

smaller cell sizes (as low as 3 μm , depending on the diameter of the starting sacrificial filler particles). In all three micrographs of Figure 1, it is evident that the original unpyrolyzed structure is retained after pyrolysis, without loss of spherical cell shape.

In preliminary tests, specimens of SiC foams made by processing from pre-ceramic polymers were exposed to arc jets, which are traditionally used to simulate the aerothermal heating environments experienced by spacecraft entering or re-entering a planetary atmosphere. These tests were con-

ducted in the NASA Ames 60-MW Interaction Heating Facility (IHF), wherein flowing air is heated by an electric discharge. In these tests, disk specimens of 1.5-in. (3.81-cm) diameter and 0.5-in. (1.27-cm) thickness were mounted in an SiC-coated graphite holder and exposed to a temperature of 1,650 $^{\circ}\text{C}$ for 90 seconds (see Figure 2). The specimens showed minimal degradation after exposure.

In summary, the use of pre-ceramic polymers with the addition of sacrificial blowing agents and sacrificial and/or reactive fillers offers a feasible approach to

forming open-cell ceramic foams. Moreover, it has been found that refractory ceramic foams having properties that are encouraging for further development can be made using processing temperatures that, for ceramics, are relatively low ($\approx 1,200$ $^{\circ}\text{C}$). This approach enables tailoring of such foam properties as composition, pore size, and strength by varying the processing conditions.

This work was done by M. Stackpoole of ELORET for Ames Research Center. Further information is contained in a TSP (see page 1). ARC-15260-1

Self-Deploying Trusses Containing Shape-Memory Polymers

Compacted structures can be used in shelters for hostile environments.

John H. Glenn Research Center, Cleveland, Ohio

Composite truss structures are being developed that can be compacted for stowage and later deploy themselves to full size and shape. In the target applications, these “smart” structures will precisely self-deploy and support a large, lightweight space-based antenna. Self-deploying trusses offer a simple, light, and affordable alternative to articulated mechanisms or inflatable structures. The trusses may also be useful in such terrestrial applications as variable-geometry aircraft components or shelters that can be compacted, transported, and deployed quickly in hostile environments.

The truss technology uses high-performance shape-memory-polymer (SMP) thermoset resin reinforced with fibers to form a helical composite structure. At normal operating temperatures, the truss material has the structural properties of a conventional composite. This enables truss designs with required torsion, bending, and compression stiffness. However, when heated to its designed glass transition temperature (T_g), the SMP matrix acquires the flexibility of an elastomer. In this state, the truss can be compressed telescopically to a configuration encompassing a fraction of its original volume.

When cooled below T_g , the SMP reverts to a rigid state and holds the truss in the stowed configuration without external constraint. Heating the materials above T_g activates truss deployment as the composite material releases strain energy, driving the truss to its original “memorized” configuration without the



Activation Sequence of an early prototype self-deploying truss shows one one-minute duration from compressed [2.5 in. (6.4 cm)] to deployed [28.5 in. (72.4 cm)].

need for further actuation. Laboratory prototype trusses have demonstrated repeatable self-deployment cycles following linear compaction exceeding an 11:1 ratio (see figure).

While this new truss technology exhibits some functionality similar to that of cold hibernated elastic memory (CHEM) structures developed in other NASA-sponsored research (previously reported in *NASA Tech Briefs*), there are important distinctions. First, the CHEM SMP is based on a thermoplastic resin, while the new truss material's high-performance SMP is a fully cured thermoset resin. The high-perform-

ance SMP molecular design has been implemented in a variety of resin systems, enabling resin selection for desired structural properties while enabling selection of a required T_g (e.g., 25–225 $^{\circ}\text{C}$ achievable in high-performance SMPs based on cyanate ester). Also, CHEM-based structures use unreinforced foam as the active component. In the new composite truss design, the high-performance SMP is integral to the structure, simplifying the design and increasing the savings in mass, cost, and system complexity. Structures employing high-performance SMP are fabricated using the

same processes as conventional composites. The composite structure's mechanical properties at temperatures below T_g are unaffected by repeated stowage-deployment cycles.

This work was done by Robert M. Schueler of Cornerstone Research Group, Inc. for Glenn Research Center.

Inquiries concerning rights for the commercial use of this invention should be addressed

to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17982-1.

Fuel-Cell Electrolytes Based on Organosilica Hybrid Proton Conductors

NASA's Jet Propulsion Laboratory, Pasadena, California

A new membrane composite material that combines an organosilica proton conductor with perfluorinated Nafion material to achieve good proton conductivity and high-temperature performance for membranes used for fuel cells in stationary, transportation, and portable applications has been developed.

To achieve high proton conductivities of the order of $10^{-1} \text{S}\cdot\text{cm}^{-1}$ over a wide range of temperatures, a composite membrane based on a new class of mesoporous, proton-conducting, hydrogen-

bonded organosilica, used with Nafion, will allow for water retention and high proton conductivity over a wider range of temperatures than currently offered by Nafion alone. At the time of this reporting, this innovation is at the concept level. Some of the materials and processes investigated have shown good proton conductivity, but membranes have not yet been prepared and demonstrated.

This work was done by Sri R. Narayan and Shiao-Pin S. Yen of Caltech for NASA's Jet Propulsion Laboratory.

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, (818) 354-2240, E-mail: iaoffice@jpl.nasa.gov.

Refer to NPO-40228, volume and number of this NASA Tech Briefs issue, and the page number.

Molecules for Fluorescence Detection of Specific Chemicals

These molecules could be used in the detection of chemical warfare agents.

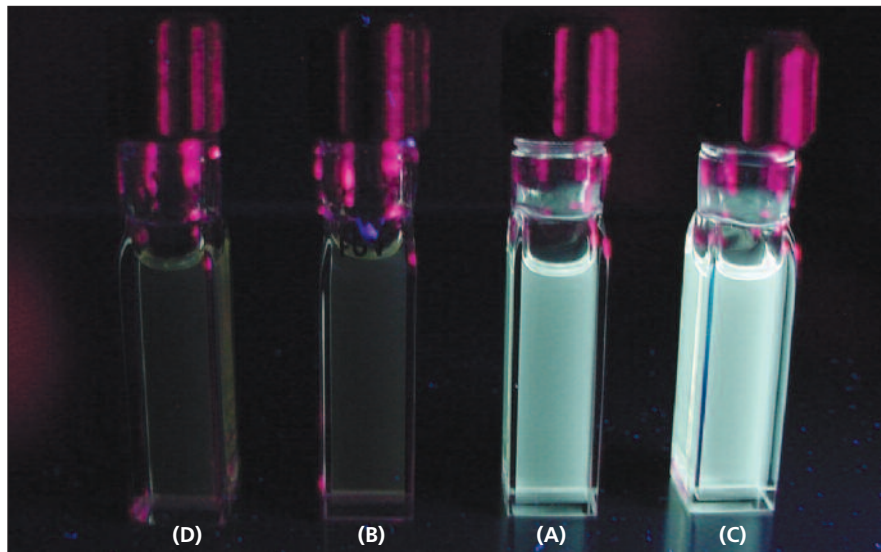
John H. Glenn Research Center, Cleveland, Ohio

A family of fluorescent dye molecules has been developed for use in "on-off" fluorescence detection of specific chemicals. By themselves, these molecules do not fluoresce. However, when exposed to certain chemical analytes in liquid or vapor forms, they do fluoresce (see figure). These compounds are amenable to fixation on or in a variety of substrates for use in fluorescence-based detection devices: they can be chemically modified to anchor them to porous or non-porous solid supports or can be incorporated into polymer films. Potential applications for these compounds include detection of chemical warfare agents, sensing of acidity or alkalinity, and fluorescent tagging of proteins in pharmaceutical research and development. These molecules could also be exploited for use as two-photon materials for photodynamic therapy in the treatment of certain cancers and other diseases.

A molecule in this family consists of a fluorescent core (such as an anthracene or pyrene) attached to two

end groups that, when the dye is excited by absorption of light, transfer an electron to the core, thereby quenching the fluorescence. The end groups

can be engineered so that they react chemically with certain analytes. Upon reaction, electrons on the end groups are no longer available for transfer to



The Effects of Adding Different Analytes are illustrated on the activation of a fluorescent "on-off" sensor. Shown are sensor molecules before activation (D), after activation by treatment with acid (A), acid treated sample that has been deactivated by treatment with base (B), and sensor molecule activated by treatment with acetyl chloride (C).