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MISSE 6 Polymer Film Tensile Experiment

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This report contains preliminary findings,
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Abstract

The Polymer Film Tensile Experiment (PFTE) was flown as part of Materials International Space Station Experiment 6 (MISSE 6). The purpose of the experiment was to expose a variety of polymer films to the low Earth orbital environment under both relaxed and tension conditions. The polymers selected are those commonly used for spacecraft thermal control and those under consideration for use in spacecraft applications such as sunshields, solar sails, and inflatable and deployable structures. The dog-bone shaped samples of polymers that were flown were exposed on both the side of the MISSE 6 Passive Experiment Container (PEC) that was facing into the ram direction (receiving atomic oxygen, ultraviolet (UV) radiation, ionizing radiation, and thermal cycling) and the wake facing side (which was supposed to have experienced predominantly the same environmental effects except for atomic oxygen which was present due to reorientation of the International Space Station). A few of the tensile samples were coated with vapor deposited aluminum on the back and wired to determine the point in the flight when the tensile sample broke as recorded by a change in voltage that was stored on battery powered data loggers for post flight retrieval and analysis. The data returned on the data loggers was not usable. However, post retrieval observation and analysis of the samples was performed. This paper describes the preliminary analysis and observations of the polymers exposed on the MISSE 6 PFTE.

Introduction

Thin film polymers are used in many spacecraft applications for thermal control (multi-layer insulation and sunshields), as lightweight structural members (solar array blankets, inflatable/deployable structures) and have been proposed for propulsion (solar sails). Polymers in these applications are exposed to the space environment and are vulnerable to degradation by solar ultraviolet radiation, solar flare X-rays, solar wind electrons and protons trapped in Earth's magnetic field, temperature and orbital thermal cycling and low Earth orbit atomic oxygen (Ref. 1). In applications where the polymer film is under tension while exposed to these environmental factors, it is important to understand the effect of stress in combination with the environment on the durability of thin polymer films. Polymer film tensile specimens were previously flown in the Polymer Film Thermal Control Experiment and the Gossamer Materials Experiment as part of the experiments included on Materials International Space Station Experiment (MISSE) 1 as well as on MISSE 3, MISSE 4, and MISSE 5 in order to expose thin polymer

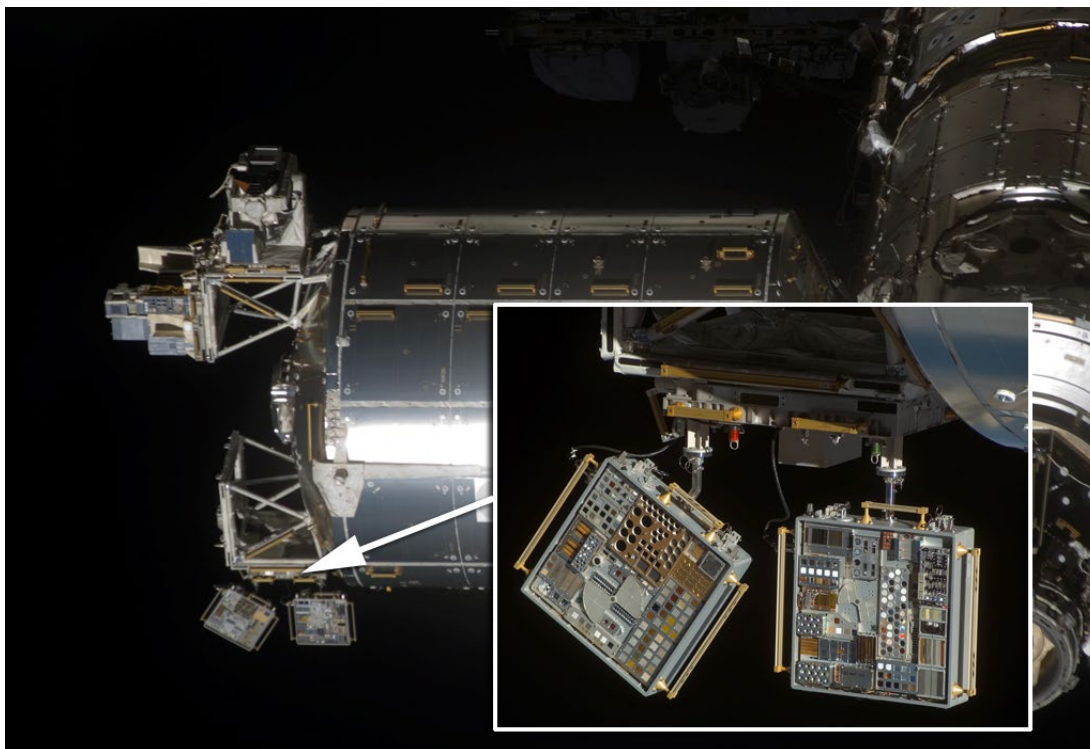


Figure 1.—Photograph of MISSE 6 location on the end of the Columbus module on ISS and a photo enlargement showing the ram side of MISSE 6A (left) and 6B (right).

film tensile specimens to the space environment under different exposure conditions for evaluation of the effect of the environment on the tensile strength and percent elongation (Refs. 2 and 3). The MISSE 6 exposure is different from prior such experiments in that a number of the samples were designed to be exposed while under tension to better simulate their use in space and determine if the stress level affects the durability. It was also planned to be an active experiment with monitoring and capture of the electrical continuity of several of the tensile dogbones utilizing dataloggers. A total of 17 samples were flown on the ram facing side of MISSE 6 and 24 samples were flown on the wake facing side. The results of the post flight initial observation and analysis are described in this paper.

MISSE 6 Environment Description

MISSE 6 was composed of two Passive Experiment Containers (PECS), 6A and 6B. Both PECS had one side of the suitcase style containers facing ram and the other side facing wake. They were both installed by astronauts on the European Columbus module of the International Space Station (ISS) on March 22, 2008 during the flight of STS-123. They were retrieved on September 1, 2009, by the crew of STS-128 after slightly over 17 months in low Earth orbit (LEO). Figure 1 shows a photo and close-up image of the ram side of the MISSE 6 PECS on ISS. Environment exposure conditions that have been determined to date are the atomic oxygen exposure level on each side and the UV radiation level. M. Finckenor (NASA MSFC) (Ref. 4) and K. de Groh (NASA GRC) (Ref. 5) provided estimates of the atomic oxygen arrival based on erosion of samples of Kapton HN that were flown as fluence monitors on individual experiments, there were also two Kapton HN/VDA tensile dogbones that were flown as part of this experiment on the wake side of MISSE 6A from which scanning electron microscope images of protected locations on the surface were used to determine the erosion depth and ultimately the atomic oxygen fluence. All of the data seemed in good agreement with an estimate of the atomic oxygen arrival fluence for the ram side of 6A and 6B of approximately 2×10^{21} atoms/cm², and for the wake side approximately 1.2 to 1.4×10^{20} atoms/cm². This indicates that the wake side of MISSE 6, which was to

have received very low atomic oxygen exposure was oriented in the ram direction long enough to have received an atomic oxygen dose about 6.5 percent that of the ram oriented side. Estimates of the UV radiation exposure in equivalent sun hours (ESH) were provided by Gary Pippin (Boeing Corp.) (Ref.6) to be 2600 ESH for the ram sides of 6A and 6B and 1950 ESH for the wake sides of 6A and 6B. Temperature, thermal cycling, and ionizing radiation estimates were not available at this time.

PFTE Experiment Description and Procedure

Experiment Design for Application of Tensile Stress

The experiment was designed to allow some of the polymer dog-bone type samples to be exposed under a tensile load typical of expected conditions for the James Webb Space Telescope sunshield. The tensile load of approximately 0.5 lb (~2.22 N) was applied by mounting the sample in a holder similar to that shown on the left side of the photo in Figure 2 and then compressing a spring with a spring constant of 2.2 lb/in. (~385 N/m) by approximately 0.227 in. (~0.0058 m) to put the sample under a tensile load. The drawing in Figure 2 shows a double sample holder where the sample on the left did not have an applied tensile stress and the one on the right did. Originally, the experiment was designed to have eight of the ram and 11 of the wake samples exposed under tension, but difficulty in applying tension to some of the samples resulted in only three of the ram facing and seven wake facing samples exposed to the environment under stress. For the exposed samples, the resulting stress was dependent on the polymer film thickness per equation 1 with an average gage width of approximately 0.126 in. (0.0032 m).

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = (\text{Force}) / ((\text{Gage width}) * \text{Thickness}) \quad (1)$$

For the majority of the samples, the stress during exposure was either ~2000 psi (~1.38×10⁷ N/m²) for 2 mil (5.08×10⁻⁵ m) polymer films or ~4000 psi (~2.76×10⁷ N/m²) for 1 mil (2.54×10⁻⁵ m) polymer films.

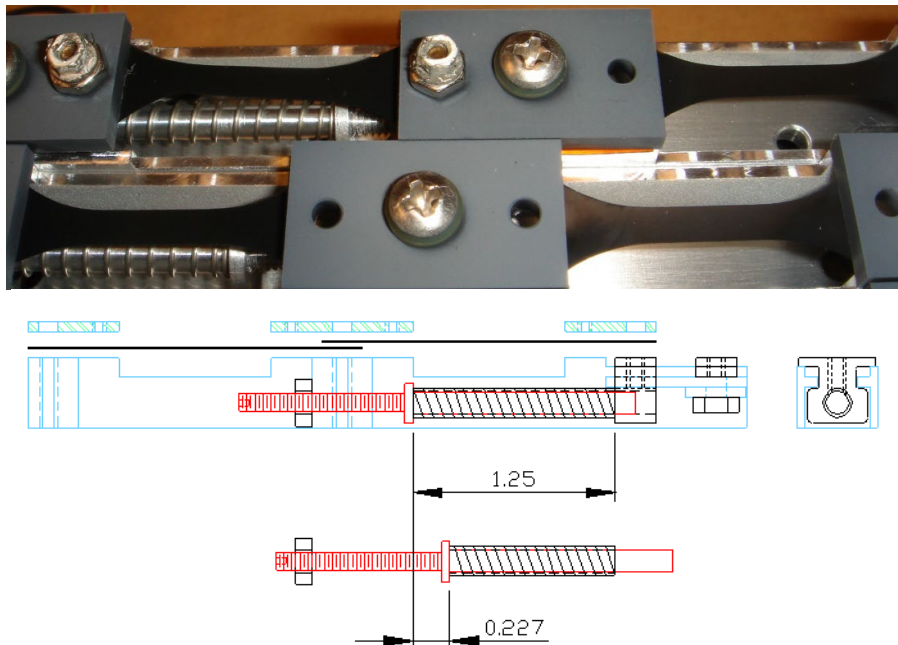


Figure 2.—Photo of stressed (left) and unstressed (right) sample holders from above, and a side view drawing of a holder showing the unstressed sample position on the left and the stressed on the right. (Dimensions are in inches.) The stressed sample is fixed on the left side and allowed to move to the right by having the mount hole on the right slotted. Tension is supplied by compression of the spring.

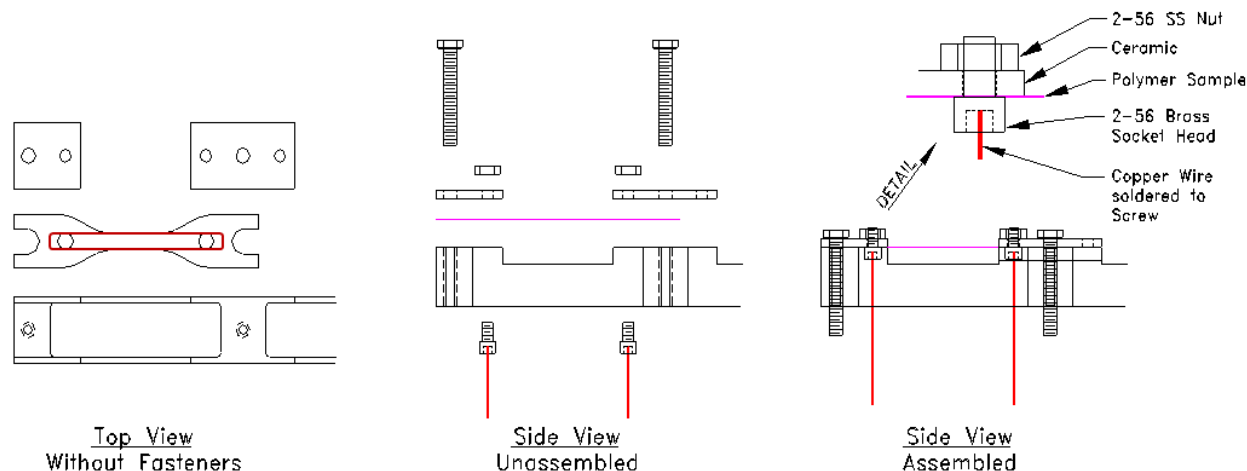


Figure 3.—Drawing on the left shows the top view of the clamping plates and support and a bottom view of the dog-bone sample with vapor deposited aluminum contact shown as a rectangular box on the sample. Drawings at center and right show an expanded and assembled side view with the electrical contacts to the sample back.

Experiment Design for Active Monitoring of the Break Point

Active monitoring of some of the tensile samples to determine the time on orbit to sample break was attempted using electrical continuity. Samples that were insulating on the side not exposed to space were coated with vapor deposited aluminum through a mask as shown on the far left of Figure 3. Black Delrin clamping plates were used to provide electrical insulation from the aluminum sample support underneath while a second set of screws inside the mount screws made electrical contact with the aluminum coating on either end of the back side of the sample. A 5 V power supply was used to supply current to the dog-bones and the voltage drop across the samples was monitored and stored in a series of dataloggers that were on MISSE 6. The data recorded was designed to indicate failure by a change in the voltage across the sample. Due to difficulty in wiring the samples without shorting, only three stressed samples on the ram side and one on the wake side were wired for flight. All three stressed samples on the ram side broke during flight but the change was not evident in the data from the dataloggers. All channels including ones that were unused registered approximately 1 V for the entire flight so the data were not usable to determine the time on orbit at which the samples on the ram side broke.

Description of Samples

The polymers that were exposed on MISSE 6B, ram facing tray G3 are listed in Table I and those flown on MISSE 6A, wake facing tray G2 are listed in Table II. Coated samples are indicated by a “/” separating each layer. The layers are listed in order from closest to farthest from the space-facing surface. Samples for flight and control were punched from sheets supplied by the sources listed in the table using a die manufactured according to specimen “Type V” under the American Society for Testing and Materials (ASTM) Standard D-638 (Ref. 7). The dog-bone shaped die had a gage length of 7.62 mm and an average gage width of 3.21 ± 0.02 mm (0.126 in.). Samples that were insulating on the non-space facing side that were to be wired for active monitoring were coated with a rectangular mask pattern of vapor deposited aluminum to provide electrical contact. These samples are noted in the table with an asterisk. Samples that were flown under stress are indicated by light gray shading in the table.

TABLE I.—MISSE 6 TENSILE SAMPLES PEC 6B, TRAY G3, AO+UV(RAM)

Sample designation	Condition	Material	Thickness, mil	Source
AO-U-1	-----	Kapton XC (Black Kapton)*	1	DuPont -100XC10E7
AO-U-2	-----	SiOx/Kapton HN*	2	Sheldahl
AO-U-3	-----	SiOx/Kapton HN*	2	Sheldahl
AO-U-4	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
AO-U-5	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
AO-U-6	-----	VDA/CP1*	1	SRS, VDA on one side
AO-U-7	-----	VDA/CP1*	1	SRS, VDA on one side
AO-U-8	-----	FEP/VDA	2	Sheldahl
AO-U-9	-----	FEP/VDA	5	Sheldahl
AO-S-1	-----	Kapton XC (Black Kapton)*	1	DuPont -100XC10E7
AO-S-2	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
AO-S-3	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
AO-S-4	Stressed and wired	VDA/CP1*	1	SRS, VDA on one side
AO-S-5	Stressed and wired	VDA/CP1*	1	SRS, VDA on one side
AO-S-6	Stressed (0.202 in.) and wired	SiOx/Kapton HN*	2	Sheldahl
AO-S-7	Taut	FEP/VDA	2	Sheldahl
AO-S-8	Taut	FEP/VDA	5	Sheldahl

*Evaporated aluminum contact applied on the back side
 1 mil = 0.001 in. = 0.0000254 m

TABLE II.—MISSE 6 TENSILE SAMPLES PEC 6A, TRAY G2, UV (WAKE)

Sample designation	Condition	Material	Thickness, mil	Source
UV-U-1	-----	Kapton XC (Black Kapton)*	1	DuPont -100XC10E7
UV-U-2	-----	Kapton XC (Black Kapton)*	1	DuPont -100XC10E7
UV-U-3	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
UV-U-4	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
UV-U-5	-----	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
UV-U-6	-----	VDA/CP1*	1	SRS, VDA on one side
UV-U-7	-----	VDA/CP1*	1	SRS, VDA on one side
UV-U-8	-----	CP1/VDA	1	SRS, VDA on one side
UV-U-9	-----	FEP/VDA	2	Sheldahl
UV-U-10	-----	FEP/VDA	2	Sheldahl
UV-U-11	-----	FEP/VDA	5	Sheldahl
UV-U-12	-----	FEP/VDA	5	Sheldahl
UV-U-13	-----	Kapton HN/VDA	2	Sheldahl
UV-S-1	Stressed (0.236 in.) and wired	Kapton XC (Black Kapton)*	1	DuPont -100XC10E7
UV-S-2	Stressed (0.227 in.)	Kapton XC (Black Kapton)*	1	DuPont -100XC10E7
UV-S-3	Stressed (0.230 in.)	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
UV-S-4	Stressed (0.233 in.)	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
UV-S-5	Stressed (0.226 in.)	Si/Kapton E/VDA/Inconel/VDA	2	Provided by GSFC
UV-S-6	Stressed (0.228 in.)	VDA/CP1*	1	SRS, VDA on one side
UV-S-7	-----	VDA/CP1*	1	SRS, VDA on one side
UV-S-8	Stressed (0.238 in.)	SiOx/Kapton HN*	2	Sheldahl
UV-S-9	-----	FEP/VDA	2	Sheldahl
UV-S-10	-----	FEP/VDA	5	Sheldahl
UV-S-11	-----	Kapton HN/VDA	2	Sheldahl

*Evaporated aluminum contact applied on the back side
 1 mil = 0.001 in. = 0.0000254 m

Post Flight Analysis

Overall and close up photos were taken of the samples post flight using a Sony Cybershot DSC T-9 camera. Initial observations were recorded and a few selected samples were gold coated and mounted for scanning electron microscopy with a JOEL JSM-6390 LV scanning electron microscope with energy dispersive analysis by x-rays (EDAX).

Results and Discussion

Overall Observations

Close-up on orbit photos of the ram tray G3 and wake tray G2 just prior to retrieval are shown in Figure 4(a) and (b), respectively. On the ram facing tray all of the stressed samples showed evidence of breaking and curling up of the tensile dog-bones, while none of the stressed samples on the wake side were broken. Also, there was a noticeable change to the black Kapton XC sample AO-S-1 which is shown on the far right of Figure 4(a). The sample appeared to be longer than when initially installed and had a silvered appearance on the end that was stretched. This sample was in a sample holder initially designed for putting the sample under a tensile load so the holder on the top side of the sample had a slotted mount hole. It appears that the sample was inadvertently bumped and the one end of the holder moved putting the sample under a tensile stress even though it was not initially intended to be stressed. There was a cable that was passed up between the G3 tray and the neighboring tray which was very close to this sample which may have provided the opportunity for inadvertent bumping of the one end of the sample holder during experiment installation.

SiO_x/Kapton HN

There were two unstressed samples of this material flown on the ram side tray (G3). Both samples appeared to have some coating defects on the surface (scratches, pinholes) that allowed some erosion of the Kapton HN around the defect site by atomic oxygen typical of that observed on previous flights (Ref. 1). Other than this, the samples appeared typical of the pre-flight samples and showed no evidence of failure. Figure 5 contains a photo of one of the unstressed samples (AO-U-2) post flight.

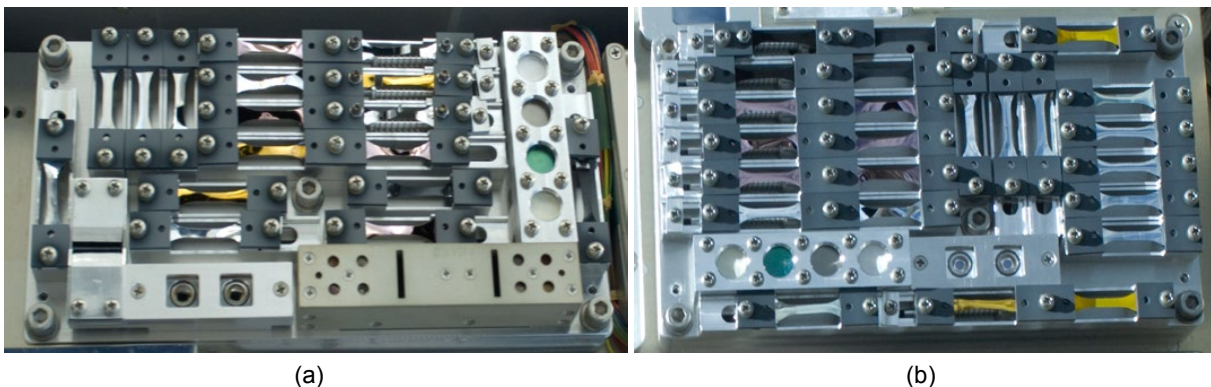


Figure 4.—(a) On-orbit photo of ram facing tray G3 on MISSE 6 prior to retrieval. (b) On-orbit photo of wake facing tray G2 on MISSE 6 prior to retrieval



Figure 5.—Unstressed SiO_x/Kapton HN sample AO-U-2 post exposure on MISSE 6.



Figure 6.—(a) SiO_x/Kapton HN stressed sample AO-S-6 from ram side tray G3 showing break. (b) SiO_x/Kapton HN stressed sample UV-S-8 from wake side tray 62 showing coating cracking.

The stressed samples (with ~ 2000 psi ($\sim 1.38 \times 10^7$ N/m²)) applied stress which is about 6 percent of the ultimate tensile strength for Kapton HN (33,500 psi (2.31×10^8 N/m²)) both on the ram and wake sides showed evidence of coating cracking. The ram side received enough atomic oxygen arrival that the sample weakened and broke at what appears to be a line of defects that extended across the width of the dog-bone sample as shown in Figure 6(a). The amount of atomic oxygen arrival would have been enough to erode completely an unprotected 2 mil (5.08×10^{-5} m) sample of Kapton HN. Figure 6(b) shows the wake facing sample which was also under stress but received much less atomic oxygen exposure (~ 7 percent that of the ram side). Even though the sample is not broken, the coating itself appears damaged. For both samples the strain (stress divided by the modulus of elasticity (379000 psi (2.61×10^9 N/m²)) for Kapton HN)) was about 0.005 or about 0.7 percent of the maximum strain for Kapton HN. Even though the level of stress and strain the samples were subjected to is low for Kapton HN, the stressed sample on the ram side still failed. It is believed that the failure is primarily due to atomic oxygen erosion at coating defect sites for this material.

Kapton HN/VDA

There were only two samples of Kapton HN/VDA flown on the wake side of MISSE 6. Both were flown unstressed and had a matte appearance post flight but no evidence of sample failure. The matte appearance was due to atomic oxygen texturing of the Kapton HN as evident in the scanning electron microscope (SEM) photos shown in Figure 7(a) and (b). Figure 7(a) shows a textured area including a micrometeoroid or debris impact and Figure 7(b) shows a butte where there was a particle on the surface that protected the Kapton HN from erosion underneath it. This area and others like it were used to determine an estimate for the atomic oxygen fluence. The erosion depth (cm) multiplied by the erosion yield (cm³/atom) for Kapton HN gives the atomic oxygen dose or fluence in atoms/cm². One interesting thing to note about the texture is that for the most part it is very vertical which indicates that the wake side was close to being directly ram oriented for most of the time it was exposed to atomic oxygen.

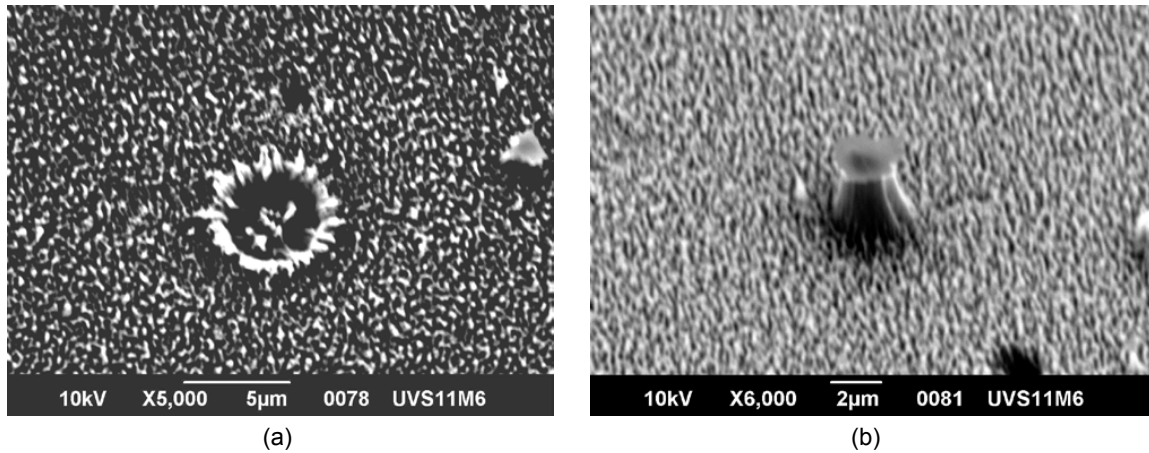


Figure 7.—(a) Kapton HN/VDA sample UV-U-13 after exposure on the wake side of MISSE 6 showing texturing due to erosion by atomic oxygen and a micrometeoroid or debris impact. (b) Kapton HN/VDA sample UV-U-13 after exposure on the wake side of MISSE 6 showing a particle on the surface that protected the sample from erosion in one spot creating a butte.



Figure 8.—(a) Si/Kapton E/VDA/Inconel/VDA sample AO-U-4 exposed on ram side of MISSE 6 unstressed. (b) Si/Kapton E/VDA/Inconel/VDA sample UV-S-4 exposed on wake side of MISSE 6 under stress showing some evidence of coating cracking

Si/Kapton E/VDA/Inconel/VDA

This material was identified for the James Webb Space Telescope sunshield, which will not be flown in low Earth orbit and will, therefore, not be exposed to significant amounts of atomic oxygen. Thus, the results most pertinent to its JWST application are those from samples flown on the wake surface. There were four unstressed samples of this material flown on the ram facing side of MISSE 6 and three unstressed samples on the wake facing side. All appeared typical of pre-flight samples and had no visual evidence of failure or change as shown in Figure 8(a). The three stressed samples were only flown on the wake facing side. They were stressed to a level of ~ 2000 psi ($\sim 1.38 \times 10^7$ N/m²) which represents about 4 percent of the ultimate tensile strength for Kapton E (50000 psi (3.45×10^8 N/m²)). The strain level (stress /modulus (800000 psi (5.52×10^9 N/m²))) was 0.0025 which was about 0.5 percent of the maximum strain for Kapton E. The stress and strain again were low but there was some slight evidence of cracking of the Si coating for these samples as shown in Figure 8(b) but no failure of the polymer.

VDA/CP1

The two unstressed samples of this material on the ram side and the three unstressed samples on the wake side all appeared typical of the pre-flight samples as did the one sample flown purposely in reverse (CP1/VDA) on the wake side which was also flown unstressed. Figure 9(a) shows one of the unstressed VDA/CP1 samples (AO-U-7). The two stressed samples on the ram side broke during the MISSE 6 exposure, while the stressed sample on the wake side did not. Figure 9(b) shows one of the broken samples of VDA/CP1 from the ram side (AO-S-5). The wake side stressed sample appeared typical of pre-flight samples like that shown in Figure 9(a). The stress on these samples during the flight was ~ 4000 psi ($\sim 2.76 \times 10^7$ N/m²), which was about 28 percent of the ultimate tensile strength (14,500 psi ($\sim 1 \times 10^8$ N/m²)). The strain (stress/modulus (315000 psi (2.17×10^9 N/m²))) was 0.013.



Figure 9.—(a) Unstressed VDA/CP1 sample AO-U-7 flown on the ram facing side of MISSE 6. (b) Stressed VDA/CP1 sample AO-S-5 flown on the ram facing side of MISSE 6. Sample broke sometime during the exposure on ISS.



Figure 10.—FEP/VDA exposed on MISSE 6 ram side in unstressed condition (AO-U-8).

FEP/VDA

Both 2 and 5 mil samples of FEP/VDA were flown on the ram and wake sides. All were flown unstressed, but one of each of the 2 and 5 mil samples were flown pulled taut on the ram side. All looked very similar in appearance with scratches and scuff marks on the surface but there was no evidence of failure or a difference in the loosely held versus taut samples that could be visually observed. Figure 10 shows a typical FEP/VDA sample flown on the ram side of MISSE 6 (AO-U-8).

Kapton XC

Two unstressed samples of black Kapton (XC) were exposed on the ram side of MISSE 6. Both samples appeared to show evidence of texturing of the surface with a darker appearance near each end of the dog-bone sample. One of these samples was inadvertently put under stress when one end of the sample holder was moved and changed the overall sample length by ~ 0.068 in. (~ 0.0017 m). This put a strain on the sample (for an undetermined length of time) which could be calculated by dividing the change in length (0.068 in. (0.0017 m)) by the original length (~ 0.934 in. (0.0237 m)) to result in a strain of ~ 0.07 . This represents approximately 26 percent of the maximum strain for Kapton XC. The resulting stress on the sample could be determined by multiplying the strain by the elastic modulus (480000 psi (3.31×10^9 N/m²)) which gives a stress of 33,600 psi (2.32×10^8 N/m²) which is greater than the yield strength of Kapton XC. This is also evident from Figure 11 by the distortion and stretching of the top end of the sample as shown in the photograph.

The appearance of the sample raises several questions. The first is why the stretched end appears silver and the second is why the black Kapton appears to be darker in the region of higher stress? In order to try to answer these questions, SEM and EDAX analysis was performed on the sample at selected locations shown in Figure 12 and Figure 13 after applying a light gold coating to the sample to reduce charging during examination at 10 kV.



Figure 11.—Kapton XC flown on ram side of MISSE 6 (AO-S-1) showing stretching of sample at silvered area at the top.

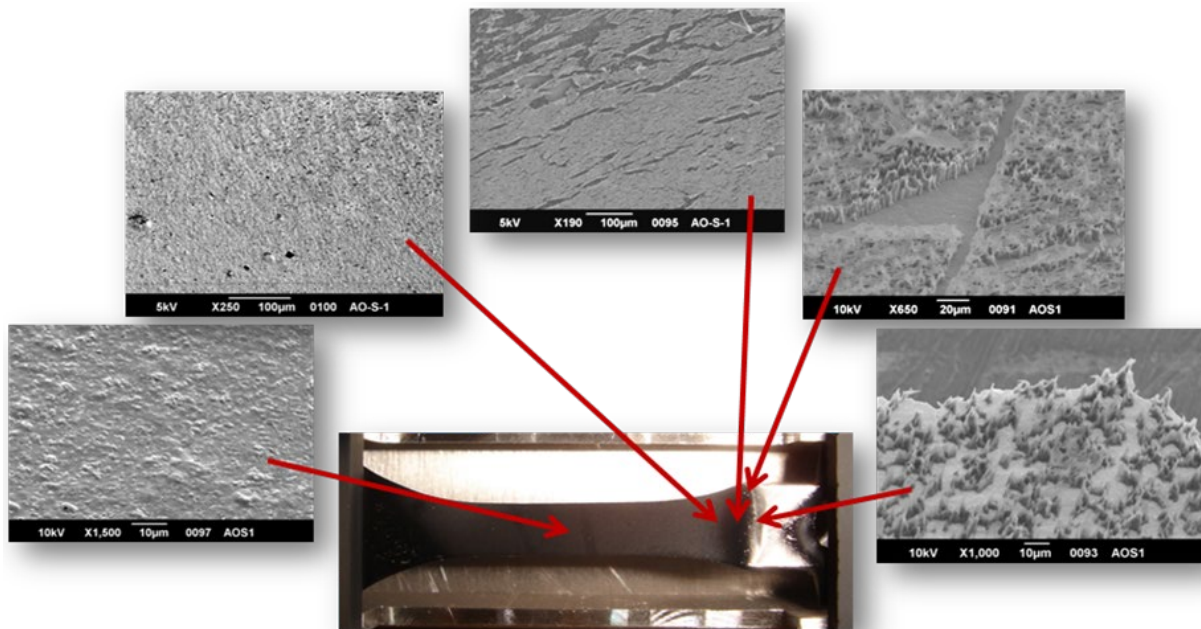


Figure 12.—SEM images of selected positions on sample AO-S-1 exposed on the ram side of MISSE 6

SEM images shown in Figure 12 show a significant change in surface morphology from the center to the edge. The center portion has a smooth lumpy appearance typical of black Kapton which progresses to an area which looks as if it had a thin film gossamer coating on it with many cracks perpendicular to the pull direction. There are fine cone-like peaks in areas where there is cracking which progresses to almost all peaks with thin wisps of film on the surface nearer to the silver area. At the edge where the sample separated, there are only a few short peaks remaining. EDAX scans shown in Figure 13 indicate mostly carbon and oxygen signals in the central region progressing to a high concentration of aluminum near the stretched end. This sample was originally intended to be put under stress and wired so there was a vapor deposited aluminum coating on the back side. It appears that as the stress on the sample is increased, the erosion rate of the black Kapton increases which results in first development of surface texture cones and a thin film of ash from oxidation of the black Kapton. This progresses to loss of ash and erosion of the

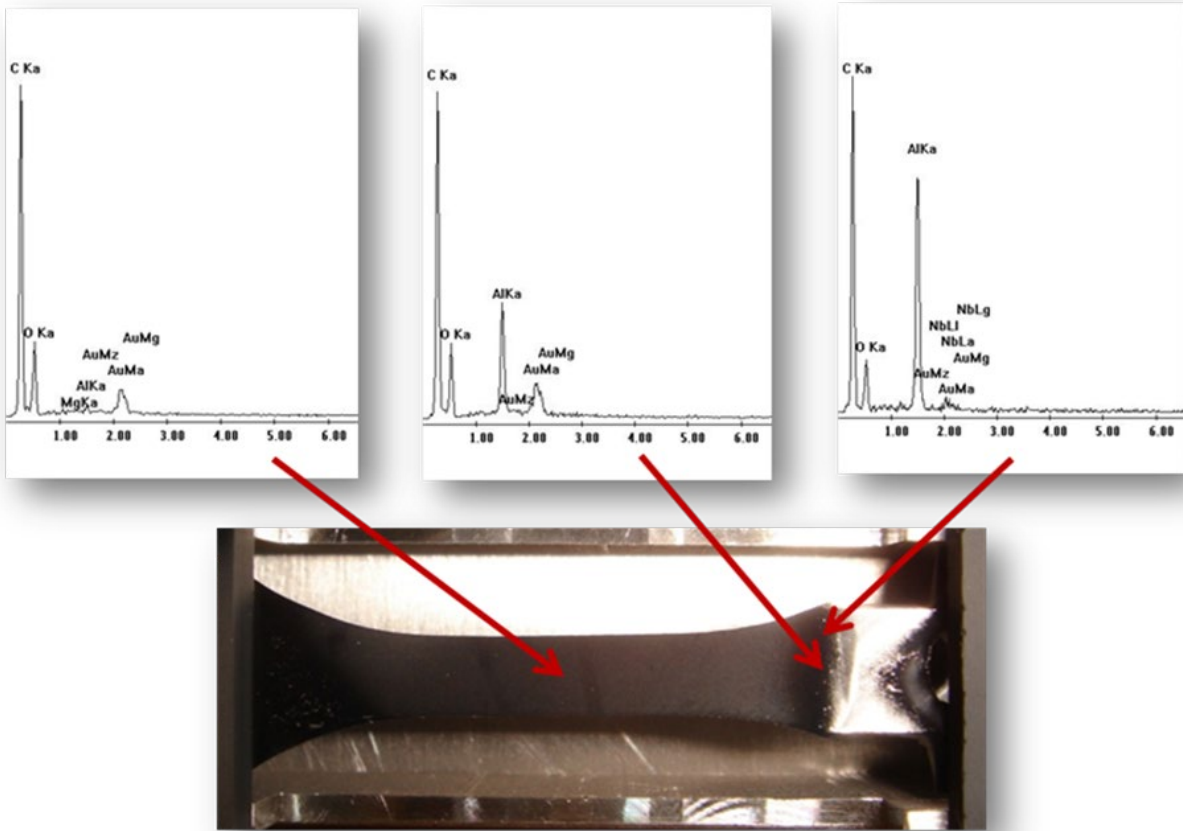


Figure 13.—EDAX scans taken at various locations on sample AO-S-1 exposed on the ram side of MISSE 6



Figure 14.—Stressed (left) and unstressed (right) black Kapton XC flown on the wake side of MISSE 6

mostly carbon cones to the point at which the vapor deposited aluminum is predominantly what is left looking like a blanket of snow at the base of the remaining carbon peaks. If erosion of the Kapton XC is dependent on the level of stress, then there should also be a difference in the samples that are under stress compared to those that are not under stress on the wake side.

The two unstressed samples on the wake side appeared to show slight evidence of texturing of the surface with the samples appearing slightly darker towards each end, while the 2 stressed samples were very dark matte black in appearance. Figure 14 shows a side-by-side comparison of one pair of the stressed and unstressed Kapton XC samples exposed on the wake side of MISSE 6.

The stress level during exposure was ~4000 psi ($\sim 2.76 \times 10^7$ N/m²). The strain (stress/modulus (480000 psi (3.3×10^9 N/m²))) for the black Kapton XC was ~0.008 which represents about 3 percent of the maximum strain. The stress on the sample was about 24 percent of the tensile strength. This does not appear to be a significant amount of strain on the material but it is enough to cause a difference in the appearance of the erosion of the material due to oxidation by atomic oxygen. Figure 15 shows side-by-side SEM images at 45° tilt of the stressed (UV-S-2) sample of Kapton XC on the left and the unstressed

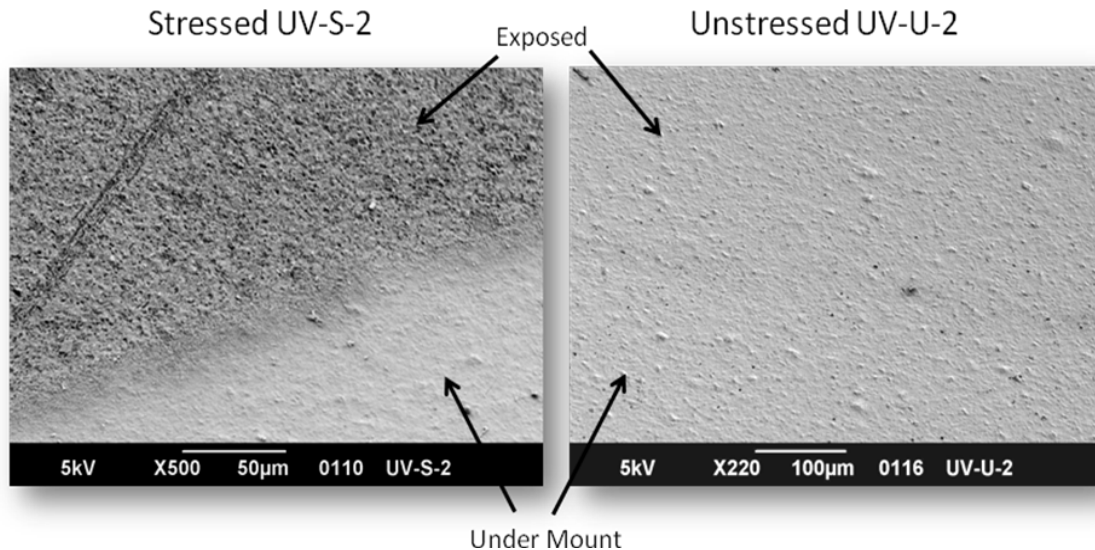


Figure 15.—Scanning electron microscope images of stressed (left) and unstressed (right) Kapton XC at 45° tilt. Top approximately 2/3 was exposed to the space environment on the wake side of MISSE 6 while the bottom ~1/3 was protected by the clamp holding the sample in place.

(UV-U-2) sample of Kapton XC on the right. There is more surface texturing occurring on the stressed sample than the unstressed sample as can be seen in the top 2/3s of the image. The bottom 1/3 was under the sample mount and protected from erosion by atomic oxygen. As can be seen from the image, the unstressed sample is only slightly different in appearance to the unexposed surface, while the surface of the stressed sample has undergone very noticeable erosion.

Conclusions

Initial observation of the polymer samples flown on the ram and wake sides of MISSE 6 as part of the polymer film tensile experiment (PFTE) show that the environmental exposure of polymers under stress can produce noticeable physical changes that are not observed when exposed to the same environment but not under stress. Samples coated with silicon dioxide and silicon showed evidence of cracking while under stress. The cracking can lead to failure of the underlying polymer if they are exposed to atomic oxygen, and if the fluence is high enough to cause enough erosion of the polymer at these coating defect sites to weaken it. This appeared to be the cause of failure for the SiO_x coated Kapton flown on the ram side of MISSE 6. The failure of polymers such as VDA/CP1 appears to be dependent on the level of environment exposure. VDA/CP1 samples under stress exposed on the ram side of MISSE 6 failed while the sample exposed under stress on the wake side did not. For some polymers such as black Kapton (XC), the rate of erosion due to atomic oxygen arrival appears to increase with the stress applied to the polymer. SEM photos of the Kapton XC samples show very little erosion on the unstressed samples, but noticeable surface texturing under slight stress, and almost complete erosion under stresses greater than the tensile yield stress. Further testing will be conducted to determine the effect of the environment and stress level on the mechanical properties of these materials.

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14. ABSTRACT The Polymer Film Tensile Experiment (PFTE) was flown as part of Materials International Space Station Experiment 6 (MISSE 6). The purpose of the experiment was to expose a variety of polymer films to the low Earth orbital environment under both relaxed and tension conditions. The polymers selected are those commonly used for spacecraft thermal control and those under consideration for use in spacecraft applications such as sunshields, solar sails, and inflatable and deployable structures. The dog-bone shaped samples of polymers that were flown were exposed on both the side of the MISSE 6 Passive Experiment Container (PEC) that was facing into the ram direction (receiving atomic oxygen, ultraviolet (UV) radiation, ionizing radiation, and thermal cycling) and the wake facing side (which was supposed to have experienced predominantly the same environmental effects except for atomic oxygen which was present due to reorientation of the International Space Station). A few of the tensile samples were coated with vapor deposited aluminum on the back and wired to determine the point in the flight when the tensile sample broke as recorded by a change in voltage that was stored on battery powered data loggers for post flight retrieval and analysis. The data returned on the data loggers was not usable. However, post retrieval observation and analysis of the samples was performed. This paper describes the preliminary analysis and observations of the polymers exposed on the MISSE 6 PFTE.					
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