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TEST REPORT / TEST RESULT

Emittance measurements for European South Observatory

Task number TO0004616

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Prepared by	**B. Bras**
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APPROVAL

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Author B. Bras	19/08/2020
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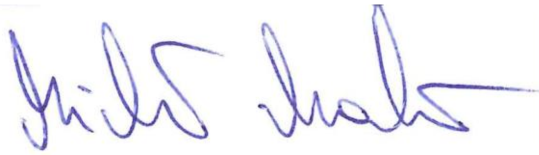
MICHAL MALICKI 	28/08/2020
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CHANGE LOG

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CHANGE RECORD

Issue Number 1	Revision Number 0		
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Table of contents:

1 SCOPE OF DOCUMENT

This document is the test report of the thermo-optical properties measurements within TEC-QEE.

2 INTRODUCTION

The European South Observatory considers the utilization of Solec's LO/MIT-II low emissivity paint in the main structure of the ELT. Therefore, the spectral emittance is needed to evaluate the suitability of this coating with respect to astronomical bands in the night sky radiation.

ESO is particularly interested in the wavelength ranges in which the transmittance through the atmosphere is high, namely between 8 µm and 14 µm and furthermore between 16 µm and 22 µm [RD02].

An FTIR spectrometer coupled with an integrating sphere was used to measure the total reflectance of the sample. The spectral emittance was calculated from the measurements.

Apart from SOLEC's LO/MIT-II paint, an additional aluminium sample was measured. The sample had been previously measured in TEC-QEE laboratories [RD01].

3 DOCUMENTATION

3.1 Applicable documents

AD01	ECSS-Q-70-09C	Measurements of thermo-optical properties of thermal control materials

3.2 Reference documents

RD01	ESA-TECQEE-LAB-TR-014763 Starlims task TO3856	Thermo-Optical properties for ESO
AD02	ESA-TECQTE-LAB-PR-002019	ECSS-Q-ST-70-09C measurement of emittance – Laboratory procedure at TEC-QEE
RD02	*e-mail communication*	*From Ronald Holzloehner to Dana Tomuta, 14th May 2020*
RD03	ESA-TECQTE-LAB-PR-002093	Technical Procedure: Themo-optical Properties Master Document WP2a

3.3 Abbreviations

ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
IR	Infra-red
MIC	Materials Identification Card
NCR	Non-Conformance Report
NIR	Near Infra-red
RH	Relative Humidity
R_T	Total (hemispherical) reflectance
TEC-QEE	Materials' Physics & Chemistry Section, Technical Reliability and Quality Division
UV	Ultra Violet
Vis	Visible
α	Solar Absorptance
ε	IR emittance

4 CUSTOMER INFORMATION

Customer: European South Observatory
Contact person: Ronald Holzloehner

5 MEASUREMENT LOCATION & CONDITIONS

The thermo-optical measurements have took place according to the following table:

Test Engineer	B. Bras
Location	TEC-Q laboratories
Date of measurements	CW 31 and 32 2020
Equipment and Method	According to Section 9.
Environnemental Conditions Temperature Relative Humidity	 22°C ± 3°C 55%RH ± 20%R

6 ACCEPTANCE CRITERIA

Not provided by the customer, the results are for information.

7 NON-CONFORMANCE REPORT (NCR)

No NCR was observed during the activity.

8 SAMPLES

Two samples were provided via D. Tomuta (TEC-MMO), in July 2020. The samples were measured as received.

8.1 Samples Description

SOLEC LO/MIT II paint

The full datasheet of this pain is in https://www.solec.org/lomit-radiant-barrier-coating/lomit-technical-specifications/. An extract is in Annex A of this document.

The sample dimensions (~15 cm x 10.5 cm) were initially large to fit in the sample port aperture of the integrating sphere. The customer agreed to cut the sample and perform the measurements on the smaller cut-out.

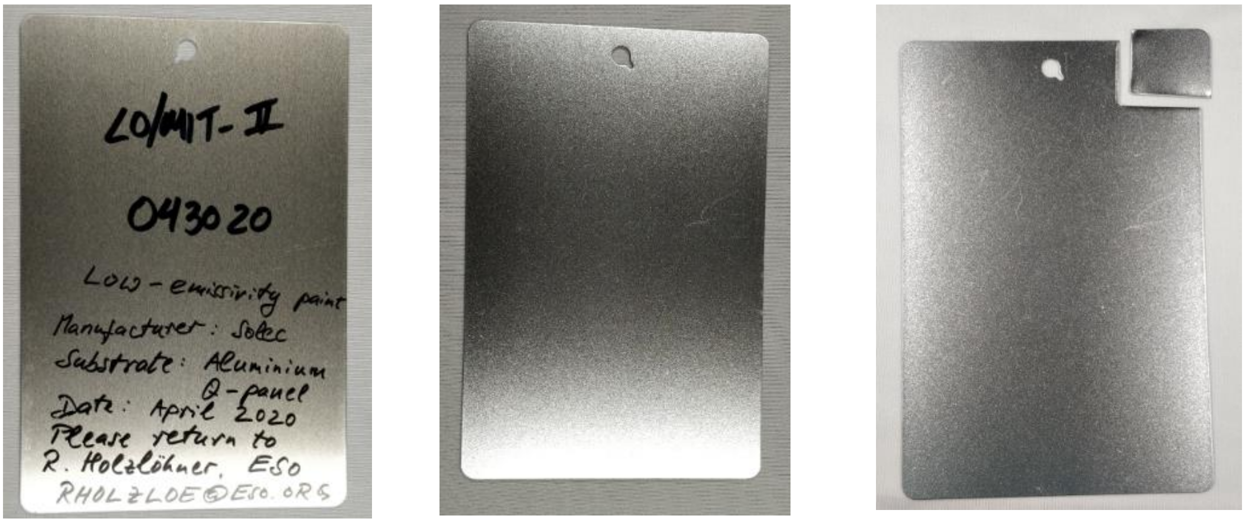
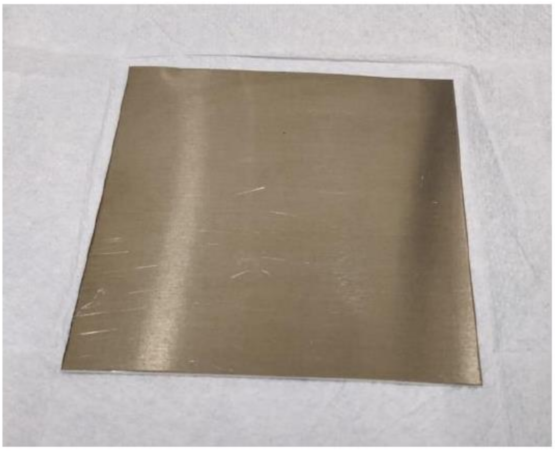


Figure 1, LO/MIT II paint sample. Left: backside. Centre: front side. Right: smaller sample cut-out.

Aluminium sample

The sample under test had been previous subjected to solar absorptance/thermal emittance measurements (RD01). It consists of Aluminium alloy EN AW-5754 (AlMg3). Measurements were performed approximately on the centre of the sample.



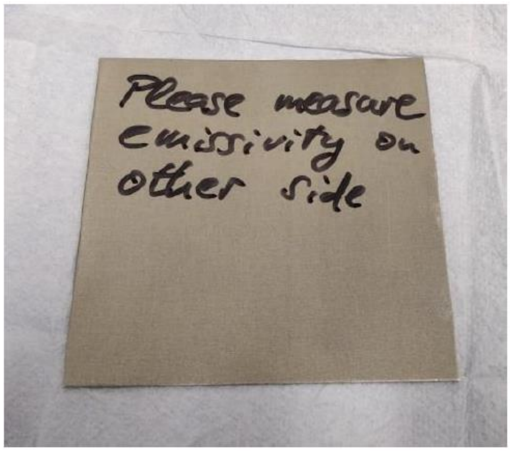


Figure 2, Aluminium sample EN AW-5457. Left: front side. Right: Backside.

9 TEST EQUIPMENT & METHODS

The following test equipment was used:

9.1 IR Reflectance with FTIR Spectrometer

Equipment: Bruker Vertex 70v; **Maintenance**: July 2020

The IR hemispherical reflectance (ρ_H) of the samples were measured using a Fourier Transform Infrared (FTIR) spectrophotometer coupled with an integrating sphere (A562, Bruker). The accessory uses a near normal incidence angle and is equipped with a DLaTGS detector.

The experimental setup was calibrated before the measurements using an NPL certified reflectance standard.

Beamsplitter: KBr beamsplitter
Range: from 2.5µm to 22.2µm (from 4000 cm-1 to 450 cm^{-1})
Standard id: Aluminium standard, Cert. Ref: E0360278/1

The uncertainty in the reflectance measurements is estimated to be ± 0.03.

10 DERIVATION OF EMITTANCE AND OTHER PHYSICAL CONSIDERATIONS

When electromagnetic radiation impinges an object, several phenomena may occur: transmittance (τ) through the object, reflectance (ρ) on the surface, and absorptance (α) of light within the object, all quantities ranging between 0 and 1.
For any given wavelength and configuration, the following expression is valid $1 = \tau(\lambda) + \rho(\lambda) + \alpha(\lambda)$.

Kirchhoff's Law of thermal radiation states that when an object is in thermal equilibrium with its environment (steady state conditions, no net heat transfer), the absorptance is equal to the emittance (α=ε).
In opaque materials $\tau = 0$, therefore the following expression applies: $\varepsilon(\lambda) = \alpha = 1 - \rho(\lambda)$.

Note that the angular direction affects the results. The portrayed set-up allows the collection of hemispherical reflectance with near normal incidence, thus the spectral quantity relevant in this report is the near normal emittance, ε_n.

$$\varepsilon_n(\lambda) = 1 - \rho_H(\lambda)$$

11 MEASUREMENT RESULTS

The plot below shows the measured spectral reflectance (ρ_H) and calculated absorptance ($\alpha = 1 - \rho_H$). As mentioned above, the absorptance is equivalent to the near normal emittance.

The LO/MIT II sample was measured in two different orientations (0° and 90° rotated).
The emittance curves do not denote particular sharp or chromatic features, with approximately 0.10 throughout the wavelength range.
Furthermore, the spectra are in agreement with the values acquired during a complementary inspection performed with the portable equipment: the near normal thermal emittance weighed over the black body radiation is 0.11 at 300K.

The IR spectra denote absorption bands which can be explained by the organic nature of the coating (acrylic), for example at 3.4 µm and 5.8 µm.

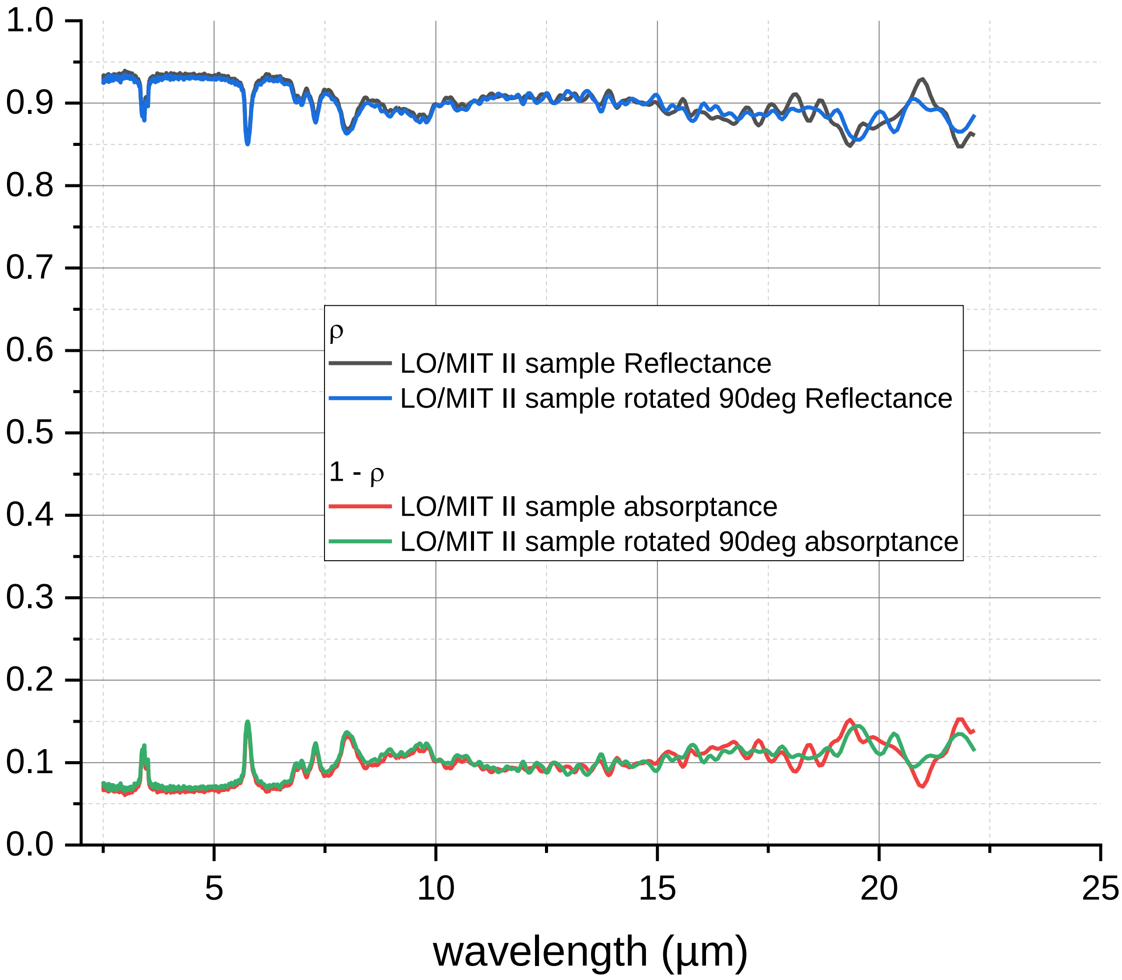


Figure 3, Spectra of LO/MIT II.

Figure 4 provides the spectral reflectance and absorptance (or emittance, as mentioned above) of the measured aluminium EN AW-5457 sample in three different orientations (0°, and rotated 90° and rotated 180°).
The orientation of the sample causes a directional effect on the measurements: higher reflectance was measured with a 90° rotation.

The results are in agreement with the values acquired during a complementary inspection performed with the portable equipment: the near normal thermal emittance weighed over the black body radiation is 0.05 at 300K.

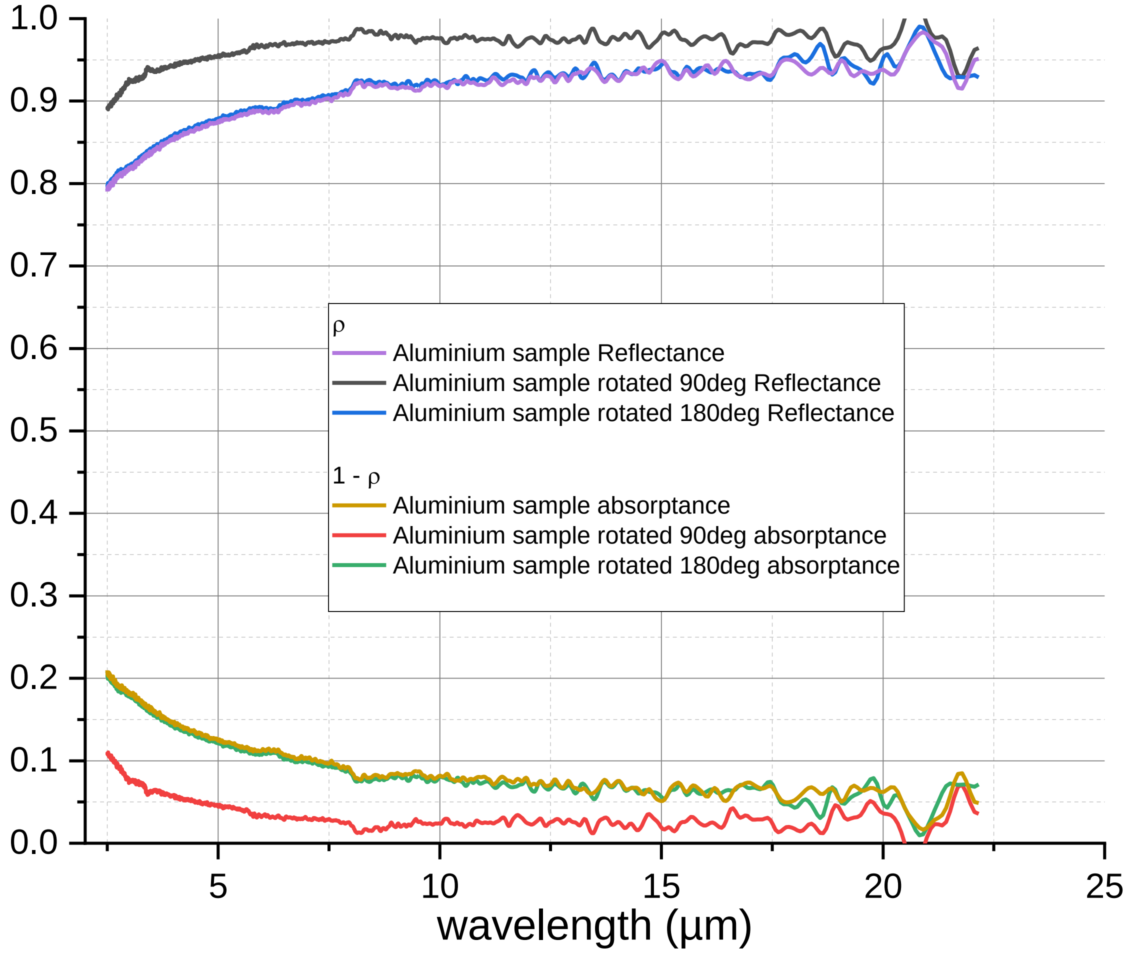


Figure 4, Spectra of AW-5457 sample.

Figure 5 provides the black body radiance at different temperatures (300K and 400K) plotted together the absorptance (emittance) curves of both samples. One can see from the plot that with increasing temperature 1) the radiance increases and 2) the peak radiance is achieved at lower wavelengths.

By weighing the Black Body radiance curve with emittance, one can calculate the emitted radiance (W/m^2) from the material at a certain temperature.

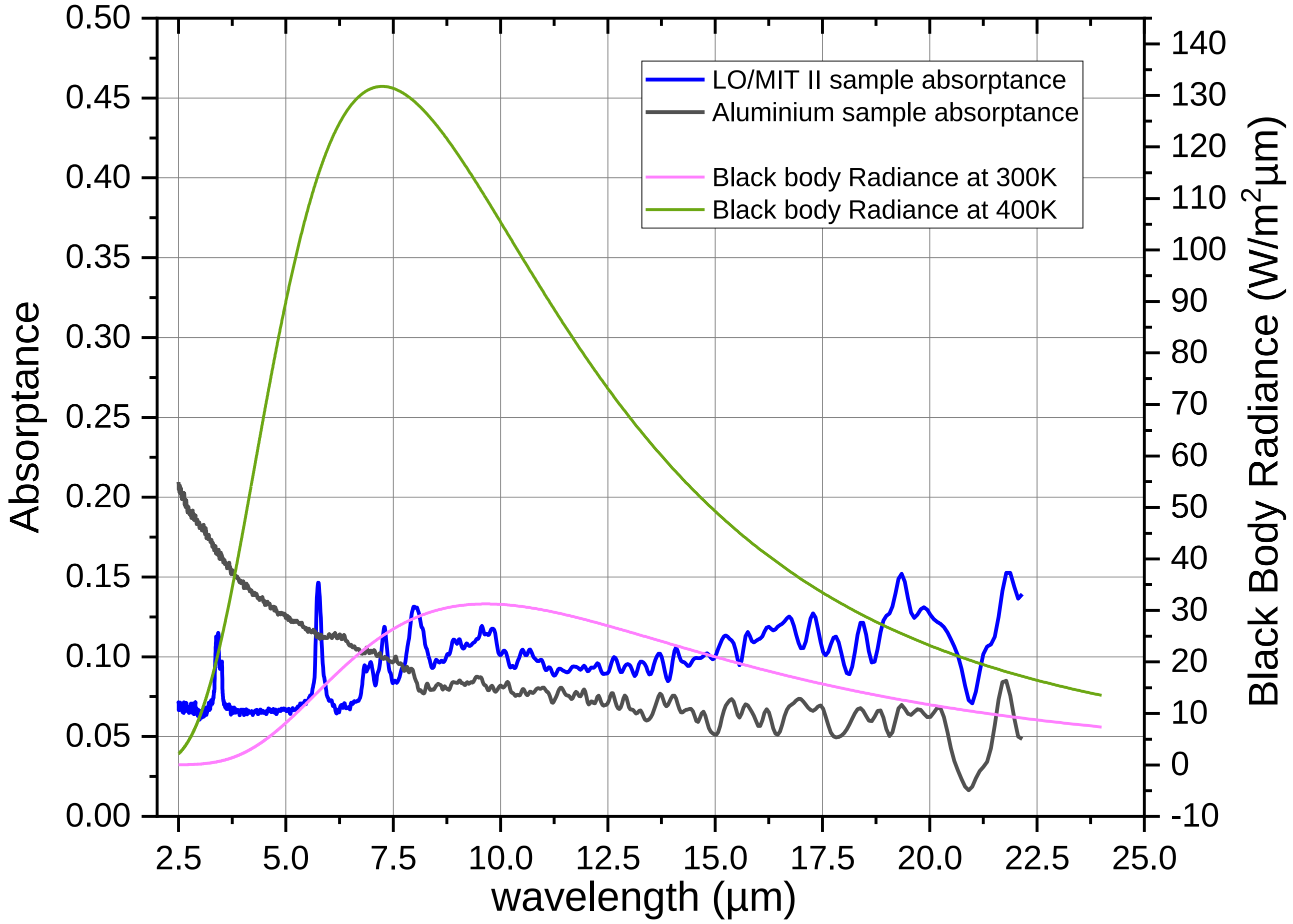


Figure 5, Black Body Radiance at 300K and 400K, plotted with the absorptance of the materials.

12 CONCLUSIONS

TEC-QEE performed IR reflectance measurements on two samples provided by the European Space Observatory.

The results show that the spectral emittance of LO/MIT-II coating is approximately 0.10 between 2.5 µm and 22.5µm, with no particular spectral features. This result is in line with the thermal emittance measured with the portable instrument (aggregated value over the black body radiation at 300K).

The second AW-5457 sample shows lower emittance above 7.5µm, however the results indicate a higher dependency upon orientation of the sample (reflectance signal increase by about 10% when rotating the sample by 90°).

Concluding remark: for the application at hand, the emissivity relevant for sky cooling should be near 0.10.

13 ANNEX A:

The product specifications were extracted from https://www.solec.org/lomit-radiant-barrier-coating/lomit-technical-specifications/ on 19th August 2020.

Solec's LO/MIT-II (non-Max version):

PRODUCT SPECIFICATIONS

WATER-BASED FORMULATIONS	LO/MIT-II
Emissivity	0.170-0.190 substrate dependent
Reflectivity	82-86% substrate dependent
Binder	Siliconized Acrylic
Solvent	DI Water
Temperature Range	-100 to +400°F (204°C)(when cured)
Storage Temperature	+40 to +80°F (+5 to +27°C)
Viscosity	2-4cP