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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
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SPACE RADIATION RESISTANT INORGANIC/POLYMER NANOCOMPOSITE SOLAR SAIL MEMBRANES

Abstract

A solar sail is an attractive spacecraft propulsion system for an extended mission because it derives thrust directly from momentum transfer of solar photons without the need for on-board fuel. The sail material though, needs to survive large temperature fluctuations, ultraviolet (UV) radiation, ultrahigh vacuum, micrometeoroid impacts, and ionizing radiation such as high energy electrons, protons, neutrons, heavy ions, gamma-rays, and X-rays from solar particle events and galactic cosmic rays. Since the durability of the sail material controls operational lifetime, understanding the effects of the space environment on the sail membrane is essential for mission success.

Recently, NASA has developed new inorganic/polyimide hybrid nanocomposites for long-duration aerospace structural applications such as solar sails. In this study, the effect of inorganic particles on the radiation-induced degradation of polyimide solar sail membranes and the mechanism of degradation was determined. LaRC SI^{TM} polyimide was chosen as a baseline matrix and several different inorganic

nanoparticles were selected as additives. To evaluate the effect of ionizing radiation, the hybrid polyimide nanocomposites were exposed to energetic electrons (about 50-60 keV and 9 nA/cm^2) or high energy photons (vacuum UV, 184.9 and 253.7 nm). The thermal, optical, and mechanical properties were characterized before and after exposure. The hybrid polyimide nanocomposites showed a weight loss of about 29% after high energy photon exposure compared to about 50% for the pristine polyimide. The nanocomposite also showed a slower degradation in mechanical properties (about 40% decrease in elongation at break of the nanocomposite versus about 85% decrease for the pristine polyimide). In light of results from dynamic mechanical analysis and Fourier-transform infrared and electron paramagnetic resonance spectroscopies, molecular mechanisms of the radiation-induced degradation are discussed. In addition, the feasibility of commercial off-the-shelf polyester membranes for a solar sail mission will be discussed based on the effects of ionizing radiation and simulated micrometeoroid impacts on the thermal, optical, and mechanical properties. Potential applications in other aerospace missions will also be discussed.