MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Specialized Technologies, including Nanotechnology (8)

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CARBON NANOTUBES AND THEIR POLYMER-BASED COMPOSITES IN SPACE ENVIRONMENT

Abstract

Future space exploration missions will be based on the availability of lightweight materials, with improved physical properties, and multifunctional/smart capabilities. Polymer based composites are extremely attractive as materials for future space exploration, due to their reduced weight, wide range of physical properties, and flexibility in designing polymeric materials for targeted applications. Nanocomposites obtained by dispersing nanoparticles of various functionalities within polymeric matrices are of particular importance due to their huge surface to volume ratio. In such materials the fraction of polymer chains involved in intermolecular interactions with nanoparticles (interphase) is large. This allows us to improve and tailor the physical properties of the polymer by engineering polymer-nanoparticle interfaces that enhance specified physical properties and eventually triggers new physical properties.

The outstanding mechanical, thermal, and electrical properties of carbon nanotubes and their huge aspect ration incited a sustained research on their physical properties and potential applications. In the last two decades an intense research effort was focused on polymer-carbon nanotubes composites with emphasis on the improvement of the physical properties of polymers by carbon nanotubes dispersion. This research demonstrated a sizable increase of mechanical properties (Young modulus), a modest improvement of the temperature stability, a decrease of the polymer flammability, and the enhancement of polymer thermal and electrical conductivities.

Commercially available carbon nanotubes are typically a collection of semiconducting and conducting nanotubes. As most polymers are thermal and electric insulators, the addition of carbon nanotubes enhances the thermal and electrical conductivity adding new features to the polymeric matrix. While the combined enhancement of mechanical strength, thermal conductivity, and electrical conductivity triggered by the dispersion of carbon nanotubes within polymers is beneficial for some applications there are cases in which such multifunctional features are detrimental (the drop in the electrical resistance in electrical insulators or the increase of the thermal conductivity in thermal insulating materials).

Carbon nanotubes have an outstanding thermal stability in vacuum or inert gas atmosphere but they are prone to oxidation in oxygen contained atmosphere. The stability of carbon nanotubes to oxidation is further reduced if atomic oxygen/zone is interacting with carbon nanotubes. The complex features of certain space environments such as Low Earth Orbit that combines ionizing radiation, electromagnetic radiation, and atomic oxygen may result in a rapid degradation of carbon nanotubes, followed by the failure of the polymer nanocomposite.

The paper concentrates on the combined effect of ionizing radiation, extreme temperatures, and oxygen/atomic oxygen on polymer carbon nanotube composites. Experimental data obtained on pristine and irradiated polymer-carbon nanotube composites are critically analyzed and compared with results reported elsewhere. The effect of carbon nanotubes on the physical properties of polymers (mechanical properties such as tensile strength, Young modulus, and elongation at break, thermal properties such as glass, crystallization, and melting temperature, and electrical features) and the subsequent modifications triggered by ionizing radiation and oxygen attack are analyzed in details.