Effect of the Sandstorms on the Solar Panels

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Abstract :

The aim of the present work is to try to correct the defects caused by sandstorms on soda-lime glass used as protective sheets of solar panels. The samples were submitted to a thermal quenching to make the glass more resistant to erosive damage. Erosion tests were carried out in laboratory by sandblasting. The results show that the optical transmission drops significantly from 91.3 up to 38.2% for a projected sand mass of 150 g and an impact angle 90°, while the roughness increases sharply and tends toward a plateau (≈ 4.17 µm). In addition to sandblasting defects, small sand particles are lodged in the impact sites. This justifies the lower photovoltaic efficiency. The presence of these defects leads to a decrease of the relative photovoltaic efficiency which decreases until 0.88% in the most unfavorable conditions (high velocity 27 m/s, great sand mass 150 g, normal impact angle 90°). To correct the surface defects and improve the optical transmission, different protocols were applied to deposit transparent silica coatings on the sandblasted samples using sol-gel technique. After coating, the results show a clear improvement of the optical transmission which increases from 38.2% to 71% for the corrected state. As consequence, the relative photovoltaic efficiency is sensitively improved. It passes from 0.88% for the sandblasted state to 0.97% for the coated samples.

Key words: Sandstorms, Solar panels, Damaged glass sheet, Photovoltaic efficiency, SiO_2 layers.

1. Introduction

In the south of Algeria, photovoltaic solar energy is used as a good mean for providing electrification, water pumping and communications. The reason is the high light intensity and the long duration of sunshine during the year [1]. As an indication, according to the meteorological services of Ouargla (south of Algeria) [2], the number of sunny days in this region is about 325/365 in 2011. This represents a major advantage for the exploitation of solar energy. Unfortunately this advantage is negatively affected by the influence of sandstorms on the performances of the protective glass sheets of solar panels [3]. At the ground level where the solar panels are exposed, the kinetic energy of the incident sand particles is sometimes sufficient to provoke damages on the glass surface. This is linked to the large size of particles which move at this level and to the high velocity induced by wind gusts.

Besides the technological limits of the silicon solar panels used in Saharan regions of Algeria, solutions should also be provided to reduce the damaging effects of sandstorms on the protective glass sheets. Previous works [4, 5, 6…] have shown that the glass surface state plays an

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important role in the various applications of glass sheets (vehicles windshields, glazing,…), because it affects their mechanical and physical properties.

During sandstorms, environmental parameters intervene in the same time and with a very randomly manner (wide range of grains size, variable shapes of grains, different velocities during the same storm, variable impact angles...). This makes the erosion process very complex. All these parameters are governed by the winds turbulence recorded at ground level. Indeed, the presence of dunes with variable sizes or sometimes habitations leads to random blasts of wind. It is evident that the exposed glass sheet should be reinforced against the influence of the sand impacts. In another work, Bousbaa et al. [7] have studied the treatments effect on the glass state in order to understand the glass behavior regarding the erosive activity. The present paper deals with the correction of defects caused by sandblasting on glass intended to be used as protective sheets of solar panels exposed in Sahara. The procedure consists to deposit a thin transparent layer of silica by sol-gel technique on the damaged surface in order to improve the efficiency and the life duration of solar panels and to avoid the dust deposition in the damaged zones.

2. Experimental Procedure

A soda-lime float glass, provided by the Algerian company Africaver [8] is used in this study. The glass sheet is delivered in its as-received state, with a thickness of 3 mm. The main chemical components are 71.56% SiO_2, 7.92% CaO and 13.73% Na_2O. Samples, with dimensions (40x40x3 mm^3), have undergone a thermal tempering in an electric furnace heated to 570°C, and cooled by a jet of compressed air.

In order to simulate the sandstorm effect on the solar cells efficiencies, a sand blower device was employed. Schematic illustration of this equipment was given in previous papers [5, 6]. The erosion tests were carried out using a stationary target which is impacted by incident sand particles. The air blower velocity fixed to 27 m/s (≈ 97 Km/h) which is a relatively high wind velocity during sandstorms in Sahara. The impingement angle was fixed at 90° (i.e. the specimens surface is perpendicular to the air flow). These test conditions (27 m/s and 90°) are considered severe enough. Prior to the erosion tests, the sand used was washed and dried in order to eliminate small particles (dust). Different sand masses (10, 20, 30, 50, 75, 100 and 150 g) were separately projected on the surface samples. The total roughness Rt and optical transmission T were measured for each sample. Erosion tests were conducted at constant temperature and humidity rates: 28°C and 43.5%RH. Finally, the eroded surfaces were examined using microscopy.

A solar generator made of 18 polycrystalline-silicon cells was used. The technical characteristics of the panel are as follows: P_{MAX} = 4.8 W, IP_{MAX} = 0.6 A, UP_{MAX} = 8 V and T_{MAX} = 70°C. The photovoltaic efficiency was determined from the exposure of one single cell having the dimensions (50x20 mm^2). There are numerous parameters that have to be taken into account when performing sandblasting simulation, and in evaluating photovoltaic efficiency of the panels. In this study, the experimental procedure consists first to sandblast the treated samples using various sand masses. The entire surface of the panel was covered with a black plate except one cell. The samples were then placed on this cell surface in order to estimate the resulting efficiency variations under ambient temperature (28°C) at midday (i.e. between 12 and 14 h GMT) in a sunny day. After measuring the parameters I and U for the different samples, the relative efficiency was determined.

3. Results and Discusion

3.1. Sandblasting

3.1.1. Microscopic observations :

After sandblasting tests, the damaged surfaces were examined by microscopy. Figure 1 shows typical defects and the general aspect of glass samples sandblasted with different masses. The micrographs show that the defects are randomly distributed on the surface. For low sand masses, the defects sizes are small. But for larger masses, the number of defects as well as their sizes increase and tend to cover the entire exposed surface. This phenomenon is usually encountered in brittle materials, such as glasses, exposed to erosion by projection of solid particles [9].

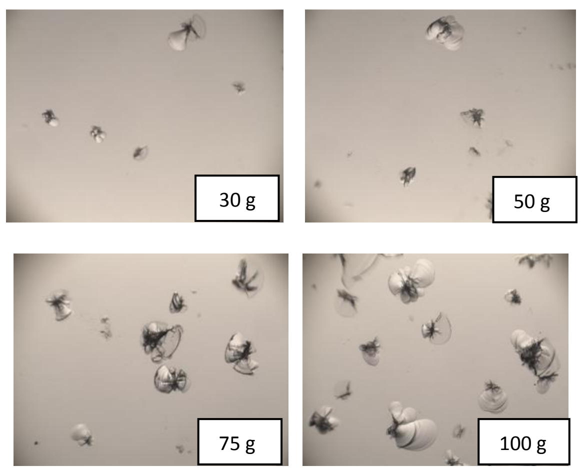

Figure 1. General aspect of glass samples sandblasted with different masses (x120).

3.1.2. Optical Transmission :

After the erosion tests and cleaning the sample surfaces, transmittance spectra are measured in the visible range between 300 and 800 nm. Around 550 nm, the initial state (without sandblasting) has a transmission of about 91.3%. Then, this value decreases almost steadily as the mass of sand projected increases. It reaches 38.2% for Mp = 150 g (figure 2). This drop in transmission is due to the increase of the defect density when the mass increases. In fact, this loss is produced by a diffusion of the light at the points of impact generated by the sand particles.

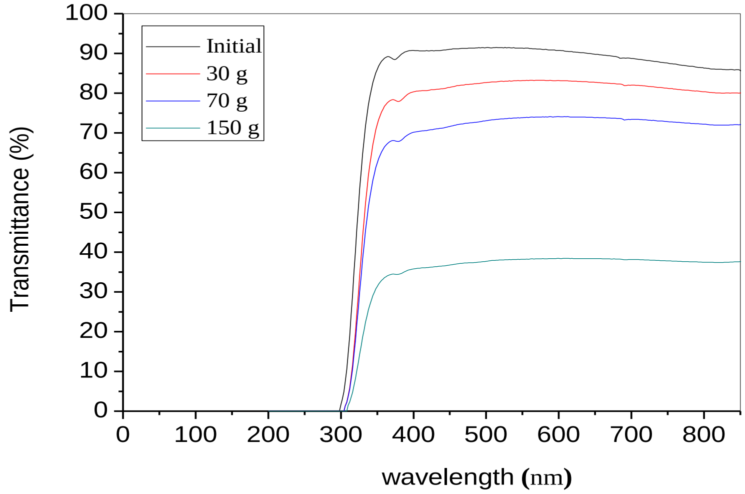

Figure 2. Transmittance spectra obtained for glass samples eroded with different sand masses.

3.1.3. Roughness :

Roughness profiles were measured for each state. Figure 3 shows the case of a sample eroded with 100 g. The obtained values are: Rt = 4.17 µm and Ra = 0.306 µm. The depth of the defects and their size are clearly marked. For this example, the total roughness Rt reached 4.17 microns, while the arithmetic roughness Ra remains relatively low (0.306 µm).

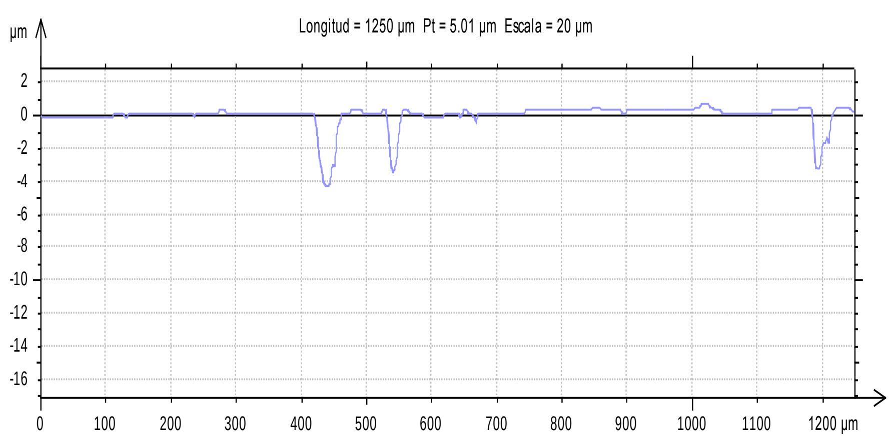

Figure 3. Roughness profile obtained for a sample eroded with 100 g of sand.

3.2. SiO_2 Deposition

The defects induced by sandblasting have an influence on the solar cells efficiency. To correct these defects and then restore the optical transmission, we set as goal the deposition of transparent layer of SiO_2 by the sol-gel method using dip-coating technique. Initially, tetraethylorthosilicate (TEOS) alone was used as a precursor of SiO_2. The thickness obtained in this case was very low (200-300 nm). It is considered insufficient compared to the measured roughness (Rt = 4.17 µm) as it does not cover fully all the defects. This is why a second protocol containing a mixture of two precursors (TEOS and MTES methyltriethoxysilane) was prepared. With this second protocol, the deposited SiO_2 layer reached a thickness of 1.7 µm. This thickness is also considered inadequate. Finally to further increase the thickness of the deposited layer, another protocol is prepared. It consists in adding to the mixture (TEOS + MTES) a colloidal solution of SiO_2 nanoparticles (Ludox 40%). Ificantly increased to 2.307 µm (see figure 4). For the time being, this thickness is estimated satisfactory for two reasons: the first is that the roughness peak (4.17 microns) is an exception compared to the average roughness on the glass surface, and the second is that the optical transmission is significantly improved compared to the sandblasted state. The refractive index measured by ellypsometry is equal to 1.39. After drying, the samples are subjected to an annealing treatment performed at 500°C during 60 min.

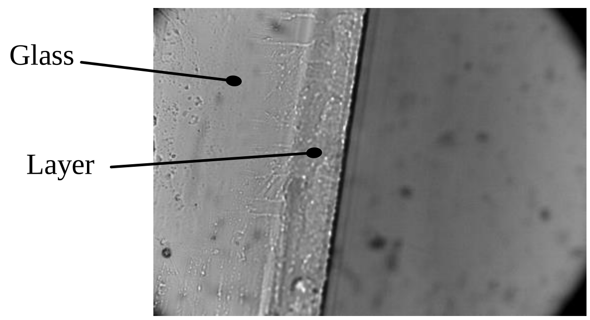

Figure 4. Micrograph showing SiO_2 layer deposited on an eroded glass (mean thickness ≈ 2.3 µm).

3.2.1. Effect on the roughness and the transmittance :

After the deposition of SiO_2 layers, the roughness is greatly reduced. After projection of 150 g of sand, Rt decreases until 1.43 µm (figure 5). In Parallel, the optical transmission shows a sharp increase. It passes from 38.2% and reaches the value of 71% (figure 6). This value is very encouraging, but needs to be improved by doubling the number of such layers for example.

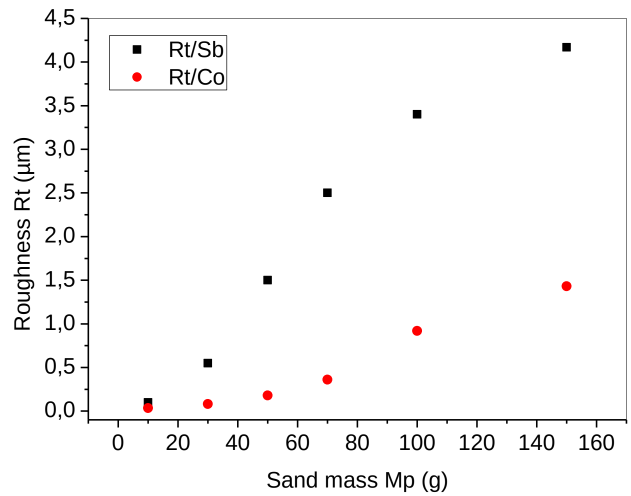

Figure 5. Roughness variation versus sand mass Mp after sandblasting (Rt/Sb) and after coating (Rt/Co).

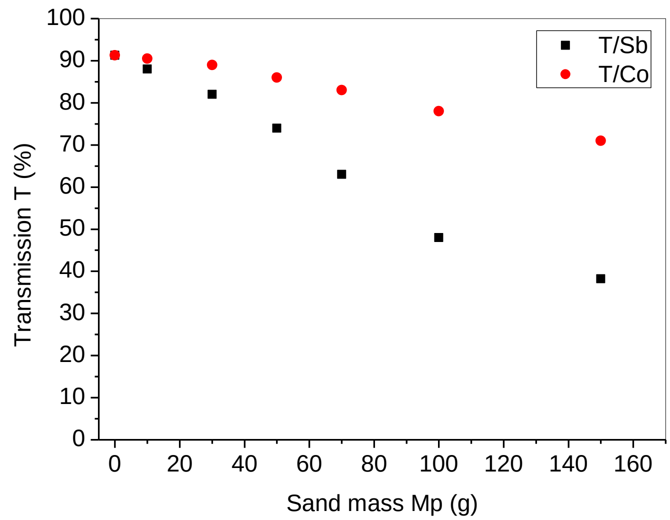

Figure 6. Transmission variation versus sand mass Mp after sandblasting (T/Sb) and after coating (T/Co).

3.2.2. Effect on Photovoltaic efficiency :

The panel's relative efficiency variations Ef versus sandblasting masses Mp are shown in figure 7, after sandblasting (Ef /Sb) and after coating (Ef /Co). The slight drop to 0.88 is mostly related to the presence of the superficial flaws on glass surface that affect the light transmission. Even of in operational uses, the dust particles of sand may be housed in the impact points formed on the surface, and thus constitute obstacles to the passage of light. After coating, relative efficiency is clearly improved and reached the value 0.97.

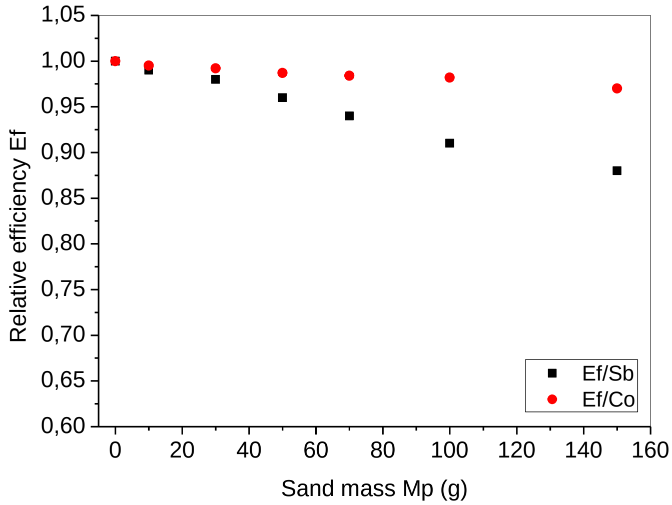

Figure 7. Relative efficiency variations Ef versus sandblasting masses Mp (Ef/Sb) and after coating (Ef/Co).

Conclusions

In order to examine the effects of sandstorms on the solar panels' efficiency, erosion tests were carried out in laboratory using a sand blower device. The results show that with increasing the projected sand masses, the roughness increases sharply, while the optical transmission decreases regularly. These parameters affect the solar panels' efficiency which decreases. It appears that the sandblasting has a relatively weak effect on the solar cells' efficiency (Ef = 0.88). Besides, dust particles can lodge in the sites produced by sand grains.

In order to improve the cells' efficiency, SiO2 layers were deposited on glass surfaces damaged with various sand masses. The aim is to cover the entire damaged surface and to restore the surface state. In order to improve the solar cells' efficiency, SiO2 layers were deposited on glass surfaces damaged with various sand masses. The aim is to cover the entire damaged surface and to restore the surface state. As consequence, the optical transmission increases and allows improving the solar panel efficiency.

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