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Uncertainties in the determination of thermal emissivity by measurement of reflectance using Fourier transform spectrometers

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Abstract

The emissivity of coated glazing is commonly determined from spectral reflectance measurements using a specular reflectance accessory or other suitable reflectance attachment. As part of the ongoing EU Thermes RTD project, a 19 laboratory intercomparison was undertaken in 2003 to establish the state-of-the-art of infrared reflectance measurement accuracy and uncertainty and to identify any needs for improvement. Six test samples were selected to provide samples with low, medium and high infrared reflectance. In addition, bare gold mirrors were prepared for distribution to each participant to serve as the reference material. Both the reference mirrors and the round robin samples were calibrated and evaluated prior to delivery to enable closely characterised and similar sample sets to be prepared. A measurement procedure requiring a sequence of 18 measurements undertaken in a strict order was developed. The outcome of the exercise is very encouraging. Participants have performed the work using a wide range of experimental conditions but the final results are in excellent agreement. This is because of the adherence to the required measurement procedure and the use of reference mirrors with known reflectance values. The analysis indicates uncertainties in the final results which are less than ± 0.01. Factors such as instrument resolution, number of scans and time of acquisition do not appear to have been significant in affecting measurement accuracy.

Keywords: Emissivity; Reflectance; Fourier transform spectrometers; Measurement intercomparison

1. Introduction

Emissivity is a key property in determining the energy-saving capability of glazing. European manufacturers determine the emissivity of coatings according to the standard EN 673 [1]. Traditionally, emissivity has been determined from spectral reflectance measurements obtained using a dispersive (grating) spectrophotometer equipped with a reflectance accessory. The manufacture of research grade dispersive spectrophotometers ceased in the 1990s and they have essentially been replaced by Fourier transform (FT) spectrometers. For the purposes of the glass industry, FT instruments and their accessories provide some problems, in part since the wavelength range that can be measured in a single experimental configuration does not cover the entire spectral range required by EN673.

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Table 1
Description of the test samples and the gold reference mirror used in the Thermes Infrared Reflectance Industry Round-Robin (TIRR)

Sample code	Sample description	Average emissivity	Variation between samples
M01	Bare gold reference mirror (glass substrate/20 nm Cr/100 nm Au)	0.012	0.0003
S01	Planitherm Std (single Ag based, low emissivity)	0.089	0.0005
S02	SS-108 (stainless steel/silicon nitride based, medium emissivity)	0.378	0.0025
S03	Mirror SGR (Ag based mirror with silicon nitride overcoat, low emissivity)	0.012	0.0010
S04	Ecologique (SnO_2:F, low emissivity)	0.152	0.0015
S05	SKN-165B (double Ag based, low emissivity)	0.028	0.0005
S06	Planilux (clear float, Sn side)	0.887	0.0003

The Thermes RTD project [2] is supported through the Growth "Measurement and Testing" component of the 5th Framework Programme. The aims of the THERMES project are to obtain a better understanding of measurements performed with FT instruments, generate a reliable measurement method, provide measurement recommendations for the industry, where necessary develop suitable new or improved reflectance accessories for FT instruments, and develop an algorithm(s) for predicting the spectral reflectance of coated glass products in any missing wavelength range.

The challenge is to solve the measurement problems being experienced with FT instruments to ensure that instrumentation and methods are available that enable the accurate and reliable measurement of thermal emissivity in accordance with European standards. The Thermes work is co-normative and contributes to the re-writing of EN673. The project has close working links with the International Commission on Glass, Technical Committee 10 (TC10) "Optical Properties of Glass".

A key component of the Thermes project is the Infrared Reflectance Industry Round-Robin (TIRR). The inter-laboratory comparison has been designed to ensure that the state-of-the-art of infrared reflectance measurement accuracy is established and to identify any needs for improvement, e.g. dedicated reflectance accessories, reference materials etc. The TIRR intercomparison was undertaken in 2003. Outcomes of the round-robin and the work of the Thermes project have been presented to the industry at a Workshop held in Paris in the autumn of 2004. In this paper the main results obtained from the TIRR intercomparison are presented.

2. Overview of the Thermes Infrared Reflectance Industry Round-Robin (TIRR)

For the TIRR exercise 6 test samples were selected to provide samples with low, medium and high infrared reflectance. In addition, bare gold mirrors were prepared for distribution to each participant to serve as the reference sample. The reference mirrors were prepared by TNO and the test samples by Saint Gobain Recherché. The spectral reflectance of all reference mirrors and the entire set of round robin samples were determined by TNO for calibration purposes and for enabling closely characterised and similar sample sets to be prepared for delivery. Subsequently, each TIRR participant received an individual set of the 6 test samples and a reference gold mirror whose optical properties had been determined.

The involvement of the participants from the European glass and glazing industry, research institutes and universities specialising in optical properties measurements was sought. 19 participants from 7 EU Member States and 3 non-EU countries undertook the measurements. The TIRR commenced in June 2003 and the measurement phase was completed in October 2003. The round-robin builds upon the recently completed inter-laboratory emissivity comparison performed coordinated by Technical Committee TC10 of the International Commission on Glass [3]. The Thermes TIRR intercomparison differs from the earlier TC10 round-

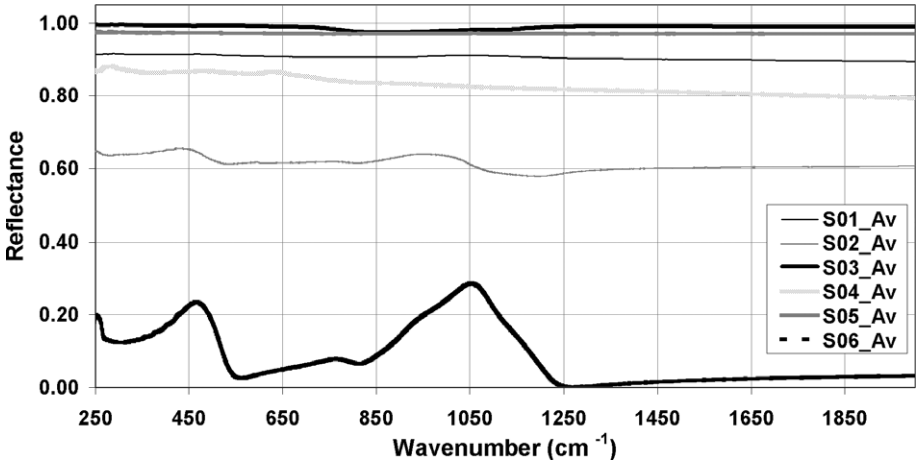

Fig. 1. Measured average of spectral reflectance of the 6 test samples used in the Thermes Infrared Reflectance Industry Round-Robin (TIRR).