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Contamination Effects on the Passive Optical Sample Assembly Experiments

H. Gary Pippin,* Suzanne L. B. Woll,† Valerie A. Loebs,‡ and Gail Bohnhoff-Hlavacek§
The Boeing Company, Seattle, Washington 98124-2499

The passive optical sample assembly I and II experiments were part of an International Space Station risk mitigation study placed on the exterior of the Mir space station. The experiment surfaces were examined postflight for the effects of contamination, atomic oxygen, solar exposure, and particulate radiation. Examination of selected Boeing specimens showed that one or more discrete contamination events distributed material over the surface of passive optical sample assembly II facing away from Mir. Detailed elemental depth profiles were produced for both passive optical sample assembly I and II experiment surfaces using x-ray photoelectron spectroscopy measurements made in conjunction with controlled ion sputtering. The depth profiles showed that the molecular contaminant layer is predominantly composed of silicon-based material. On the space-facing side of passive optical sample assembly I, the thickness of molecular contamination layer was determined to be as great as 3000–4800 Å in certain locations. The likely source of this layer was outgassing from a nearby stowed solar array. The emittance of numerous passive optical sample assembly II specimens was observed to decrease by approximately 0.01 (Mir-facing side) to 0.02 (space-facing side), independent of material type. For certain specimens, the emittance decrease was even greater.

Nomenclature

α = solar absorptance
ε = thermal emittance

Introduction

THE passive optical sample assembly (POSA) experiments were part of the Mir Environmental Effects Payload (MEEP). MEEP consisted of five experiments: the orbital debris collector (ODC), the polished plate meteoroid and debris experiment (PPMD), the POSA I and II experiments, and the passive experiment carriers (PEC) that held the four payloads. These combined experiments were an International Space Station (ISS) contamination risk mitigation experiment, flown for the purpose of assessing contamination levels around a large structure in space. Figure 1 is a preflight photograph of the POSA II experiment integrated into its PEC that shows the layout of the specimens.

Originally, there was only one POSA experiment. A concern that silicone-containing specimens might cross contaminate other specimens and make interpretation of the contamination data difficult led to the decision to fly a second POSA experiment. Thus, POSA I contained no silicone materials whatsoever. Materials with silicone coatings or paint specimens with silicone-based binders were assigned to fly on POSA II.

The Energetic Oxygen Interaction with Materials (EOIM) experiment-type trays that were used to hold the specimens were precision cleaned preflight to NASA level A (essentially, the nonvolatile residue < 1 mg/0.1 m^2). The cleaning was accomplished with a detergent wash, a deionized water rinse, and then three solvent rinses: acetone, ethanol, and then a mixture of 3:1 1,1,1-trichloroethane and ethanol. A few elastomeric specimens and coatings were wiped down once with isopropyl alcohol; however, no special cleaning was carried out for most specimens. Individual specimens were stored in Fluoroware® containers prior to installations into the trays. The Fluoroware storage containers were also precision cleaned as just described before use. The flight specimens are identified in this work by their numbered tray position.

On-Orbit

The MEEP payloads were carried to Mir in the side wall containers of the space shuttle cargo bay during the Space Transportation System STS-076 flight. The MEEP experiments were deployed on the docking module between the STS and Mir by astronaut extravehicular activity (EVA) on 25 March 1996, after the rendezvous of STS-076 with Mir. POSA II was placed on the nominal ram side of the docking module. Numerous orientation changes occurred during the exposure period. POSA I was placed on the opposite side of the docking module from POSA II. There was no line of sight between POSAs I and II. Figure 2 shows the MEEP payloads deployed on the docking module. This photograph was taken during the approach of the space shuttle to Mir during the STS-079 mission in September 1996.

In addition to the deployment and retrieval missions, the Mir was visited three times by the STS (STS-079, STS-081, STS-084) during the exposure of the POSA experiments. A photograph survey was made during each visit of the space shuttle to the Mir. Figure 3 shows a close-up of the POSA I experiment taken during the STS-079 mission. The Boeing-provided specimens on the POSA I experiment were mounted in the EOIM tray that contained both 1-in.- and 0.5-in.-diam specimens. These visits occurred during September 1996, January 1997, and May 1997. By the STS-79 visit, deposits were already visible on mirrored surfaces of certain specimens on POSA I.

Mir traveled in a 100% sunlight orbit for several consecutive orbits three times during the flight of the MEEP experiments. The effect of at least one, and possibly two, of these periods is observed in the x-ray photoelectron spectroscopy (XPS) depth profiles of specimens from the space/STS-facing side of POSA I. The June 1997 event was also detected by temperature-controlled quartz crystal microbalances (TQCMs) on the optical properties monitor (OPM) experiment, mounted near POSA II. The deposition rate on the TQCMs increased dramatically during this period. In late June 1997, Mir underwent a collision with one of its Progress modules during testing of a manual docking system. Although this event disrupted the attitude of the Mir, it caused no apparent harm to the MEEP payloads.

The MEEP payloads were retrieved on 26 September 1997 during the visit of STS-084 to Mir. Figure 4 shows the POSA II PEC being

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*Senior Specialist Engineer, M/S 73-09, P.O. Box 3999, Non-Metallic Material Technology, Phantom Works. Member AIAA.

†Senior Specialist Engineer, M/S 73-09, P.O. Box 3999, Non-Metallic Material Technology, Phantom Works.

‡Process Materials and Component Analyst, M/S 3W-50, P.O. Box 3999, Analytical Engineering, Phantom Works.

§Technical Principal, M/S 8H-01, P.O. Box 3999, Radio Frequency and Photonics, Phantom Works.

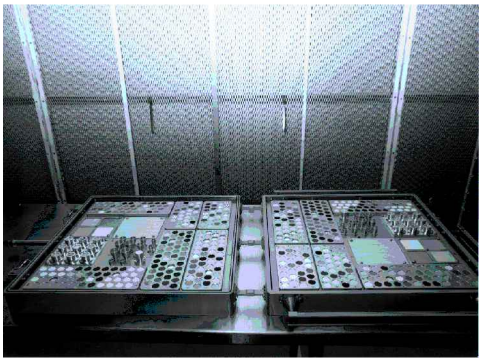

Fig. 1 POSA II, preflight (NASA photograph).

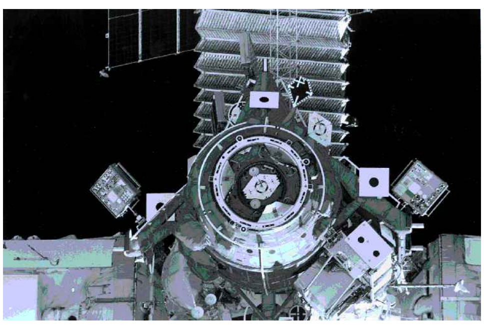

Fig. 2 MEEP experiments deployed on the space suttle/Mir docking module (NASA photograph).

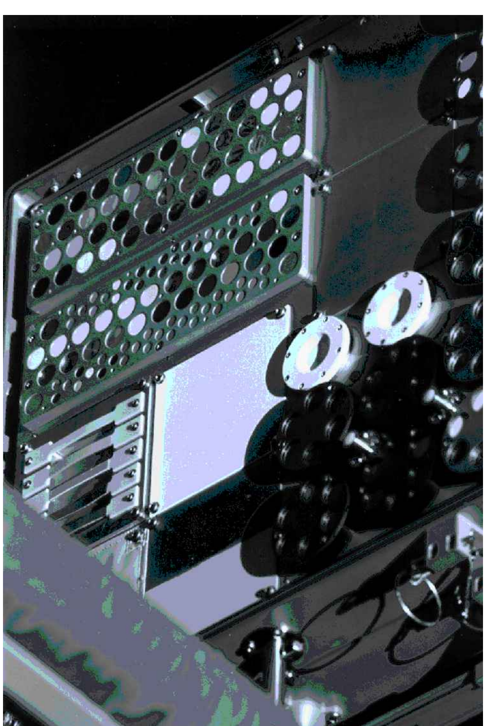

Fig. 3 POSA I, on-orbit (NASA photograph).

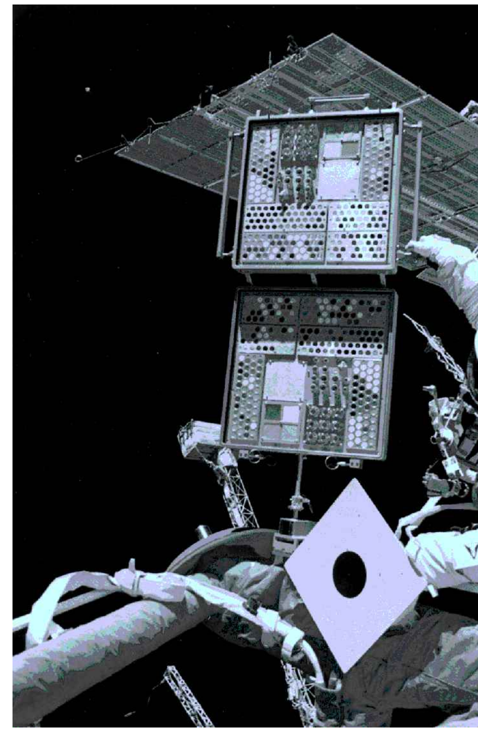

Fig. 4 POSA II, EVA retrieval (NASA photograph).

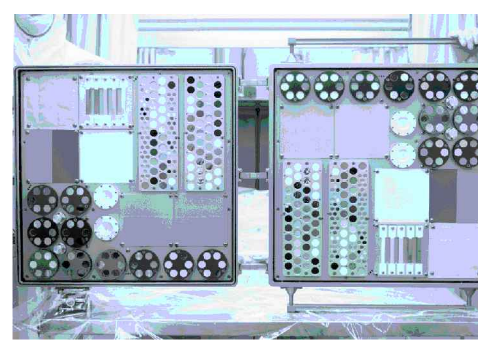

Fig. 5 POSA I, postflight (NASA photograph).

Fig. 6 POSA II, postflight (NASA photograph).

closed by an astronaut during the retrieval EVA. The MEEP payloads were placed back in the side wall containers of the space shuttle cargo bay and returned to Earth.

The PEC containing POSA experiments were removed from the space shuttle at NASA Kennedy Space Center within about three days of the space shuttle return to Earth. The PEC were immediately double bagged, placed in shipping containers, and brought to NASA Marshall Space Flight Center (MSFC) for deintegration and the start of postflight examination and testing. Figures 5 and 6 are postflight photographs of the POSA I and II experiments that were taken in the clean room at NASA MSFC immediately after the containers were opened for initial postflight inspection.

Atomic Oxygen and Solar UV Environments

The atomic oxygen fluence estimates for each POSA experiment tray are shown in Table 1. The fluence values are calculated based on the mass loss of Kapton® specimens flown on each tray and on a Kapton recession efficiency of 3×10^{-24} atoms/cm^3. Heavy contamination on the POSA I space/STS-facing side caused mass increases on the Kapton witness samples and did not allow a determination

Table 1 Atomic oxygen fluences on POSA surfaces

POSA	Location (facing side)	Atomic oxygen fluence, atoms/cm^2
I	Space/STS	——
I	Mir	7×10^{19}
II	Space/STS	2.1×10^{20}
II	Mir	8×10^{19}

Table 2 Solar exposures on POSA surfaces

POSA	Location (facing side)	Solar exposure, ESH
I	Space/STS	576
I	Mir	——
II	Space/STS	571
II	Mir	413

of atomic oxygen fluence for this surface. Atomic oxygen measurements taken on the OPM experiment, flown from April 1997 until January 1998 and mounted near POSA II indicate that the atomic oxygen fluences were potentially twice the values reported here.

The solar exposure estimate in equivalent solar hours (ESH) was made with vacuum ultraviolet (VUV) sensitive photodiodes. The solar exposure for POSA I was estimated to be 413 ESH on the Mir-facing side and 571 ESH on the space/STS-facing side. The solar exposure estimate for POSA II on the space/STS-facing side was 576 ESH. The diode on the POSA II Mir-facing side did not operate properly; however, the POSA II Mir-facing side likely had solar exposure levels less than the space-facing side. The results are summarized in Table 2.

Contamination

Discrete Event

Postflight examination showed an obvious, macroscopic pattern of streaks and droplets distributed over virtually the entire space/STS-facing side of the POSA II, PPMD, and ODC experiments. Further examination of the streaks of the contaminant material on POSA II indicated that the distribution had a slight fan shape with an apparent point of origin approximately 25 deg above the plane of the space/STS-facing side of POSA II along the docking module towards the STS. No line-of-sight source was obvious. The discrete contamination event (or events) is presumed to have occurred prior to deployment of the OPM near the POSA II experiment in late April 1997. OPM remained exposed on the docking module until January 1998 and had no such pattern of splattered material.

Results of a discrete event or events that left splatter patterns show no significant change in optical properties of the many surfaces analyzed. Analysis of the geometry of the splatter patterns suggests that the material generally approached the POSA II PEC from about 25 deg above the plane containing the STS/space-facing samples and from near one corner of the PEC. No obvious line of sight to a likely contamination source has been determined. Ray tracing suggests that a cloud of material came from a point about 2–3 m from the POSA II experiment. This analysis implies that the material either struck or passed very near the docking module. As a result of this experiment, the operating procedures of the STS with regard to venting have been reviewed and adjusted for operations in proximity to ISS.

Evidence of encounters of hardware with vent products has been observed prior to POSA. During examination of particulate contamination on numerous surfaces from the Long Duration Exposure Facility, contamination deposits were observed that were biological in origin.[1] These deposits included human skin, spittle, and human waste products. Researchers concluded that some of this material was deposited preflight and some was deposited on orbit. The depositions were relatively few and were not generally visible to the naked eye, as was the case on POSA II.

The impact patterns from some of the contaminant spots on POSA II are characteristic of a heterogeneous mixture of material. Analysis of the contaminant material indicated that at least part of the material is representative of human waste. Samples of the splattered material were washed from the surface of one of the EOIM-type sample holders and tested for uric acid content. The test was positive and was then repeated, again giving a positive indication of the presence of uric acid.

X-ray photoelectron spectroscopy was performed in conjunction with controlled ion sputtering on certain specimens in areas where spots of the splattered material were present. In no instance was any spot sputtered long enough to reach a steady state or clear the sputter spot area. All spots were sputtered for at least 1000 s, except for the spot on sample E1B-27, which was only sputtered for 200 s. On most of the samples, the spots were areas of elevated carbon concentrations and all samples contained oxygen, sodium, and molybdenum. Many spots also contained phosphorus. Some of the spots were thin enough or patchy enough to allow the substrate material to be detected. The only other elements detected (low end sensitivity of approximately 0.1%) were copper on the surface of E1SB-24, fluorine on the surface of E3B-29, and boron throughout the 1000 s of sputtering on E2B-36. The spots on E3B-32 (nickel substrate) had a crazed, glazed appearance. Unlike any of the other spots that were probed, the sputter ion beam caused the spot material to crack and flake off in chunks. In general, the substrate morphology seemed to affect how the spot material sat on the substrates. Some rougher surfaces caused the spot material to bleed out across the sample, whereas, on other substrates, the spots remained more raised and isolated.

X-Ray Photoelectron Spectroscopy

Surfaces

Selected samples from each side of the POSA I and II experiments and their ground controls were examined for surface elemental composition using XPS analysis. The first material specimens examined were 6061 aluminum substrate sulfuric acid anodized (SAA) and seal coated with NiF, cyanate ester resin with P100 fibers and boric sulfuric acid anodized (BSAA) 6061 aluminum.

Measurements were made at two locations on the ground control specimen of each material. The cyanate ester ground control showed silicon and fluorine present on the surface, probably due to a mold release agent. No fluorine was seen on any of the cyanate ester flight samples examined to date. It is likely that this material was removed as atomic oxygen attacked the composite resin.

The surface composition of a contamination deposit on the cyanate ester flight specimen (from the POSA II side facing space or the space shuttle) shows no silicon present, but includes sodium, phosphorous, and molybdenum. The data suggest that the surface contamination occurred after the silicon deposition and that the contaminant event occurred late in the mission. The contaminant was relatively easy to wash off the substrate surface.

Little or no aluminum was observed on the surface elemental analysis of the boric-sulfuric acid anodized (BSAA) Mir-facing flight specimen, and aluminum was observed on the surface of the BSAA space/STS-facing flight specimen. These data indicate that the silicon-based contamination layer was thicker on the side of POSA II looking generally toward Mir. Depth profiles from subsequent samples support this conclusion.

Results of XPS surface analysis of SAA-coated aluminum specimens show a pattern similar to the BSAA-coated specimens. The Mir-facing SAA specimen shows very little ($<1\%$) aluminum on the surface and over 28% Si. The space/STS-facing flight specimen shows 14–15 mol% aluminum and only 16–17 mol% Si on its surface. These results confirm the presence of a thicker contaminant layer on the Mir-facing side of POSA II, relative to the space/STS-facing side.

Depth Profiles

Specimens from each side of POSA I and II were probed using XPS analysis coupled with controlled ion sputtering. The elemental composition data as a function of sputter depth was then examined to determine the thickness of the silicon-based contamination. The values reported for selected samples in Table 3 are essentially the thickness of the SiO_x layer plus half of the transition region. Samples

Table 3 Thickness of Si-based contaminants on POSA specimens

Specimen	POSA	Si-based contamination depth, Å
14-14	I	450
15-14	I	4800
14-23	I	250
15-23	I	3600
14-65	I	310
15-65	I	3000
E1A-27	II	300
E1A-27 (unexposed)	II	Trace amounts (∼20)
E1B-27	II	20
E1SA-24	II	280
E1SA-24 (shadow)	II	130
E1SB-24	II	<100
E2A-22	II	325
E2A-26	II	470
E2A-28	II	275
E2A-36	II	350
E2SA-25	II	200
E3A-7	II	300
E3A-29	II	300
E1B-1	II	20
E2B-22	II	100
E2B-26	II	325
E2B-28	II	100
E3B-7	II	25
E3B-29	II	25
E2SB-25	II	40

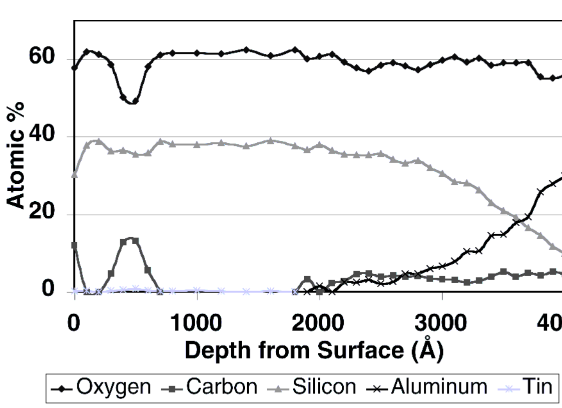

Fig. 7 SAA on 2219-T851 plate, specimen 15-23.

with the designation A are from the Mir-facing side of POSA I or II. Samples with the designation B are from the space/shuttle-facing side POSA I or II. Samples labeled 14- were located on the STS/space-facing side of POSA I. Samples labeled 15- were located on the Mir-facing side of POSA I.

It is clear that there is a SiO_x-type crust on each specimen, a transition region of up to several hundred angstroms that reflects varying composition associated with the surface roughness, and then a region where the silicone is filling in any voids or pores in the substrate. No depth profile of anodized aluminum material sputtered deep enough to even approach the underlying aluminum substrate. For such anodized samples, the procedure was stopped when the sputtering was clearly in the aluminum oxide anodized layer. Resolution on the XPS depth profiles is 25 Å at best.

The detailed depth profiles for several specimens from the space-facing side of POSA I show a dip in the oxygen elemental percentage and a corresponding increase in the carbon elemental percentage at a few hundred angstroms below the surface and then again deeper in the profile. These profiles also show very thick depositions of silicone-based contaminant. The depth profile for specimen 15-23 that exhibits these features is shown in Fig. 7.

It is believed that the arrival rate of silicone to the POSA I surface was so great during this time period that the atomic oxygen flux was not sufficient to oxidize all of the silicone to silicate. In support of this theory, it is known that there were three times during the POSA exposure period that the Mir went into a 100% sun orbit. The surface warming during these times would have increased the silicone outgassing rate from a nearby stowed solar array panel. This solar array panel had a direct line-of-sight view to the space-facing side of POSA I. In addition, large increases in the deposition rate were observed by OPM during the 100% sun exposure orbits in June 1997.

Recession Data

Recession rates for a few materials were determined from the mass changes of individual specimens, the estimated atomic oxygen fluence on each surface, and the density of the specific material. The average results for a number of specimens of each material are shown in Table 4. The values in Table 4 have not been adjusted for the silicon deposits or the splattered material distributed over the STS-facing side of POSA II.

Solar absorptance and thermal emittance measurements were made on trays E2A and E2B immediately following the postflight removal of the specimens from these trays. Trays E2A and E2B

Table 4 Recession rate measurements

Material	Density,[a] g/cm^3	Recession rate, 10^{-24} cm^3/atom
Fluorosilicone	1.4	1.74
Cyanate ester	1.42	1.85
Tefzel®	1.7	1.6

[a]Assumed.

Table 5 Optical properties on POSA II BSAA trays E2A and E2B

Side	α	ε
E2A		
Exposed (front)	0.355	0.49
Unexposed (back)	0.37	0.48
E2B		
Exposed (edge, no splatter)	0.39	0.48
Exposed (edge, with splatter)	0.39	——
Exposed (center)	0.38	——
Exposed	——	0.515
Unexposed	0.37	0.50

Table 6 Optical properties of Z93 and Z93P POSA specimens

Specimen	POSA	Preflight		Postflight	
		α	ε	α	ε
Z93					
E1SA-15 (Mir)	II	0.157	0.926	0.161	0.906
E1SB-15 (space/STS)	II	0.163	0.926	0.169	0.187
Z93P[a]					
E1SA-25 (Mir)	II	0.131	0.916	0.129	0.913
E1SB-25 (space/STS)	II	0.129	0.917	0.128	0.914
E1SA-28 (Mir)	II	0.146	0.917	0.144	0.913
E1SB-28 (space/STS)	II	0.135	0.917	0.135	0.914
Ground control	——	0.139	0.915	——	——
Z93P					
14-3	I	0.152	——	0.139	0.901
15-3	I	——	0.919	0.194	0.906
15-4[b]	I	0.240	(0.91)	0.296	0.891
14-4[b]	I	0.231	0.910	0.230	0.895
14-7	I	0.161	——	0.155	0.909
15-7	I	0.163	——	0.216	0.902
14-47	I	0.182	0.921	0.249	——
15-47	I	0.198	0.923	0.295	——
15-59	I	0.174	0.922	0.274	——
E3A-35	II	0.145	0.919	0.165	0.903
E3B-35	II	0.150	0.920	0.118	0.902
E2SA-11[b]	II	0.26	0.91	0.26	0.89
E1SA-12	II	0.213	0.912	0.213	0.896
E1SB-12	II	0.208	0.914	0.202	0.896

[a]Specimens and data provided by NASA John H. Glenn Research Center at Lewis Field.
[b]Fabricated with ZYP binder.

has a BSAA finish. Measurements on tray E2B included areas with and without the contaminant splatter as well as measurements on the unexposed (back) side of the tray. Similar measurements were made on tray E2A that did not have any splatter. The back of each tray served as the control because these surfaces were not directly exposed to the atomic oxygen and solar environments and there were no preflight optical measurements for these surfaces. The data are provided in Table 5. From this data set, it appears that the influence of the splattered material on the optical properties of BSAA aluminum is negligible. For each tray, E2A and E2B, the average differences in both and between front and back are less than 0.02.

Table 7 Optical properties for S13/GLO-P POSA specimens

		Preflight		Postflight	
Specimen	POSA	α	ε	α	ε
E1A-28	II	0.16	0.89	0.185	0.88
E1A-39	II	0.16	0.92	0.22	0.90
E1A-43	II	0.20	0.92	0.225	0.91
E1SA-18	II	——	——	0.209	0.903
E1SB-18	II	——	0.92	0.209	0.896
E1B-28	II	0.135	0.917	0.135	0.914
E1B-39	II	0.17	0.92	0.22	0.89
E1B-43	II	0.195	0.92	0.22	0.90
E1B-44	II	0.16	0.92	0.23	0.91

Table 8 Optical properties for YB-71P POSA specimens

		Preflight		Postflight	
Specimen	POSA	α	ε	α	ε
14-5[a]	I	0.239	0.866	0.243	0.849
15-5[a]	I	0.242	0.865	0.289	0.855
14-6	I	0.140	(0.900)	0.149	0.886
15-6	I	0.138	0.900	0.229	0.893
14-8	I	0.336	0.903	0.335	0.887
15-8	I	0.351	0.905	0.399	0.889
E1A-20[a]	II	0.250	0.865	0.258	0.850
E1B-20[a]	II	0.248	0.866	0.256	0.850
E1A-32	II	0.144	0.896	0.193	0.880
E1B-32	II	0.146	0.898	0.187	0.874
E2SA-12	II	0.25	0.87	0.26	0.85
E2SB-12	II	0.24	0.865	0.25	0.85
E2SA-19	II	0.15	0.91	0.18	0.88
E2SB-19	II	0.145	0.91	0.17	0.89
E2SA-20	II	0.145	0.90	0.20	0.88
E2SB-20	II	0.135	0.90	0.18	0.88

[a]Fabricated with YB-71 and ZYP binder.

Optical property measurements were made preflight and postflight for most of the POSA I and II material specimens. Solar absorptance and thermal emittance values are reported here in Tables 6–8 for some commonly used spacecraft paints (Z93/Z93P, S13/GLO-P, and YB-71/YB-71P). The specimens listed in Tables 6–8 contained no preflight contamination deposits. Detailed reflectance spectra have been archived in a database.

A number of specimens on POSA II were coated preflight with CV1144 silicone. The samples were prepared by first applying a pigmented ink to 0.003-in. matte vinyl coated aluminum (1145-H19). Silicone was then vapor deposited onto initially clean sample surfaces in a vacuum chamber using a TQCM to monitor the amount of material deposited. A small area, approximately 0.64 cm in diameter, in the middle of most specimens was left uncoated by silicone.

The optical property measurements provided in Table 9 were made before and after flight. A summary of the data is given in Table 10 that shows a decrease in thermal emittance of 0.07 and no change in solar absorptance. There is no apparent difference in optical property changes between samples flown on the Mir-facing side compared with samples flown on the space/STS-facing side despite that the space/STS-facing side was obviously splattered by some contamination during flight.

Discussion

A survey of POSA flight specimens shows that sources from Mir supplied approximately 300–400 Å of silicone-based contamination to the sides of POSA I and II that were facing Mir during flight. No significant difference was found in the amount of contamination collected on the POSA I and II experiment tray facing Mir. This finding implies that there was virtually no significant cross contamination between silicone-containing and nonsilicone-containing specimens on POSA II. The space/STS-facing side of POSA II had a minimal film of silicone-based material (~30–40 Å), whereas the

Table 10 Summary of CV1144 Si-coated POSA specimen data

	Average change in optical property	
Side	$\Delta\alpha$	$\Delta\varepsilon$
A	0.01	−0.07
B	0.00	−0.07[a]
All	0.00	0.07[a]

[a]Calculated without E2-15B data.

Table 9 CV1144 Si-coated POSA specimen data

POSA II specimen				Solar absorptance			Thermal emissivity		
Ink	Silicone	ID	t (ms)	Preflight	Postflight	Δ	Preflight	Postflight	Δ
Blue	CV11440	E2-9A	1.5	0.632	0.634	0.00	0.666	0.587	−0.08
Blue	CV11440	E2-9B	1.0	0.635	0.621	−0.01	0.662	0.586	−0.08
Blue	CV11440	E2-36A	0.5	0.629	0.671	0.04	0.842	0.756	−0.09
Blue	CV11440	E2-36B	0.5	0.624	0.652	0.03	0.840	0.756	−0.08
Black	CV11440	E2-25A	1.0	0.958	0.947	−0.01	0.912	0.901	−0.01
Black	CV11440	E2-25B	1.5	0.959	0.938	−0.02	0.912	0.899	−0.01
Black	CV11440	E2-35A	0.5	0.704	0.700	0.00	0.841	0.762	−0.08
Black	CV11440	E2-35B	0.5	0.702	0.691	−0.01	0.849	0.771	−0.08
Black	CV11440	E2-37A	1.0	0.946	0.940	−0.01	0.798	0.664	−0.13[a]
Black	CV11440	E2-37B	1.0	0.946	0.905	−0.04	0.768	0.624	−0.14[a]
Red	CV11440	E2-15A	1.0	0.518	0.540	0.02	0.588	0.474	−0.11
Red	CV11440	E2-15B	0.5	0.517	0.510	−0.01	0.581	0.188	−0.39[b]
Red	CV11440	E2-24A	1.0	0.618	0.624	0.01	0.902	0.875	−0.03[a]
Red	CV11440	E2-24B	1.0	0.617	0.621	0.00	0.902	0.877	−0.03[a]
Red	CV11440	E2-26A	0.5	0.628	0.622	−0.01	0.852	0.762	−0.09
Red	CV11440	E2-26B	0.5	0.618	0.621	0.00	0.850	0.762	−0.09
Red	CV11443	E2-29A	2.0	0.557	0.579	0.02	0.810	0.751	−0.06
Red	CV11443	E2-29B	1.5	0.556	0.560	0.00	0.801	0.747	−0.05
Yellow	CV11445	E2-22a	3.0	0.452	0.476	0.02	0.890	0.849	−0.04
Yellow	CV11445	E2-22B	4.0	0.454	0.468	0.0	0.891	0.845	−0.05

[a]Samples E2-24 and E2-25 were completely coated with CV11440; no uncoated area in center.
[b]The emissivity value for E2-15B appears anomalous.

thickness of the silicon-based film on the POSA I space/STS-facing side ranged from 3000 to over 4800 Å as shown in Table 3. The likely source of this very thick deposit was a solar array panel stored near POSA I. Additional details of the POSA I experiment have been published elsewhere by NASA MSFC researchers.[2]

A general decrease in emissivity of approximately 0.01–0.02 was observed on a significant percentage of specimens. The small decrease in emissivity is likely due to smoothing of the surfaces as has been observed previously on many materials with thin contaminant deposits.[3] Some specimens visibly darkened during the flight.

Selected specimens were contaminated with CV1144 silicone and then exposed to approximately 2000 ESH of VUV radiation to fix the silicone on the surface before flight. The purpose of the preflight deposition and VUV dose was to extend the effective range of the flight exposures. Changes in the optical properties of precontaminated specimens on POSA II were less than expected. XPS measurements made in conjunction with controlled ion sputtering suggest that much of the contamination diffused into the pore structure of the anodized aluminum rather than remaining on the surface. An investigation is currently being conducted on precontaminated ground specimens that will hopefully shed some understanding on this data set.

The extremely thick layers on the STS/space-facing side of POSA I are several times thicker than the allowed silicon contamination limits on ISS (130 Å/year) of 1300 Å in 10 years. Solar absorptance changes for all specimens examined from the heavily contaminated side of POSA I were still within the acceptable limits.

Conclusions

Materials of interest with respect to interest to ISS generally performed as expected, with minimal changes observed beyond the effects of contamination. The POSA experiments confirm the acceptable performance of ISS materials for 18 months exposure. The POSA experiments were conducted during solar minimum conditions. Atomic oxygen flux rates were low relative to any other part of the solar cycle. The question still remains as to how the materials examined will perform under conditions of maximum solar activity.

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A. C. Tribble
Associate Editor