

JAPAN'S MATERIALS SPACE EXPOSURE EXPERIMENTS BEFORE SM/MPAC&SEED

Mineo SUZUKI¹, Hiroyuki SHIMAMURA¹ and Kichiro IMAGAWA²

¹ *Institute of Aerospace Technology, Japan Aerospace Exploration Agency, Tsukuba, Ibaraki 305-8505, Japan*

² *Human Space Systems and Utilization Mission Directorate, Japan Aerospace Exploration Agency, Tsukuba, Ibaraki 305-8505, Japan*

Overview of Japan's materials space exposure experiments before SM/MPAC&SEED is presented. They are EOIM-3, EFFU and ESEM. EOIM-3 and ESEM experiments were carried out on board the Space Shuttle, while EFFU was mounted on SFU free flyer. In these experiments, there were many valuable findings, but contradictory phenomena were sometimes observed for similar materials, possibly due to the differences of the space environment and the specimens experiment-by-experiment. These experiences greatly contributed to planning and successful completion of SM/MPAC&SEED experiment.

Keywords: Materials space exposure experiments, EOIM-3, EFFU, ESEM

1. Introduction

Space is harsh environment for materials. Materials might be degraded by space environments such as radiation, ultraviolet (UV) rays, atomic oxygen (AO), thermal cycling and so on. Thus the effects of these environment factors on various materials have been examined in simulated ground-based tests, as well as space exposure experiments.

Space Shuttle opened new era for materials space exposure experiments. The exposed samples can be easily retrieved and detailed analysis is possible on ground. Meanwhile, Space Shuttle demonstrated necessity of materials space exposure experiment: serious AO effect was recognized in Low Earth Orbit (LEO) in early flights (e.g. Ag was blackened by AO during 1 week exposure). Later, combined effect of AO and UV became clear on some materials, but ground simulation technique was not yet established. ISS (International Space Station) program urged evaluation of materials degradation by long duration exposure to LEO environment. Thus a number of materials space exposure experiments were carried out, including EOIM (Evaluation of Oxygen Interaction with Materials), LDEF (Long Duration Exposure Facility) and EURECA (European Retrievable Carrier).

After construction of early phase of ISS, materials space exposure experiments were carried out almost on the ISS, such as MISSE (Materials International Space Station Experiment), and SM/MPAC&SEED (Service Module/ Micro -Particles Capturer and Space Environment Exposure Device). ISS is suitable for long duration experiments.

Japan had conducted three materials space exposure experiments before SM/MPAC&SEED experiment. They are:

- EOIM-3 (Evaluation of Oxygen Interaction with Materials - 3)
- EFFU (Exposed Facility Flyer Unit) on SFU (Space Flyer Unit)
- ESEM (Evaluation of Space Environment and Effects on Materials) on MFD (Manipulator Flight Demonstration)

In this paper, overview of these experiments is presented.

2. EOIM-3

Launched on STS-46 (Atlantis) on July 31, 1992, EOIM-3 pallet containing 46 Japan's samples (26 kinds) were exposed to the space environment, and returned to the Earth on Aug.8, 1992. EOIM-3 was Japan's first materials space exposure experiment. EOIM was NASA's materials space exposure project [1], and Japan participated in the NASA project. The objective of Japan's experiment was to confirm the phenomena occurred on the material surface induced by space exposure, and to pursue the degradation mechanisms, mainly due to atomic oxygen.

The overview of EOIM-3 experiment is shown in Fig.1. The samples were typical materials already used for Japanese satellites, and to be used for JEM (Japanese Experiment Module) of ISS. The exposed samples were:

- Thermal control film & paint : 11 kinds, 19 samples
- Structural materials: 3 kinds, 8 samples
- Insulating materials: 4 kinds, 7 samples
- Adhesives: 3 kinds, 5 samples
- Optical materials: 5 kinds, 7 samples

The estimated environments for about 1 week flight were:

- AO Fluence
 - Thermospheric model: $2.0\text{-}2.2 \times 10^{20}$ atoms/cm²
 - Kapton erosion: $2.3\text{-}2.5 \times 10^{20}$ atoms/cm²
 - Mass spectrometer: $2.2 \pm 0.4 \times 10^{20}$ atoms/cm²
- UV Fluence
 - 25 ESH (Equivalent Solar Hours)
- Temperature
 - 5°C-20°C during exposure period
- Contamination
 - 2 nm thickness silicone

Retrieved samples were examined by using surface analysis techniques such as SEM(Scanning Electron Microscope), XPS(X-ray Photoelectron Spectroscopy), AES(Auger Electron Spectroscopy), FTIR(Fourier Transform InfraRed spectroscopy), SIMS(Secondary Ion Mass Spectrometry), focusing on the effect of AO. AO erosion yields of several materials were compared with the reported values.

The observed degradation phenomena were similar with that in

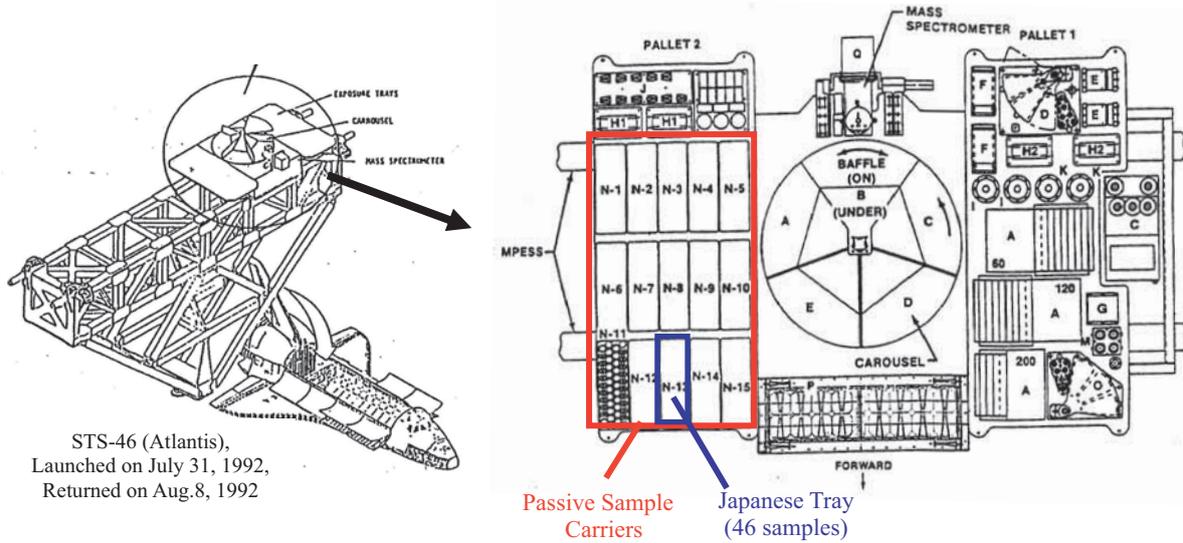


Fig.1 Overview of EOIM-3 experiment

the other EOIM experiments, and with that caused by ground-based atomic oxygen (AO) irradiation. The importance of AO effects on materials was recognized.

The degradation mechanisms were also pursued. But available data were too limited to elucidate the mechanisms. In addition, some samples showed different results from the former experiments. The major findings of the experiment are reported in ref. [2].

3. EFFU

EFFU was attached to exterior of SFU, and launched on March, 1995 by H-2 rocket. After 10 months flight in 482 km orbit, SFU was retrieved into STS-72 (Endeavour) on January, 1996. EFFU was Japan's first long duration materials space exposure experiment. The major purpose of the experiment was to confirm the adequacy of materials design for JEM-EF (Japanese Experiment Module - Exposed Facility) to be jointed to ISS. The overview of EFFU experiment is shown in Fig.2.

EFFU carried following 22 kinds of samples.

- Solid lubricant: 7 kinds
- CFRP: 3 kinds
- Cover glass: 2 kinds
- Anodized aluminum: 4 kinds
- Thermal control film & paint :5 kinds
- Insulating materials: 1 kind

Unique samples were solid lubricant films. JEM-EF has moving mechanical components, which will be partly exposed directly to space environment.

Accumulated fluxes of UV and AO for about 10 month's exposure were estimated by using monitoring materials, as follows:

- AO Fluence
 - +Z: 2.5×10^{19} atoms/cm²
 - X: 4.7×10^{19} atoms/cm²
- UV Fluence
 - +Z: very small
 - X: 150 ESD (Equivalent Solar Days)

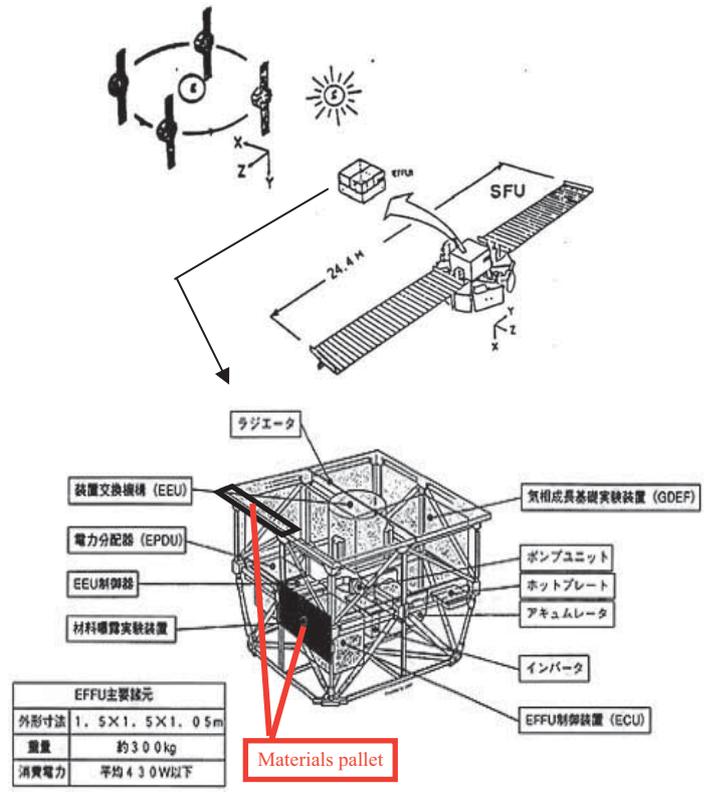


Fig.2 Overview of EFFU experiment

EFFU Sample analysis revealed that the degradation was similar with that in other space exposure experiments, and with that in ground-based simulation experiments (e.g. erosion of PTFE in β -cloth). The degradation was within the design margin, thus the soundness of JEM materials design was confirmed.

The exposed solid lubricant film showed longer wear life, possibly due to hardening of the organic binder material by UV. It was pointed out, however, that further hardening may cause rupture of the film. Contamination of SiO_x was identified. It is recognized that effects of the contamination should be included to evaluate the effect of actual space environment on materials.

This experiment gave the first insight of long-term space exposure effect on materials for Japanese researchers. The major findings of the experiment are reported in refs. [3][4].

4. ESEM

ESEM pallet containing 29 kinds of samples was attached on the support structure of MFD, and launched on STS-85 (Discovery) on Aug.7, 1997. After about 12 day's exposure, ESEM was returned to the Earth on Aug.19, 1997. ESEM was a follow-on experiment to confirm soundness of JEM materials design. Figure 3 shows the location of ESEM pallet and the appearance of ESEM sample trays.

The exposed samples were:

- Solid lubricant: 7 kinds
- Solar cell: 2 kinds
- Cover glass: 4 kinds
- Adhesives: 3 kinds
- Thermal control film & paint :9 kinds
- Insulating materials: 1 kind
- Inter-connector materials: 3 kinds

In addition, 6 kinds of samples were attached on the sample tray for the evaluation of the exposed environment such as radiation, atomic oxygen, and ultra violet flux.

Accumulated fluxes of UV and AO for about 12 day's exposure were estimated as follows:

- AO Fluence
3.0 – 9.7×10^{19} atoms/cm² (depended on the location)
- UV Fluence
1.8 -2.7 ESD (depended on the location)

Analysis of the retrieved samples gave similar results with the former space exposure experiments. In a follow-up experiment of solid lubricant films, binder itself was exposed. The binder was eroded away, but never hardened. The effect of space environment might be different between composite materials and their constituents. Contamination of organic materials as well as SiO_x was detected.

Detailed analysis results of the retrieved samples are summarized in ref. [5].

5. Concluding remarks

In EOIM-3, SFU/EFFU, and MFD/ESEM experiments, there are many valuable findings. However, the effect of space environment on materials and the degradation mechanism are still obscure, especially for the combined effect (e.g. AO+UV, AO+contaminants). In addition, contradictory phenomena were sometimes observed for similar materials, possibly due to the

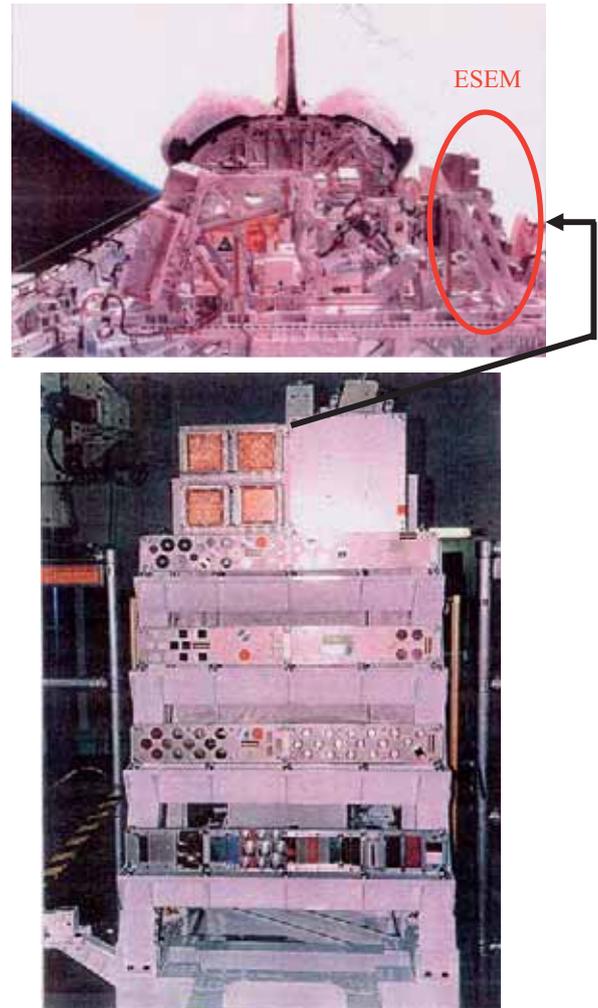


Fig.3 ESEM sample trays and mounted location

difference of space environment experiment-by-experiment (orbit, attitude of the sample tray and duration). Apparently further experiments are needed to fully understand the effect of space environment on materials.

In SM/MPAC&SEED experiment the same 3 sample sets were exposed to the same space environment, but different exposure duration (about 1, 2, and 3 years), to grasp the degradation process more precisely. This method is effective to deduce the degradation process by the space environment. The detailed experimental results of SM/MPAC&SEED are reported in other papers in this proceedings.

ISS is now being utilized for materials space exposure experiments such as MISSE, EuTEF/MEDET (European Technology Exposure Facility/ Material Exposure and Degradation Experiment) and, in the near future, JEM/MPAC&SEED. However, opportunity of materials space exposure experiment is still limited. In these circumstances, cooperation and information exchange among researchers and engineers related to space environment effect on materials will be mandatory.

References

- [1] D.E. Brinza et al: Final report on the NASA/JPL Evaluation

- of Oxygen Interactions with Materials-3 (EOIM-3), NASA CR-198865 (1994).
- [2] Analysis of the exposed samples- EOIM-3 experiment, Contractor report, Toshiba SPD15-K93078 (1993). (in Japanese)
- [3] M. Takei, Y. Torii et al.: Space environmental effects on space exposure materials of EFFU, Proc. 47th IAC, IAF-96-1.5.01 (1996)
- [4] T. Fukatsu, Y. Torii, Y. Koyari et al.: Post-flight analysis of the exposed materials on EFFU, Proc. 7th ISMSE, ESA SP-399 (1997) 287.
- [5] Evaluation and Analysis of Parts and Materials installed on MFD-ESEM, NASDA Technical Memorandum NASDA-TMR-000011 (2001)