MEASUREMENTS OF THERMO-OPTICAL PROPERTIES OF MATERIALS WITH MEDIUM REFLECTANCE

Andreas Witzke(1), Julian Heine(2)

(1) DLR Institute of Space Systems, Robert-Hooke-Str. 7, 28359 Bremen, Germany, andreas.witzke@dlr.de
(2) DLR Institute of Space Systems, Robert-Hooke-Str. 7, 28359 Bremen, Germany, julian.heine@dlr.de

The methodology of measurements of thermal-optical properties with a spectrometer is described in ECSS-Q-ST-70-09C and ASTM E903 (only solar absorptance). It bases on the detection of a specimen’s hemispherical reflectance by means of integrating spheres. The most commonly used type of sphere is a “wall-mounted” type where an incident beam is directed to the specimen that covers an aperture in the sphere wall. In this case the measured signal has always to be corrected with the signal of a calibrated reference material (standard) in order to gain the absolute hemispherical reflectance of the tested sample.

There are principally two possibilities to apply the standard: (1) the specimen is removed from the aperture and is replaced by the standard (substitution method) or (2) the standard is placed at a second aperture and the direction of the incidence beam changes between standard and specimen (comparison method). The substitution method, however, generates a systematic error as the mean reflectance of the inner sphere alters when the sample is replaced with the standard. This error is negligible for materials with a very low and a very high reflectance but grows for materials with medium reflectance. The quantity of the error depends on the reflectivity of the chosen standard and on the properties of the used sphere, more precisely on the reflectance of the sphere material and on the port to total surface ratio (port fraction).

In this paper we present results of reflectance measurements of diffuse reflecting materials with known hemispherical reflectance to investigate the differences between substitution and comparison method. These measurements were carried out with the FTIR spectrometer “Bruker Vertex 80v” equipped with a white integrating sphere “Bruker #1000692”. The sphere is made of PTFE and has a diameter of 75 mm. If the samples are diffuse reflecting it allows to apply the substitution methods as well as the comparison method by switching the position of an internal mirror. The port fraction of the sphere is 0.04 and meets the requirement in ECSS-Q-ST-70-09C.

The differences between both methods were at first estimated by calculations. They reveal a decrease of more than 0.07 in case of a sample with an actual reflectance of 0.5 and a decrease of 0.03 in case of materials with an actual reflectance close to 0.1 or 0.9 when the substitution method is applied instead of the comparison method (standard “Spectralon 0.99”) (Fig. 1). These theoretical results were verified by the test of three materials with diffuse reflectance. The materials are calibrated for hemispherical reflectance and show values of 0.02, 0.60, and 0.82 at a wavelength of 1.5 µm. The measured results both with substitution and comparison method exhibit again a clear decrease in hemispherical reflectance in case of the substitution method and match the modelled values within the measurement error of +/-1% (Fig. 1).

The presented studies show that significant errors in the determination of thermos-optical properties can occur in case of materials with medium reflectance if the measurement procedure and the sphere design are not carefully selected. This is of interest as the ECSS standard does not address these topics in contrast to the ASTM standard. Especially in degradation tests, where the hemispherical reflectance of materials often changes from high values to lower values, the observed differences can lead to a wrong estimation of effects.