Comparison of Dust Deposition Reduction Performance by Super-Hydrophobic and Super-Hydrophilic Coatings for Solar PV Cells

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Abstract: Dust deposition on solar photovoltaic (PV) cells will dramatically reduce the photovoltaic power output. Self-cleaning coating may be a novel method to decrease dust deposition problems. This paper compares self-cleaning performances and mechanisms of super-hydrophobic and super-hydrophilic coating on dirt deposition decrease for solar photovoltaic cells by experimental measurement. In the process of the deposition of dust on solar cells, covering glass, coated and uncoated, is conducted under natural settling conditions. Moreover, the dust removal efficiency of the glass samples with and without coatings is studied under water spraying conditions. The wettability of different surfaces, dust deposition mass, dust removal efficiency, self-cleaning mechanisms, and transmittance of glass samples are investigated and analyzed. Under natural settling conditions, the deposition mass reduction ratio by the super-hydrophilic coating is only 8.1%, while it can reach 85.8% by the super-hydrophobic coating because of surface micro-structures and low surface energy. However, after the water spraying process, the remaining dust mass ratio for the super-hydrophobic surface is only 16.5%, while it is 18.6% for the super-hydrophilic surface. The self-cleaning mechanism of super-hydrophobic coating is that most deposited particles of dust are removed from glass samples by the rolling of liquid droplets. However, the self-cleaning mechanism of super-hydrophilic coating is the breakup of the liquid film. Therefore, both coatings can effectively reduce dust deposition under water spraying conditions. The average transmittance of super-hydrophobic and super-hydrophilic coatings after the water spraying process is 91.1% and 86.4%, respectively, while it is only 61.1% for the uncoated glass sample.

Keywords: dust deposition; super-hydrophobic coating; super-hydrophilic coating; spectral transmittance; solar cells

1. Introduction

As a clean and environmental way of energy utilization, solar photovoltaic technology is developing all over the world rapidly [1–3]. For the sake of enhancing the manufacturing efficiency and generating efficiency of solar cells, Bashier and Hossain et al. conducted in-depth studies on solar cells’ transmission, electrode optimization, anode film thickness, and phosphorus doping time. Bashier et al. [4] investigated the effect of pyramid texturing on the optical surface reflectance of monocrystalline silicon PV cells by systematically changing the etching time and chemical concentration to optimize the surface reflectance. For the manufacture of efficient solar cells, Bashier et al. [5] also studied the optimization of phosphorus doping time in the emission region of monocrystalline silicon solar cells and the surface morphology of textured silicon wafers, which may help in the manufacture of efficient monocrystalline silicon solar cells. Hossain et al. [6] investigated the effect of the thickness change of γ-irradiated dye sensitize solar cell (DSSC) photoanode TiO2 film on its structure, morphology, and optical performances. Hossain et al. [7] also studied the optimization of electrode production parameters in order to improve the efficiency of
natural-dye-sensitized solar cells. The results show that improving the sensitivity of natural
dyes by optimizing the electrode parameters is helpful to improve its power generation
efficiency. However, dust particles carried by the wind flow will deposit on solar PV panels
and significantly decrease the PV power efficiency [8–10]. This is because the transmittance
of solar cells’ covering glass decreased by deposited dust particles. Vivar et al. [11] found
that the PV power output reduces by 26% during four months because of dust deposition
on solar cells’ covering glass. Moreover, Fan et al. [12] studied the influence of dust
deposition on solar photovoltaic panels in an arid plateau region. They found that the PV
efficiency can reduce by 25% due to dust deposition. Therefore, dust deposition on solar
cells’ covering glass becomes a serious problem for solar PV panels. Artificial or mechanical
washing by water is the common method to reduce the dust deposition problem for solar
photovoltaic cells. Nonetheless, the traditional method of water cleaning has high costs and
is not efficient. Therefore, development of novel cleaning methods is necessary to avoid
deposition of dust on the solar cells.

Over the past several decades, the influences of dust deposition on solar PV cells have
been studied by researchers [13–18]. Goossens [19] studied the effect of airflow velocity
on dust deposition characteristics on solar PV panels. They found that the photovoltaic
efficiency reduction increases in the wake of the rise of wind velocity. Jiang et al. [20]
investigated the relationship of dust deposition on solar cells and solar PV output by
experimental measurement. The results revealed that the photovoltaic output degeneration
almost increases linearly in the wake of the rise of dust deposition density. Recently,
Lu et al. [21–23] used numerical simulation to study dust deposition behavior on solar PV
panels. The results indicated that medium dust in solar cells has the highest deposition rate.

Although the influence of dust deposition on solar PV efficiency has been investigated
by a lot of researchers, the research of an effective solution on dust deposition is limited.
Recently, on solar cell covering glass, super-hydrophobic and super-hydrophilic coatings
were applied to reduce dust deposition [24–26]. Piliougine et al. [27] examined the self-
cleaning performance of anti-soiling coatings on solar PV panels. The daily PV energy loss
can decrease by 0.8% when the anti-soiling coating is used on the solar cells. Quan et al. [28]
prepared hyaline hydrophobic coatings for solar cells. On solar cells, both the super-
hydrophobic and hydrophobic coatings reduce dust deposition. Wang et al. [29] studied
the self-cleaning property of different super-hydrophobic coatings for solar PV panels.
The silicon-based coating has higher self-cleaning efficiency than that of the fluorne-
based coating. Prabhu et al. [30] accomplished the preparation of super-hydrophilic rGO–
TiO₂ coatings applied on solar PV cells. The coating can decontaminate the adsorbed
pollutants under simulated solar light irradiation. Besides, Lei et al. [31] modified α-
zirconium phosphate nanoplatelets to obtain highly transparent and super-hydrophilic
coatings on glass. The results showed that the contact angle of the coating can be close
to 0° and we can use it on solar cell covering glass. Nevertheless, the comparison of
self-cleaning performance on super-hydrophobic and super-hydrophilic coatings has been
seldom investigated. The self-cleaning mechanisms of the two coatings may be quite
different. Huang et al. [32] investigated anti-soiling properties of four transparent coatings,
including hydrophilic, super-hydrophilic, hydrophobic, and super-hydrophobic coatings.
The results showed that the decrease in PV efficiency of super-hydrophobic coating was
the least, followed by hydrophobic, hydrophilic, and super-hydrophilic coatings. However,
the water spraying experiment was not conducted in the study. Lately, the authors [33,34]
studied the influence of super-hydrophobic coating on dust deposition reduction for diverse
dust performances and surface structures. The results showed that, because of low surface
energy and surface micro-structure, the coating obviously reduces dust deposition rate,
even without water. At the same time, the authors [35] also studied the dust prevention
performance of solar photovoltaic cells under the condition of water spraying. In the
process, in the wake of the increase in water spraying time, the dust deposition quality
of naked glass and coated glass samples dramatically reduced; in addition, with the
increase in deposition and spraying inclination, the dust deposition quality significantly
reduced. However, in this study, the dust removal effects of super-hydrophobic and super-hydrophilic coatings on solar photovoltaic cells were not compared.

In this paper, the self-cleaning performances and mechanisms of super-hydrophobic and super-hydrophilic coatings on dust deposition reduction for solar cells are investigated by experimental measurement. After preparation of self-cleaning coatings, the experiment of the dust deposition on solar cell covering glass with and without coatings is conducted under natural dust settling conditions. Furthermore, the self-cleaning performance of different surfaces on dust removal efficiency is studied under water spraying conditions. The wettability of different surfaces, dust deposition mass, dust removal process, remaining dust mass ratios, and spectral transmittance of glass samples are studied and analyzed. Comparing the effect of dust removal on super-hydrophobic and super-hydrophilic surfaces under water spraying conditions, the study results can provide a reference for choosing super-hydrophobic or super-hydrophilic coating schemes in different regions and may concentrate on a dust deposition reduction solution in solar PV engineering application.

2. Experiments

2.1. Experimental Method

Figure 1a,b shows, respectively, the schematic design and realistic picture of the test rig for dust deposition on solar cell covering glass. The test chamber is 0.8 m in length, 0.5 m in width, and 0.5 m in height. A fan is adopted to generate airflow inside the chamber, while the glass samples are installed with a certain inclination on the bottom of the chamber. To ensure natural settling of dust particles on the solar cell covering glass, airflow velocity produced by the fan is very low. Dust particles are uniformly injected into the chamber by a dust generator, and a particle counter (LZJ-01D3, Suzhou Xingyuan Clean Environment Technology Co., Ltd., Suzhou, China) is used to measure the dust particle concentration in the test chamber. The tilt angle of the solar cell covering glass is 30° in this study, which is a common tilt angle in realistic solar PV panel application. The deposition mass on the coated and uncoated glass surfaces after the dust deposition process and water spraying process is measured by a precious balance. Besides, the transmittance of the glass samples after the water spraying process is gauged by a UV spectrometer (U-3010, HITACHI, Tokyo, Japan). The contact angles of different surfaces are gauged by a contact angle meter (OCA20, Dataphysics, Filderstadt, Germany).

![Figure 1. Cont.](a) Schematic design
2.2. Experimental Dust

We buy the dust particles adopted in the test from Powder Technology Inc., Arden Hills, MN, USA. We use a laser particle analyzer (S3500, Microtrac Inc., York, PA, USA) to gauge the cumulative volume fraction distribution of dust particles, which can be seen in Figure 2a. It can be found that the dust diameter is from 0 μm to 20 μm. Moreover, it is about 90% of, that is, the volume fraction of the dust particles is no more than 10 μm. Figure 2b reveals the chemical component of dust particles, which are measured by a soil composition analyzer (DPO-6000, OLYMPUS, Tokyo, Japan).

![Figure 1. Experimental schematic of dust deposition on solar cell covering glass.](image)

**Figure 1.** Experimental schematic of dust deposition on solar cell covering glass.

2.3. Preparations of Self-Cleaning Coatings

The preparation of super-hydrophobic coating can be found in our previous paper [28] and the literature [31], which is not repeated here. The preparation of super-hydrophilic coating is as follows: the titanium dioxide and silica sol were prepared from tetraethyl titanate and ethyl silicate, respectively. Tetrabutyl titanate was mixed with ethanol and agitated for 30 min. Then the acetic acid, distilled water, and ethanol were added slowly to the mixture of tetrabutyl titanate and ethanol. After that, the mixture solution was agitated at room temperature and the TiO₂ sol was obtained. Meanwhile, the SiO₂ sol was fabricated by the mixture of ethyl silicate, ethanol, and polyethylene glycol. The prepared TiO₂ and SiO₂ sol were mixed and continuously stirred for 4 h. Finally, the sol was uniformly coated on the bare glass sample with a coating thickness of 100 nm. It was subsequently dried at the temperature of 40 °C for 3 h. We used an electron microscope scanner (SEM, S-8820, HITACHI, Tokyo, Japan) to acquire the scanning electron microscope (SEM) images of the super-hydrophilic coating and super-hydrophobic coating, as displayed in Figure 3.

![Figure 2. Cumulative volume fraction](image)

**Figure 2.** Cumulative volume fraction and composition of dust particles.
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![Graph of Dust Composition](image)

**Figure 2.** Cumulative volume fraction and composition of dust particles.

**Figure 3.** SEM images of surfaces with different self-cleaning coatings.

As shown in the infrared spectrum of Figure 4a, it has obvious absorption peaks at 3358 cm$^{-1}$, 2958 cm$^{-1}$, 1687 cm$^{-1}$, 1604 cm$^{-1}$, 1510 cm$^{-1}$, 1461 cm$^{-1}$, 1436 cm$^{-1}$, 1325 cm$^{-1}$, 1288 cm$^{-1}$, 1251 cm$^{-1}$, 1195 cm$^{-1}$, 1088 cm$^{-1}$, 845 cm$^{-1}$, and 725 cm$^{-1}$, of which the sharp and strong absorption peak at 3385 cm$^{-1}$ is N–H stretching vibration; the absorption peak near 2958 cm$^{-1}$ is caused by the C–H symmetric and antisymmetric stretching vibrations...
in CH$_3$; the absorption peaks at 1687 cm$^{-1}$ and 1604 cm$^{-1}$ are N–H stretching vibrations; the peaks near 1510 are N–H bending vibrations; 1461 cm$^{-1}$, 1325 cm$^{-1}$, and 1251 cm$^{-1}$ are C–H surfaces in CH$_3$ internal bending vibration; the antisymmetric stretching vibration of Si–O–Si is at 1195 cm$^{-1}$ and 1088 cm$^{-1}$; the symmetric stretching vibration of Si–O–Si is at 845 cm$^{-1}$; and the absorption peak near 764 cm$^{-1}$ is CH out-of-plane bending vibration.

Figure 4. FTIR spectra of super-hydrophobic and super-hydrophilic coating.
As shown in the infrared spectrum of Figure 4b, the broad peak at 3649 cm\(^{-1}\) is O–H stretching vibration; the absorption peak at 1785 cm\(^{-1}\) is acetic acid carbonyl C=O stretching vibration; the absorption peak at 1479 cm\(^{-1}\) is C–H bending vibration; the absorption peaks at 1155 cm\(^{-1}\) and 866 cm\(^{-1}\) are antisymmetric and symmetric stretching vibrations of Si–O–Si; and the absorption peak at 442 cm\(^{-1}\) is caused by the Ti–O peak.

3. Results and Discussion

3.1. Wettability for Contrasting Surfaces

To compare the wettability of the bare glass surface, super-hydrophobic coating, and super-hydrophilic coating, the contact angles of different surfaces are shown in Figure 5. The contact angle of the surface of the glass sample A is 158°. It indicates the glass sample A is super-hydrophobic, as the contact angle exceeds 150°. The super-hydrophobic surface includes surface micro-structure and low surface energy, which will greatly affect the dust deposition characteristics. The adhesion force of dust particles on the super-hydrophobic surface is significantly lower than that of the normal surface [28,29]. Moreover, the rebound behaviors of dust particles on surface micro-structures will also be quite different with the normal surface. For the glass sample B, the contact angle is 5°, which presents as super-hydrophilic. The super-hydrophilic surface consists of high surface energy and surface micro-structures. The droplets can be widely spread on the super-hydrophilic surface and the liquid film flow can be formed to take away the deposited dust particles. For the bare surface, the contact angle reaches 76°. The bare surface is hydrophilic, as the contact angle is less than 90° [30,31].

![Super-hydrophobic surface](image1.png) ![Super-hydrophilic surface](image2.png) ![Bare surface](image3.png)

Figure 5. Contact angles of solar cell covering glass with and without coating.

3.2. Dust Deposition Mass on Different Surfaces

The dust deposition process is conducted on the coated and uncoated surfaces under natural settling conditions. The dust deposition period in a real engineering application
usually lasts for a long time. Therefore, a high concentration of dust is always used to decrease the test period in the laboratorial experiment. Figure 6 shows the dust concentration of different particle diameters with time in the test chamber. With deposition time, the concentration of dust particle number universally reduces. Nevertheless, the number concentration of large particles decreases faster than that of small particles because of stronger gravitational settling.

![Figure 6](image_url)

**Figure 6.** Dust particle concentration during the deposition process.

Figure 7 shows the density of dust deposition on the glass samples with and without coating. The density of dust deposition is gauged every 3 min. The total deposition time is 15 min. The dust deposition quality of glass samples B and C increases almost linearly in the wake of the rise of deposition time. The difference in dust deposition mass between the glass sample B and C is not large. It implies that the super-hydrophilic coating has no obvious self-cleaning effect under natural settling conditions. This is because the high surface energy of the super-hydrophilic coating may enhance dust deposition. However, the surface micro-structures can decrease the dust deposition. Therefore, the final dust deposition mass for the super-hydrophilic surface is similar to that of the bare surface. The deposition mass reduction ratio by super-hydrophilic coating is only 8.1%, compared to the naked glass sample case. However, the dust deposition mass for the glass sample A slightly rises in the wake of the deposition time. The dust deposition mass of \( t = 12 \) min is even less than that of \( t = 9 \) min. This is because some dust particles slide down from the glass sample due to the airflow and gravitation force. Moreover, the dust deposition mass for the glass sample A is much less than that of glass samples B and C. The deposition mass reduction ratio by super-hydrophobic coating is 85.8%, compared to the case of the naked glass sample. Thus, the super-hydrophobic coating dramatically reduces dust deposition mass, even without water spraying process. This is because both low surface energy and micro-structures can decrease the dust deposition rate. Thus, the dust rebound rate is enhanced and the deposition mass can decrease. Moreover, the surface micro-structures can decrease the area of contact between the surface and the dust; then, they also reduce dust deposition rate. The experimental results are the same as those found in the literature \[32\], which shows that the photovoltaic efficiency reduction of the super-hydrophobic coatings is minimal during dust deposition and the super-hydrophilic coatings are slightly less effective.
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![Graph showing dust deposition mass on solar cell covering glass with and without coatings.](image)

**Figure 6.** Dust deposition mass on solar cell covering glass with and without coatings.

### 3.3. Dust Removal Performance for Different Surfaces

In real engineering application, the self-cleaning process by super-hydrophobic or super-hydrophilic coating is always conducted under rainwater washing or artificial water washing. Therefore, the dust removal process is conducted for different surfaces under water spraying conditions. During the water spraying process, the spraying flow rate is 1.5 mL/s. The dust cleaning process under water spraying for the super-hydrophobic coating is shown in Figure 8a–i. Figure 8a reveals the initial dust deposition pattern for the glass sample A. We can find that the dust particles are not uniformly distributed on the surface. This may be related with the surface micro-structures of the super-hydrophobic coating. When the water spraying process starts, small liquid droplets immediately form on the super-hydrophobic surface and roll down from the glass sample. The rolling droplets carry the deposited dust particles away from the sample surface, as displayed in Figure 8b,c. When the water spraying process continues, small water droplets gradually merge to large waterdrops and more dust particles are taken away by large waterdrops, as displayed in Figure 8d–f. Finally, almost all the dust particles are removed by larger waterdrops, as displayed in Figure 8g–i. Therefore, the self-cleaning property of the super-hydrophobic coating is quite effective under water spraying conditions.

The dust cleaning process under water spraying for the super-hydrophilic coating is displayed in Figure 9a–i. The initial deposition pattern of dust for the glass sample B can be seen in Figure 9a. The dust particles are not uniformly distributed on the super-hydrophilic surface, which is similar with the case of super-hydrophobic coating. When the process of water spraying starts, liquid film is shaped on the super-hydrophilic surface and falls down from the glass sample, as shown in Figure 9b. This is very different from the super-hydrophobic surface case. However, the liquid film cannot completely cover the glass sample B. When the water spraying process continues, the liquid film becomes larger and gathers on the bottom of the glass sample due to the gravitational force, as shown in Figure 9c. The liquid film reaches the maximum pattern and includes many particles of dust, as displayed in Figure 9d. Then, the liquid film is broken up as a result of gravity and many dust particles are removed from the glass sample by the broken liquid film flow, as shown in Figure 9e. The similar process can be seen from Figure 9f–h. Many dust particles are taken away again by the second liquid film flow. Finally, the majority of deposited dust particles are brought away from the sample surface by the liquid film flow. Therefore, the self-cleaning property of super-hydrophilic coating is also effective under
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Figure 7. Dust cleaning process under water spraying for the super-hydrophobic coating.

Figure 8. Dust cleaning process under water spraying for the super-hydrophobic coating.

Figure 10a–i shows the dust cleaning process under water spraying for the naked
glass sample. We can see the initial deposition pattern of dust for the glass sample C in
Figure 10a and know the deposited dust particles are relatedly uniform on the bare surface.
This may be because the bare glass surface does not include roughness micro-structures.
When the water spraying process starts, small liquid droplets can be found on the bare
sample surface, as displayed in Figure 10b–d. Whereas, unlike the super-hydrophobic
surface or super-hydrophilic surface, the liquid droplets neither roll down from the sample
surface nor form the liquid film. When the water spraying process continues, small water
droplets can merge to large water droplets, as displayed in Figure 10e–i. However, the
large liquid droplets just stay or slide down for a little distance on the sample surface due
to the surface wettability of the bare sample. Therefore, very few particles of dust can be
removed from the sample surface. The dust removal property of the bare glass sample is
not effective under water spraying conditions.
The dust cleaning process under water spraying for the super-hydrophilic coating is displayed in Figure 8a–i. The initial deposition pattern of dust for the glass sample B can be seen in Figure 8a. The dust particles are not uniformly distributed on the super-hydrophilic surface, which is similar with the case of super-hydrophobic coating. When the process of water spraying starts, liquid film is shaped on the super-hydrophilic surface and falls down from the glass sample, as shown in Figure 8b. This is very different from the super-hydrophobic surface case. However, the liquid film cannot completely cover the glass sample B. When the water spraying process continues, the liquid film becomes larger and gathers on the bottom of the glass sample due to the gravitational force, as shown in Figure 8c. The liquid film reaches the maximum pattern and includes many particles of dust, as displayed in Figure 8d. Then, the liquid film is broken up as a result of gravity and many dust particles are removed from the glass sample by the broken liquid film flow, as shown in Figure 8e. The similar process can be seen from Figure 8f–h. Many dust particles are taken away again by the second liquid film flow. Finally, the majority of deposited dust particles are brought away from the sample surface by the liquid film flow. Therefore, the self-cleaning property of super-hydrophilic coating is also effective under the condition of water spraying, although the cleaning method is completely different from the super-hydrophobic coating case.

Figure 8. Dust cleaning process under water spraying for the super-hydrophilic coating.

To quantificationally evaluate the self-cleaning performance of the coated and uncoated sample surfaces, Figure 11 shows the remaining dust mass ratio for different samples under the water spraying process. The remaining dust mass ratio is the ratio of deposited dust mass after and before the water spraying process. It can be observed that the remaining dust mass ratio for the super-hydrophobic surface first decreases rapidly and then decreases slowly during the water spraying process. This is on account that, at the commencement of the water spraying process, most of the dust particles are brought away by rolling water droplets. Then, the rest of the dust particles are removed by large water droplets, as discussed in Figure 8. However, the remaining dust mass ratio curve for the super-hydrophilic surface is quite different from the super-hydrophobic surface. The remaining dust mass ratio for the super-hydrophilic surface first decreases slowly, and then decreases dramatically during the water spraying process, as shown in Figure 11. This is on account that few dust particles can be brought away from the surface of the sample before the liquid film breaks up, as discussed in Figure 9. However, when the liquid film breaks up, a lot of dust particles will be removed by the water film flow. Thus, the remaining dust mass ratio for the super-hydrophilic surface decreases dramatically at the second half of the water spraying process. Nevertheless, it needs to be noted that, on the super-hydrophilic surface and super-hydrophobic surface, the final remaining dust...
mass ratios are almost the same. The remaining dust mass ratio for the super-hydrophobic surface can reach 16.5, while it is 18.6 for the super-hydrophilic surface. For the bare glass sample, the remaining dust mass ratio slightly decreases during the water spraying process. As discussed in Figure 10, this is because the liquid droplets hardly roll down from the bare sample surface. The remaining dust mass ratio for the bare sample surface is only 86%. Thus, we can conclude that either super-hydrophobic or super-hydrophilic coatings can effectively decrease dust deposition under water spraying conditions. The results are the same as those acquired in the paper [36] conducted in desert areas.

Figure 9a–i shows the dust cleaning process under water spraying for the naked glass sample. We can see the initial deposition pattern of dust for the glass sample C in Figure 9a and know the deposited dust particles are relatedly uniform on the bare surface. This may be because the bare glass surface does not include roughness micro-structures. When the water spraying process starts, small liquid droplets can be found on the bare sample surface, as displayed in Figure 9b–d. Whereas, unlike the super-hydrophobic surface or super-hydrophilic surface, the liquid droplets neither roll down from the sample surface nor form the liquid film. When the water spraying process continues, small water droplets can merge to large water droplets, as displayed in Figure 9e–i. However, the large liquid droplets just stay or slide down for a little distance on the sample surface due to the surface wettability of the bare sample. Therefore, very few particles of dust can be removed from the sample surface. The dust removal property of the bare glass sample is not effective under water spraying conditions.

Figure 10. Dust cleaning process under water spraying for the bare surface.
Thus, we can improve the transmittance by self-cleaning coatings, in particular, for the regions such as Qinghai or Xinjiang in the northwest of China. However, if rainfall is sufficient, this may be important for self-cleaning of solar PV panels installed at dry and dusty regions without water, compared with super-hydrophilic coating.

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### 3.4. Spectral Transmittance for Different Surfaces

The spectral transmittance of solar cell covering glass is critical to improve production efficiency of solar photovoltaic cells. The main reason for the decrease in photovoltaic output is the transmittance loss by dust deposition [6,7]. Thus, the transmittance of glass samples after the water spraying process is measured and shown in Figure 12. We can calculate the spectral transmittance of glass sample $\tau$ in this way:

$$\tau = \frac{I_I}{I_0} \times 100\%$$

where $I_I$ represents the magnitude of light passing through a glass sample; and $I_0$ represents the magnitude of the incident ray on the glass sample. The transmittance of different glass samples is measured by the UV spectrometer (U-3010, HITACHI, Tokyo, Japan). The spectral transmittance of different glass samples after the process of water spraying is shown in Figure 12. Compared with the bare glass sample, both super-hydrophobic and super-hydrophilic surfaces have much higher transmittance. However, the transmittance of the super-hydrophobic surface is slightly higher than that of the super-hydrophilic surface. The mean transmittance is, respectively, 91.1%, 86.4%, or 61.1% for the sample A, B, or C. Thus, we can improve the transmittance by self-cleaning coatings, in particular, for the super-hydrophobic coating.

![Figure 11. Dust deposition mass on solar cell covering glass with and without coating.](image)

**Figure 11.** Dust deposition mass on solar cell covering glass with and without coating.

![Figure 12. The spectral transmittance of glass samples after the process of water spraying.](image)

**Figure 12.** The spectral transmittance of glass samples after the process of water spraying.
4. Conclusions

In this study, the self-cleaning performances and mechanisms of super-hydrophobic and super-hydrophilic coatings on solar photovoltaic cells are compared by experimental measurement. Super-hydrophobic coating has high self-cleaning performance, even under natural settling conditions without water, compared with super-hydrophilic coating. This may be important for self-cleaning of solar PV panels installed at dry and dusty regions, such as Qinghai or Xinjiang in the northwest of China. However, if rainfall is sufficient, both super-hydrophobic and super-hydrophilic coatings can be used for the self-cleaning of solar cells. Then, the durability and economy of the self-cleaning coating may be the most important concern for choosing the self-cleaning coating. This may be investigated in our future study.

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