BRDF variability of typical diffuse reflectance standards between 380 nm and 1700 nm

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Comparison of the reflectance properties of different diffuse reflectance standards provides guide to select the standard most adequate for a given application. IO-CSIC and PTB have studied the variation of the spectral BRDF with respect to the standard bidirectional geometry 0°:45° of the four most typical diffuse reflectance standards (barium sulphate, opal glass, ceramic tile and Spectralon), within the spectral range [380-1700] nm. IO-CSIC measured the variation in-plane spectral BRDF at several incidence angles, whereas PTB measured its out-ouf-plane variation at a fixed 45° incidence angle.

INTRODUCTION

The assumption that the reflectance properties of diffuse reflectance standards are identical to those of perfectly reflecting diffuser (PRD) makes these standards adequate to characterize the reflectance factor of any surface at any irradiation/collection geometry by simple comparison. However, this assumption is only true within certain limits, and, in some cases, the requirement level imposes being more specific about the slight difference in reflectance between a given diffuse reflectance standard and the PRD. In recent years, National Metrology Institutes (NMIs) and other research centres have developed complex robot–based goniospectrophotometers to measure the bidirectional reflectance of surfaces with as few geometrical restrictions as possible [1-3], even facilitating measurements at out-of-incidence-plane geometries ('out-of-plane' to be short). We investigated the variation of the Bidirectional Reflectance Distribution Function (BRDF) with respect to the bidirectional geometry 0°:45° for the four most typical diffuse reflectance standards (barium sulphate, opal glass, ceramic tile and Spectralon), whose detailed descriptions in terms of reflectance can be found in [4]. PTB and IO-CSIC have available their own diffuse reflectance standards made of the above-mentioned materials. They had previously and independently measured their reflectance at bidirectional geometries using their own goniospectrophotometers [1, 3], and had presented their results within the spectral range [380-780] nm [4, 5]. PTB and IO-CSIC have extended the spectral range of their instruments to 1700 nm as a first step to calibrate multi-angle diffuse reflectance standards. Both institutes measured the spectral BRDF between 380 nm and 1700 nm with independent experimental procedures. The variation of the reflectance within this extended spectral range for the four diffuse reflectance standards is presented and thoroughly discussed.

BRDF MEASUREMENTS

A measurement geometry is specified by the spherical coordinates of their irradiation and collection directions. θ_i and θ_r angles are the polar coordinates for irradiation and collection directions, respectively, whereas ϕ_i and ϕ_r angles are their azimuth coordinates. We fixed $\phi_i = 0°$ in all cases, and, therefore, the value of ϕ_r can be regarded as the difference between the azimuth angles of the irradiation and collection directions. The goniospectrophotometer GEFE available at IO-CSIC was previously described in [1-2], The goniospectrophotometer facility at PTB is described in detail in [3].

RESULTS

The BRDF spectra $[f_r(\theta_i, \phi_i; \theta_r, \phi_r; \lambda)]$ were normalized with respect to the BRDF spectrum at the standard bidirectional geometry 0°:45°, which will be used as reference geometry. This normalization ($f_{r,rel}$) allows the variation of the spectral BRDF to be better shown. Two descriptors are derived from ($f_{r,rel}$) to account for the non-Lambertian behaviour and the spectral variation with respect to the standard geometry 0°:45°. They are defined, respectively, as:

$$\Delta_r f_r = \langle f_{r,rel} \rangle_\lambda - 1 \qquad (1)$$

and