB) provided various compositions of the

polymer. The preferred material, due to the relative ease of casting the film, and its relatively low hygroscopic nature, was a 2:1 ratio of CMVB to VB.

Testing confirmed that at room temperature, the new membranes outperformed commercially available membranes by a large margin. With fuel cells now in use at NASA and in transportation, and with defense potential, any improvement to fuel cell efficiency is a significant development.

*This work was done by Sri R. Narayan and Shiao-Ping S. Yen of Caltech, and Prakash V. Reddy and Nanditha Nair of Missouri University of Science and Technology for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46457*

## Electrospun Nanofiber Coating of Fiber Materials: A Composite Toughening Approach

**Companies could apply this technology in producing fabric products for use in composite manufacturing.**

*John H. Glenn Research Center, Cleveland, Ohio*

Textile-based composites could significantly benefit from local toughening using nanofiber coatings. Nanofibers, thermoplastic or otherwise, can be applied to the surface of the fiber tow bundle, achieving toughening of the fiber tow contact surfaces, resulting in tougher and more damage-resistant/tolerant composite structures. The same technique could also be applied to other technologies such as tape laying, fiber placement, or filament winding operations. Other modifications to the composite properties such as thermal and

electrical conductivity could be made through selection of appropriate nanofiber material.

Investigations of the failure and damage mechanisms of textile composites has led to the conclusion that toughening of the matrix material would result in increased material performance. Several approaches exist in which the bulk of the matrix is modified either through chemical formulation or the addition of fillers. These methods can detrimentally affect the processability of the resulting matrix material. Other methods exist

that rely on modification of the fiber material (so-called "fuzzy fiber" approaches) that results in reduced fiber performance.

Control of the needle electric potential, precursor solution, ambient temperature, ambient humidity, airflow, etc., are used to vary the diameter and nanofiber coating morphology as needed. Post-coating heat treatments may also be used for the purpose of curing, drying, oxidation, annealing, etc. The array of electrospinning jets may be varied as needed to achieve uniform,

quality coatings, and may involve the controlled use of gas flow to direct nanofiber deposition. An adhesive coating may also be applied (pre- or post-application) to the receiving material to enhance the mechanical stability of the nanofiber coating. Additionally, any number of different nanofiber materials can be simultaneously applied.

This method produces a product with a toughening agent applied to the fiber tow or other continuous composite precursor material where it is needed (at interfaces and boundaries) without interfering with other composite processing characteristics.

*This work was done by Lee W. Kohlman and Gary D. Roberts of Glenn Research Cen-*

*ter. 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-18844-1.*