Evaluation of Low-Earth-Orbit Environmental Effects on International Space Station Thermal Control Materials

Many spacecraft thermal control coatings in low Earth orbit (LEO) can be affected by solar ultraviolet radiation and atomic oxygen. Ultraviolet radiation can darken some polymers and oxides commonly used in thermal control materials. Atomic oxygen can erode polymer materials, but it may reverse the ultraviolet-darkening effect on oxides. Maintaining the desired solar absorptance for thermal control coatings is important to assure the proper operating temperature of the spacecraft.

Thermal control coatings to be used on the International Space Station (ISS) were evaluated for their performance after exposure in the NASA Lewis Research Center's Atomic Oxygen-Vacuum Ultraviolet Exposure (AO-VUV) facility. This facility simulated the LEO environments of solar vacuum ultraviolet (VUV) radiation (wavelength range, 115 to 200 nanometers (nm)) and VUV combined with atomic oxygen. Solar absorptance was measured *in vacuo* to eliminate the "bleaching" effects of ambient oxygen on VUV-induced degradation. The objective of these experiments was to determine solar absorptance increases of various thermal control materials due to exposure to simulated LEO conditions similar to those expected for ISS. Work was done in support of ISS efforts at the requests of Boeing Space and Defense Systems and Lockheed Martin Vought Systems.

In one test, samples consisted of the white paint thermal control coating Z-93-P (zinc oxide pigment in potassium silicate binder formulated by the Illinois Institute of Technology Research Institute) applied to 0.9375-in.-diameter aluminum substrates. These samples were coated with approximately 1000 angstroms of products of Tefzel (DuPont) fluoropolymer degradation to simulate the on-orbit contamination that may occur from the degradation of power cable insulation. Samples thus coated in Boeing facilities were then exposed to VUV radiation of up to 2400 equivalent sun hours (ESH) in the Lewis facility, the equivalent of over 7 years in LEO for ISS radiator surfaces. These samples experienced a greater increase in solar absorptance than an uncoated control sample of the same Z-93-P coating. The implications of these results are that Z-93-P surfaces on ISS may degrade at a faster rate when they are in an environment where they can be contaminated by the degradation of fluoropolymer power cable insulation. This test represented a worst-case scenario for Z-93-P solar absorptance degradation because atomic oxygen, which may remove some of the fluoropolymer contaminants and may reverse the darkening due to vacuum ultraviolet radiation, was not present during testing.

In two additional tests, samples of 0.9375-in.-diameter samples of silvered FEP Teflon (FEP/silver/inconel/acrylic adhesive/aluminum substrate), SiO_2-coated silvered FEP Teflon (SiO_2/FEP/silver/inconel/acrylic adhesive/aluminum substrate), and white paint Z-93-P coatings (Z-93-P/aluminum substrate) were exposed to the combined environments of

VUV radiation and atomic oxygen. These samples experienced negligible changes in solar absorptance upon exposure to up to approximately 1300 ESH of VUV radiation combined with a fluence of $4x10^{21}$ oxygen atoms/cm^2. Samples were thus exposed to a LEO equivalent of approximately 4 years of atomic oxygen and 2.5 to 4 years of VUV radiation. This test verified the solar absorptance durability of thermal control materials selected for use on ISS in the absence of contaminants. Although these tests were specifically designed to simulate ISS conditions, the results are applicable to many missions that use these common thermal control coatings.

Results from the three tests are shown in the table. Error for the solar absorptance values is expected to be 0.007.

SOLAR ABSORPTANCE CHANGES IN COATINGS EXPOSED TO SIMULATED LEO CONDITIONS

Sample	VUV exposure, ESH VUV atoms/cm^2	Solar absorptance		
		Prior to exposure	After exposure	Increase
Test 1 (no atomic oxygen exposure)				
Tefzel-contaminated Z-93-P, #1	1700	0.154	0.208	0.054
Tefzel-contaminated Z-93-P, #2	2200	0.156	0.207	0.051
Tefzel-contaminated Z-93-P, #3	2400	0.168	0.236	0.068
Pristine Z-93-P	2200	0.133	0.159	0.026
Test 2 (atomic oxygen exposure, $4.40x10^{21}$ atoms/cm^2)				
SiO_2/FEP Teflon/Ag...,[a] #1	850	0.072	0.07	-0.002
SiO_2/FEP Teflon/Ag..., #2	1100	0.072	0.074	0.002
SiO_2/FEP Teflon/Ag..., #3	1000	0.069	0.062	-0.007
Pristine Z-93-P	1300	0.132	0.125	-0.007
Test 3 (atomic oxygen exposure, $4.20x10^{21}$ atoms/cm^2)				
FEP Teflon/Ag...,[b] #1	1100	0.064	0.06	-0.004
FEP Teflon/Ag..., #2	850	.065	.06	-.005

FEP Teflon/Ag..., #3	980	.064	.061	-.003
Pristine Z-93-P	1300	.117	.11	-.007
[a]SiO_2/FEP/silver/Inconel/acrylic adhesive/aluminum substrate. [b] FEP/silver/Inconel/acrylic adhesive/aluminum substrate.				

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