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(Statement A)

Submitted for an ORAL Presentation

Synthesis and Atomic Oxygen Erosion Testing of Space-Survivable POSS (Polyhedral Oligomeric Silsesquioxane) Polyimides

Rene I. Gonzalez¹, Sandra J. Tomczak¹, Gar B. Hoflund², Timothy K. Minton³ and Amy Brunsvold³. (1) AFRL/PRSM, Materials Applications Branch, Air Force Research Laboratory, 10 E. Saturn Blvd, Bldg. 8451, Edwards AFB, CA 93524, Tel: (661) 275-5252, Fax: (661)-275-5471, rene.gonzalez@edwards.af.mil, (2) Department of Chemical Engineering, University of Florida, Gainesville, FL 32611 (3) Department of Chemistry and Biochemistry, Montana State University, 108 Gaines Hall Bozeman, MT 59717

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The harsh environment present in both Low-Earth and Geosynchronous Orbit (LEO and GEO) combined with the need for lighter weight and lower cost man-made orbiting bodies necessitates the design of multi-functional, space-survivable materials. Over the last two decades it has been well established that conventional polymers used in the construction of space vehicles undergo severe degradation resulting in reduced spacecraft lifetimes. In particular the polyimide Kapton has been studied at length since it is widely used as a flexible substrate for lightweight high power solar arrays because of its inherent strength and desirable thermal properties. In addition to Kapton, thin films of fluorinated polymers such as Teflon FEP are used as the outer layer of multi-layer thermal control insulation because of their superior optical properties, including low solar absorptance and high thermal reflectance. These polymeric materials degrade because spacecraft surfaces must endure a high incident fluences of atomic oxygen (AO), bombardment by low and high-energy charged particles, and thermal cycling along with the full spectrum of solar radiation.

Hybrid inorganic/organic polymers have the potential to meet the requirements of space-survivable materials by bridging the gap between ceramics and plastics, resulting in the prevention of AO and radiation damage that has hampered the widespread application of organic polymers in space. The Polymer Working Group at the Air Force Research Laboratory at Edwards AFB has incorporated inorganic POSS (Polyhedral Oligomeric Silsesquioxane) frameworks into traditional polymer systems resulting in hybrid POSS-polymers with dramatic

property enhancements. Addition of these POSS nanostructured frameworks into polymers results in increased use and decomposition temperatures, improved mechanical properties, and oxidation resistance. These nanoscopic POSS frameworks are comprised of a three dimensional inorganic core with a 3:2 O-Si ratio. They may be functionalized with a polymerizable group or groups and are surrounded by inert organic groups at the remaining vertices. These nonreactive organic groups (cyclopentyl, cyclohexyl, phenyl, isobutyl, methyl) aid in the compatibilization of the POSS macromers within the polymer matrix.

Our previous research has shown that POSS nanostructures can be easily dispersed throughout the polymer matrix by chemical manipulation of these inert organic groups surrounding the POSS cage. This has allowed us to synthesize completely transparent materials at high POSS loadings. We have also shown that polymers containing POSS rapidly form a ceramic-like, passivating and self-healing silica layer when exposed to high incident fluxes of AO. We believe that this self-healing nature is a direct result of POSS compatibility and dispersion throughout the polymer matrix. If the resultant glassy silica layer erodes or suffers a microdefect, it would quickly reform due to the uniform POSS dispersion. This process potentially prolongs the lifetime of the material in space therefore extending the time between repairs of spacecraft surfaces. This talk presents several characterization studies of the surfaces of newly synthesized POSS-containing polymers, specifically polyimides before and after exposure to AO. Atomic oxygen exposure testing was conducted independently at the University of Florida and Montana State University revealing comparable data. A variety of POSS-containing copolymers were examined because they have diverse properties and might perform well in different space-related applications. The exposed surfaces were characterized using X-ray photoelectron spectroscopy, and atomic oxygen erosion rates were calculated using stylus surface profilometry. Experiments were carried out in-situ because air exposure modifies the reactive surfaces formed during exposure to AO. The data indicates that just a 10 wt% (1 mole %) addition of POSS in a kapton-like polyimide can result in over a tenfold improvement in the AO erosion rate while a 20 wt% addition results in over a twentyfold improvement. These high-performance, self-healing POSS polyimides are a revolutionary step forward in space-survivable materials and should enable the long-term deployment of space inflatable structures and membranes for antennas, solar arrays and solar sails.