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→ A KINETIC STUDY OF RADIATION INDUCED CONTAMINATION EFFECTS

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INTRODUCTION

UV/VUV radiation induced contamination on surfaces of spacecraft, their optical instruments and solar arrays in space can result in significant loss of their performance and eventually in their complete failure. Several studies have been focused on the prediction of the contamination effects on different sensitive surfaces in the presence of UV/VUV radiation and outgassing products from different materials [1,2]. Surface photofixation of gas-phase organic molecules outgassing from materials of a spacecraft under UV/VUV radiation is considered as a main mechanism of surface contamination. A detailed photofixation modelling was developed in [2]. An experimental approach to investigate radiation induced contamination effects was developed during the BepiColombo mission development and presented in [1]. Here surface contamination is a result of a competition between the deposition of incoming contaminants, their re-emission, the surface temperature of the target and the temperature of the source(s) as well as radiation intensities [1].

However, there is a lack of experimental information related to the dependence of the degradation rate of thermo-optical surfaces on the impingement rate of gas molecules (contamination flux) and intensity of UV/VUV radiation (photon flux). This information is crucial for predicting the performance of long duration space mission and for the ground testing when UV/VUV intensities and/or contamination fluxes are increased to accelerate the testing. Moreover, further transformation of molecules in the contamination deposit is also contributing to the changes of surface reflectivity and must also be taken into account.

Presented here are the preliminary results of an experimental parametric study of the VUV radiation induced contamination on different surfaces in vacuum. Contamination sources and ceramic coatings were representative of materials used for the BepiColombo mission. During the experiments the optical degradation of samples was measured *in-situ* by two independent spectroscopic instruments specifically designed for this investigation. Obtained data allowed us to study *in-situ* the kinetics of the sample degradation as a function of contamination fluxes, VUV intensities and temperatures.

EXPERIMENTAL SETUP

The Cross 3M environmental testing facility located in ESA's Materials and Electrical Components Laboratory at ESTEC was used for this study. Its main feature is the ability to perform reflectance measurements on samples directly in vacuum conditions during test execution.

VUV lamps pointing into the test chamber can be switched on exposing the samples to high energy radiation. Initially the samples are kept at -15±5°C while organic molecules are released from the Knudsen cell creating a contamination environment around the sample plate. The Knudsen cell is then closed and the samples are ramped to high temperature at a rate of 5°C/hour.

Test parameters:
- Pressure: < $5x10^{-7}$ mbar
- Temperature range -100°C -> 400°C
- VUV exposure 1–10 Solar Constants
- Knudsen cell -> contaminant environment
- Two LED lamps illuminate sample plate

Test materials:
- Three generations of white ceramic coating NV14
- CFRP contaminant source

Test instruments:
- In-situ UV/VIS/NIR camera
- In-situ UV/VIS/NIR spectrometer
- IR camera
- Two Cryogenic QCMs

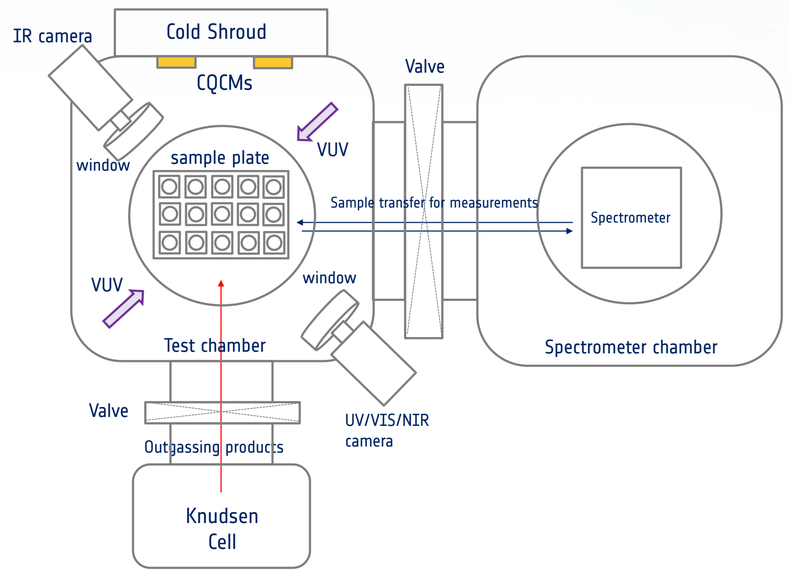

Figure 1. Schematic of Cross 3M facility.

RESULTS

The figures below show results from a subset of the data collected thus far. Samples were exposed to two levels of VUV intensity and contaminant flux over several tests. Reflectance data was measured at 436 nm.

In each test there is a clear degradation of sample reflectance during:
- VUV exposure – intrinsic degradation of the material itself
- VUV exposure & contaminant environment – accumulation of contaminant layers through adsorption/re-emission, substrate excitation/de-excitation, photofixation of contaminants to the surface
- High temperature – transformation of contaminant deposits to sp^2-like amorphous carbon during non-isothermal conditions

The degradation rate increases for higher contaminant flux at the same VUV intensity. However this increase appears to be less at lower VUV intensities as shown in Figure 5.

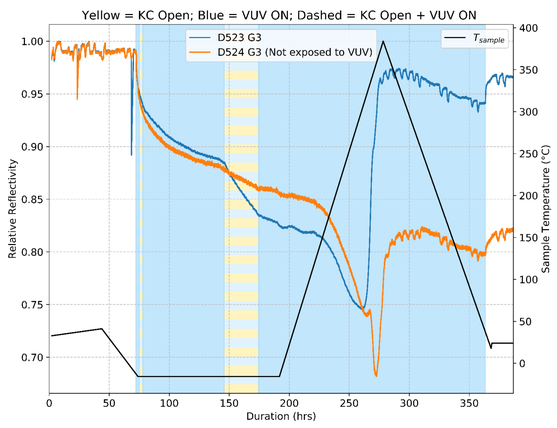

Figure 2. VUV 7±2 SC. Contaminant flux 0.122 $ngcm^{-2}$.

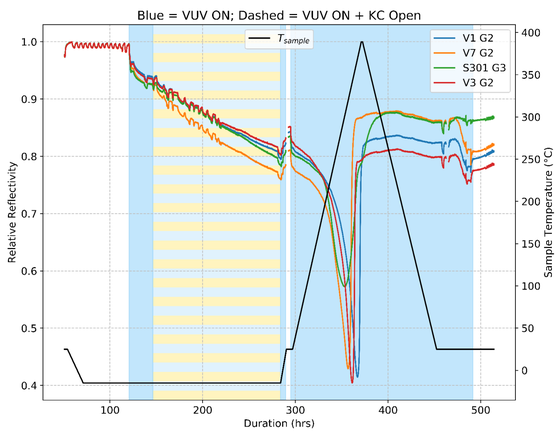

Figure 3. VUV 7±2 SC. Contaminant flux 0.039$ngcm^{-2}$.

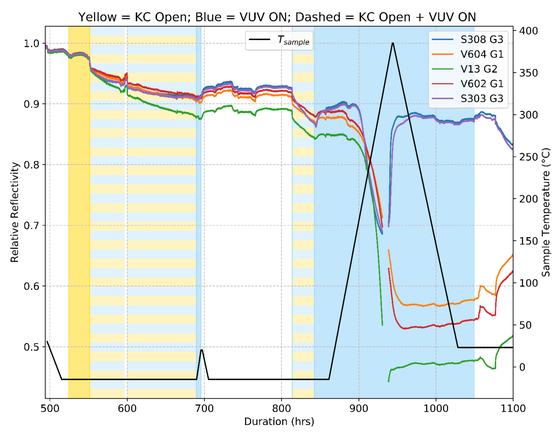

Figure 4. VUV 1±0.5 SC. Contaminant flux 0.0395$ngcm^{-2}$, 0.1454$ngcm^{-2}$.

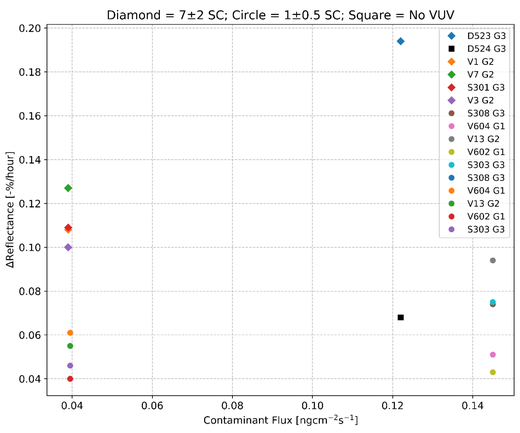

Figure 5. Degradation of sample reflectance vs contaminant flux for two different VUV intensities.

CONCLUSIONS

- Experimental method to determine the limiting parameter between photon flux and contaminant flux in relation to the degradation rate of thermo-optical properties has been established.
- Kinetic parameters of the transformation of contamination deposits and "bleaching" effects (exposure to air) are under current investigation.

REFERENCES

1. C.O.A. Semprimoschnig, Y.V. Butenko, A.W. Polsak, R. Rampini, P. de Heij, B. Bras, R. Martins, L. Levan, and V. Cesar-Auguste "An Overview of the latest Materials Engineering Challenges for the preparation of ESA's Mercury Mission", ISMSE-13, the 13th International Symposium on Materials in the Space Environment, Pau, France, 22-26 June 2015.
2. J.-F. Roussel, E. Vanhove, and T. Tondu, Ultraviolet Fixation of Molecular Contamination: Physical Model Numerical Implementation and Validation, Journal of spacecraft and rockets, published online on 27 July 2016.