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J Kleiman
Integrity Testing Laborator, Inc

Z Iskanderova
Integrity Testing Laboratory, Inc

C Best
ViaSat

JR Dennison
Utah State Univesity

Brian Wood
Utah State University

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LONG-TERM STABILITY OF ION-BEAM TREATED SPACE POLYMERS IN GEO-SIMULATED ENVIRONMENT

J. Kleiman[1], Z. Iskanderova[1], L. Krishtein[2], JR Dennison[3], Brian Wood[3], C. Best[4]

1 - Integrity Testing Laboratory, Inc, Markham, Ontario, Canada; 2 - Kvarc, Mississauga, Ontario, Canada
3 - Utah State University, Logan, Utah, USA; 4 – ViaSat, Tempe, AZ, USA

Abstract

As part of a large, multi-year program, a number of ion beam processes were developed [1- 2] in which the treated polymer-based materials and space structures attained controlled surface resistivity (SR) in a wide range of SR values. These materials had, low SR temperature dependence and low RF losses, with enhanced resistance against spacecraft charging and total dose effects for applications in GEO environment. A unique set of long-term space effects experiments was performed on these materials and structures in three world-recognized GEO simulation facilities, covering proton, electron, and UV exposure in a wide range of GEO-like irradiation conditions.

A multi-purpose GEO environment simulation facility at Kompozit, Russia, was used to expose a number of ion-beam treated samples with impaired SR properties to separate electron (10-50 keV) and proton (10-50 keV) environments and to synergistic exposures of electrons, protons and UV, with total irradiation fluencies that were equivalent to up to 15 years of GEO space exposure. All treated materials and parts successfully passed the testing program, showing that the SR properties remained in the functional charge dissipative range [1]. The ion beam treated/deposited charge dissipative polymer surfaces also successfully survived and maintained the functional surface properties for tests simulating the MEO environment for a long-duration MEO mission.

In another project the smooth and the rough polymer-based surfaces of flexible cable conductors, used for solar arrays in GEO, were made fully charge dissipative by a specially developed method of ion-beam surface treatment with simultaneous surface renewal [2]. The results of space qualification program and extended long-term exposure to simulated GEO orbit charging at the SIRENE testing facility confirmed that all tested surfaces, including rough surfaces with foreign embedded particles, acquired the required SR at room temperature and stayed charge dissipative over a wide ±150 °C temperature range. The modified surfaces successfully survived testing for 15 year's space-equivalent GEO orbit at SIRENE, with all surfaces keeping the charge dissipative properties. Electrostatic discharge (ESD) testing demonstrated the long-lasting charge-dissipation properties of the treated surfaces, fully preventing them from building up critical charges in a GEO orbit environment, when a reliable grounding path is ensured for the surfaces.

To evaluate the ability of polymer materials to provide a pathway for charge dissipation, in case of internal charging effects in radiation-induced conductivity situations, a number of ion beam treated Kapton HN and PEEK samples of various thicknesses with charge dissipative surface properties were irradiated with a 25 MeV linear accelerator electron beam at the Idaho Accelerator Center (IAC) at Idaho State University [3]. A scatter foil was used to produce an incident energy distribution centered at 7.8MeV with an approximate dose rate of 45 MRad (Si) per hour. The samples were exposed at ambient temperature in a dry nitrogen environment to three sequential doses of ~15 MRad (Si), then 30-170 MRad (Si), and finally 65-230 MRad. In total, the samples were exposed to between 0.1 Grad and 0.4 Grad. The SR of the samples, being one of the most important parameters in hostile GEO environment, was monitored before and after each irradiation interval. A remarkable survivability of the SR of the specimens with the IBD coatings was recorded. They showed a very modest increase in SR with the total ionizing dose increasing only a factor of 1 to 3 times for these large doses. These results are consistent with the notion that the coatings behave similarly to graphitic carbon, which is very radiation tolerant, rather than to typical polymeric materials.

All tests conducted at all of the described facilities demonstrated that the ion-beam processes that were used for development of the various surface treatments of polymer-based materials for GEO applications, provide reliable, long lasting, charge-dissipative effects that remain practically unchanged in the most severe GEO environment conditions simulating up to 15 years of operation in GEO.

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2. Z. Iskanderova, Jacob Kleiman, et al., "Surface Modification of Space-Related Flat Cable Conductors by a Novel Technological Process", J.of Spacecraft and Rockets, Vol. 53, No. 6 (2016), pp. 1068-1076.
3. J. C. Gillespie, "Measurements of the Temperature Dependence of Radiation Induced Conductivity in Polymeric Dielectrics," MS Thesis, Utah State University, 2013; http://iac.isu.edu/pdf/25MeVLINAC_IACandAirport.pdf .