High-Temperature Shape Memory Polymers

The shape memory behavior is provided by a non-polymer additive.

John H. Glenn Research Center, Cleveland, Ohio

Shape memory materials undergo physical conformation changes when exposed to an external stimulus, such as a change in temperature. Such materials have a permanent shape, but can be reshaped above a critical temperature and fixed into a temporary shape when cooled under stress to below the critical temperature. When reheated above the critical temperature (T_c, also sometimes called the triggering or switching temperature), the materials revert to the permanent shape.

The current innovation involves a chemically treated (sulfonated, carboxylated, phosphonated, or other polar function group), high-temperature, semicrystalline thermoplastic poly(ether ether ketone) (T_g ≈140 °C, T_m = 340 °C) mix containing organometallic complexes (Zn^{++}, Li^{+}, or other metal, ammonium, or phosphonium salts), or high-temperature ionic liquids (e.g. hexafluorosilicate salt with 1-propyl-3-methyl imidazolium, T_m = 210 °C) to form a network where dipolar or ionic interactions between the polymer and the low-molecular-weight or inorganic compound forms a complex that provides a physical crosslink. Hereafter, these compounds will be referred to as "additives." The polymer is semicrystalline, and the high-melt-point crystals provide a temporary crosslink that acts as a permanent crosslink just so long as the melting temperature is not exceeded. In this example case, the melting point is ≈340 °C, and the shape memory critical temperature is between 150 and 250 °C. PEEK is an engineering thermoplastic with a high Young's modulus, nominally 3.6 GPa.

An important aspect of the invention is the control of the PEEK functionalization (in this example, the sulfonation degree), and the thermal properties (i.e. melting point) of the additive, which determines the switching temperature. Because the compound is thermoplastic, it can be formed into the "permanent" shape by conventional plastics processing operations. In addition, the compound may be covalently crosslinked after forming the permanent shape by S-PEEK by applying ionizing radiation (γ radiation, neutrons), or by chemical crosslinking to form a covalent permanent network.

With respect to other shape memory polymers, this invention is novel in that it describes the use of a thermoplastic composition that can be thermally molded or solution-cast into complex "permanent" shapes, and then reheated or redissolved and recast from solution to prepare another shape. It is also unique in that the shape memory behavior is provided by a non-polymer additive.

This work was done by Mitra Yoonessi of Glenn Research Center and Robert A. Weiss of the University of Akron. 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-18756-1.

Modular Flooring System

Lighter material is easier to transport and assemble.

Goddard Space Flight Center, Greenbelt, Maryland

The modular flooring system (MFS) was developed to provide a portable, modular, durable carpeting solution for NASA's Robotics Alliance Project's (RAP) outreach efforts. It was also designed to improve and replace a modular flooring system that was too heavy for safe use and transportation. The MFS was developed for use as the flooring for various robotics competitions that RAP utilizes to meet its mission goals. One of these competitions, the FIRST Robotics Competition (FRC), currently uses two massive rolls of broadloom carpet for the foundation of the arena in which the robots are contained during the competition. The area of the arena is approximately 30 by 72 ft (≈9 by 22 m). This carpet is very cumbersome and requires large-capacity vehicles, and handling equipment and personnel to transport and deploy. The broadloom carpet sustains severe abuse from the robots during a regular three-day competition, and as a result, the carpet is not used again for competition. Similarly, broadloom carpets used for trade shows at convention centers around the world are typically discarded after only one use. This innovation provides a green solution to this wasteful practice.

Each of the flooring modules in the previous system weighed 44 lb (≈20 kg). The improvements in the overall design of the system reduce the weight of each module by approximately 22 lb (≈10 kg) (50 %), and utilize an improved "module-to-module" connection method that is superior to the previous system.

The MFS comprises 4-by-4-ft (≈1.2-by-1.2-m) carpet module assemblies that utilize commercially available carpet tiles that are bonded to a lightweight substrate. The substrate surface opposite from the carpeted surface has a module-to-module connecting interface that allows for the modules to be connected, one to the other, as the modules are constructed. This connection is hidden underneath the modules, creating a smooth, co-planar flooring surface. The modules are stacked and strapped onto durable, commercially available drywall carts for storage and/or transportation. This method of storage and transportation makes it very convenient and safe when handling large quantities of modules.

This work was done by Robert Thate of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-16240-1

Non-Toxic, Low-Freezing, Drop-In Replacement Heat Transfer Fluids

Lyndon B. Johnson Space Center, Houston, Texas

A non-toxic, non-flammable, low-freezing heat transfer fluid is being developed for drop-in replacement within current and future heat transfer loops currently using water or alcohol-based coolants. Numerous water-soluble compounds were down-selected and screened for toxicological, physical, chemical, compatibility, thermodynamic, and heat transfer properties. Two fluids were developed, one with a freezing point near 0 °C, and one with a suppressed freezing point. Both fluids contain an additive package to improve material compatibility and microbial resistance.

The optimized sub-zero solution had a freezing point of –30 °C, and a freezing volume expansion of 10-percent of water. The toxicity of the solutions was experimentally determined as LD_{50} > 5g/kg. The solutions were found to produce "minimal" corrosion with materials identified by NASA as potentially existing in secondary cooling loops.

Thermal/hydrodynamic performance exceeded that of glycol-based fluids with comparable freezing points for temperatures $T_f < 20°C$. The additive package was demonstrated as a buffering agent to compensate for CO_2 absorption, and to prevent microbial growth. The optimized solutions were determined to have physically/chemically stable shelf lives for freeze/thaw cycles and long-term test loop tests.

This work was done by J. Michael Cutbirth of Mainstream Engineering Corp. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24547-1

Materials That Enhance Efficiency and Radiation Resistance of Solar Cells

John H. Glenn Research Center, Cleveland, Ohio

A thin layer (≈10 microns) of a novel "transparent" fluorescent material is applied to existing solar cells or modules to effectively block and convert UV light, or other lower solar response waveband of solar radiation, to visible or IR light that can be more efficiently used by solar cells for additional photocurrent. Meanwhile, the layer of fluorescent coating material remains fully "transparent" to the visible and IR waveband of solar radiation, resulting in a net gain of solar cell efficiency.

This innovation alters the effective solar spectral power distribution to which an existing cell gets exposed, and matches the maximum photovoltaic (PV) response of existing cells. By shifting a low PV response waveband (e.g., UV) of solar radiation to a high PV response waveband (e.g. Vis-Near IR) with novel fluorescent materials that are transparent to other solar-cell sensitive wavebands, electrical output from solar cells will be enhanced.

This approach enhances the efficiency of solar cells by converting UV and high-energy particles in space that would otherwise be wasted to visible/IR light. This innovation is a generic technique that can be readily implemented to significantly increase efficiencies of both space and terrestrial solar cells, without incurring much cost, thus bringing a broad base of economical, social, and environmental benefits.

The key to this approach is that the "fluorescent" material must be very efficient, and cannot block or attenuate the "desirable and unconverted" waveband of solar radiation (e.g. Vis-NIR) from reaching the cells. Some nano-phosphors and novel organometallic complex materials have been identified that enhance the energy efficiency on some state-of-the-art commercial silicon and thin-film-based solar cells by over 6%.

This work was done by Xiadong Sun and Haorong Wang of Sun Innovations, Inc. 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-18781-1.