1. **Title**
   FY2001 Ground-based Research Announcement for Space Utilization Research Report (Summary)

2. **Research Term**
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3. **Research Fields**
   Space Utilization Technology Development

4. **Research Categories**
   Phase IB Research

5. **Research Theme**
   Combined Effects of Radiation and Atomic Oxygen Exposures on Flexible Films Under Tensile Load

6. **Investigators**
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8. **Summary of Research**

   **8.1. Objective**
   In recent years, applications of polymeric materials have been extended into space technology such as heat resistant materials for spaceships, materials for solar cell panels, and inflatable structures. Especially for realization of inflatable structures in Low Earth Orbit (LEO), it is necessary to clarify durability of polymer sheets against Atomic Oxygen (AO) and various radiations. In this research, we organized such experiments in the ground facilities that tension loaded PEEK sheets were exposed to AO and various radiations for the purpose of clarifying synergetic effects between tensile stress and some environmental factors affecting degradation behavior of polymeric materials. Then, we compared our ground test results with results of the other experiment collaborated with the Japan Aerospace Exploration Agency (JAXA) which exposed polymer sheets to the real space environment in LEO for 10 months using the International Space Station (ISS) Russian Service Module, and discussed some further issues lying in the evaluation of degradation processes in the space environment based on the results of ground experiments.

   **8.2. Methods**
   Materials used were Poly-Ether-Ether-Keton (PEEK) sheets with 0.4mm thickness. PEEK sheets were exposed to irradiations of AO, Electron Beam (EB) and UV (Ultraviolet ray) with three kinds of initial stresses set to 0, 1.6, and 4.7MPa. The amount of each irradiation corresponded to 0.5 year, one year, and three years in LEO of ISS. For these exposure experiments, we used ground facilities of JAXA. After the exposure experiments, physical, chemical and mechanical properties were investigated to reveal degradation behavior. Then, we compared the results of the ground control experiments with those of real space experiments conducted in LEO.

   **8.3. Experimental Results**
   (1) **Materials exposed to AO:** By AO irradiation, the test piece showed damages by ragged surface within a few μm. The amount of thickness reduction caused by this damage almost increased in proportion to AO fluence. Reaction efficiency had a tendency of increase based on stresses. Mechanical properties, however, remained unchanged in spite of tensile load. This is because reactive layer of material is too thin compared with the thickness of material. Accordingly, material strength after AO irradiation can be almost estimated by the amount of thickness reduction.

   (2) **Materials exposed to EB:** After EB irradiation, no changes were observed in material surface and mass. No significant differences were shown in mechanical properties, either. Results of FT-IR and DSC measurements showed no changes. From these, under approximately 0.5-year exposure in LEO, PEEK is so highly resistant to EB that it shows no significant changes in
material properties despite of loaded stresses.

(3) Materials exposed to UV:

(3-1) Effects of exposure: UV irradiation showed no visual damages or mass loss as AO. However, the color of material surface was changed into brown and its optical properties were changed. Concerning mechanical properties of exposed material without stress, elongations at break decreased sharply and yield strength leaped upward. The yield strength went up as the amount of exposure increased. Results of measurements by FT-IR, XPS, and DSC showed that UV irradiation caused molecular chains cross-linked, and the degree of cross-linkage increased as the amount of exposure increased. The changes in mechanical properties result from this kind of molecular structure. When PEEK sheet is used in the space, we should pay attention to sunlight, particularly UV.

(3-2) Effects of temperature change and applied stress: Under UV exposure, the effect of stress over mechanical properties of material differed by cooling condition. In case of materials without cooling, the amount of increase in yield strength and the amount of decrease in elongation at break became more distinctive, while materials with cooling did not show such tendency. Load stress dependence in mechanical properties presumably resulted from the orientation of molecular chains by synergetic effect of temperature cycling from 10 to 130 ºC and stress. Considering that such temperature cycling and stress are interacted simultaneously in the space, we must evaluate their synergetic effect.

(4) Materials exposed to the space environment: For the space exposure samples in LEO, observed were a change in surface color into brown and mass reduction, which resulted from synergetic effect of AO and UV. The exposed area showed contaminants attached. Approximate reaction efficiency of the flight samples was slightly lower than those of AO exposed samples, but both were in the order of 10^-24 cm^3/atom. To clarify this difference, it is necessary to consider the change in molecular structure by UV as described in (3-1) and the effect of contaminants attached to the material surface. Nevertheless, the fact that reaction efficiency of the flight samples did not show so much difference from that of the ground AO exposure tests indicates that we can generally estimate possible damages in the space by ground control experiments.

8.4. Potential for space experiment

From the results shown in 8.3., for the evaluation of material durability in LEO, we recommend to quantify effects of damage by AO in UV environment and temperature cycling. This is a significant finding to narrow down analysis objects and to improve conditions of tensile load in the future space experiment.

9. Publication List


10. URL

N/A