Ground Control Monitoring for the Organics Experiment on the EXPOSE-R Facility on the International Space Station


1 Bay Area Environmental Research Institute, Moffett Field, CA 94035
2 NASA Ames Research Center, Moffett Field, CA
3 Leiden Institute of Chemistry, The Netherlands
4 Dept. of Terrestrial Magnetism, Carnegie Institute of Washington, Washington, DC
5 ESA-SCI-S, The Netherlands
6 University of Münster, Germany
7 LEME, France
8 NASA Goddard Space Flight Center, Greenbelt, Maryland, 20771

kathryn.bryson@nasa.gov, farid.salama@nasa.gov, p.ehrenfreund@chem.leidenuniv.nl

ABSTRACT

The Organics experiment is integrated into the multi-user facility EXPOSE-R mounted on the International Space Station (ISS). In this experiment organic samples of astronomical interest are exposed for a long duration to the space environment and will remain 24 months on-board the ISS before they are returned to Earth in March 2011. The radiation dose that is collected by the samples during flight exceeds the limits of simulations in the laboratory and the results will greatly enhance our knowledge on the evolution of large molecules in space environments. We describe the experimental components that are being used on the ISS for the exposure experiments and in the laboratory for ground-control measurements and present spectra measured in the UV-Vis range monitoring the ground control samples.

1. Introduction

Aromatic networks are likely the most abundant organic material in space. Specifically, PAHs and fullerenes have been identified in meteorites (Sephton et al. 1998) and are
thought to be among the carriers for numerous astronomical absorption and emission features (Mathis, J.S. 1994; Salama et al 1996; Allamandola et al 1999; Tielens 2008). Recently, the fullerenes $C_{60}$ and $C_{70}$ neutral molecules have been discovered in the young planetary nebula Tc 1 (Cami et al 2010). PAHs and fullerenes seem widely distributed in space and to obtain knowledge on the stability of these molecules is crucial to enhance our understanding about the evolution of organics in space. Thin films of selected PAHs and fullerenes are being subjected to the low Earth orbit environment as part of the Organics experiment on EXPOSE-R onboard the ISS. The Organics experiment will monitor the chemical evolution, survival, destruction, and chemical modification of the samples in the space environment.

2. EXPOSE-R facility

EXPOSE-R is a multi-user facility attached to an external platform at the outer hull of the Service Module of the Russian Segment of the International Space Station (RS-ISS). The external platform, called URM-D, provides mechanical, electrical and data interfaces. EXPOSE-R accommodates 10 biological and biochemical experiments, which are mounted in three removable trays (see Fig. 1). EXPOSE-R allows defined long-term and/or short-term exposure of experiments to solar UV under vacuum or controlled atmosphere.

EXPOSE-R with its experiment trays launched on flight 31P on November 26, 2008 with an unmanned PROGRESS cargo ship on a SOYUZ launcher from Baikonur, Kazakhstan. After a storage period inside the RS-ISS, it was mounted to the external URM-D by EVA on March 10, 2009 to start the exposure of the experiments to the space environment. All trays carry dark samples that are shielded from the UV photons and enable us to discriminate between the effects of exposure to photons and cosmic rays. Space exposure is planned for a period of at least 18 months, which will provide $\sim$2000 h effective exposure. The trays will be recovered by EVA in early spring 2011 and returned to Earth.
3. **Organics experiment**

The Organics experiment on EXPOSE-R consists of 12 PAHs (see Table 1) and the fullerenes C\textsubscript{60}, C\textsubscript{70}, and a C\textsubscript{60}/C\textsubscript{70}/C\textsubscript{84} mixture. The goal is to test the stability of such compounds when exposed to space conditions. PAH molecules such as those in Table 1 are expected to reside in the interstellar medium. It was our goal to identify the most stable PAH and fullerene species to gain insights into PAH chemistry. The PAH samples selected include a few small PAHs (e.g. tetracene) as well as large PAHs of catacondensed and pericondensed structure that were specially synthesized for this space experiment (at high purity: 99.9 \%). Some of the PAHs and C\textsubscript{60} have previously flown on the Organics experiment on BIOPAN V (Ehrenfreund et al. 2007), which had 58 h exposure with effective solar pointing.

<table>
<thead>
<tr>
<th>PAH (formula)</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chrysene (C\textsubscript{18}H\textsubscript{12})</td>
<td>4 ring, catacondensed</td>
</tr>
<tr>
<td>Triphenylene (C\textsubscript{18}H\textsubscript{12})</td>
<td>4 ring, catacondensed</td>
</tr>
<tr>
<td>Tetracene (C\textsubscript{18}H\textsubscript{12})</td>
<td>4 ring, catacondensed</td>
</tr>
<tr>
<td>Perylene (C\textsubscript{20}H\textsubscript{12})</td>
<td>5 ring, pericondensed</td>
</tr>
<tr>
<td>Coronene (C\textsubscript{24}H\textsubscript{12})</td>
<td>7 ring, pericondensed</td>
</tr>
<tr>
<td>Diphenantrho[9,10-b:910-d]thiophene (C\textsubscript{28}H\textsubscript{16}S)</td>
<td>7 ring, catacondensed</td>
</tr>
<tr>
<td>Ovalene (C\textsubscript{32}H\textsubscript{14})</td>
<td>10 ring, pericondensed</td>
</tr>
<tr>
<td>Dinaphtho[8,1,2-abc:2,1,8-klm]coronene (C\textsubscript{36}H\textsubscript{16})</td>
<td>11 ring, pericondensed</td>
</tr>
<tr>
<td>Circobiphenyl (C\textsubscript{38}H\textsubscript{16})</td>
<td>12 ring, pericondensed</td>
</tr>
<tr>
<td>Dibenzo[jk,ab]octacene (C\textsubscript{40}H\textsubscript{22})</td>
<td>10 ring, pericondensed</td>
</tr>
<tr>
<td>Tetrabenzo[de,no,st,cd]heptacene (C\textsubscript{42}H\textsubscript{22})</td>
<td>11 ring, pericondensed</td>
</tr>
<tr>
<td>Dicoronylene (C\textsubscript{48}H\textsubscript{20})</td>
<td>15 ring, pericondensed</td>
</tr>
</tbody>
</table>

The samples were deposited as thin (∼few hundred nm) films by sublimation onto MgF\textsubscript{2} windows to allow efficient penetration of UV photons (Ehrenfreund et al. 2007). The samples were analyzed before exposure to the space environment with UV-VIS and IR spectroscopy. The same analyses will also be performed after space exposure. 70 flight samples are being exposed on the EXPOSE-R facility.

4. **Ground control measurements**

Eight sample carriers remained on Earth. Two of these samples carriers are being ground truth monitored through UV-VIS spectroscopy every three months in the Astrophysics and Astrochemistry Laboratory at NASA Ames Research Center (Fig. 2). The samples are stored in a dark desiccator between measurements. Figure 3 shows the first and last UV-VIS
absorption spectra collected of the ground sample tetracene (C\textsubscript{18}H\textsubscript{12}) and its stability over 1.5 years.

Fig. 2.— Ocean Optics HR4000 UV/VIS Spectrometer with x-y-z slide assembly in the Astrophysics and Astrochemistry Laboratory at NASA Ames setup for ground truth monitoring.

Fig. 3.— The ground control monitoring UV-Vis spectra of a thin film of the PAH tetracene sublimed onto MgF\textsubscript{2}, displaying a strong band system around 500 nm.

The Organics experiment monitors the chemical evolution, survival, destruction and chemical modification of PAHs and fullerenes in space environment. From the results we shall determine constraints on the photochemistry of these compounds in the interstellar medium. Since PAHs are also present in meteorites, the obtained data are also relevant for the reconstruction of events in the early Solar System.

The authors acknowledge the support of the NASA SMD APRA program.

REFERENCES

Ehrenfreund, P. et al. 2007, PSS, 55, 383

This preprint was prepared with the AAS \LaTeX\ macros v5.2.