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Experimental Studies of Space Weathering Effects on Thin Membranes in Planetary Defence Applications and Asteroid Surface Materials by a Complex Irradiation Facility

Maciej Sznajder[1,2], Jan Thimo Grundmannn[1,3], Thomas Renger[1,4]
[1]*DLR Institute of Space Systems, Robert-Hooke-Strasse 7, 28359 Bremen, Germany*
[2]*+49-(0)421-24420-1623, Maciej.Sznajder@dlr.de*
[3]*+49-(0)421-24420-1107, Jan.Grundmann@dlr.de*
[4]*+49-(0)421-24420-1607,Thomas.Renger@dlr.de*

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ABSTRACT

A number of very low area density objects are known in high Earth orbit where most environmental conditions are similar to near-Earth interplanetary space. These objects are probably thermal protection system (TPS) foils degraded to the point of disintegration and separation from operationally calm spacecraft such as geostationary comsats.

Several methods proposed in the context of planetary defense involve the use of lightweight deployable membrane structures which as a whole or in some of their layers are derived from foils used in spacecraft TPS, e.g. Multi-Layer Insulation (MLI) stacks or individual MLI layers. Membranes are exposed to mechanical stresses

much higher than in TPS applications when they are used as e.g. large lightweight photovoltaic generators on manoeuvering spacecraft, agile solar sails, precisely formed solar concentrator reflectors, Yarkovsky/YORP modification wraps or devolatilization containers around small asteroids or boulders. Hence, effects or conditions leading to serious degradation of the foils' required properties should be of utmost concern.

The Complex Irradiation Facility (CIF) was designed and commissioned with the aim to perform material investigations under simultaneous irradiation of both corpuscular and electromagnetic radiation. The complete facility has been built in Ultra High Vacuum (UHV) technology. It is free of organic compounds to avoid self-contamination. The differential pumping system achieves a final pressure in the 10^{-10} mbar range.

The CIF is equipped with electron and proton linear accelerators. The kinetic energy of both species can be set separately within a range of 1 keV to 100 keV. The minimum achievable current of both types of projectiles is 1 nA while the maximum current is 100 µA. Also, three electromagnetic sources are available: an argon VUV source, a deuterium lamp, and a Xenon lamp. All three sources working simultaneously cover wide wavelength range from 40 nm to 2500 nm.

Recently, the CIF was used in an experimental study of the formation of tiny molecular hydrogen blisters formed on vacuum-deposited aluminium (VDA) layers. The blisters of approx. 0.4 µm diameter were produced by exposure of the VDA to a flux of low energy protons at only 2.5 keV. The hydrogen gas results from recombination processes of the incident protons and the metal's electrons. The studies revealed environmental conditions, i.e. dose and kinetic energy of the incident protons as well as the temperature of the specimens, at which the blistering process takes place. Formation of the blisters has a major impact on reflectivity of the VDA which has a broad application in thermal insulation foils and membranes of lightweight deployable structures like solar sails.

The CIF can irradiate materials in UHV at temperatures. From the sample's irradiated α/ε equilibrium temperature, they can be artificially heated by halogen lamps to 450^{o}C or cooled down to LN_2 level of -193^{o}C.
Low-energy corpuscular and high-energy electromagnetic radiation interacts at the immediate surface of regolith grains where the spectrum of reflected sunlight is formed. The CIF can thus help to improve the connection between spectral classification of asteroids and inferred composition by space weathering experiments simulating different heliocentric distances.

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