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VUV/EUV transmittance and light scattering characterization of contaminated optical components

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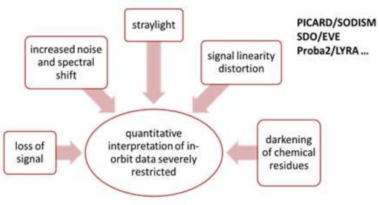
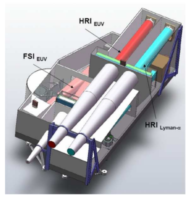
INTRODUCTION



In-orbit Lessons learned of solar instruments

Observations in the UV and EUV allow many diagnostics of the outer layers of the stars and the Sun so that more and more space telescopes are developed to operate in this fundamental spectral range. However, absorption by residual contaminants causes critical effects such as loss of signal, spectral shifts, stray light… Thus, a cleanliness and contamination control plan has to be defined to mitigate the risk of damage of sensitive surfaces. In order to specify acceptable cleanliness levels, it is paramount to improve our knowledge and understanding of contamination effects, especially in the UV/EUV range. Therefore, an experimental study has been carried out in collaboration between CNES and IAS, in the frame of the development of the Extreme UV Imager suite for the ESA Solar Orbiter mission (to be launched in 2020) ; this instrument consists of two High Resolution Imagers and one Full Sun Imager designed for narrow pass-band EUV imaging of the solar corona, at wavelengths 17.4 nm, 30.4 nm and 121.6 nm, all highly sensitive to contamination.



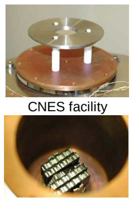
EUI telescope suite

The purpose of this joint experimental study was to assess transmittance loss and scattering effect of different representative optical components used for EUI (metal filters, Lyman-α filters and multilayer mirrors), contaminated at CNES at different levels by the outgassing products of three polymer materials.

MATERIALS & OPTICS

- **Contaminants** (outgassing products from typical space materials)
  - EC2216 epoxy resin
  - RTV-566 Silicone elastomer
  - M55J/RS-3C Carbon fiber-polycyanate resine composite honeycomb
  - *2-3 contamination levels of the 3 contaminants*
- **EUV samples**
  - MgF_2 substrates with one side coated
  - Mirrors (Al/Mo/SiC coating on SiO_2 substrate)
  - Filters (Al sheet on hexagonal grid)

FACILITIES



CNES facility

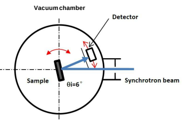
deposits under vacuum (P<10^{-4} Pa)
weighing before and after test
contamination levels :
between 10 and 100 µg/cm²

overview of APEX branch

sample holder

- ✓ energy range : 60 - 300 nm
- ✓ spectral resolution : 0.1 nm
- ✓ beam size : about 4 x 4 mm²

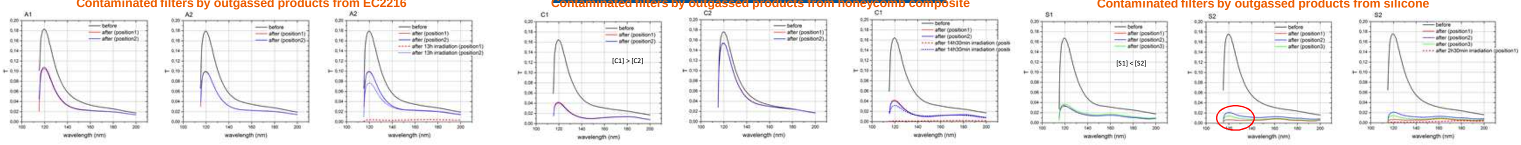
Since the optical characterization of EUV instrument components requires a very intense, continuous spectrum and a clean, small and collimated light source, only a synchrotron source can satisfy these criteria.



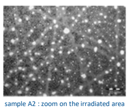
- ✓ wavelength : 17.4 nm
- ✓ beam : 0.1 x 0.2 mm, divergence negligible
- ✓ detector : Si photodiode + 1.5 mm pinhole, on 287.5 mm long arm
- ✓ incidence : 0° (for transmitting filters) / 6° (for mirrors)
- ✓ measuring range : +/- 3°

initial optical measurement of optical components → contamination process and deposit assessment → optical measurements of the contaminated components *(and after UV exposure for MgF_2)*

MAIN MEASUREMENTS RESULTS

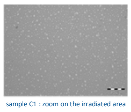


- effect quite strong despite the quantity of contaminant (too small to be assessed)
- peak transmittance drops by 43-44%, with local variations of a few percent
- baking effect more drastic : only 2% of the initial transmittance
- reduced effect of the baking beyond the irradiated area



sample A2 : zoom on the irradiated area

- loss of transmittance not proportional with the contaminant amount : threshold ?
- transmittance remains locally constant (uniform deposit)
- baked sample virtually opaque : only 0.7% of the initial transmittance
- reduced transmittance even outside of the irradiated area



sample C1 : zoom on the irradiated area

- high loss of transmittance (> 80%)
- strong dispersion on the most contaminated filter due to the presence of drops
- baked sample opaque after a short UV exposure
- baking spread beyond the irradiated area
- complex texture of the deposit : hardening and cracking

sample S2 : zoom on the irradiated area

Fig 1. VUV transmittance of contaminated LYMAN-α filters

deposits = droplets of different shapes and sizes

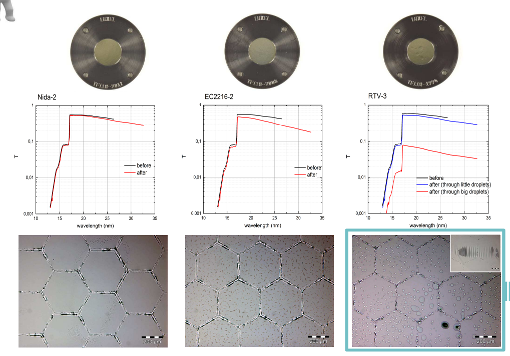
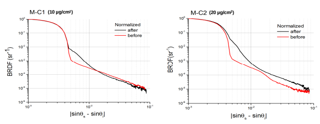


Fig 2. EUV transmittance of contaminated Al filters



significant scatter increase on mirrors

Fig 3. BRDF of composite-contaminated mirrors

Sample FS-1 (50 µg/cm²) :
scatter not increased, but specular peak narrowed

Sample FS-2 (70 µg/cm²) :
scatter slightly increased and specular peak more narrowed

Sample FS-3 (115 µg/cm²) :
measurements on droplets alone areas and aiming at large drops
scatter not increased, but specular peak narrowed
Non-scatter effect : large drops impact ?

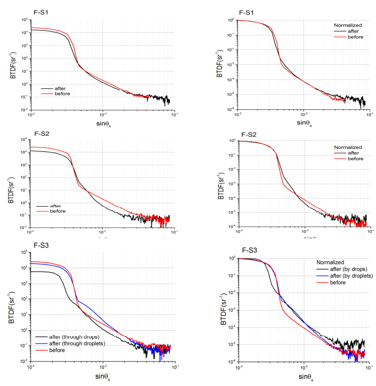


Fig 4. Focus on BTDF of silicone-contaminated Al filters

CONCLUSION

This paper reported on an overview of the last results of performance loss of different optical components before and after contamination. Furthermore, some of them have been analyzed after a long exposure to VUV-visible radiations to characterize the irreversible degradation due to photo-polymerization of the organic deposits. This experiment was a first exploration of yet poorly known effects : it confirmed how critical molecular contamination is for UV instruments. The results showed that filters transmittance can drop to a fraction of the initial one depending on the nature and the amount of contaminants. Besides, mirrors reflectance can decrease significantly by absorption of these contaminants and by scattering effect due to the large amount of droplets. Thus, the sensitivity and the measurement quality of the optical instrument may be highly affected by contamination. In particular, scatter can degrade the Point Spread Function (PSF) and reduce the contrast.
However, it is too early for establishing a predictive model of performance loss vs. contamination levels. More extensive and exhaustive measurements campaigns with more different contaminants deposits levels are needed.

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