able cells. This previous work has shown that although the measured capacitance is relatively insensitive to temperature, the ESR can rise rapidly at low temperatures, due to decreased electrolyte conductance within the pores of the high-surface-area carbon electrodes. Most of these advanced electrolyte systems featured tetraethylammonium tetrafluoroborate (TEATFB) as the salt. More recent work at JPL indicates the use of the asymmetric quaternary ammonium salt triethylmethylammonium tetrafluoroborate (TEMATFB) or spiro-(l,l')-bipyrrolidium tetrafluoroborate (SBPBF4) in a 1:1 by volume solvent mixture of acetonitrile (AN) and methyl formate (MF) enables double-layer capacitor cells to operate well below –40 °C with a relatively low ESR. Typically, a less than two-fold increase in ESR is observed at –65 °C relative to room-temperature values, when these modified electrolyte blends are used in prototype cells. Double-layer capacitor coin cells filled with these electrolytes have displayed the lowest measured ESR for an organic electrolyte to date at low temperature (based on a wide range of electrolyte screening studies at JPL). The cells featured high-surface-area (≈2,500 m/g) carbon electrodes that were 0.50 mm thick and 1.6 cm in diameter, and coated with a thin layer of platinum to reduce cell resistance. A polyethylene separator was used to electrically isolate the electrodes.

This work was done by Erik J. Brandon, Marshall C. Smart, and William C. West 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:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-47327, volume and number of this NASA Tech Briefs *issue, and the page number.*

Sustainably Sourced, Thermally Resistant, Radiation Hard Biopolymer

A sustainably sourced biopolymer provides simultaneous thermal insulation and radiation protection.

Goddard Space Flight Center, Greenbelt, Maryland

This material represents a breakthrough in the production, manufacturing, and application of thermal protection system (TPS) materials and radiation shielding, as this represents the first effort to develop a non-metallic, non-ceramic, biomaterial-based, sustainable TPS with the capability to also act as radiation shielding. Until now, the standing philosophy for radiation shielding involved carrying the shielding at liftoff or utilizing onboard water sources. This shielding material could be grown onboard and applied as needed prior to different radiation landscapes (commonly seen during missions involving gravitational assists).

The material is a bioplastic material. Bioplastics are any combination of a biopolymer and a plasticizer. In this case, the biopolymer is a starch-based material and a commonly accessible plasticizer. Starch molecules are composed of two major polymers: amylase and amylopectin.

The biopolymer phenolic compounds are common to the ablative thermal protection system family of materials. With similar constituents come similar chemical ablation processes, with the potential to have comparable, if not better, ablation characteristics. It can also be used as a flame-resistant barrier for commercial applications in buildings, homes, cars, and heater firewall material.

The biopolymer is observed to undergo chemical transformations (oxidative and structural degradation) at radiation doses that are 1,000 times the maximum dose of an unmanned mission (10–25 Mrad), indicating that it would be a viable candidate for robust radiation shielding. As a comparison, the total integrated radiation dose for a three-year manned mission to Mars is 0.1 krad, far below the radiation limit at which starch molecules degrade. For electron radiation, the biopolymer starches show minimal deterioration when exposed to energies greater than 180 keV.

This flame-resistant, thermal-insulating material is non-hazardous and may be sustainably sourced. It poses no hazardous waste threats during its lifecycle. The material composition is radiation-tolerant up to megarad doses, indicating its use as a radiation shielding material. It is lightweight, non-metallic, and able to be mechanically densified, permitting a tunable gradient of thermal and radiation protection as needed. The dual-use (thermal and radiation shielding), sustainable nature of this material makes it suitable for both industrial applications as a sustainable/green building material, and for space applications as thermal protection material and radiation shield.

This work was done by Diane Pugel of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16177-1