RADIATIVE PROPERTIES OF GLASS AND COATINGS

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ABSTRACT

Spectral radiative properties of panel glass and coatings are measured, like transmittance and reflectance. The coating influence on the panel behavior is presented. Material properties like index of refraction and the absorption coefficient are determined. Such determination takes place in the visible and near infrared region of the electromagnetic spectrum. The property determination is performed with transmittances and reflectances measurements in different wavelengths from 400 to 4000 nanometers. Total visible and solar transmittance is calculated, based on these data. The complete experimental set-up, the numerical models, as well as some results are presented and discussed in the paper. As a consequence, the presented properties and model allow calculate total transmittance and reflectance of a specific panel sheet, according to the incident angle and the material thickness.

KEYWORDS

Glass panel, coatings, thermal radiation, transmittance, reflectance.

INTRODUCTION

It is known that energy transport through the glazing into and out of buildings is often many times larger than that one transported through masonry panels. New materials have been incorporated, sometimes following aesthetic reasons, increasing the glazing area on the building with the reduction of the masonry area, rising energy transport. Based on such tendency, a series of experimental and numerical works have been done in such domain, bringing lights to the involved phenomena and giving to the professionals of such area new tools and knowledge to a better design, taking into account comfort, thermal and economic aspects.

Some works are pointed out, as the work presented by Pfrommer et al (1995), where a simulation program is developed, including the simulation of the glass and the coatings behavior. Coated and tinted glazings are used, models are developed and data for several materials and incident angles are presented. Arasteh (1994), presents a paper about the advances in window technology, including different aspects related to the thermal behavior of composite windows. Ismail and Henríquez (1998), have modelled the heat transfer through composite windows and have also investigated the behaviour of a pcm-filled one. Caram

(1998), has characterised some semi-transparent materials relatively to the optical properties and has analysed its influence on building thermal comfort.

A review about transparent thermal insulating materials (TIM) is presented by Wittwer and Platzer (2000), in which the efficiency of such materials is defined and discussed. The experimental characterisation of thermal properties, the availability in the market, the plants of demonstration are also discussed. TIM and glass coatings are remembered as competitive solutions to reduce the energy consumption in buildings. Another approach is considered by Hugo (2000), which proposes a reduction on the wall emissivities in the infrared in order to reduce the energy consumption in the buildings and to increase the thermal comfort.

An experimental apparatus has been applied to determine semitransparent materials properties and these results used to identify intrinsic properties of this media. Clear and colored glasses have been considered introducing special identification methods to obtain the absorption coefficient and the index of refraction, both of them as spectral dependent property (Nicolau and Balen, 2000), (Nicolau and Maluf, 2001). In this paper some coatings are used and properties as transmittance and reflectance are measured. The respective total properties in the visible and infrared are calculated and discussed.

THEORY

Reflection of the thermal radiation incident on a specular surface, *ρ(θ),* is governed by Fresnel´s equation, represented in Eqn. (1), Siegel and Howell (1992). The refraction angle *(χ)* depends on the incidence angle *(θ)* and on the medium; this one represented by the index of refraction *(n)*, following the Snell's Law, Eqn. (2). Inside the medium of thickness L, the radiation is progressively attenuated, giving a transmittivity τ, following Beer's Law, Eqn (3).

$$\rho(\theta)=\frac{1}{2}\frac{\sin^2(\theta-\chi)}{\sin^2(\theta+\chi)}\left[1+\frac{\cos^2(\theta+\chi)}{\cos^2(\theta-\chi)}\right]; \qquad \frac{sen\theta}{sen\chi}=n; \qquad \tau=\exp(-aL/\cos\chi); \qquad (1); (2); (3)$$

The interaction between the beam and the media includes a series of reflections when the beam strikes each interface air-glass and glass-air. Computing all the outcoming beams from the incident surface, the result is the reflectance (R), given by Eqn. (4). The sum of the outcoming fractions in the opposite surface is the transmittance (T), Eqn. (5). The reflectance and the transmittance are, in fact, bulk properties, because of the dependence on the sample thickness, the incidence angle and on the intrinsic material's properties, as the index of refraction and the absorption coefficient.

$$R=\rho\left[1+\frac{(1-\rho)^2\tau^2}{1-\rho^2\tau^2}\right]=\rho(1+\tau T); \qquad T=\frac{\tau(1-\rho)^2}{1-\rho^2\tau^2} \qquad (4); (5)$$

Computing all the fractions of absorbed energy inside the sample, one can obtain the sample absorptance (A). Therefore, absorptance can be summed with the reflectance and transmittance to obtain the unitary value.

All the preceding equations are based on a monochromatic beam; they are associated to a particular wavelength. As a consequence, the intrinsic properties index of refraction (n) and absorption coefficient (a) are spectral properties and a dependence on the wavelength can exist (the spectral dependence is not specified in order to simplify the notations).

Properties related to a wavelength range, like visible, infrared or solar range can be obtained from the spectral distribution, using integration as Eqn. (6), in such a case applied for transmittance calculation in the visible range (400 nm to 780 nm). Similar expressions can be used to reflectance and absortance and to another spectral range. G(λ) is the solar irradiation incident onto the ground (Nicolau and Maluf, 2001).

$$T_{vis} = \int_{400}^{780} T(\lambda)G(\lambda)d\lambda \Big/ \int_{400}^{780} G(\lambda)d\lambda \qquad (6)$$

When the described properties are known, the specified model can be used to calculate the interaction between the incident beam and the slab of glass or another semitransparent homogeneous materials, with different thickness or incident angle.

PROPERTIES MEASUREMENT

An experimental setup based on a monochromator and some different gratings is used and sketched in Figure 1.

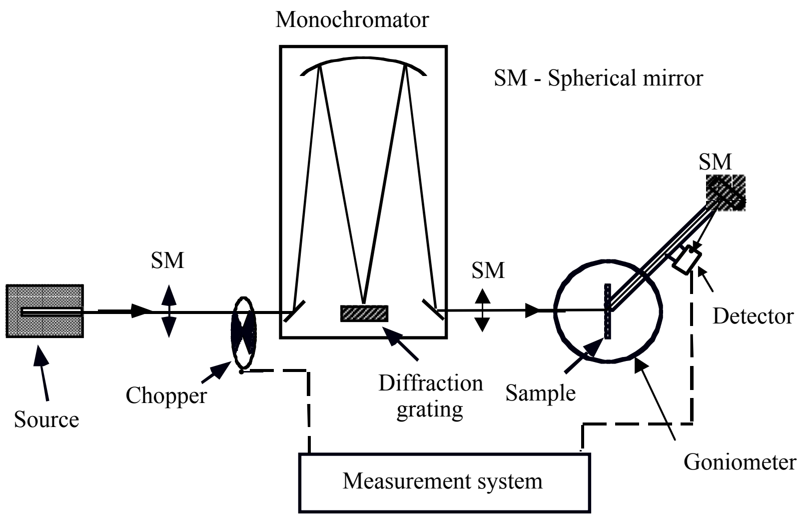

Figure 1 - Experimental apparatus based on monochromator.

The radiation source is a tungsten lamp that allows covering the visible and the infrared wavelength range up to 4000 nm. The beam is projected into the monochromator and by interference, promoted by a grating, only a chosen wavelength band is send to the exit window and strikes the sample. The incident flux is measured with the detector aligned to the incident beam and without sample in the respective place. The transmitted flux is measured in the same way, putting the sample in its special holder. To measure the reflected flux, the goniometer is turned around the sample, placing the detector in the specular direction of reflection. An angle θ=5° between sample normal direction and incident beam is used to measure all the quantities.

An identification method, described in Nicolau and Balen (2000), allows obtain the spectral distribution of the transmittance and reflectance. These results are used in order to achieve the intrinsic properties of glass material, the index of refraction and the absorption coefficient.

EXPERIMENTAL RESULTS

Figure 1 represents the transmittance and the reflectance spectral radiation incident on a slab of clear glass (4 mm of thickness). A high transmission can be observed in the visible and near infrared region, corresponding to the solar region of the spectrum. After 2700 nm this transmittance is reduced, the reflectance changes a little bit and, of course, the absorption is the most important destination of the incident energy. Using a blue colored polyester coating, code 60SRC, has some effects on the transmission in the visible wavelength region, mainly in the longwave side (red color), giving a bluish appearance to the glazing. The transmission and the reflection observed taking the incident beam on the coating or on the glass side is almost the same. Results for transmittance, reflectance and absortance in the visible, infrared range are presented in Table 1.

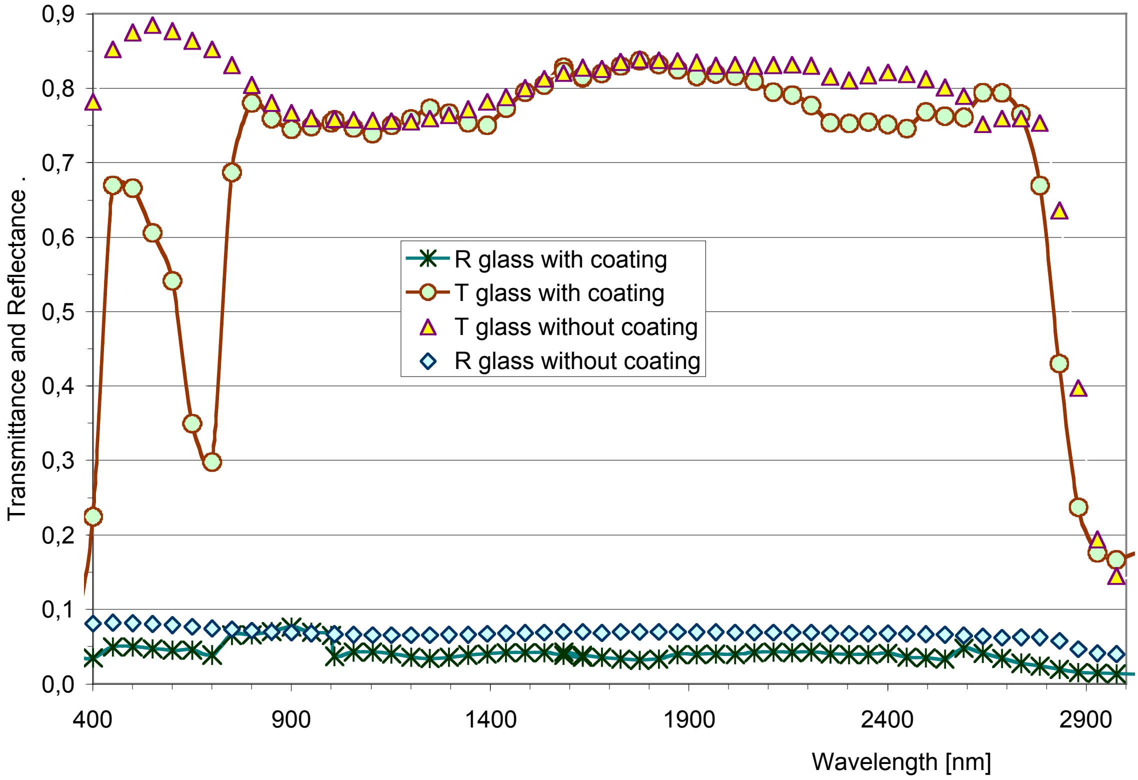

Figure 2 - Transmittance and reflectance of polyester coating (60SRC), over a 4 mm thick glass slab.

TABLE 1
Transmittance, reflectance and absortance for glass with and without coating.

	$T_{visible}$	$R_{visible}$	$A_{visible}$	$T_{infrared}$	$R_{infrared}$	$A_{infrared}$	T_{vis+ir}	R_{vis+ir}	A_{vis+ir}
Glass without coating	0.86	0.08	0.06	0.78	0.07	0.15	0.82	0.07	0.11
Glass wit coating 60SRC	0.47	0.05	0.48	0.76	0.05	0.19	0.60	0.05	0.35

Figure 3 shows the result obtained with a specific white translucent coating, that promotes a certain scattering in the transmitted and reflected radiation. At a first glance the coating seems to have a specular surface, but inside there is a scattering component giving an aspect of whitish color. As a consequence, the specular reflectance and the direct transmittance are very low, because radiation is spread in different angles of reflection and transmission. The transmission is more important in the infrared range, with no difference concerning the

incident beam on the coating or on the glass side. The more important reflection obtained with the beam incident onto the glass side is promoted by the glass surface itself.
Another coating has the results depicted in the Figure 4. It is a silver translucent coating, with similar results for transmission and reflection. In this case the reflection is higher than transmission, with more reflection when the beam strikes the glass side. This low level of transmission and reflection in a specific direction is not an indication of a strong absorption. A more complete series of measurement including other direction are necessary.

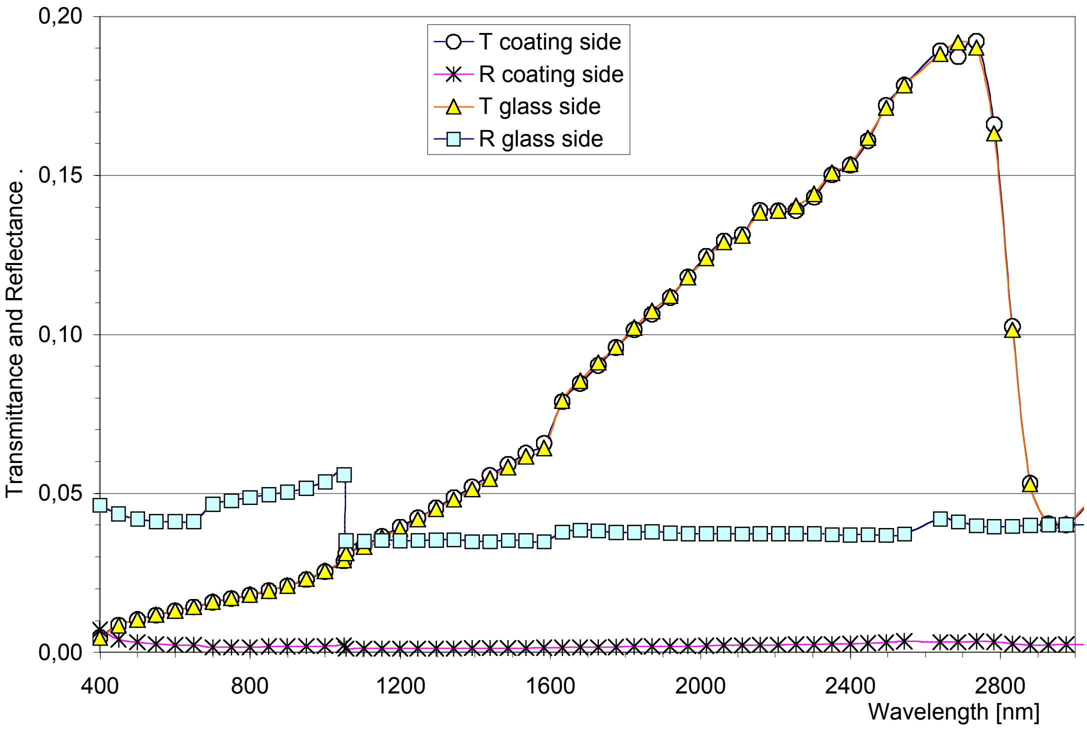

Figure 3 – Transmittance and reflectance of a translucent white coating on a 4mm thick glass slab.

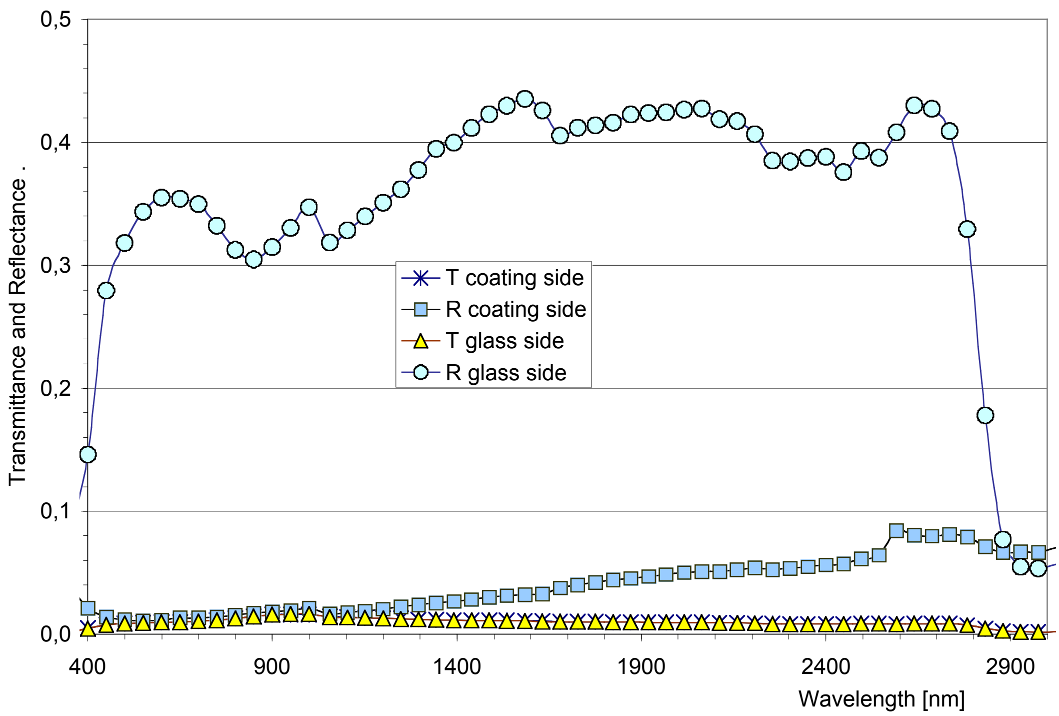

Figure 4 – Results for a silver translucent coating on a 4mm thick glass slab.

CONCLUSION

Some results have been presented as an attempt to understand the influence of a coating on a simple glazing. These results have shown a complex behavior of some kind of coatings and only global transmittance and reflectance results are possible, considering glass and coating together with the presented experimental set-up. However the goal must be an individual identification of properties (glass and coating), in order to compose them, which allows to calculating transmittance, reflectance and absortance when a coating is placed onto a glazing of different thickness with a diverse incidence angle. Nevertheless the experimental results obtained have a special importance as they show a spectral dependence, with higher information level than total measurement properties.

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