SOILING AND ABRASION TESTING OF SURFACES FOR SOLAR ENERGY SYSTEMS ADAPTED TO EXTREME CLIMATIC CONDITIONS

E. Klimm, Thomas Kaltenbach, Daniel Philipp, Marvin Masche, Karl-Anders Weiss, Michael Koehl
Elisabeth.Klimm@ise.fraunhofer.de, Phone +49-761-4578-5034
Fraunhofer Institute for Solar Energy Systems ISE
Heidenhofstrasse 2, 79110 Freiburg, Germany

ABSTRACT: Extreme climatic locations, such as arid or maritime regions, are very demanding for solar energy systems. In this paper we share experiences about the soiling of surfaces, exposed for one and two years at outdoor weathering tests sites with different climatic conditions, and their effect on the surface properties. We describe an in-house developed soiling test, to qualify glazing with realistic dust for reproducible and homogeneous test results. The second part of this paper describes characterization measurements by spectral transmittance, especially after applying the dusting method. Next to soiling, a roughening of glazing surfaces in arid areas is most likely to occur, especially due to sand storms. To simulate this abrasive stress an additional test of the stability of the functional coatings is developed and applied. The abrasion test is conducted with an in-house developed sand trickling test stand according to DIN 52 348. Results of the outdoor and indoor tested material show the strong influence of dust types and material properties on soiling and durability of the surfaces.

Keywords: Abrasion, Outdoor Exposure, Soiling, Solar Glazing, Reliability

1 INTRODUCTION

Soiling is defined as dust particle deposition onto surfaces. The glazing material of PV modules ensures stability and insulation, but also has to maintain high transmittance even when exposed to extreme climatic conditions. Extreme loads of dust occur especially in arid regions, e.g. in Middle East and North Africa (MENA). Deposited dust particles reduce the transmittance and increase the scattering of the irradiation. Former publications showed extreme efficiency losses due to soiling [1]. Also outdoor exposed solar glass shows different soiling effects in different climates. Interaction of dust particles with exposed surfaces can deteriorate the surface structures of anti-reflective coatings leading to lower efficiencies. Anti-soiling measures are needed to facilitate dust mitigation, such as dust repellent coatings, which must be abrasion-proof.

2 EXTREME CLIMATE AT OUTDOOR EXPOSURE

It is of exceptional importance towards qualitative statements about functionality and reliability of functional solar surfaces to understand and reproduce outdoor conditions. The influence of environmental conditions towards adhesion of dust on surfaces in arid and maritime climate are optically recorded and spectrally measured by FT spectrometry.

Results of the visual inspection of solar glass samples exposed for 2 years in the Negev Desert and on the Canary Islands are shown in Figure 1 and Figure 2.

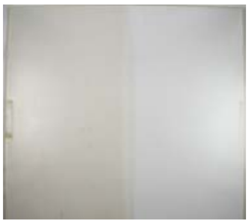

Figure 1: Glass sample after 2 years exposure at Negev Desert, Israel

Figure 2: Glass sample after 2 years exposure at Canary Island, Spain

Samples have been cleaned from dust and dirt on the right side. Both sides are spectrally measured. Figure 3 shows the corresponding spectral transmittance of the PV module glass samples.

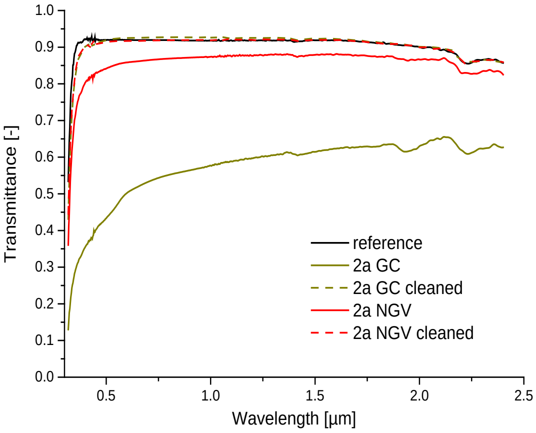

Figure 3: Spectral transmittance of glass after 2 years at Negev Desert (NGV) and Canary Islands (GC)

Comparing the transmittance of the cleaned side after outdoor exposure with the initial reference measurement show no changes after to 2 years in maritime or arid climate. Selected surfaces are stable for this mid-term time period in extreme climate. Nethertheless a significant variation of the soiling characteristics are found. Appearance and distribution of the particle are different. A strong soiling effect at the maritime location (Canary Islands) is detectable. The reported quantities refer to dust which is adhering tightly to the surface. Compared to the maritime location the arid location in the Negev Desert shows a less thick soiling layer sticking to the uncoated solar glass surface.

Results for, up to now 2 years, outdoor exposed solar glazing and additionally performance values of PV systems for even longer time periods are also available for tropic and moderate climates, next the presented arid and maritime climate. All results are used as benchmark for further reliability testing, such as indoor soiling tests to qualify material. Comparing soiling results from indoor testing done with the original dust types from outdoor test fields makes it possible to correlate a transmittance and yield loss with the adhering dust.

3 ARTIFICIAL DUST DEPOSITION

3.1 In-house developed soiling method

A set-up for sensitive dusting tests is developed. This method has its application in the qualification of materials. Real dust from specific regions and real exposure conditions help to simulate and understand the functionality and stability of materials. The test equipment, which is developed in house, is schematically shown in Fig. 4.

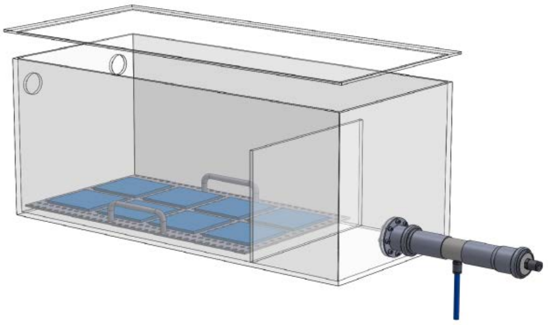

Figure 4: Schematic drawing of the dusting chamber to simulate realistic dust deposition on small samples

3.2 Results of the soiling method

The transmittance homogeneity of the solar glass samples has been already statistically proofed in the range of 0.09 % [2]. An optical characterization of the artificially soiled glass samples is performed. The dust is applied homogeneously, which is in terms of the outdoor exposed sample in arid climate very realistic. The transmittance of the soiling test is correlated including its dust deposition amount with the spectral transmittance loss of the outdoor exposure in Figure 5.

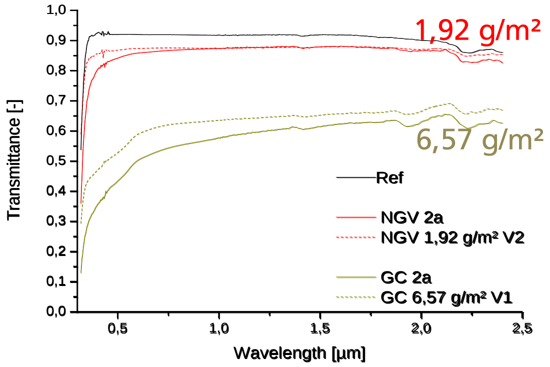

Figure 5: Spectral transmittance of glass after 2 years at Negev Desert (NGV) and Canary Islands (GC) and transmittance values of indoor dusting with dust deposition amounts.

Differences of dust adhesion between the different locations over time are significant.

4 ARTIFICIAL SAND ABRASION

4.1 Sand trickling method in accordance to DIN 52 348

Abrasive Stress, although not yet significant in the outdoor exposed samples by transmittance measurements is found to effect surfaces in the researched extreme climates. Here an abrasive stress test is built in-house and processed in accordance to DIN 52 348. The abrasive stress due to sand trickling (Figure 6) on surfaces is realized with standardized sand and original sand (Origin from Negev Desert and Gran Canaria/Canary Islands). The test is performed with sand quantities of 0.75 kg, 1.50 kg and 3.00 kg. The inclination of the sample is chosen to obtain an impact angle of 45° and 60°. [3]

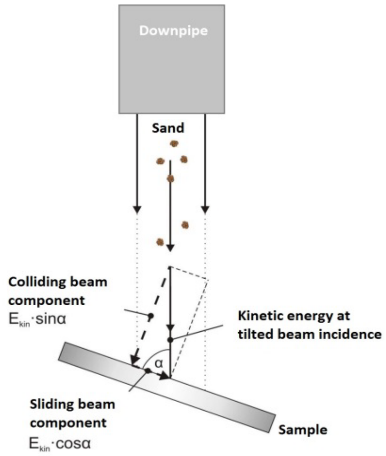

Figure 6: Abrasive wear testing by the sand trickling method in accordance to DIN 52 348

4.2 Results of the abrasive wear testing

During abrasion testing with standardized sand, differences in transmittance loss are noted, which can be correlated to the impact angle and amount of sand impinging on the glass surface (Table 1, Figure 7).

Table I: Dependency of abrasion from sand quantity and impact angle α during sand trickling test on glass sample

Glass	$(T_0 - T_1) / T_0$ * [100%]	
Amount of sand	**1.5 kg**	**3.0 kg**
α = 45 °	4.1 %	4.9 %
α = 60 °	1.0 %	2.1 %

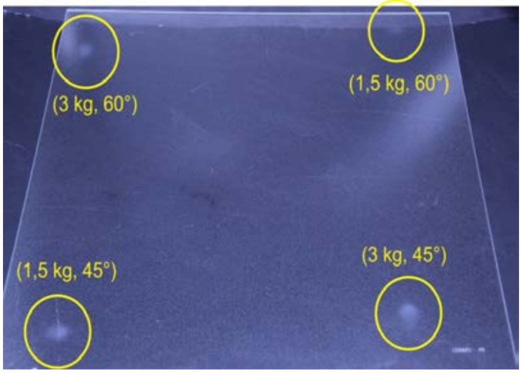

Figure 7: Visible abrasion spots on glass sample after sand trickling method

A direct, close to linear dependency between the amount of used sand and the calculated abrasion rate at the impact angle of 60 ° has been found. When the glass sample inclination changed from α=60° to α=45°, the abrasive impact increased by factor 4 with 1.5 kg of sand and by factor 2 with 3 kg of sand. This effect can be explained with an increased momentum component of the sand particles in the glass plane associated with increased friction.

Further investigation now target to correlate abrasive stress effects on glass samples, which are outdoor exposed on a long-term base to extreme climate.

7 SUMMARY AND CONCLUSION

Aiming towards a simulation of real world soiling and abrasive degradation of solar glazing, indoor tests for soiling and abrasion are developed and test devices are constructed. Since outdoor exposed glazing shows differences in soiling effects depending on the climatic and regional conditions, test adaptions to real world conditions are always necessary.

Spectral transmittance measurements allow a sensitive analysis of soiling and abrasion effects on solar glass samples.

On these samples realistic dry-dust soiling tests lead to transmittance losses comparable to transmittance losses of exposed samples in extreme climatic conditions (maritime and arid). With indoor soiling tests using real dust a conclusion about the amount of adhering dust on these outdoor exposed samples can be drawn. During outdoor exposure the chosen maritime location seems to have a stronger soiling effect.

Next to the soiling effect also the abrasion effects on solar glass due to sand are investigated. A sand trickling method according to DIN 52 348 has been implemented. With the sand trickling test a direct, nearly linear dependency between the amount of sand and the measured degree of abrasion can be found, at an impact angle of 60°. Further investigations towards abrasive effects appearing after outdoor exposure of more than 2 years are aspired. An atomic force microscopy, as surface sensitive method, will complement the characterization methods to investigate changes in the topography, like a surface roughening.

ACKNOWLEDGEMENT

The authors would like to thank the industrial partners and the German Federal Ministry for Economic Affairs and Energy (FKz. 0325969A) for their support and funding.

REFERENCES

[1] Schill C., et. al (2011), Impact of heavy Soiling on the Power Output of PV-Modules. Proceedings of SPIE. 8112:811207

[2] Development of Accelerated Aging Tests for Solar Thermal Collectors and their Components, www.speedcoll.de

[3] Masche M. (2014) Konzeptionierung einer Prüfmethode zur Untersuchung der abrasiven Einflüsse von Sandpartikeln auf Komponenten von solaren Energie-systemen, Abschlussarbeit am Fraunhofer-Institut für Solare Energiesysteme (ISE) Freiburg, eingereicht an der Brandenburgischen Technischen Universität Cottbus-Senftenberg 07/2014