A new tool for measuring patterned and diffuse glass

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Abstract

A standard tool used by the glass industry and glass testing laboratories for the optical characterisation of glazing is a UV/Vis/NIR Spectrophotometer equipped with an Integrating Sphere unit. Although Integrating Spheres are designed for measurements of light- redirecting and light-scattering glazing samples, it has become clear by comparing results obtained by different laboratories that the present commercial available integrating spheres are not really suitable for measuring accurately the transmittance of these products.

The paper discusses in detail the nature of the various measurement problems involved in measuring transmittance and reflectance of light- redirecting and light-scattering samples and further discusses how solutions for these problems were implemented in the design of the new tool

Introduction

The use of light-diffusing samples such as patterned cover glasses used in solar cells and textured/coated glasses used in buildings and greenhouses is increasing.

For the Glass Industry the photovoltaic market offers great potential. At the beginning of this century, the glass industry has launched new types of patterned glazing specially dedicated to photovoltaic applications.

The ability to accurately measure the transmission and reflection properties of these materials is a key requirement in the development and manufacture of high efficiency solar cells and light-diffusing glazing.

Integrating spheres are widely used for the reflectance and transmittance of light-diffusing samples. For many applications including diffuse reflection measurements small sphere accessories are an excellent choice. However, the increasing demand for accurate diffuse transmittance measurements of light-diffusing materials poses a challenge for smaller spheres.

For this reason, part of the R&D performed in OMT Solutions BV has been focussed on identifying the nature of the systematic errors involved in using integrating spheres for measuring diffuse transmittance. In the following sections we discuss these systematic errors and our new Integrating Sphere unit that is specially designed to avoid or minimise them.

Measurement problems

Figure 1 illustrates the first major problem. When a light-diffusing sample is illuminated by a spectrophotometer beam, an area much larger than the beam diameter is transmitted due to internal scattering. With the widely used 150 mm integrating spheres having standard port sizes of ca. 20 mm much of the transmitted radiation falls outside the port area and is not measured.

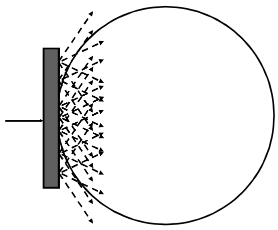

Figure 1 Light beam exiting a light - diffusing sample

For accurate transmittance measurements a sphere with a transmission port as large as 100 mm is required to capture all the transmitted light (see Figure 2).

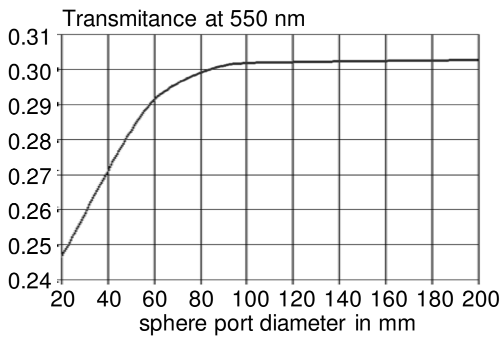

Figure 2 Effect of the port diameter on the measured transmittance of a glass laminated diffusing foil.

Another challenge lies in the ordinate calibration for Transmittance. This is achieved by measuring the 100% transmittance level without a sample present in the beam. During calibration with traditional spheres the beam will hit a flat target at the reflection port, from which it is scattered in all directions within the sphere (see Figure 3).

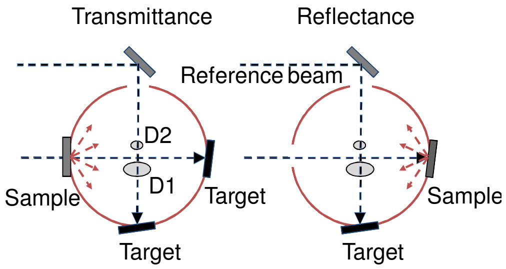

Figure 3 Configuration of a typical 150 mm integrating sphere.D1 and D2 are the UV/Vis and NIR detectors

The detector can only capture radiation that is reflected off the sphere wall and is prevented from directly capturing the radiation reflected off the target by the presence of a small baffle that obscures the view of the reflection port. A similar baffle is present to block the detector's view of the sample port for the same reason.

Placing a diffusing sample in front of the integrating sphere however results in illumination of the sphere wall that has a different average reflectance compared to that of the flat target used for calibration. This introduces an error in the sample measurement.

If the target has a lower reflectance due to contamination, the transmittance of the sample will be overestimated. If on the other hand the sphere wall has a lower reflection due to ageing and the reflection target is new, the transmittance will likely be underestimated.

Another major systematic error occurs due to the way baffles are implemented to prevent the detectors from seeing the sample at the transmittance and reflectance ports directly. In an ideal integrating sphere the light has to inter-reflect on the sphere wall enough times to produce a uniform illumination. The detector should preferably only see a uniform illuminated sphere wall to be insensitive for the way the light is distributed.

Light directly coming from the sample and light reflected of the area where the transmitted beam hits the sphere wall has a higher intensity towards the detector than the light reflected of the rest of the sphere wall. For this reason, baffles are introduced to prevent the detector from seeing the transmission and reflection ports of the sphere

In case of the reference measurement without sample the beam first hits the target which due to its almost Lambertian properties illuminates the rest of the sphere.

When a light-diffusing sample is put in front of the sphere the transmitted beam not only hits the target but also the surrounding area that is not screened from the detector. As a result, the transmittance of the sample will be overestimated.

For light scattering samples like for instance ”frosted” glass or laminated glass with a diffuse foil between the glass panes or glass, The first type of error related to the small port size is dominant and for these types of samples the measured transmittance is largely underestimated, sometimes even up to 20% of the true value.

For light redirecting samples like patterned glass the other types of error are dominant resulting in an overestimated value of the transmittance, usually by 1 – 2%.

Another problem with measuring patterned samples is related to a relatively small beam size which is usually wavelength dependent when measuring in the NIR, causing a step in the spectrum at the wavelength where the detector switch occurs.

The new sphere design

Schematic drawings of the new sphere design are shown in Figure 4. The Spectralon™ integrating sphere has an internal diameter of 270 mm The single horizontal (upward-facing) port facilitates measurement for large samples.

The sample is illuminated by a circular 20 mm diameter beam that is constant for all wavelengths, providing adequate pattern sampling to ensure representative spectra. Using inserts, a 50 mm or 100 mm port size can be selected.

The 50 mm port size is sufficient for patterned glass and results in the lowest measurement noise, whereas the 100 mm port size, although yielding a lower detector signal, provides the most accurate values on scattering samples.

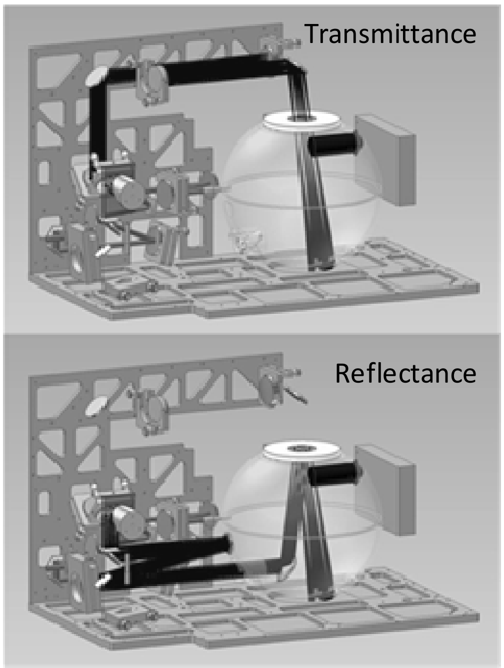

Figure 4 Schematic drawing of the optical path in the new sphere design.

Measurements

Figure 5 shows a comparison of measurement results obtained on two samples with three different set-ups. Sample a) consists of two 4 mm clear flat glass samples laminated with a diffuse PVB foil. Sample b) is a 6 mm flat glass sample with a ceramic frit on one side.

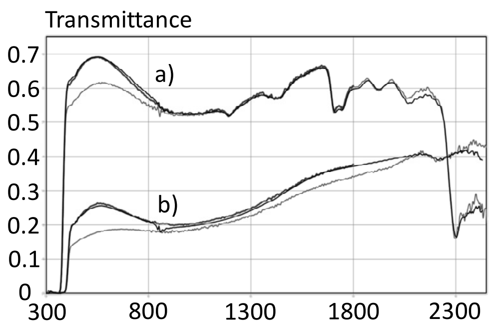

Figure 5 comparison of three different integrating spheres (see text).

The (lower) grey curves in fig. 5 represent the measurements performed with a Standard 150 mm integrating sphere on a PerkinElmer Lambda 1050 UV/Vis/NIR spectrophotometer. The black curves up to 2500 nm were obtained with the same spectrophotometer equipped with the new 270 mm upward looking sphere. The black curves up to 1800 nm were obtained with a large 630 mm BaSO4 coated integrating sphere with a UV/Vis and NIR diode array spectrometers and a broadband light source to illuminate the sample with a beam larger than the port.

Conclusion

The nature of the systematic errors involved in using integrating spheres for measuring diffuse transmittance where identified and a new sphere (see figure 5) was designed to avoid or minimise these errors.

A comparison of measurements on diffuse transmitting samples clearly demonstrate that the results obtained with the standard 150 mm sphere are inaccurate while the results obtained with the new 270 mm sphere agree well with the results of the much larger 630 mm sphere.

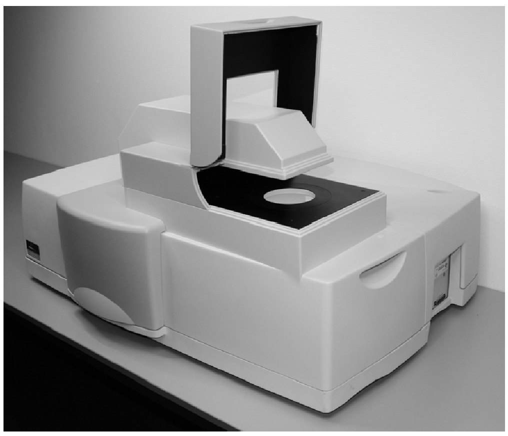

Figure 5 Photograph of our new 270 mm upward looking integrating sphere installed in the Lambda 1050 spectrophotometer.