Protected silver coating for Ariel telescope mirrors: study of ageing effects

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INTRODUCTION

Ariel is ESA adopted M4 mission in the "Cosmic Vision" program, for the study of exoplanetary atmospheres [1].
Ariel features an off-axis Cassegrain **telescope composed of a sequence of mirrors made of Al 6061-T651**, with the primary mirror (M1) being the largest - a 1.1m by 0.73m ellipse. This is followed by a hyperbola (M2), a re-collimating off-axis parabola (M3) and a plane fold mirror (M4).
To increase the reflectance of the optical surface in the working spectral range (0,5µm-7,8µm), a protected Ag coating has been applied. However, this coating is vulnerable to humidity, sulfur, chlorine pollutants and ageing [2].

The aim of this poster is to analyze potential aging effects that may occur during storage in an ISO 6 cleanroom. The applied standard is ECSS-Q-ST-70-17C "Durability testing of coatings" standard[3].

SAMPLES

The samples of Al 6061-T651 with a protected Ag coating are disks of 25 mm of diameter, 6 mm of thickness.
The protected silver coating of the mirrors is a composite stack, consisting of an adhesion layer of NiCr, which ensures the bond between the substrate (Al 6061-T651) and the reflective Ag layer and at the top a protective layer.
Five representative samples have been chosen:
Sample SN1 is part of the first test deposition run conducted on April 3rd, 2019 by Cilas[1].
Samples SN02M, SN04M, SN06M, SN08M are from the qualification run carried out on December 12th, 2019 by Cilas.
See Table 1 for processes and treatments experienced by the selected samples.

	Humidity	Thermal	Adhesion lv 2	Cryotest	Cleaning	Abrasion
SN1			yes	yes	yes	
SN02M			yes			
SN04M	yes		yes			
SN06M			yes	yes		
SN08M	yes	yes	yes	yes	yes	yes

Table 1: Processes to which the samples have been subjected.

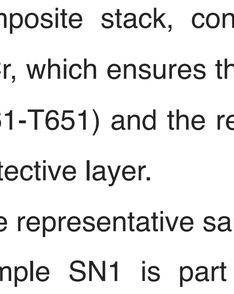

Fig. 1: Picture of sample SN02 after tests.

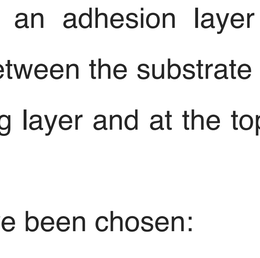

Fig. 2: Picture of sample SN04 after tests.

METHODS

1. Visual Inspection, conducted according to ISO 9211-4 Annex C**,** to identify any defects present on the optical surface of the samples.

2. For qualitative analysis of surface topography and surface roughness measurement, an **atomic force microscope (AFM)** was employed, in non-contact mode. The scans were taken with a Park System XE-Series 70 microscope and Park NX10, and processed with the provided proprietary software XEI.

Fig. 3: Setup for topography: Park NX10 by Park Systems.

3. Fourier Transform Infrared Spectroscopy (FTIR Spectroscopy) was operated in a specular reflection (SR) configuration, to acquire reflectance surface information. The samples were examined with a Nicolet i5s FTIR spectrometer interfaced to a '10Spec' accessory by Pike Technologies, with the Nicolet 'OMNIC' software.

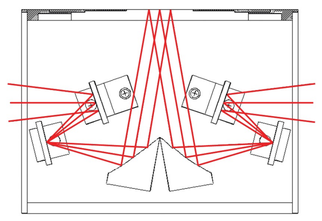

Fig. 4: Setup for IR reflectivity: detail of 10Spec by Pike Technologies.

RESULTS

- Photographs and drawings of the samples from April 2022 have been compared with the ones taken in October 2023. No signs of degradation were observed following the storage period.
- AFM result: the surface topology is qualitatively equivalent and surface roughness still below the required 10nm RMS (M1 requirement). The samples measured were SN02M, SN04M, SN06M, and SN08M because they had been previously measured at CNR in Padova, allowing for a meaningful comparison.

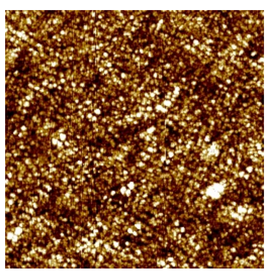

Fig. 5: Sample SN06M – height map.

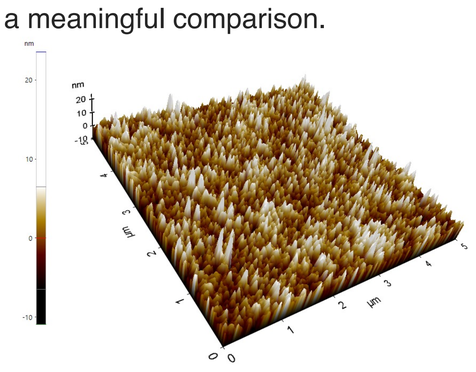

Fig. 6: Sample SN06M - 3D topography.

Roughness measurements, expressed as Rq (nm) for line profiles and Sq(nm) for sample area, were conducted using the Park NX10 microscope and the Park System XE-Series 70 microscope, respectively. Fig. 7 and 8 show that the roughness of the samples is in the range [3,318-4,925] nm.

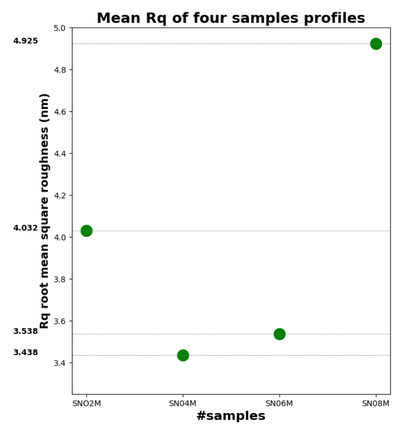

Fig. 7: Rq graph of selected samples

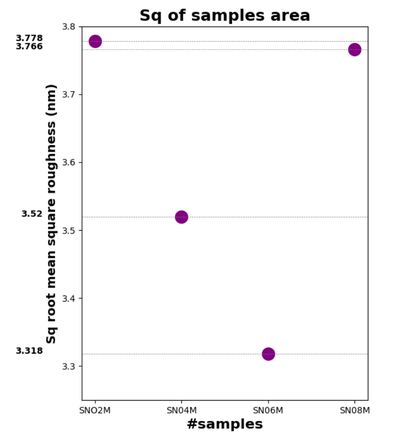

Fig. 8: Sq graph of selected samples

- The specification limit for reflectance is 90%, while the goal is 95%. These measurements were conducted for the first time at CNR and will be taken into account for future comparisons.

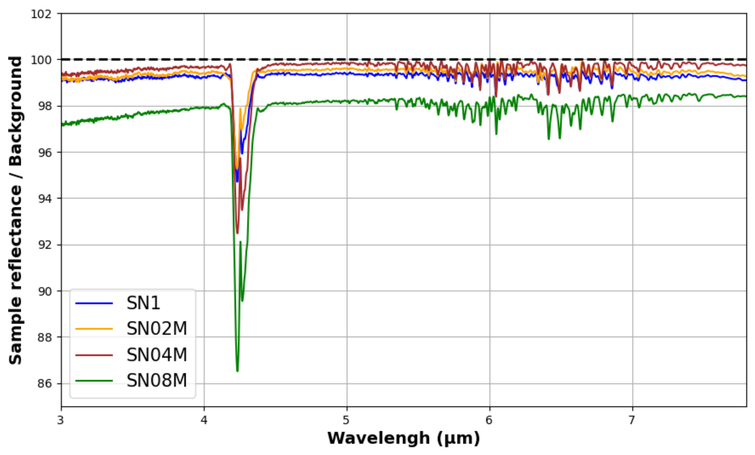

Fig. 9 Reflectance of samples

CONCLUSIONS

Visual inspection results in no signs of degradation following the storage period.

AFM data presents surface roughness below 10 nm and in the ± 1nm range of previously measured RMS.

In the **reflectance** spectra, the drop at around 4,2 µm is due to the absorption of IR light by the CO_2 present in the atmosphere. All reflectance measurements are within acceptable limits; however, sample SN08M, which has undergone more treatments, exhibits a lower reflectance value in the range.

The ageing effect, although not presenting critical issues at this time, must be monitored in the future.

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