ATOMIC OXYGEN FLUX MEASUREMENTS VIA PYROLYTIC AND THERMOFORMED KAPTON INTEGRATED WITH THE ON-ORBIT MATERIALS DEGRADATION DETECTOR (ORMADD)

Ronen Verker, Asaf Bolker, Yacov Carmiel, Irina Gouzman, Eitan Grossman, Timothy K. Minton, Alexandre K. Jones, Kendra P. Fischer, Stephanie Remaury

(1) Soreq NRC, 4111 Rd, Yavne, 81800, Israel, rverker@soreq.gov.il
(2) Montana State University, Dept. of Chemistry and Biochemistry, Bozeman, MT 59715, USA, tminton@montana.edu
(3) CNES, 18 avenue Edouard Belin, Toulouse, 31401, France, Stephanie.Remaury@cnes.fr

ABSTRACT

Atomic oxygen (AO) is the predominant neutral specie in the low Earth orbit (LEO) environment and is considered to be one of the main hazards to spacecraft materials. Obtaining accurate on-orbit AO flux data can contribute to the design of the next generation of spacecraft by facilitating reliable prediction of material durability for a specific mission. AO flux can be measured by a variety of techniques, including mass spectrometry, actinometry, catalytic probes, surface recession, and witness sample mass loss either in-situ by a quartz crystal microbalance (QCM) or ex-situ by a microbalance. These methods are either extremely expensive, require retrieval of samples, or difficult to implement on board a spacecraft.

In this study, we use the On-Orbit MAterials Degradation Detector (ORMADD), which was developed in Soreq NRC, in a series of ground-based AO flux measurements. ORMADD is based on photo-voltaic cells and can measure real-time space environment components, such as AO or UV fluxes. The goal of this study is to validate the accuracy of ORMADD during AO flux measurements under severe conditions, which includes, in addition to AO, solar illumination and extreme thermal cycling.

The validation of ORMADD is a step toward its integration with the THERME experiment. THERME was developed by CNES, in order to provide real-time ageing measurements of thermal control coatings through measurement of temperature change related to solar absorptivity changes. The combined THERME-ORMADD detector will allow correlation between real-time space environment components and ageing of materials.

ORMADD’s AO flux measurements were performed using either an oxygen RF plasma system or a laser detonation source of 5 eV AO. A Xe lamp, equipped with a specially designed optical homogenizer, was used as a solar simulator. During these measurements, two photo-voltaic cells were used. One served as a reference and the other was covered with a semi-transparent material. The transparency of the semi-transparent material is changing in reaction to AO exposure. Each cell was equipped with a thermocouple in order to correlate its output to the surrounding temperature. Simulation of night and day were performed by blocking the lamp’s beam for a period of 40 min. every 90 min.

ORMADD reveals a large dynamical range through the usage of various materials. An amorphous carbon (a:C) coating was used for AO flux measurements at low AO fluences, on the order of $10^{19}$ O atoms cm$^{-2}$. However, in order to extend ORMADD’s dynamical range to fluences of $10^{20}$-10$^{21}$ O atoms cm$^{-2}$ while maintaining its accuracy, newly developed materials were used. These materials are based on pyrolytic and thermoformed Kapton. Pyrolytic Kapton was formed by exposure of Kapton to high temperature under an inert environment. The result is a darker form of Kapton exhibiting a low optical transmittance. Thermoformed Kapton was formed by exposure of Kapton to high temperature and mechanical strains under an inert environment. The result is a dark Kapton film with designated spring-like characteristics, which enables measurements of thin polymeric films attached to it.

By using these three types of materials, ORMADD validation for AO flux measurements was performed. During the measurements, pristine Kapton samples were also exposed and were used for AO equivalent fluence and flux measurements, using accurate AO erosion depth profilometry. The results of the two measurement methods, ORMADD and erosion depth profilometry, were compared, showing the ability of ORMADD to measure real-time and accurate AO fluxes while being exposed to thermal cycles of 50-125°C and extreme AO test environment. This work demonstrates the potential of ORMADD as material degradation detection platform and a tool for in-situ measurements of on-orbit AO flux, as will be performed with the THERME-ORMADD project.