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Combining Solar Control Technologies for Optimal Performance

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Modern façade glass elements need to meet high standards of solar performance, as well as thermal insulation, while maintaining transparency requirements. These requirements are key to provide comfort for the building users and minimize energy requirements for heating and/or cooling. In today's urban environment, likely additional requirements for reflectivity, glare and acoustic performance are in place. Advanced glass coatings have come a long way in meeting many of the requirements, and have developed to the extent that further development provides diminishing returns, either in their own performance, or in combination with other coatings. There are applications in the architectural space that have relied on other technologies to meet the requirements if the use of coatings was somehow restricted, e.g. warm bent glass, applications where edge deletion is not acceptable, or where coatings interfere with electromagnetic signal transmission. An example of such a technology are solar absorbing PVB interlayers for laminated safety glass. This paper illustrates how coating technologies and solar absorbing PVB interlayers can be combined to optimize façade glass performance.

Keywords: Glass coating, laminated safety glass, solar energy, PVB foil

1. Introduction

The selection of a glass configuration with the appropriate solar and thermal characteristics is relatively complex, as a myriad of (coated) glass products is available, generic climate conditions and incident radiation vary with season, and a building typically has different façade orientations. The position of the windows in a building (e.g. under an overhang or set-back in the facade) plays a role, along with other architectural features that are potentially present such as fins or shades, or other solar control elements such as blinds and screens. The transparency of the glass elements themselves can be changed by a print of frit. In this article, the focus is on solar control using coatings and/or PVB interlayers only, as an element of a more holistic approach, that comprises all the elements above in actual building design.

There are a couple of parameters that are of primary importance in characterizing the solar control performance of a glazing. The visible light transmittance (VLT) is the fraction of the incident light that is transmitted by the glass. The heating of a building through glass is driven by the solar energy transmittance or solar factor (g-value) of the glazing. The solar factor is calculated as the sum of the solar direct transmittance and the secondary heat transfer factor of the glazing towards the inside, the latter resulting from heat transfer by convection and longwave IR-radiation of that part of the incident solar radiation which has been absorbed by the glazing. The selectivity (S) of the glass towards visible light over total radiation can be characterized by ratio of VLT over the g-value, as per equation 1.

$$\text{Selectivity S} = \text{VLT}/g\text{-value} \tag{1}$$

A significant part of the energy in solar radiation is in the visible range, and therefore S is practically limited to 2 – 2.5 at the physical extreme.

Reflected light is important for the appearance of a building (visible light reflectance, fraction of the incident light that is reflected by the glass) and potential for creating "hot spots" in the surroundings of a building (solar direct reflectance, fraction of the incident solar radiation that is reflected by the glass).

Finally, the change in color of an object as a result of the light being transmitted by the glass, as characterized by the color rendering index, is an increasingly important parameter. Extensive glossaries of terms and measurement methods are given in various standards or guidance documents, most notably EN 410, ISO 9050 and NFRC 300 (see references for complete information).

Contemporary solar control (SC) coatings are typically produced using the magnetron-sputter process, although some pyrolithic coatings are still produced. Highly selective coatings may be produced by using complex, thin layered structures of dielectric layers (metal oxides and nitrides) and conductive layers (mostly silver). The latter make the coatings very reflective to near infra-red radiation, which is the basis of their solar performance. These coating types are almost invariable used inside the cavity of an insulated glazing unit (IGU), where they are protected from external influences. Even in this case, edge deletion is required to prevent potential contact with the external environment, resulting in coating deterioration. Coatings that be used on monolithic glass, or on the outside of laminated glass are available, but tend to have lower selectivity.

As compared to glass, PVB interlayers typically only cut out almost all UV-radiation (300 – 400 nm wavelength range), and are essentially transparent to light in the visible range (wavelength 400 – 780 nm) and near infra-red region (wavelength 780 – 2500 nm). As such, they have a high VLT, but low selectivity. Additives can be used to increase the absorption of near infra-red radiation to the point where the interlayers become fairly selective. Such PVB types will be referred to as solar PVB interlayers. Table 1 provides a succinct and simplified overview of material choices.

Table 1. Generic solar control coating and PVB interlayer solar performance.

	S[1)]	Color options	VLT range	Edge deletion required	Usable outside IGU
SC Coating type					
Extremely selective	2.2	No	Limited	Yes	No
Very selective	1.8	Limited	Broad	Yes	No
Robust	1.0 – 1.3	Many	Broad	No	Yes
PVB type					
Regular	1.1	No[2)]	>99 %	No	Yes
Solar	1.4	No[2)]	Defined	No	Yes

1) 6| 16 |4; coated position #2 for coating or 33.2 laminates for PVB interlayers
2) Except when used with colored or translucent interlayers

It should be noted that the possibility to use the more robust SC coating types outside an IGU is typically associated with possibilities to put a ceramic print to the coated side or to laminate PVB interlayers to the coated side. The latter should always be verified for the individual coating/PVB combination for preservation of generic performance characteristics and durability, including permanence of adhesion.

2. Spectral performance of base material

To provide a physical basis for the performance of the materials mentioned thus far, the typical spectral characteristics of the materials of Table 1 are given in transmission in Figure 1, and in reflection in Figure 2. The wavelength in the figures was restricted from 300 to 1000 nm to be able to clearly see the differences. The SC coatings are referred to as generically described in Table 1 and are applied on position #2 of a 6 mm glass. SC coatings with a fairly neutral appearance and VLT between 60 and 70 % were used in the example, as these are most commonly used. The same base glass was used in all cases.

The glass itself is transparent to most wavelengths, except the short UV wavelengths. The selective SC coatings clearly have very low near-infrared transmittances, and some of the UV radiation is removed from the transmitted spectrum. The PVB interlayers take out almost all UV radiation, with the solar PVB having the better performance. The VLT of the solar PVB is somewhat lower than that of the regular PVB, but more importantly the transmitted radiation in the near infrared region decreases rapidly. The major difference with selective SC coatings is in the reflected radiation. At only 800 nm, these SC coatings already reflect more than 60 % of the incident radiation, whereas the reflection of the interlayers is essentially the same as the base glass. Selective SC coatings thus increase solar performance by reflection, whereas solar PVB increase solar performance by absorption. Since coatings of the “robust” type and the interlayers technologies both can be used outside an IGU and do not require edge deletion, it was decided to explore if these technologies could be complementary through modelling and experimentation.

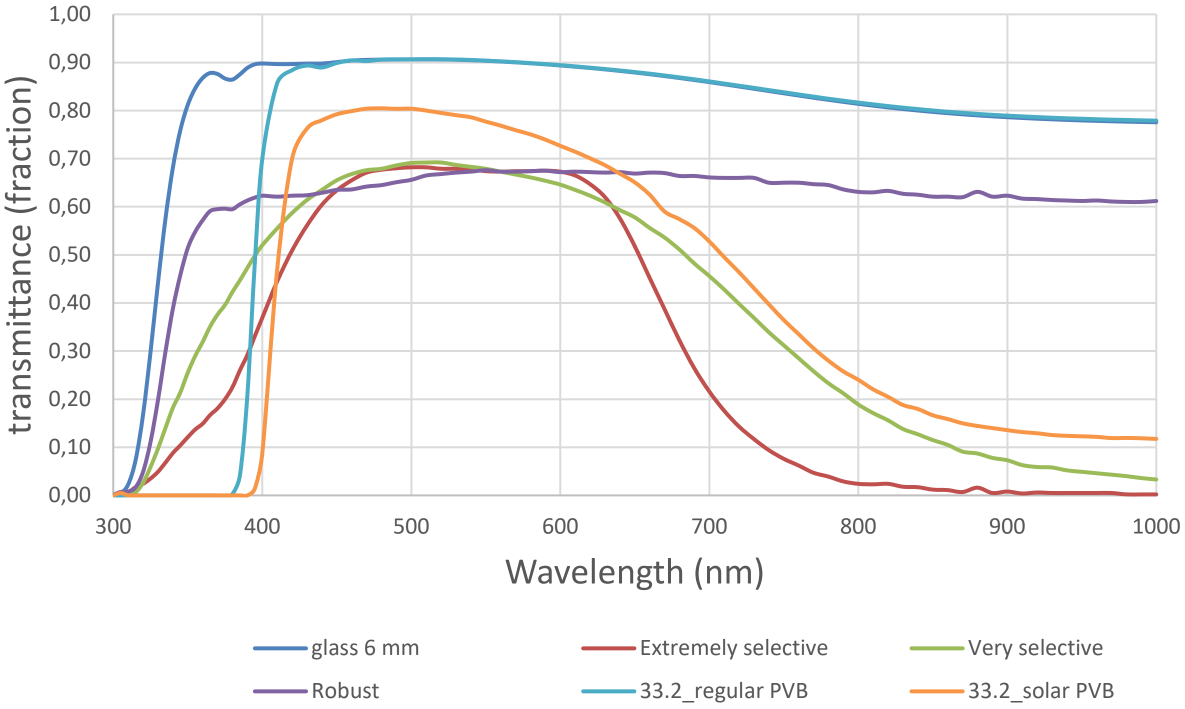

Fig. 1. Spectral performance of nominally 6 mm glass configurations as indicated (glass, SC coated glass (three coating types) laminated glass (two interlayer types), transmission

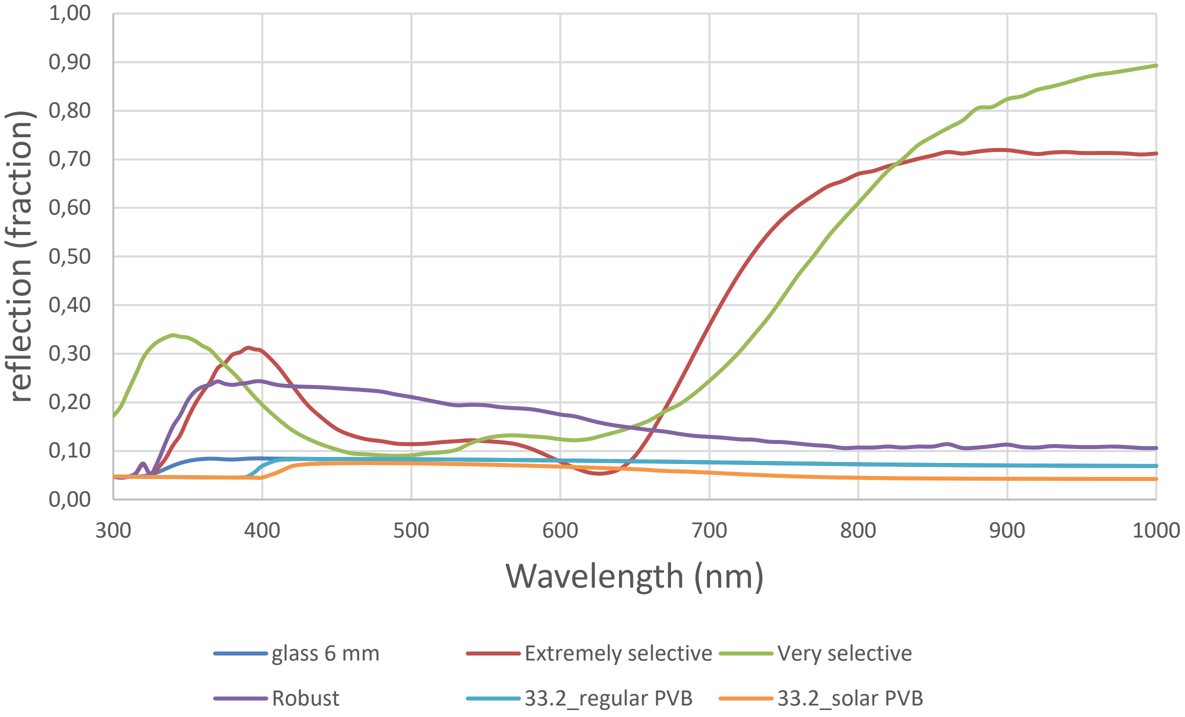

Fig. 2. Spectral performance of nominally 6 mm glass configurations as indicated (glass, coated glass (three coating types) laminated glass (two interlayer types), reflection

3. IGU modelling study

In an initial study, the use of regular and solar PVB in combination with the three different coating types of two major coated glass suppliers was executed. As a base configuration, a 66.2c#2 | 16| 6, configuration was chosen (laminated outer pane, coating towards the IGU cavity side; monolithic inner pane). Representative results given in table 2 for the different SC coating types in combination with regular and solar PVB.

Table 2. Performance of solar PVB in different coated IGU types

Coating type	PVB type	VLT (%)	*g*-value	Solar reflection (%)	Visible reflection (%)
None	Regular	80	0.70	11	14
	Solar	68	0.43	7	11
Extremely selective	Regular	59	0.25	35	11
	Solar	50	0.23	8	9
Very selective	Regular	59	0.30	29	13
	Solar	50	0.25	7	10
Robust	Regular	60	0.57	12	18
	Solar	51	0.36	8	15

The more selective the coating, the smaller the impact of a solar PVB is on the solar factor. If anything, the presence of a solar PVB helps to reduce solar reflections, which can be important for certain facades with a net curvature. However, a significant reduction of the solar factor in the configuration based on the robust coating is observed. This is readily understood based on the spectral information of the individual components. As the latter coating type is mostly used in non-IGU applications, such as outer skins of ventilated double skin facades, the experimental work focused on the combination of the robust SC coating type and solar PVB.

4. Experimental study

Five different SC coating types were obtained from 2 major producers, as applied on 6 mm glass of the extra clear type (≈ 500 ppm iron). All coatings can be used outside an IGU with a VLT range between 50 and 70 %. Two coating types were neutral in appearance (coatings A and B), two coatings were more reflective (coatings C and D) and the final coating had a faint blue appearance (coating E). Two different types of laminates were prepared in all cases: a solar PVB was laminated onto a coating in position two, or with the coating in the laminate on position four. The two variations are schematically depicted in Figure 3.

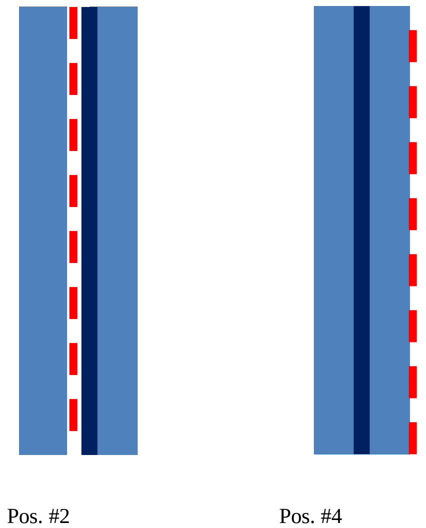

Fig. 3. Schematic position of coating position in measured laminates (glass light blue, solar PVB dark blue, coating red dotted line)

The solar PVB interlayer used was Saflex® SG41 solar PVB interlayer, with lamination carried out in accordance with the guidelines of the manufacturer. The coating position results in only a subtle appearance change, as shown for coating E in Figure 4. The spectral data were collected and processed on a PerkinElmer Lambda 950 spectrophotometer according to EN 410. Both sides of the laminates were measured to obtain front and back reflectances. Transmission data were independent of the measured side, as expected. As a reference, configurations with regular PVB were modelled. A succinct overview of the results is provided in Table 3.

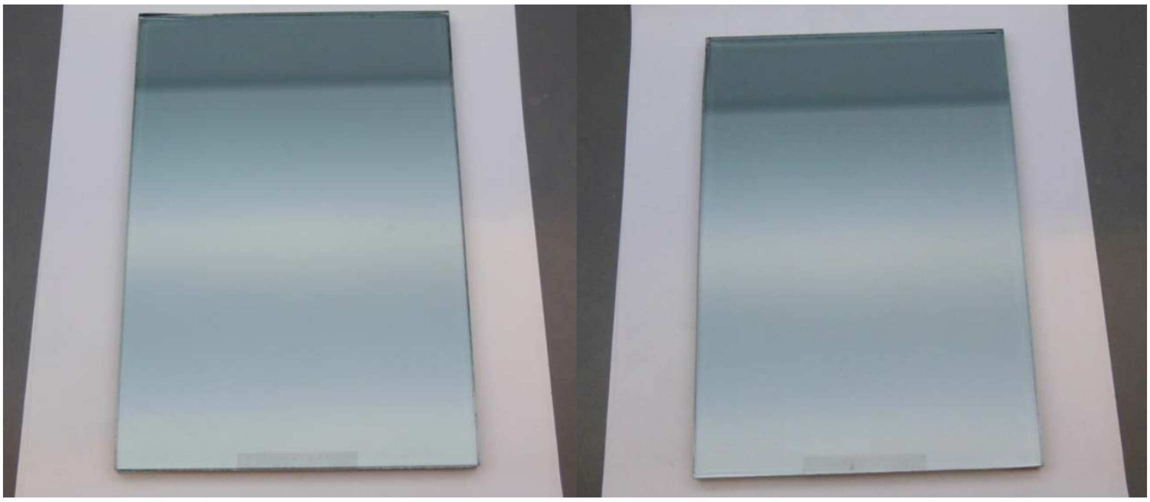

Fig. 4. Photograph of coating E, in position #2 (left side) and position #4 (right side) (illuminant D65 on white paper)

Table 3. Basic solar properties of robust coating/solar PVB combinations

Coating		PVB interlayer	VLT (%)	VLR (%)	g-value
No coating		Regular	89	8	0.80
		Solar	76	8	0.53
Coating A	pos#2	Solar	60	14	0.46
	pos#4	Solar	55	15	0.45
	pos#4	Regular	64	16	0.62
Coating B	pos#2	Solar	61	10	0.47
	pos#4	Solar	56	15	0.45
	pos#4	Regular	66	19	0.65
Coating C	pos#2	Solar	64	23	0.46
	pos#4	Solar	55	26	0.44
	pos#4	Regular	65	31	0.63
Coating D	pos#2	Solar	65	16	0.49
	pos#4	Solar	57	23	0.45
	pos#4	Regular	65	29	0.62
Coating E	pos#2	Solar	48	16	0.41
	pos#4	Solar	45	15	0.41
	pos#4	Regular	51	15	0.53

The solar factor of the configurations is reduced both vs. the coated controls with regular PVB, and the stand alone use of solar PVB, so the combination can be used effectively in glazings that require robust coating systems. There is a pronounced difference between the configurations measured with the coating in position #2 and #4 in terms of light transmission. Putting the coating in position #4 results in a much lower light transmission than with the coating in position #2, with the PVB apparently affecting the coating characteristics. However, the reduced transmission leads to more absorption, rather than reflection, leading to g-values that are only slightly lower if the coating is used in position #4 as compared to position #2, because the reduced transmission levels are partially offset by secondary heat transfer. The visible light reflectance levels are high for the coating not in contact with the PVB, even if light reflected by the coating passed the absorptive PVB twice. However, levels are lower than when a regular PVB interlayer is used.

Careful consideration of glass type for projects where a combination of coating and solar PVB is considered needs to take place with respect to thermal breakage. The total solar energy absorption of the glazings listed varies between 48 % (coating C, pos. #2) and 68 % (coating E, pos. #4). Strengthened glass types would be recommended for the latter configuration, and it should be considered for the former configuration. There might be other reasons to use strengthened glass types, such as structural requirements or requirements driven by the fixation systems. In these cases, the solar control package is only a secondary driver for the glass type choice.

5. Conclusions

The performance in terms of solar factor of solar control coatings can be improved using solar PVB interlayers in combination with the solar coating, even if the overall transmittance and appearance of the glazing should be reviewed for acceptability. The combination of solar PVB interlayers and solar control coating is most applicable on glazings where coatings are used outside an IGU, given the performance limitations of these robust coating types. Although coatings were successfully used in both position #2 and position #4 of the laminates studied, and there is no a priori preference for either configuration, the solar and optical properties are different and must be considered project-by-project. The coating in position #4 always provides the lower light transmission value. If the use of a specific coating/solar PVB is considered, the generic performance characteristics, potential for thermal breakage, and durability, including permanence of adhesion should be verified before installation.

Acknowledgements

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