control the velocity of exploration vehicles (EVs) when entering Earth or other planetary atmospheres. Since entry of aeroshells and inflatable structures. Exposures could be done, for example, using a radiation "oven" through which a conveyor belt passes.

This work was done by Henry C. de Groh III, Bernadette J. Puleo, and Deborah L. Waters of 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-18948-1.

### High-Temperature Adhesives for Thermally Stable Aero-Assist Technologies

These adhesives feature high thermal conductivity and increased thermal decomposition temperature.

**Marshall Space Flight Center, Alabama**

Aero-assist technologies are used to control the velocity of exploration vehicles (EVs) when entering Earth or other planetary atmospheres. Since entry of EVs in planetary atmospheres results in significant heating, thermally stable aero-assist technologies are required to avoid the high heating rates while maintaining low mass. Polymer adhesives are used in aero-assist structures because of the need for high flexibility and good bonding between layers of polymer films or fabrics. However, current polymer adhesives cannot withstand temperatures above 400 °C.

This innovation utilizes nanotechnology capabilities to address this need, leading to the development of high-temperature adhesives that exhibit high thermal conductivity in addition to increased thermal decomposition temperature. Enhanced thermal conductivity will help to dissipate heat quickly and effectively to avoid temperature rising to harmful levels. This, together with increased thermal decomposition temperature, will enable the adhesives to sustain transient high-temperature conditions.

A first principle analysis showed that the adhesive can have a beneficial impact on the high-temperature stability of aeroshells and inflatable structures. Silicones and polyimides are used as high-temperature adhesives, and prior efforts have been made to incorporate thermally conductive ceramic powders such as aluminum oxide and boron nitride into silicone formulations to increase thermal conductivity. These high loading levels of ceramic particles present several problems. Viscosity rises, necessitating the use of a solvent, which then needs to be removed at a later stage. Adhesive and mechanical properties deteriorate. A way to decrease the additive loading level while achieving the desired thermal performance was needed.

For conventional composite structures, a three-dimensional percolative network is required to achieve significant performance enhancement, which typically results in a high-volume loading of particles. In contrast, advances were made in creating a new paradigm in non-three-dimensional percolative composites. The emphasis is on nanoparticle composites, but the concept applies equally well to all particulate composites (i.e., both nanoscale and microscale). As a result, the desired thermal properties can be obtained at relatively low loading levels of nanoparticles, without the detrimental effect on processing and other properties, such as mechanical strength and bonding.

The thermal conductivity of silicone material can be significantly enhanced by adding high-aspect-ratio nanoparticles at relatively low levels. For example, the thermal conductivity is drastically increased by a factor of 3.7 when 10 wt % of high-aspect-ratio nanoparticles is added to a commercial silicone adhesive. In addition, it was shown that there is a synergistic effect when spherical nanoparticles and high-aspect-ratio particles are present. An array of samples that had unique nanoparticle characteristics and nanocomposite morphology was fabricated, and a set of characterization protocols was developed.

This work was done by Kenneth Eberts and Runqiu Ou of NEI Corp. for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32899-1.