Materials in a Space Environment

Spacecraft typically operate in extremely harsh environments, presenting a significant challenge for their materials. The nature of the environment depends greatly on the spacecraft's mission, but common elements that arise are space vacuum, extreme temperatures, thermal cycling, charged particles, neutral molecules and radicals, electromagnetic radiation, micrometeoroids and debris, and self-contamination. The high velocity of spacecraft leads to high collision velocities with some of these species and enhances the effects of their interactions. For example, high velocity interactions between spacecraft and oxygen atoms in low Earth orbit result in oxidation and/or erosion of a host of organic and inorganic materials. In addition, synergistic effects from the combined interactions of two or more environmental species may enhance the rate of materials degradation far beyond the rate of one species acting alone. After more than 50 years of space exploration, the space environment and its effects on spacecraft materials are still of major concern and need to be understood and mitigated against in order to ensure the success of missions in space.

Because material degradation mechanisms on spacecraft are diverse, ranging from complex chemical reactions to impact physics, aerospace engineers often favor an empirical approach that relies on testing in actual and simulated space environments to provide data that when combined with models will allow the space durability of a material to be predicted. As data and performance results on more and more materials are accumulated, they serve as the basis for databases and protocols that can be used to improve the design of future spacecraft. Such an approach has great utility and undoubtedly reduces the risk to subsequent missions. However, breakthroughs in materials, testing, and durability prediction will come from a mechanistic understanding of the degradation mechanisms, which is generally in the purview of scientists. Thus, the field of space environmental effects is made of a wide array of scientists, engineers, database managers, and project managers.

These people who have an interest in space environmental effects gather occasionally at national and international meetings to exchange information and learn about progress on the various fronts in the field. The largest regular meeting is the International Symposium on Materials in a Space Environment (ISMSE), which is held every three years and has been jointly organized in Europe since the late 1970s by the European Space Agency (ESA), the French Space Agency (Centre National D'Etudes Spatiales, CNES), and the French Aerospace Lab (Office National d'Etudes et Recherches Aérospatiales, ONERA). The 11th ISMSE was held in Aix-en-Provence, France, on September 14−18, 2009. About 120 people attended the conference, from universities, national laboratories, and industry. There were 64 oral presentations and 56 posters.

Following the conference, authors who presented research on chemistry relating to the interactions of materials with a space environment or to the design of relevant new materials were invited to submit their work for publication in *ACS Applied Materials & Interfaces*. After submission and peer review, six papers have been accepted for publication, and these papers form a collection that constitutes a special virtual issue representing applied materials chemistry in the field of space environmental effects. Access to this Virtual Special Issue is available free online at http://pubs.acs.org/page/aamick/vi/1. One paper, by Orru and co-workers, focuses on the production of ultrahigh temperature ceramics based on TaB_2, which may be useful for surviving re-entry into the Earth's atmosphere. Another paper, by Rasmussen et al., demonstrates a method of screening the susceptibility of polymeric materials to degradation by heat and ultraviolet light. This method follows the degradation kinetics in situ by ESR spectroscopy. A paper by Tagawa and co-workers also relates to materials testing, as they show that the exact nature of the testing environment can have a profound effect on the atomic-oxygen-induced erosion of FEP Teflon—a topic that has been debated for more than 20 years. A new atomic-oxygen-resistant material has been synthesized and characterized by Fischer et al. This material has the potential to form a passivating oxide layer and be durable in the harsh oxidizing conditions encountered by spacecraft in low Earth orbit. The remaining two papers focus on the protection of polymers from oxidation, ultraviolet light, and charging in space environments. The paper by Gouzman et al. uses a novel liquid-phase deposition technique to coat a polymer surface with

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a thin layer of TiO_2. The paper by Minton et al. describes the protection afforded by TiO_2 and other metal oxide coatings that are prepared by atomic layer deposition.

Researchers continue to develop new materials and coatings that can withstand the extreme environments to which materials are subjected on spacecraft. The high cost associated with testing materials in space motivates high fidelity ground-based testing that can be used to make reliable predictions about materials degradation in the complex space environment. Whether in the production of new materials or the design of a test, the most accurate predictions will come from a knowledge of the relevant chemistry, which has been elusive because of the extreme and complex nature of the chemical interactions. Further research into the underlying chemical mechanisms of space environmental effects on materials will continue to drive the development of more durable spacecraft materials. *ACS Applied Materials & Interfaces* provides a natural venue for the publication of research in this area of applied chemistry.

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