Micrometeoroid from MISSE Examined to Understand the Effects of the Space Environment on Space Suit

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Micrometeoroid from MISSE Examined to Understand the Effects of the Space Environment on Space Suit

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Overview of SUSpECS on MISSE-6

MISSE-6 is just one part of the MISSE project that aims to subject various materials to the space environment and document the effects in a controlled setting. In order to do this the MISSE-6 sample was deployed, launched into space, suspended off of the International Space Station, and then returned to Earth in pristine condition for analysis. The Utah State University SUSpECS project was a unique student experiment on MISSE-6.

Pre- and Post-Flight Comparisons

Optical microscopy and normal specular reflectance of pre-and post-flight samples are compared to assess on-flight degradation.

Before After Before After Before After Before After
Black Kapton Acquadag Black Kapton Ag coated Mylar and from SUSpECS III with water exposure (Ag). Note the full Ag (atomic oxygen) oxidation of the Ag coated Mylar sample and the UV yellowing of the polymer.

Future Work

Work on analysis of the effects of space environment exposure on the 188 samples has only begun. Measurements of optical and physical properties, FTIR, emissivity, mass loss, electron, ion- and photon-induced electron emission, photodegradation, AES, photomission, and variable angle UV/VIS/NIR reflectivity will continue. Work will also progress in collaboration with the AEDC space simulation facility to understand the origins of these effects and quantify their impacts.

References/Acknowledgements

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Abstract

Samples that were part of the Materials International Space Station Experiment (MISSE) experienced varying effects whilst exposed to the space environment; perhaps the most intriguing effect was the crater created by a micrometeoroid impact into a thin film of Vapor Deposited Aluminum (VDA) coated Mylar. Approximately 160 samples of various materials used in space-component design were flown on MISSE-6 and spent 18 months suspended off the side of the International Space Station. The Utah State University SUSpECS project was a unique student experiment that allowed for pre- and post-flight analyses of these material samples which were returned in pristine condition after exposure to the space environment. Despite micrometeoroids being a common occurrence, there is a significant lack of data pertaining to the effects of micrometeoroids on space components. Further examination of the micrometeoroid impact sample will allow us to determine the impact velocity, mass, and composition of the micrometeoroid and its influence on materials in space. Micrometeoroids pose a serious threat to space operations and in turn require constant observation. It is of particular interest to note that Mylar is a major component in the construction of astronaut suits; the knowledge gained from our evaluation of this meteoroid will allow us to determine the mass required to penetrate through a spacesuit.

Mylar with Micrometeoroid Impact

The VDA coated Mylar sample underwent vast changes in composition whilst in the ISS environment, beyond just the impact of the micrometeoroid. The most obvious would be the removal of VDA by Atomic Oxygen, exposing the underlying Mylar. Another is the UV yellowing of the initially white Mylar due to excessive UV exposure. Also evident is the degradation of the Mylar, again, due to Atomic Oxygen.

The estimated size of the micrometeoroid is found by matching the kinetic energy of the energy required to vaporize a hole of the observed size.

Penetrating a Spacesuit

Mass of a Penetrating Micrometeoroid:
Based on a 500 μm thick spacesuit, on typical meteoroid density and an observed relation for crater diameter and depth the minimum mass required to penetrate and ultimately kill an astronaut would be approximately 0.7 g.

Spacessuit Thickness:
A typical spacesuit has approximately seven 50 μm Mylar layers, one 50 μm Beta Cloth layer, and two other 50 μm layers totaling the suit’s thickness at 500 μm.

Modern astronaut spacesuits are designed with a dual-layer system containing bumer plates to protect the wearer from supervelocity impact by foreign objects. This additional space allows for the compression of the space suits to lessen the force of the impact.

References:

Mylar with Micrometeoroid Impact

Sample and Impact Specifications:

| Diameter of Exposed Mylar: | 9mm |
| Diameter of Vaporized Region: | 1.0 mm |
| Diameter of Spall volume: | 1.5 mm |
| Diameter of Micrometeoroid: | 10 mm |
| Thickness of Mylar Sample: | 13 × 10^-4 mm |
| Volume of Micrometeoroid: | 7.7 × 10^-4 cm³ |
| Density of Micrometeoroid: | 3.5 g/cm³ |
| Mass of Micrometeoroid: | 2.7 × 10^-5 g |

Impact Vector

Spalled Volume
Vaporized Volume
Metastatic Volume

Abstract:

MISSE-6 Time Line

1/2005 Sample selection completed
12/2005 PEC’s completed and tested for flight
3/2008 Launch on Space Shuttle ISS-123
9/2009 Return of samples from space

MISSE-6 Sample and Impactor Imaging:

Figure: MISSE-6 A and B sample containers prepared for flight.

SUSpECS Objective

The purpose of SUSpECS is to characterize the performance of prospective spacecraft materials when subjected to the stochastic effects of the space environment, enabling more durable spacecraft assembly.

Applications

Material degradation in the space environment is a highly relevant study today. The most common application is the construction of spacecrafts and satellites (see figure of communication satellite below that identifies many common such materials that were flown on SUSpECS). An example of the application of such knowledge is the James Webb Space Telescope (JWST), shown below. The JWST is scheduled for launch in 2014 to replace the Hubble Telescope. This sensitive optical equipment on a massive platform the size of a tennis court will be launched further into the vastly unknown space environment than any permanent equipment thus far with an operational lifetime measured in decades. It therefore requires careful consideration in choice of materials for maximum time before erosion renders it useless.

The USU Materials Physics Group has worked on materials testing of JWST materials for the last 6 years. Tests were done with lab simulations of the space environment and with exposure on MISSE-6. SUSpECS samples include JWST heat shield materials, cable insulation, structural composites and optical materials. Our tests will determine if changes in these materials due to space environment interactions will lead to dramatic changes in the operating temperature of JWST and its ability to take state of the art images to test our theories of the universe.

MISSE-6 SUSpECS Test Samples

This large communication satellite incorporates materials which are contained in SUSpECS.

Graphite Composite
Al/Mylar
Kapton
Black Kapton
Acquadag

White Paint
ITO
RTV
FIMA
Coverglass

SUSpECS Sample Sources:

- Wide array of common spacecraft materials (see above).
- Basic materials and key contaminants of ISS solar arrays and structure.
- Materials from CReRS satellite designed to study environment-induced charging.
- Materials used in Floating Potential Measurement Unit plasma probe for ISS.
- Critical thermal control and optical materials for SOFOTS.
- Composite and ceramic materials of the ATK Thermal Protection and Lightweight Structure Systems.
- Solar Probe Mission Heat Shield Insulator Samples tests.