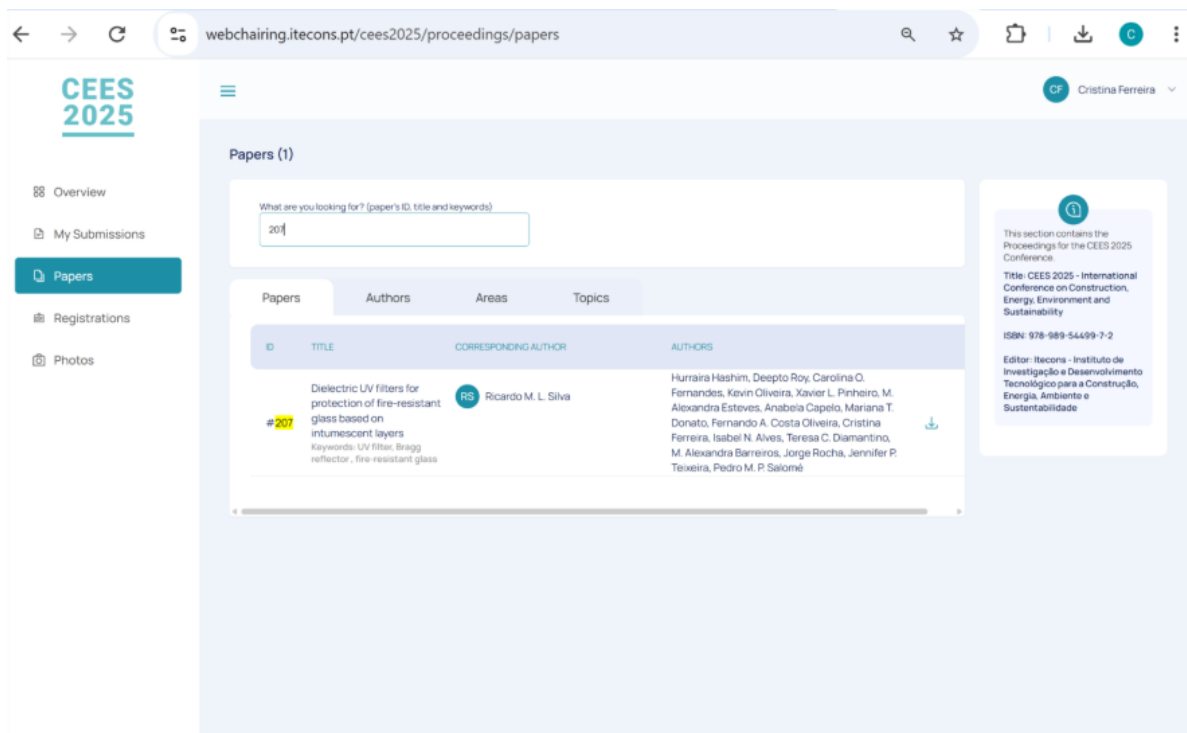


## Proceedings for the CEES 2025 Conference.

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ID	TITLE	CORRESPONDING AUTHOR	AUTHORS
#207	Dielectric UV filters for protection of fire-resistant glass based on intumescent layers Keywords: UV Filter, Bragg reflector, fire-resistant glass	RS Ricardo M. L. Silva	Hurraira Hashim, Deepto Roy, Carolina O. Fernandes, Kevin Oliveira, Xavier L. Pinheiro, M. Alexandra Esteves, Anabela Capelo, Mariana T. Donato, Fernando A. Costa Oliveira, Cristina Ferreira, Isabel N. Alves, Teresa C. Diamantino, M. Alexandra Barreiros, Jorge Rocha, Jennifer P. Teixeira, Pedro M. P. Salomé

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## Dielectric UV filters for protection of fire-resistant glass based on intumescent layers

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**Abstract.** Structures such as OLEDs, perovskite solar cells, intumescent glasses, and other components in modern devices and buildings contain materials susceptible to degradation when exposed to UV radiation, requiring protection to withstand outdoor environmental conditions. In this work, multilayer coating configured as a Bragg Reflector on glass is employed as spectral filtering to protect the intumescent component of fire-resistant glass from degradation due to prolonged UV solar radiation exposure. By alternating low-n (SiO<sub>2</sub>)/high-n (TiO<sub>2</sub>) dielectric layers through spin-coating, precise control over film thickness could be achieved, allowing the fabrication of thin (<700 nm) UV filters with high transmission of visible sunlight – 88% of the 780 to 380 nm wavelength range – while reflecting almost all the incident UV – 90% of the wavelength below 380nm. Using relatively simple techniques, high precision coating was successfully achieved, resulting in an effective UV radiation protective barrier applied to enhance the durability of the components in fire-resistant glass.

**Keywords:** UV filter, Bragg Reflector, Fire-Resistant Glass.

## 1 Introduction

With the rapid advancement of urbanization, the efficiency of land use has been increasing. Many new super high-rise buildings are emerging in urbanized areas around the world. However, in the event of a fire, the energy-efficient windows, which are a part of the building facade, often break due to inadequate fire insulation. Numerous fire disasters have led to loss of lives and injuries, such as the 2009 fire at the North distribution building of CCTV's new site in Beijing, China, and the 2022 fire at a 19-story residential apartment in New York, the USA [1].

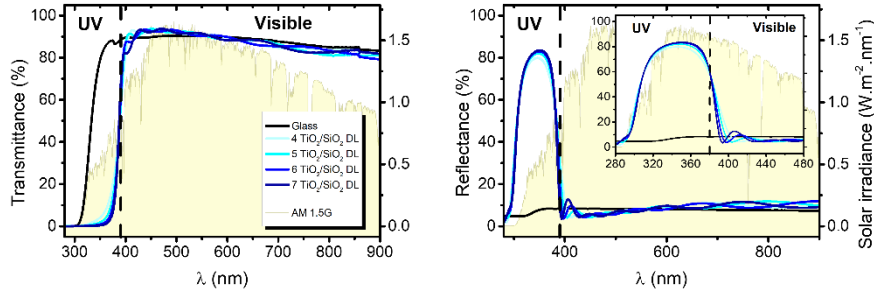
Traditional laminated glass is composed of layers of soda–lime glass (SLG) and organic transparent membranes. Due to the excellent adhesion of the organic membranes, the sandwiched layers can maintain their integrity and absorb only a small amount of the thermal impact energy during the initial stage of fire (less than 5 min) [1]. However, the flammability of the organic membrane can lead to the rapid thermal fracture of the SLG when exposed to flames for an extended period. This results in the release of toxic fumes, making it unsuitable as fire-resistant glass for protecting people and property [1], [2].

Laminated fire-resistant glass is usually designed using laminated glass with inter-layers of organic fire-resistant compounds or alkali metal silicate-based materials [2]. However, when these fire-resistant materials are exposed to outdoor conditions, they often develop defects like yellowing, softening, and opacity within a year due to their poor resistance to UV radiation [2], [3]. To counteract this UV-induced degradation, an additional layer of coating must be added to the glass which brings unwanted attributes including increase of the thickness of the glass, reduced transparency, and placement of higher structural demands. To improve the durability of fire-resistant glass while also providing integrated UV protection, it is essential to develop a suitable UV filter with reduced weight, while preserving the visible light transmittance and fire safety functionality. Here we developed a UV filter for fire-resistant glass. The glass is composed of a metal alkali-silicate-based intumescent material layered between sheets of clear float glass. UV exposure causes the intumescent layer to dim, which can compromise the light transmission and fire safety. To address this issue, an ultrathin  $\text{TiO}_2/\text{SiO}_2$  bi-layer coating was created based on the principle of distributed Bragg reflector (DBR). This coating effectively blocks UV radiation while maintaining visible light transmittance, while adding negligible weight to the structure. The UV filter was produced using spin coating, a cost-effective and scalable process without the need for a vacuum chamber, making it suitable for industrial applications.

## 2 Simulations

For the development of the UV filter, a DBR based on an alternating scheme of low- $n$  ( $\text{SiO}_2$ )/high- $n$  ( $\text{TiO}_2$ ) was studied. The  $\text{TiO}_2/\text{SiO}_2$  DBR was established via optical simulations performed using the open-source software OpenFilters [4]. **Fig. 1** presents the transmittance and reflectance results for DBR configurations with 4 to 7 stacked bi-layers, shown in panels (a) and (b), respectively, calculated for a target wavelength ( $\lambda_t$ )

of 350nm. The best optical performance was achieved with a 6 bilayer stacks of the  $\text{TiO}_2/\text{SiO}_2$  scheme, resulting in a total thickness of 679 nm.



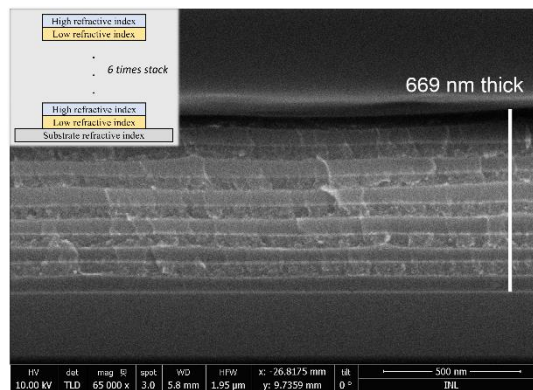
**Fig. 1.** Simulation results of transmittance **(a)** and reflectance **(b)** for 4, 5, 6, and 7 bilayers of stacked  $\text{TiO}_2/\text{SiO}_2$ .

### 3 Fabrication and characterization methods

The 6 bilayer  $\text{TiO}_2/\text{SiO}_2$  stacks were spin-coated using commercial precursors. Their thickness was measured by ellipsometry and verified via Scanning Electron Microscopy (SEM), which also assessed layer formation. Optical properties were analyzed using UV-Vis spectroscopy.

### 4 Results and discussion on the UV filter optical performance

The 6 bilayer stacks of  $\text{TiO}_2/\text{SiO}_2$  UV presented a thickness variation  $< 2\%$  from the simulated value, as confirmed by ellipsometry measurements and as observed through SEM (**Fig. 2**).



**Fig. 2.** SEM cross-section of the UV filter. Representation of the stacked films on the top-left.

The optical performance of the filter was assessed using UV-Vis measurements, with the results of transmittance and reflectance summarized in **Table 1**. The UV transmitted through bare glass accounts for up to 71% of the total solar irradiation. With the developed filter, this value decreases to around 7%. Simulation indicates that only 3% of the UV is transmitted, suggesting potential for further improvement. In the Vis range, the filter can transmit up to 88%, which matches the simulated values and is virtually the same as the transmittance of bare glass (89%). Regarding the reflected UV light, the filter exceeded expectations by reflecting 90% of the UV radiation, significantly higher than the simulated value of 78%, and much greater than the mere 8% reflection measured for bare glass.

**Table 1.** Results from the optical performance of the Transmitted and Reflected light through the 6 bilayers of stacked TiO<sub>2</sub>/SiO<sub>2</sub> UV filter.

Light range	UV (<380 nm)	Visible (380 -780 nm)
Bare glass (%T)	71	89
Glass + UV filter – simulated (%T)	3	88
Glass + UV filter – experimental (%T)	7	88
Bare glass (%R)	8	9
Glass + UV filter – simulated (%R)	78	8
Glass + UV filter – experimental (%R)	90	9

The filter has been successfully applied to the outmost surface of the fire-resistant glass assembly (glasses and intumescent interlayers). Further characterization of the entire system is currently in progress.

## 5 Conclusions

In this work, the application of a DBR was utilized as UV filter. It effectively reflects the solar UV radiation while allowing the Vis light to pass through, adding negligible weight to the glass. The fabrication methods involve low-cost chemical deposition techniques, which have the potential for scalability and economic viability for mass production.

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**Disclosure of Interests.** The authors have no competing interests to declare that are relevant to the content of this article.

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