PHOTOMETRIC EVALUATION OF PHOTO-VOLTAIC THIN-FILM SHADING ELEMENTS

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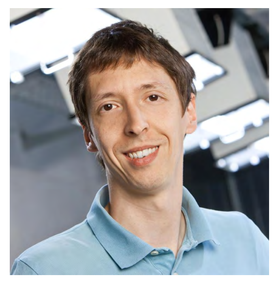

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Abstract

The national research project „multifunctional plug & play facade“ (MPPF) considers the building envelope as active part of an overall energetic building concept. Within the MPPF-project innovative photovoltaic (PV) modules have been installed in a demonstration façade. In this case, PV fulfills the function of a façade element and of an active energy system. It provides shading and daylight in the interior. Photometric studies have been performed on different shading systems including PV-panels and conventional shading systems. This allowed to compare different shading systems quantitatively. The investigation shows, that the implementation of shading systems has direct impact on interior comfort, visual impression and health aspects (e.g. at the office).

PV integration in a prototype facade

All investigations were done in-situ in a MPPF-prototype façade. The façade is integrated in a test-building including a facade test facility and adaptable interior and exterior structure (i.e. offices and façade), see figure 1, left. Two kinds of investigations were done:

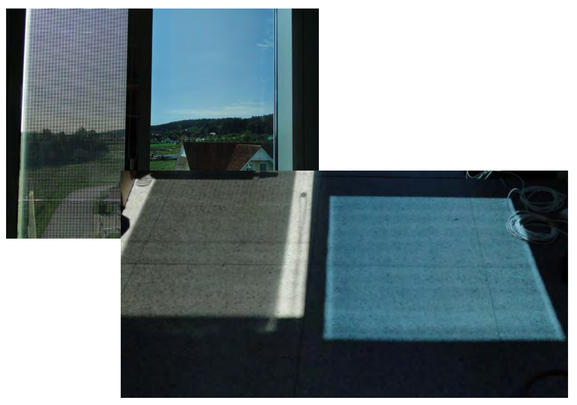
1. **Visual appearance with respect to architectural aspects**
2. **Photometric parameters**

All comparisons were done for semitransparent PV-modules (a-Si), with 10% and 20% transmission, respectively, partial-transparent PV-modules (glass/glass crystalline modules) (PT), standard sun shading glazing, standard shading as well as an electrochrome glass-shading system (EC). All technologies were implemented in the south-façade of the FIBAG test building, for an example see the semi-transparent a-Si module in figure 1, right side. The visual appearance was compared qualitatively using photographs of the shading systems, e.g. a-Si and EC in figure 2, left side. The photometric studies were done using a grid-spectrometer measuring the spectral resolved transmission of the shading systems, see figure 2, right side.

Fig. 1**: Left:** Test site in the FIBAG-Test building. The building combines a façade test facility, an adaptable test façade and adaptable interior rooms. **Right:** Semi transparent PV-module.

Visual appearance

The visual appearance is of high importance for the architectural usage of PV as shading elements. Figure 2, left shows the comparison of the interior color appearance of a-Si and EC. The EC has a very blue color transmission. Figure 3 shows the appearance of shading systems in the field of view. While the EC is completely homogenous (figure 2, left), as is standard sun-shading glass, structured shading systems disturb the field of view in different ways (i) focused on the shading system and (ii) focused to the horizon through the shading system, see figure 3 (a)-(d). **The semi-transparent a-Si shows a nice appearance** for (i) and (ii).



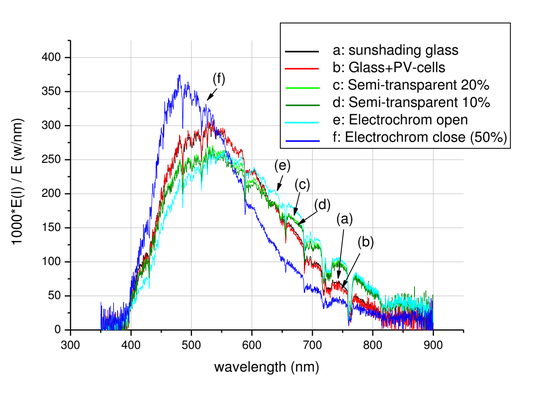


Fig. 2: **Left:** Visual appearance for a-Si and EC. **Right:** Spectral resolved transmission of the shading systems. Both show the drastic blue-shift of the electroschrome shading system.

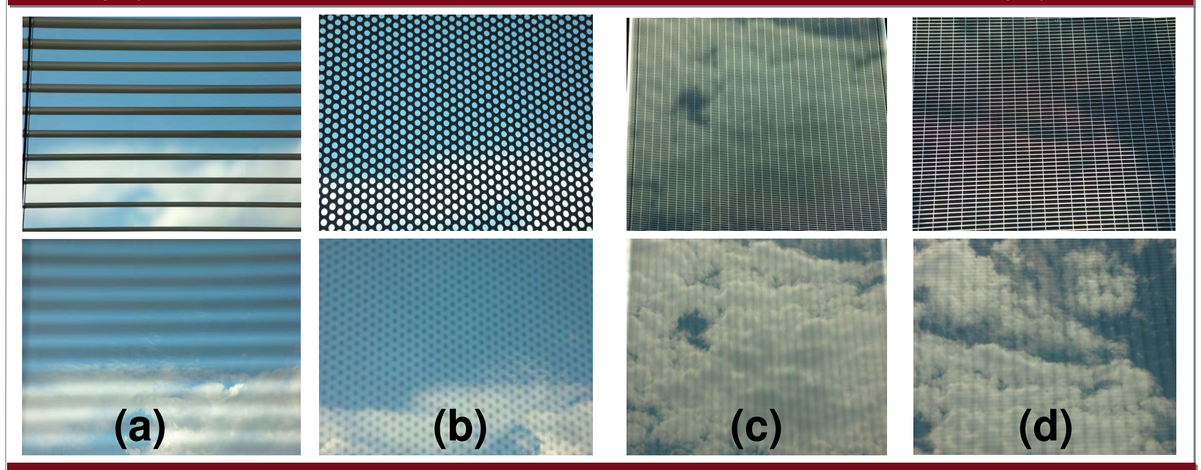


Fig.3: Visual appearance of the shading systems focused close and to the horizon; (a) sun-blind, (b) perforated metal plate, (c) a-SI 20% transmission, (d) a-Si 10% transmission.

Photometric evaluation

Spectral Transmission:
The Photometric studies allowed to compare different shading systems quantitatively, see e.g. figure 2, right side. It shows the comparison of the transmitted sun spectrum of different PV-modules and glass shading systems. The EC results in a shift of the transmitted light towards the blue end of the visible spectrum, whereas the a-Si is attenuating the light of all wave length equally, without influencing much its color.

RGB-Color Scheme:
Further analysis allow to calculate the technically used RGB-color scheme (CIE-standard-color table, D65-light source, 10deg-opening angle) from the corresponding spectral measurements see figure 4, left. The transmitted light lies along an iso-color line from white to an spectral color between blue and red. We find:

standard glass	**(x = 0.34, y = 0.39)**	**→ close to the white point**
a.Si 20%	**(x = 0.35, y = 0.39)**	**→ sun light attenuated “grey”**
EC open	**(x = 0.36, y = 0.34)**	**→ slight shift to the red**
EC closed	**(x = 0.29, y = 0.36)**	**→ significant shift to visible blue**

The measurement again shows that the EC shading system is strongly shifting the transmitted light to the blue, whereas the photovoltaic system is not. All results are compared to standard solar glass (grey lines and circles in figure 4, left).

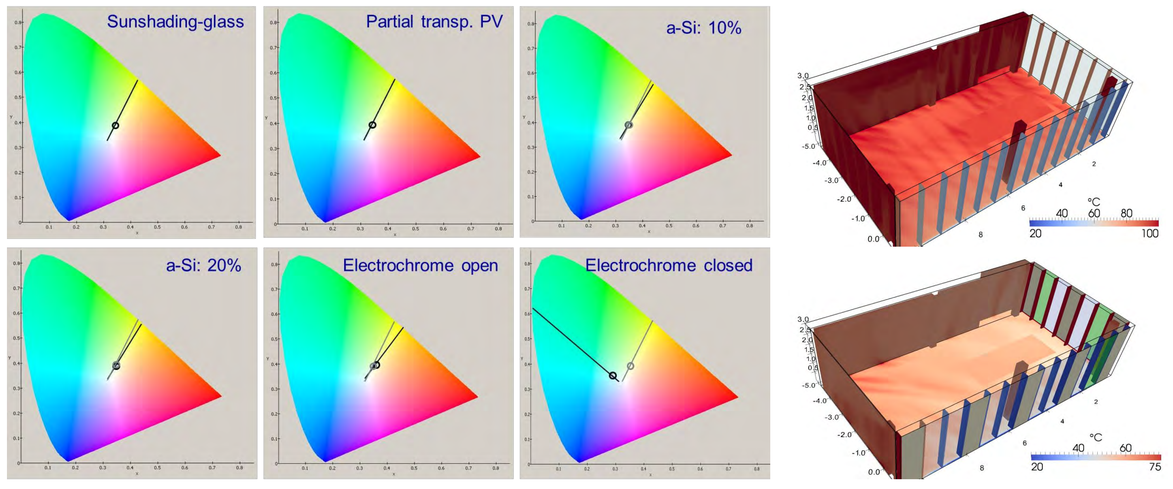


Fig. 4: **Left:** Colour value (o) for different shading systems within the RGB-color space. It shows the „white“-point (center), and iso-color lines. Common sun-shading glass is shown in grey. **Right:** CFD-simulation of heat-input reduction by use of the PV-shading elements.

Passive Cooling potential via CFD-Simulation

A computational fluid dynamics (CFD) simulation of the test-office room for the prototype facade of the FIBAG building was done to show the passive cooling potential by using PV-shading systems integrated in the façade. The results, figure 4, right, show that the PV-shading elements can reduce a huge part of the radiation energy entering the room via the glass façade. For a decoupled and not-cooled room e.g. the a-Si PV-shading system reduces the overheating for about 30° C.

Conclusion

We showed that the color appearance of different shading systems can be analyzed in-situ in a façade. Photometric measurements give information about color reproduction and visual comfort. The main benefit of the use of photovoltaic as shading system is beyond the visual appearance is its multifunctional character, combining lightening, technical aspects, weather shielding, insulating, energy converting and shading functions

Further, the multifunctional approach of building-integrated or façade-integrated PV and the flexible system integration in the complex façade system was the focal point of all investigations.

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