Identification of Soiling Properties for Different Minerals on Solar Mirrors via Artificial Soiling Setup

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1. Introduction

In order to assess the performance of solar reflectors or photovoltaic modules over their lifetime, standardized accelerated aging tests are often being applied. They are especially tailored to meet the environmental conditions where the components are going to be exposed during their service life. Already a number of standards are developed which deal with e.g. temperature and air humidity cycles, application of various chemical agents and radiation stresses. However, those accelerated durability tests do not involve the effect of soiling. Because solar industry is progressively targeting arid areas for their projects where an augmented aerosol concentration is present, efficiency losses due to soiling are gaining more an more importance in current research. The reliable and accurate laboratory simulation of this phenomenon is one of the first steps for improving O&M processes and also achieve technological progress in the development of novel components or coating systems [1]. In this work a possible artificial soiling (AS) setup to conduct such experiments is presented, its applicability is verified by the comparison to an outdoor soiling exposure. Furthermore, the setup is used to gain an understanding of the soiling properties of different minerals.

2. Methodology

The prototype of the artificial soiling (AS) setup is displayed in Fig 1 (left). The most important features of the setup are on the one hand an ultrasonic nebulizer capable of producing a fine water mist. Thanks to this device, humidity is applied on the specimen in a realistic manner. On the other hand, the aerosol generator unit needs to be highlighted. It is a SAG410/L from TOPAS GmbH (Dresden, Germany) and facilitates the dispersion of dry dust material. For the current investigation, two artificial dusts are used. They consist of the pure minerals: quartz and calcite. Those materials are chosen in accordance with mineralogical analysis from natural sand samples and are representing common mineral fractions in natural soil. The dusts were purchased from KSL GmbH (Lauingen, Germany) and present a very similar particle size distribution (PSD) as shown in Fig 1 (right), to exclude the effect of different particle sizes for the soiling phenomenon. In addition to the artificial types, natural dust from the Plataforma Solar de Almería (PSA) in Spain is used in order to have an adequate comparison to the reflectors that are exposed to natural soiling at the PSA. This dust was obtained by sieving ground soil down to diameters smaller than 53 µm. XRD analysis of the soil shows that most of the material can be described as quartz and clay mineral.

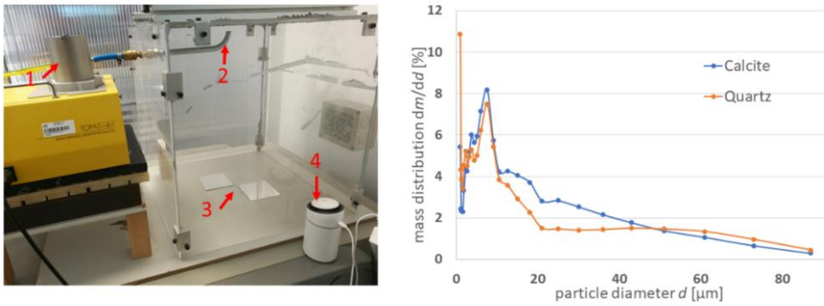

Fig 1: Left: Artificial soiling setup: 1) TOPAS aerosol generator (2) dust injection nozzle into the transparent box (3) sample position – here only two samples are shown (4) ultrasonic nebulizer – during the aerosol generation it remains outside the transparent box; Right: particle size distribution of the two artificial dusts.

In the first part of the study, a proof of the soiling concept is given. Four similar reflector samples are artificially soiled in the soiling chamber with PSA dust smaller than 53 µm and the 10 minutes of water vapor from the humidifier. After the soiling procedure and subsequent complete drying of the sample, the mass increase, via weighing on a high precision balance, and the loss of the monochromatic specular reflectance at an half-acceptance angle of 12.5 mrad and 660 nm, $\rho_{\lambda,s}$, via measurement with the D&S reflectometer, is determined. In the next step, a custom-made artificial rain simulation which reproduces a precipitation of around 7 mm/m² acts on the soiled samples and the samples are left to dry at ambient conditions. The remaining mass of the still adhering dust and the resulting $\rho_{\lambda,s}$ is determined. Microscope images of the resulting glass surface are compared to images taken from the reflectors which were exposed outdoor at the PSA for 30 days without cleaning. For the second part of the study, the dust material was changed and two artificial dust types are used in the soiling procedure instead of the natural dust.

3. Results and Conclusion

In Fig. 2, microscope images of the artificially soiled and rain-cleaned, and the outdoor exposed reflector are shown. The results of the experiment can be summarized as follows: The developed laboratory procedure is capable of producing very similar soiling characteristics to the ones observed after the outdoor exposure. This is in contrast to many other artificial soiling setups where homogeneous soiling layers are obtained [1]. Due to the high reproducibility of the AS setup, the dust layer which was established on the reflectors before the rain experiment was very constant at around 0.8 g/m². Even though this mass coverage is constant for calcite and quartz and their PSD is quite similar, the resulting $\rho_{\lambda,s}$ was measured to 80.0±1.3 and 63.5±1.2 % for the sample soiled with calcite and quartz, respectively. This might be because of small differences in the PSD for very small particles and because of different optical properties of the two minerals. After the application of artificial rain a calcite particle layer, the characteristic stains and particle lines can be seen as they are present on the sample exposed outdoors and the sample after the AS with PSA dust. For the AS with quartz, those effects cannot be seen and more material remains deposited on the sample after the rain experiment. $\rho_{\lambda,s}$ is increased to 92.2±1.2 % and 70.3±2.0 % for the sample soiled with calcite and quartz, respectively. This might be explained by different particle shapes or the solubilities in water leading to different adhesion forces to the glass surface [2] and is investigated further in the full paper. Additionally, gypsum, a third artificial material is added to the study.

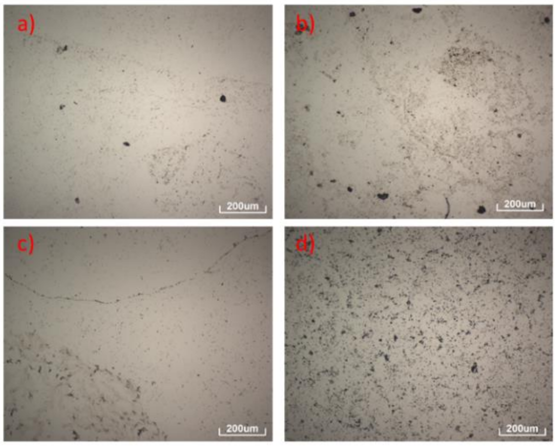

Fig 2: microscope images of reflectors: a) AS with PSA dust, b) outdoor soiling at PSA, c) AS with calcite and d) AS with quartz.

References

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2. Ilse, K.K., et al., *Comprehensive analysis of soiling and cementation processes on PV modules in Qatar.* Solar Energy Materials and Solar Cells, 2018. **186**: p. 309-323.