Polymeric Materials Resistant to Erosion by Atomic Oxygen

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Problem

- Polymer-matrix composites are ideally suited for space vehicles because of high strength to weight ratios
- The principal component of the low earth orbit (LEO) is atomic oxygen
- Atomic oxygen causes surface erosion to polymeric materials

Objectives and Approaches

To develop durable polymer films for the space environment

Incorporate organometallic additives into high performance polymers (polymer/additive system)

To measure durability of the materials

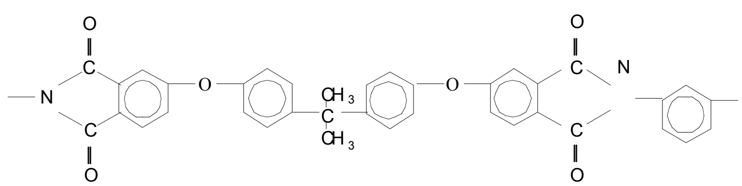
Expose materials to atomic oxygen in a laboratory-based instrument

Actual space environment exposures on OPM/MIR and MISSE

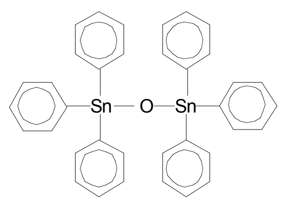
Advantages of a Polymer/Additive System

- Eliminates the specialized facility and separate processing required for protective coating
- No limitations on the shape and size of film coated
- Additive is uniformly distributed throughout the polymeric material
- No risk of damage to the coating from manufacturing, handling, storage, etc.
- Material is self-healing by forming a new protective surface if damaged
- Leads to enhanced durability

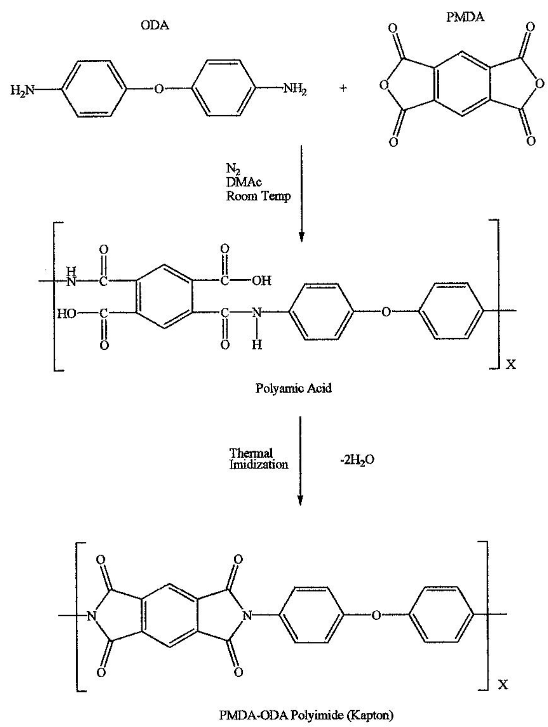
Molecular Structures



POLYETHERIMIDE (ULTEM)

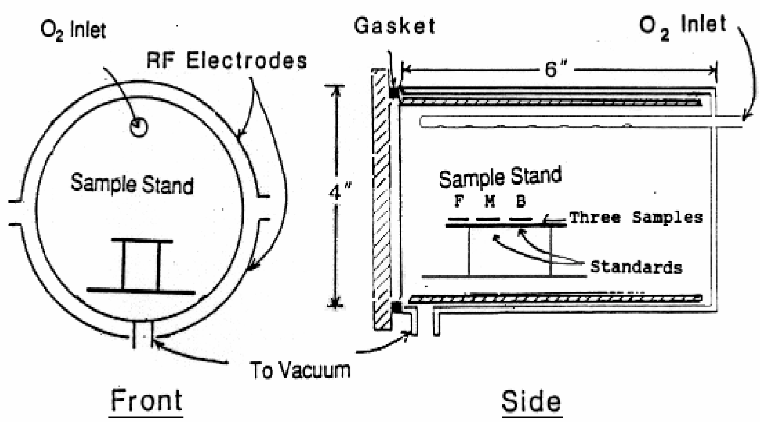


BIS(TRIPHENYLTIN) OXIDE (BTO)


ODA
PMDA
H_2N
NH_2
+
N_2
DMAc
Room Temp
Polyamic Acid
Thermal Imidization
$-2H_2O$
PMDA-ODA Polyimide (Kapton)

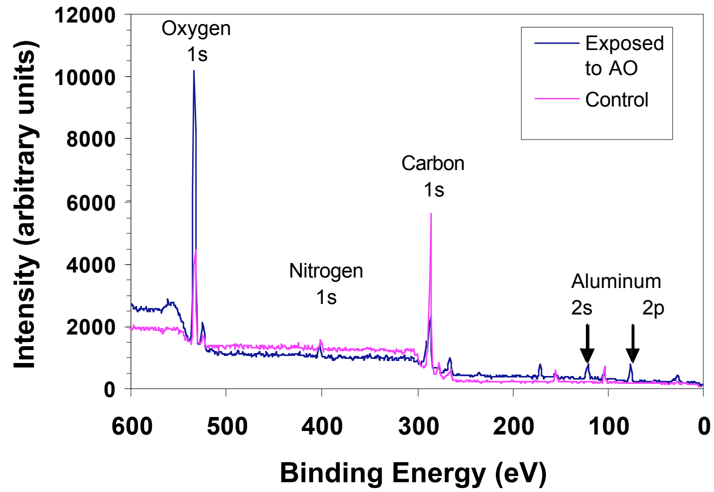
$[CH_3COCH{=}C(O\text{-})CH_3]_3Al$

Aluminum Acetylacetonate (Alacac)



Reaction Chamber for Atomic Oxygen Experiments

X-ray Photoelectron Spectroscopy of Kapton with 10% Alacac

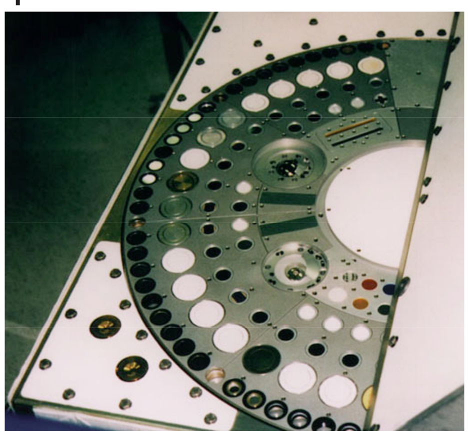


	Atom Percent		
	C	O	Al
Control	71.3	19.0	0.2
Exposed to AO	34.3	45.9	8.9

Table showing the changes in surface composition of Kapton/10% Alacac after exposure to AO.

The Optical Properties Monitor (OPM) Experiment

As part of the Optical Properties Monitor experiment, three Ultem /BTO samples were exposed in space from April 29, 1997 to January 8,1998 on the MIR Space Station.



Optical Properties Monitor (OPM)

Russian MIR

Results of OPM/MIR Flight Experiment

Material	Mass Loss Data		Atom % from XPS: Post-flight Pre-flight		
	Mass Loss (mg)	% Mass Loss	C	O	Sn
Pure Ultem	0.33	1.67	52.5 81.0	33.0 14.2	-
Ultem/10% BTO	0.32	1.42	24.7 79.7	50.1 15.2	8.7 0.6
Ultem/20% BTO	0.19	1.04	24.6 77.7	50.2 17.2	10.1 0.8

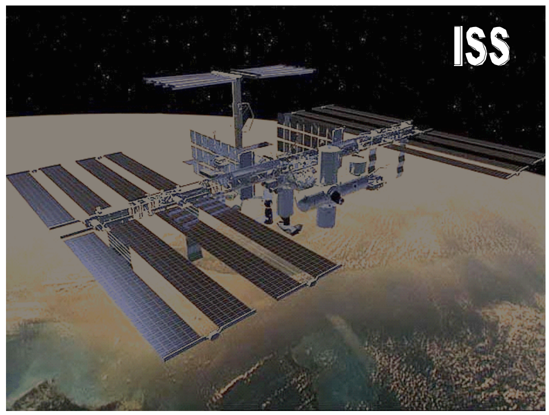
Materials

International

Space

Station

Experiment



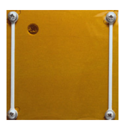
The Materials on the International Space Station Experiment (MISSE) is designed to expose materials to the space environment either with or without exposure to AO. Two of our samples are exposed in the ram direction (AO and UV) and three samples are exposed in the wake direction (UV only).

MISSE Specimens

2-K1
Kapton

2-K2
Kapton with 10% by weight aluminum acetylacetonate(Alacac)

AO plus Solar exposure

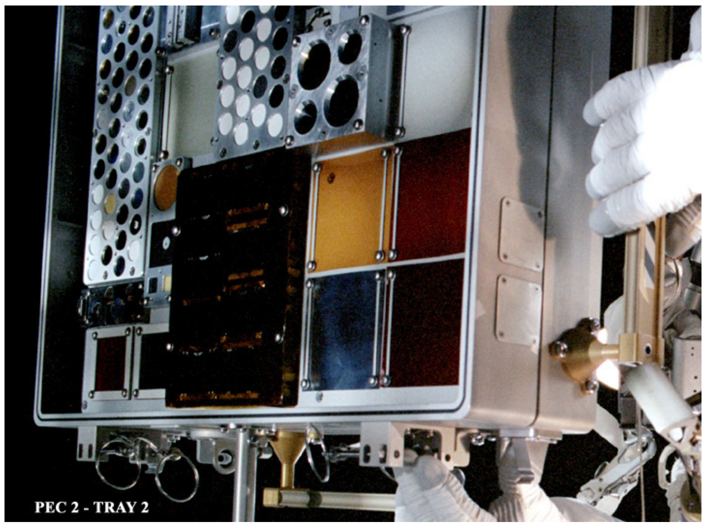


1-J11
Kapton

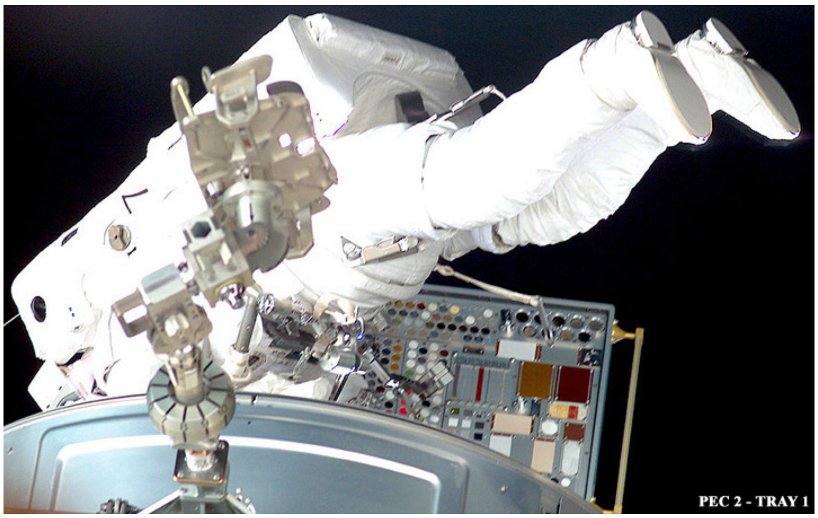
1-J12
Kapton with 10% Alacac

1-J13
Kapton with 15% Alacac

Solar exposure only (no AO)



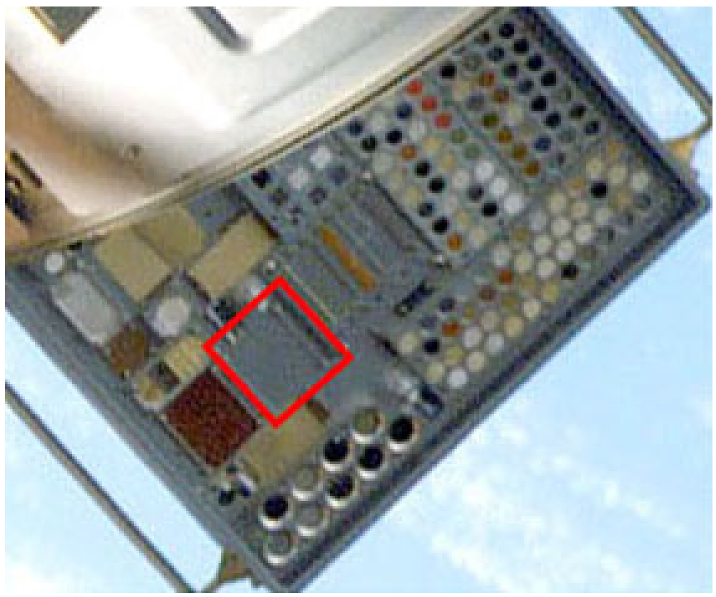
Deploying samples in the wake direction (UV only) on 08/10/01



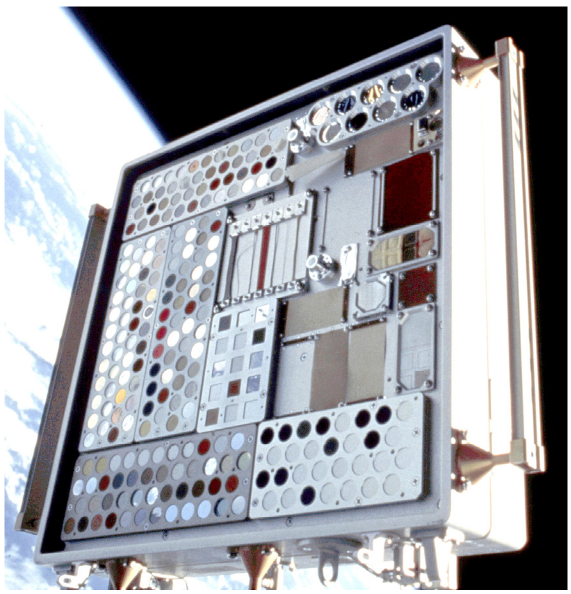
Deploying samples in the ram direction (AO and UV) on 08/10/01

Ram direction of MISSE photographed on 12/05/01 showing samples still intact

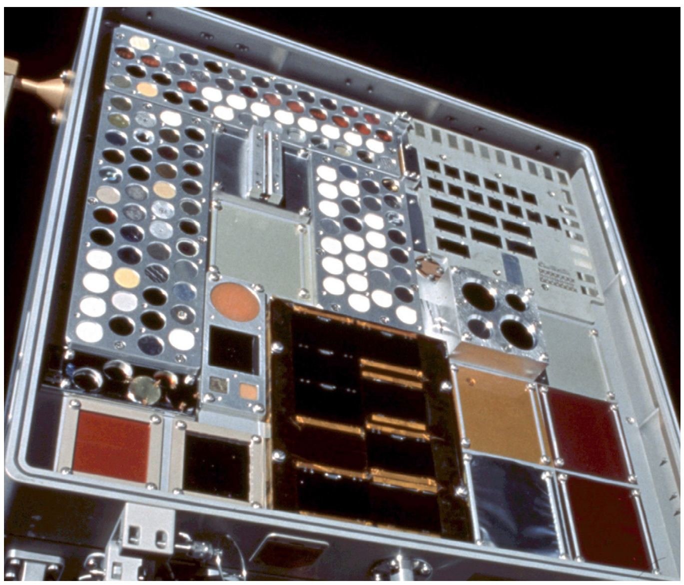
Ram direction of MISSE photographed on 04/08/02 showing the pure Kapton film gone



MISSE ram direction photographed in May, 2002 showing the pure Kapton film missing but the Kapton/10%Alacac intact



MISSE wake direction photographed in May, 2002, showing samples still intact



Conclusions

Polymer films with an organometallic additive showed greater resistance to atomic oxygen than the pure polymer in laboratory experiments and in the OPM/MIR experiment.

In MISSE, the film with the organometallic additive was still intact after the pure film had completely eroded.