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Lighting characterization of a new coating for window retrofit

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ABSTRACT

The present paper describes a new high-performance coating used for the retrofit of existing glazing systems. The easy application of this new coating on the internal side of the glazing makes possible to reduce quickly the solar heat gain coefficient of an existing window. A full laboratory characterization both from the thermal and light transmissibility point of views is presented. Moreover, the paper reports the results of long-term studies aiming at assessing the risks of aging and related performance reductions for the investigate coating.

KEYWORDS

Glazing coating; light transmissibility; window retrofit; high-performance window.

INTRODUCTION

The heat flow across a window assembly results by a combination of different heat transfer modes. In particular, two distinct types of radiation heat transfer take place: long-wave radiation heat transfer in the range from 3 to 50 microns (3000-50.000 nm), and short-wave radiation heat transfer in the range from 0.3 to 2.5 micron (300-2500 nm). The short-wave range includes the ultraviolet, visible (from 380 nm to 780 nm), and solar-infrared radiation. Common glass is transparent to solar-infrared radiation and it is opaque to long-wave infrared radiation. Strategic utilization of this behavior may allow to realize high-performance glazing. In fact, even though the physical process of heat radiation transfer is the same, there is no overlap in the heat transfer at long-wave radiation and short-wave radiation, and so the glass properties may be modified, adding coatings or through glass treatments.

The properties of glazing that affect the radiant energy transfer are the transmittance, reflectance, and emittance. These properties are generally expressed using three coefficients:

- Light Transmittance, which refers to the percentage of radiation that can pass through a glazing. In particular, the Visible Transmittance (VT) indicates the amount of visible light transmitted through the glass, i.e. the transmittance in the range from 380 nm to 780 nm;
- Solar Heat Gain Coefficient (SHGC), ruling the ability to control the heat gain by direct or indirect solar radiation, and hence a significant factor in determining the cooling and heating load of a building;
- U-factor (U-value), assessing the heat lost or gained by the combined effects of conduction, convection, and radiation.

Figure 1 helps to understand how ideally a glazing system should behave in different climates or for different building loads. Building envelope specialists typically target high transmittance in the visible range and aim to control the rest of the spectrum in different ways:

- If low solar heat gains are preferred, the glazing should have a treatment (typically a low-E coating) designed to transmit the visible light and reflect the solar-infrared radiation;
- If high solar heat gains are preferred, the idealized transmittance of a glazing should be such that the visible light and solar-infrared radiation are both transmitted.

Figure 1. Ideal spectral transmittance: 1 for low-solar heat gains and 2 for high-solar heat gains.

With the recent advances in glazing technology, manufacturers can control how a glazing behaves in the different portions of the spectrum. For example, a window optimized for daylighting and for reducing overall solar heat gains should transmit light in the visible portion of the spectrum, while excluding heat gains from the near-infrared part of it.

Coatings may control the passage of long-wave solar radiation, through transmission and/or reflection. In the past, windows that reduced the solar gain (with tints or coatings) also reduced the visible transmittance. However, new high-performance tinted glass and low-solar-gain low-E coatings have made possible to reduce the solar heat gain with little reduction in the visible transmittance. This paper aims to present several tests done on single glazing and IGUs which were coated with a new product designed to be used for retrofit applications.

GLAZING COATING TRENDS

With conventional clear glazing, a significant amount of solar radiation passes through the windows; then, the heat radiated from internal surfaces within a space is radiated back towards the glass and from this to the outside. A glazing design for maximizing energy efficiency during the heating period should allow the solar spectrum to pass through, and should block the re-radiation of heat from the inside of the space (Rezaei et al., 2017).

Spectrally selective coatings, which act in specific portions of the spectrum, transmit the desirable wavelengths and reflect the rest. A coated glazing material can hence be designed to control (and optimize) the solar heating gain, daylighting, and cooling demand. Originally, the first low-E coatings, intended mainly for residential applications, were designed to have a high solar heat gain coefficient and a high visible transmittance to allow the maximum amount of sunlight into the interior. A glazing designed to minimize the (summer) heat gains, but to maximize the Visible Transmittance for daylighting purposes, would allow most visible light through, but would block all other portions of the solar spectrum, including the ultraviolet and near-infrared radiation, as well as the long-wave heat radiated from outside objects. These new low-E coatings which still allow to obtain a low U-factor, are designed to reflect the solar near-infrared radiation, thus reduce the total SHGC, while provide high Visible Transmittance (Fig.2).

Figure 2. Sunlight transmitted by a clear glass with different coatings.

METHODOLOGY

A new coating (SNG) intended for window retrofit was investigated in this paper. This coating is composed of n-Butyl-acetate, Ethylene glycol monobutyl acetate, and 1-Methoxy-2-propanol acetate. For this study, the following samples were prepared: single glasses with a thickness of 3, 6, and 8 mm both clear and treated with the new SNG coating; insulating glass units (IGUs) clear, treated with a low-e coating, treated with the new coating, and treated with both a low-E coating and the new coating. The IGUs which had both a low-E coating and the SNG coating were realized with the coatings on the same glass (in positions #3 and #4 respectively) and on different glasses (in positions #2 and #4 respectively). The coating was applied with a special custom 6" high density foam rollers. The applied product was in the range of 25 grams of products per square meter. The thickness of the cured product was 8-10 microns. The product hardened in 2-4 hours (depending on the curing environment).

The intent of the study was to investigate the following properties: solar transmittance; visible transmittance (VT); UV transmittance; solar heat gains coefficient (SHGC); U-factor; and aging effects for exposure to extreme temperature and UV.

In order to determine the light transmittance, a spectrophotometer VARIAN CARY 5000 was used. This equipment makes possible to record the light passing through a glass between 190 nm and 3300 nm. The measurements were done at 5 nm intervals. Below the results will be shown only from 300 nm to 2500 nm, where the accuracy of the equipment is higher.

In order to predict the long-term performance, a series of accelerated aging tests was performed. Like any building material, which needs constant performance while being subject to weathering events, the thermal conductivity and light transmissibility of the glazing were tested after exposing the samples to various environmental loads designed to make sure the coating still performed as expected. Accelerated tests were performed at elevated temperature, extreme temperature fluctuations (freeze-thaw cycles), and combining UV exposure with high temperatures and relative humidity levels, following the methodology presented in previous studies (Berardi and Nosrati, 2018).

The samples were placed in several types of accelerated aging equipment and their long-term behaviour was assessed after an age acceleration equivalent to 10 years in natural outdoor conditions. The aging conditions included both thermal cycling aging (freeze-thaw cycles) and UV exposure aging. To investigate the durability of the different glazing against weathering caused by temperature, moisture, and UV light exposure, the effects of these factors were studied in the QUV accelerated weathering tester by Q-LAB Corp using the

cycle based on ASTM G154 standard (2016). Each cycle consisted of 8 hours of UV radiation at 60 °C black panel temperature, and 4 hours of condensation at 50 °C (Fig.3).

Figure 3. QUV accelerated weathering tester for studying the effects of temperature, moisture, and UV light exposure.

RESULTS

Figure 4 shows the light transmittance through a 6 mm clear glass and through the same 6 mm glass treated with the SNG coating. As it can be seen, the clear glass has a light transmittance in the range between 75% and 90% from 350 nm to 2500 nm. The 6 mm glass treated with SNG resulted in a lower light transmittance in the visible range, especially below 400 nm and above 600 nm (only reaching values above 70% from 400 nm to 600 nm), and had a transmittance below 20% in the range from 900 nm to 1750 nm. Similar results were obtained for the tests done for clear and treated 3 mm and 8 mm glass panes, which showed a shift of the results towards higher and lower absolute values of the light transmittance respectively.

Figure 4 - Light Transmittance of 6 mm in the range from 300 nm to 2500 nm.

Figure 5 shows the light transmittance results for IGUs with clear non-treated (3mm /15mm space air filled/ 3mm), low-E non-treated, clear treated on one side on #4 and low-E treated glasses. The following resulted emerged:

- the clear non-treated IGU has a light transmittance consistently between 70% and 80% across the range from 300 nm to 2500 nm, with higher values in the visible range;
- the low-E non-treated IGU results in some lower transmittance in the wavelength range up to 400 nm, no significant difference in the rest of the visible range, and a significant lower

transmittance above 800 nm, with values linearly reducing down to a 10% transmittance above 2000 nm. However, the results in the range from 400 nm to 800 nm show minimal reduction compared to the clear non-treated IGU;

- the clear treated with SNG IGU results in lower transmittance in the wavelength range up to 430 nm compared to the low-E non-treated IGU. Light transmittance values between 10% and 20% were recorded in the range from 850 nm and 1800 nm, while the transmittance values increased above this wavelength. The light transmittance values increased linearly from 1400 nm to 2500 nm from 10% up to 40% respectively;
- the low-E treated IGU (basically the IGU with two coatings) results in lower transmittance in the wavelength range up to 430 nm, significant reduction above this wavelength, with values always below 10% above 900 nm.

Treating one glass in the IGU with a low-E coating resulted in a reduction of the transmittance mainly below 460 nm and again an appreciable reduction above 600 nm. The IGU with both a low-E and a SNG coating showed a transmittance substantially overlapping the IGU with the SNG coating, as the low-E showed a generally limited effect in the higher wavelengths in the visible range.

Figure 5 - Light Transmittance of the IGUs in the range from 300 nm to 2500 nm.

Table 1 reports a summary of the light transmissibility tests. The table reports the UV transmission factor, the VT Light transmission factor, the direct transmission of solar energy, and the color rendering index. The VT index for a clear glass decreases from 89% to 76% for a treated SNG glass, a reduction of 13%. Assessing the IGUs, it emerges that the VT was 82% for the clear non-treated glass, 80% for the low-E non-treated glass, which means that the low-E resulted in a particularly small reduction of the VT, and 70% and 69% for the clear treated with SNG and low-E treated with SNG IGUs respectively. This means that treating the IGU with a coating of SNG resulted in a reduction of 12% on average of the VT factor. The UV transmission factor which was 60% for a clear glass and 54% for a clear non-treated IGU, reduced significantly with a low-E coating and became zero once a SNG coating is applied.

The color rendering index (CRI) showed that the clear glass, the IGU clear non-treated and the IGU with a low-E only had a CRI close to a perfect perception of the color, whereas treating the glass with the new coating (SNG) resulted in a difference of the CRI of 4 to 5, and

in a final CRI value for clear treated SNG of 94 to 95. This may be considered a good result, since the coating does not alter the perception of the color in a substantial way.

Finally, the direct transmission of solar energy (%) shows a significant reduction from values as high as 81% for a clear glass and 75% for a clear non-treated IGU, to the value of 60% for a IGU with a low-E coating and 43% for a IGU with a face covered with a SNG coating. Applying the SNG coating to an IGU with a low-E coating resulted in a direct transmission of solar energy of 39%.

Table 1 – Indices resulting from the light transmissibility tests.

	UV transmission factor (%)	VT light transmission factor (%)	Direct transmission of solar energy (%)	Color rendering index
Clear 6 mm glass	60.16	89.30	80.98	99
Treated (SNG) 6 mm glass	0.91	75.98	46.59	94
IGU 3/15/3 clear non treated	54.39	81.89	74.61	99
IGU 3/15/3 low-E non treated	22.50	79.79	60.51	99
IGU 3/15/3 clear treated SNG	0.92	69.87	42.70	94
IGU 3/15/3 low-E treated SNG	0.61	68.70	39.46	95

The results of the aging tests performed on the different glazing systems proved no risks of the coatings over an equivalent life of 10 years. In particular, the light transmissibility tests showed results perfectly overlapping to the related sample in pristine, non-aged, conditions. This shows that the coating is strong and does not suffer thermal cycling or UV radiation at a rate equivalent to a life-span exposure.

Interesting tests regarded the UV exposure of the samples TOO. Based on the experiences of over four weeks of testing in the QUV machine which were calculated as a period equivalent to 10 years in typical application in a moderate climate following the methodology presented in Berardi and Nosrati (2018), no visible effect was perceived on the single panes and IGU systems, confirming the robust behavior of the SNG coating, and it was impossible to distinguish the sample that underwent the UV exposure to the one that did not.

CONCLUSIONS

Based on the measured results, it can be concluded that the application of the new coating on a glazing unit (IGU) allows to block 99% of the ultraviolet (UV), allows to block over 80% of the infrared (IR), with indices as high as 85% if assessed in the IR range where most of the sun radiation falls, allows to have a SHGC in the range between 0.30 and 0.33, and allows to obtain a visible transmittance in the range of 70%. This means that the performance of the coating overcomes that of a low-E coating with the only exception being the capability to limit transmittance above 2000 nm, which showed to be better for the low-E coating, and the reduced color rendering index which resulted in a slightly blue color of the glass.

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