Ageing Performance of New Solar Cover Materials after Outdoor Exposure

Florian Ruesch, Stefan Brunold

SPF Institute for solar technology, HSR, Rapperswil (Switzerland)

Abstract

In an outdoor exposure project for solar cover materials, anti-reflex and anti-soiling coated glass and polycarbonate with protective layers where analyzed. Therefore, degradation and soiling effects where quantified by measuring the change in transmittance. For 21 different types of AR coated glass, no relevant transmission losses were observed in a rural environment after seven years of exposure. On the other hand, the effect of soiling resulted in elevated transmission losses of 10-15% at the urban exposure site.

Keywords: outdoor weathering; ageing; anti-reflective coatings

1. Introduction

About 60 different collector covering materials where tested in a long-term outdoor exposure study running in the years from 1985 to 2005. Since the beginning of this study new coatings became available to increase performance, avoid soiling or protect UV sensitive materials such as polycarbonate (PC). Anti-reflective (AR) coatings have become a standard in the PV and solar thermal industry within the past ten years. The share of AR coated glass in the PV-module production increased from less than 10% in 2008 to more than 90% (Nampalli 2014). Due to the market entrance of new coatings, a follow up study was initiated in 2010, concentrating on glass with anti-reflective coatings partly in combination with anti-soiling properties (21 types), but also including some samples of polycarbonate (PC) with UV / weather / scratch - protective layers. In this contribution, preliminary results from an exposure duration of seven years are presented.

Resently there have been published various reports on the preparation of durable sol-gel antireflective coatings where durability have been assessed by accelerated ageing with enhanced temperature and/or moisture (for example Li et al. 2013; Yuan et al. 2015; Xin et al. 2013; San Vicente et al. 2009) or with respect to abrasion resistance (Ye et al., 2011). Results from real outdoor weathering over periods of several years are rare. There are several studies on the effect of sand-storm erosion for concentrating mirrors (reviewed by García-Segura et al. 2016). Said et al., 2015 analyze the effect of surface structure and anti-reflective coatings on dust fouling in Saudi Arabia for two month.

2. Method

Both, the procedure and the locations of exposure in Rapperswil (central European, urban) and Davos (alpine, rural) are analogous to the outdoor weathering campaign carried out between 1985 and 2005 and are described in detail by Ruesch & Brunold 2008. Samples where attached to uninsulated but selective “mini-collectors” in order to increase the thermal load similar than in a solar thermal collector. These mini-collectors reach air temperatures in the order of 60 °C on sunny days.

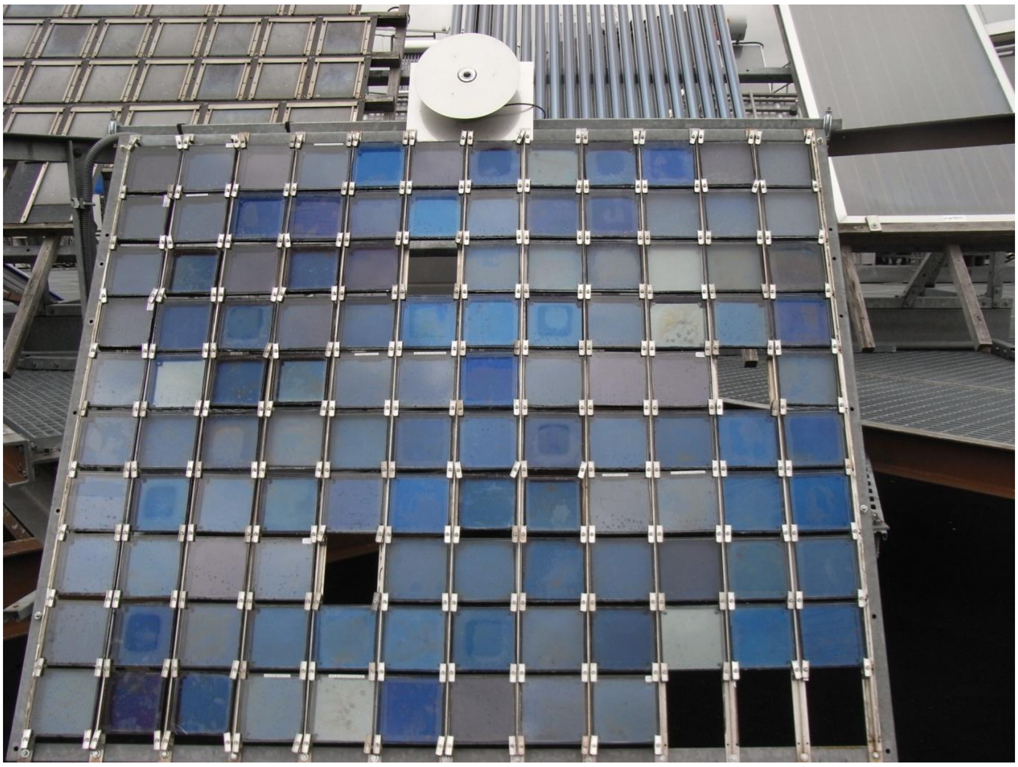

Figure 1: Outdoor exposure site in Rapperswil with samples mounted on mini collectors.

Samples were collected and examined after a period of one and three years of exposure. In 2017, a third batch of samples were collected and analyzed after seven years of exposure. A final collection is planned for a longer exposure period of about 20 years. After collection, a photographic documentation recorded the general conditions of the samples. Furthermore, the transmission spectra were measured for both, the exposed state and after cleaning half of the sample with a mild soap solution. Solar transmittance was calculated according to ISO 9845. The samples were then stored in special archiving containers. Thus, there is an archive of differently aged samples, which can be used for further examinations at any time.

3. Results

3.1. Glass with AR coating

As in the earlier outdoor weathering study, there is a distinct difference between the two exposure sites. At the alpine location of Davos the transmission losses of the glasses are marginal in the cleaned and even in the uncleaned condition. For some samples, transmission has even improved slightly compared to the non-exposed reference (see Figure 1). Due to confidentiality issues sample names are anonymized, numbers refer to the raw material and the capital letters to the coating type. The good performance of all AR-coated glass samples in Davos shows that the tested coatings are basically stable and don't show a relevant degradation due to weather influences such as rain/moisture, snow, irradiation and temperature changes. In Rapperswil (urban location near the railway station) an elevated soiling effect is observed. This effect is very pronounced for all AR-coated glass types and results in transmission losses of 10-18% after seven years of exposure (See Figure 2). Even after cleaning with mild soap transmission losses of 1-6% remained. Coatings with declared "self-cleaning" properties (coating "B") shows the lowest losses caused by soiling when applied to Glass "02", but behaves very similar to other coatings when applied to the other glasses. Another coating declared as "anti-soiling" (coating "F") does not specifically protect against transmittance losses compared to other coatings.

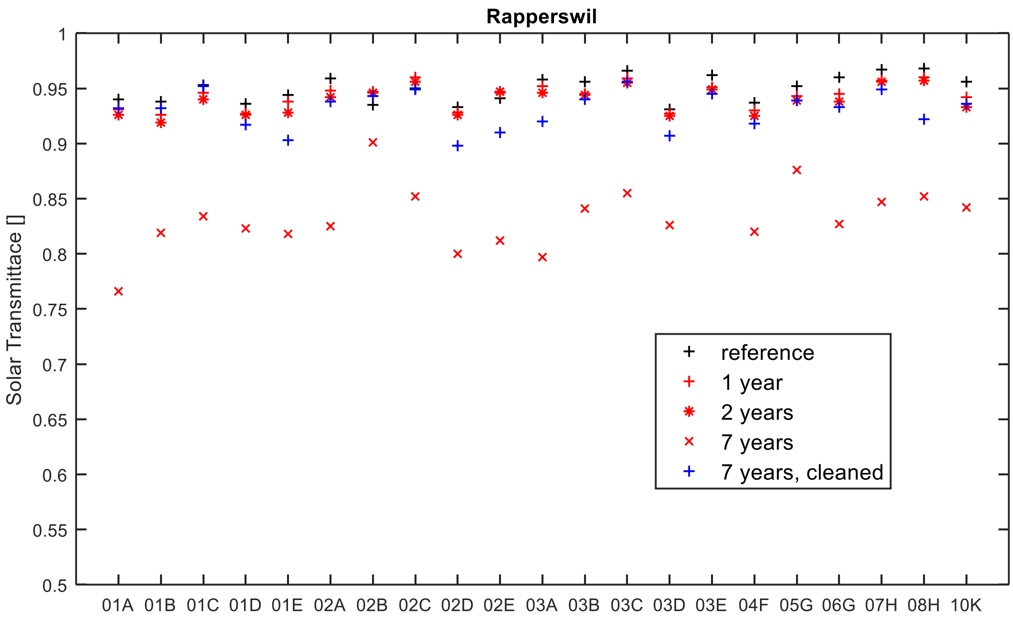

Figure 2: Solar transmittance of all tested AR-coated glass samples after different periods of outdoor exposure in Davos.

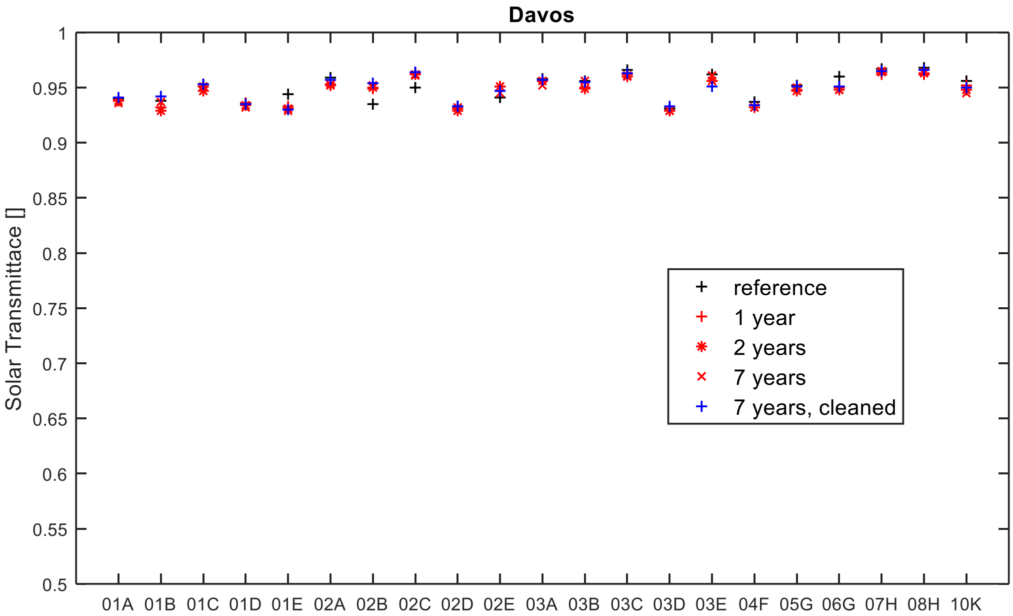

Figure 3: Solar transmittance of all tested AR-coated glass samples after different periods of outdoor exposure in Rapperswil.

In figure 4 the transmittance spectrum of different exposure times are given for sample "01A" as an example. The spectrum of the seven years exposed sample in Rapperswil shows a clear effect of soiling. The losses in transmittance are dependent on the wavelength and are more pronounced for short wavelength. Also in Davos a slight shift in spectral transmittance can be observed. Transmittance is reduces below 500 nm, but increased in the range above, in order that the integral transmittance value remains similar. This effect could be observed in different intensity for all tested samples. However it is not clear if it is due to a change in the AR coating or the glass.

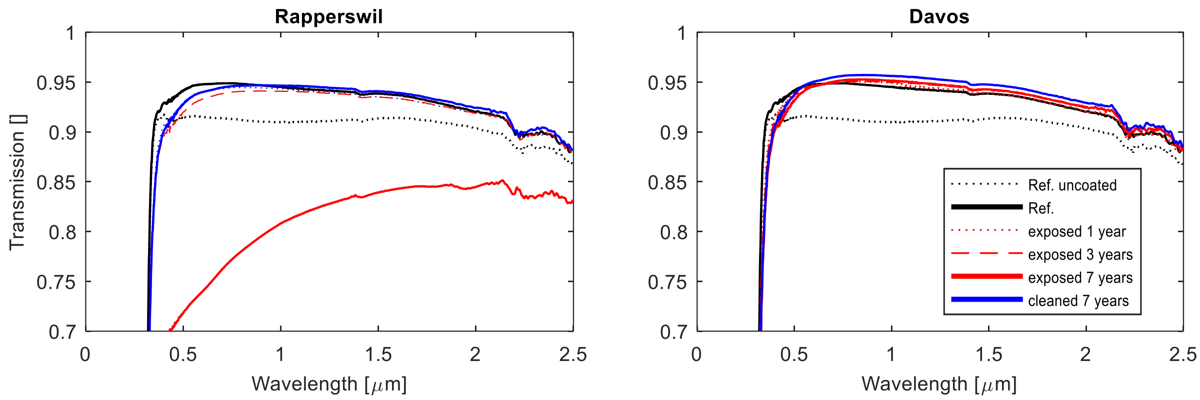

Figure 4: Solar transmittance of all tested AR-coated glass samples after different periods of outdoor exposure in Rapperswil.

3.1. Polycarbonate

For the tested PC samples (see Figure 5), the difference between the two exposure sites where less pronounced. For Rapperswil transmission losses are in the range of 5-9% and for Davos 2-6%. This shows that soiling is less pronounced of PC than on glass. Especially for one material ("09"), which was tested with two different protective coatings, there were some remaining losses in the range of 3-5% after cleaning in Rapperswil and Davos. Another Material ("11") was tested with three different protective coatings, for which transmission losses could be recovered with cleaning independent form the site or the coating.

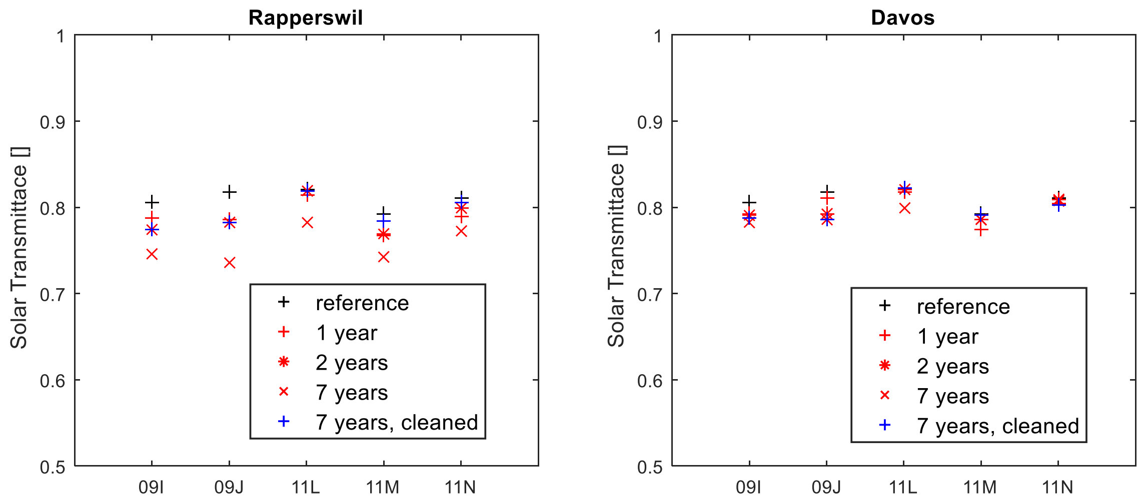

Figure 5: Solar transmittance of all tested AR-coated glass samples after different periods of outdoor exposure in Rapperswil.

4. Discussion

The results from the glass types with AR coatings are very similar to the results from the predecessor study with uncoated glass. The low transmittance losses in Davos and the fact that the elevated losses in Rapperswil practically vanished after cleaning with mild soap lead to the conclusion, that the tested coatings where stable during the seven years of outdoor exposure. However, soiling induced losses in solar transmittance of a cover glass directly affects the efficiency of an according solar collector or PV module.

The samples are collected and measured after one, two and seven years. Therefore the measurements only give an insight to their conditions at the collection day. The previous exposure study showed, that the weather before the collection day has a strong influence on the soiling induced transmittance losses, therefore the measured losses of 10-15% in Rapperswil are subjected to an elevated uncertainty and will fluctuate with the weather (especially rainfall) conditions. However, these results give an order of magnitude of possible efficiency losses from soiling in urban environments after several years and what can be regained by cleaning.

The influence of the exposure site on transmittance losses is pronounced. However, it is not clear which aspect of the environment is responsible for the elevated losses in Rapperswil. More investigations are needed to analyze the soiling potential of the different micro- and macro-climatic conditions. As the order of magnitude of the losses is in a range where it becomes relevant for the economic success of a solar installation, soiling issues can become more important for the evaluation of construction sites especially for large solar installations. There was an approach to simulate soiling effects and their contribution to the economic feasibility in combination with typical weather data by Lorenz et al. 2014. However, more research is needed to adapt such simulation models to different climates and environment and to validate such simulations.

5. Conclusions

- All tested AR coatings are stable in real outdoor exposure in a rural environment for seven years.
- Soiling can cause important transmission losses (10-15%) in urban environment after several years. Also for AR coated glass, a regular cleaning can be recommended to ensure the performance of solar installations.
- No significant improvement could be observed from coatings with “anti-soiling” or “self-cleaning” properties.
- In contrary to the predecessor study, there are polycarbonate products which doesn’t show relevant degradation when used as solar collector cover. However, also some of the modern products were submitted to remaining transmission losses.

The exposure of the last samples is going on and further results will be published after an exposure time of 20 years.

6. Acknowledgement

The authors would like to thank the Swiss Federal Office of Energy (SFOE) for the financing support received under the project ARDUST.

7. References

Ruesch, F., Brunold, S., 2008. Ageing Performance of Collector Glazing Materials – Results from 20 Years of Outdoor Weathering. Presented at the EuroSun2008 International conference on Solar Heating, Cooling and Buildings, Lisbon, Portugal.

García-Segura, A., Fernández-García, A., Ariza, M.J., Sutter, F. & Valenzuela, L., 2016. Durability studies of solar reflectors: A review. Renewable and Sustainable Energy Reviews, 62, p.453–467.

Li, J., Lu, Y., Lan, P., Zhang, X., Xu, W., Tan, R., Song, W. & Choy, K.-L., 2013. Design, preparation, and durability of TiO2/SiO2 and ZrO2/SiO2 double-layer antireflective coatings in crystalline silicon solar modules. Solar Energy, 89, p.134–142.

Lorenz, T., Klimm, E. & Weiss, K.-A., 2014. Soiling and Anti-soiling Coatings on Surfaces of Solar Thermal Systems – Featuring an Economic Feasibility Analysis. Energy Procedia, 48, p.749–756.

Nampalli, N., 2014. Market share for anti-reflection coated glass to reach 75% in 2014. Available at: http://www.solarchoice.net.au/blog/news/market-share-for-anti-reflection-coated-glass-to-reach-75-in-2014-030214/ [Accessed August 31, 2018].

Said, S.A.M., Al-Aqeeli, N. & Walwil, H.M., 2015. The potential of using textured and anti-reflective coated glasses in minimizing dust fouling. Solar Energy, 113, p.295–302.

San Vicente, G., Bayón, R., Germán, N. & Morales, A., 2009. Long-term durability of sol–gel porous coatings for solar glass covers. 7th International Conference on Coatings on Glass and Plastics (ICCG7), 517(10), p.3157–

3160.

Xin, C., Peng, C., Xu, Y. & Wu, J., 2013. A novel route to prepare weather resistant, durable antireflective films for solar glass. Solar Energy, 93, p.121–126.

Ye, H., Zhang, X., Zhang, Y., Ye, L., Xiao, B., Lv, H. & Jiang, B., 2011. Preparation of antireflective coatings with high transmittance and enhanced abrasion-resistance by a base/acid two-step catalyzed sol–gel process. Solar Energy Materials and Solar Cells, 95(8), p.2347–2351.

Yuan, Y., Chen, Y., Chen, W.L. & Hong, R.J., 2015. Preparation, durability and thermostability of hydrophobic antireflective coatings for solar glass covers. Solar Energy, 118, p.222–231.