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DEPOSITION AND EVALUATION OF HYDROPHOBIC COATING BY WIPING METHOD

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A modest, low-cost and time-saving method for preparing self-cleaning hydrophobic coating using wiping technique is reported in this paper. Commercially available hydrophobic solution was deposited on the sodalime glass substrate. By implementing the uniform wiping with a microfiber cloth, a water contact angle of 110.49° and transmittance value of 93% were obtained. The prepared coated glass presented good self-cleaning and able to maintain the efficiency of the coating under the performance test by rain droplet simulator. The proposed approach could be used as an effectual strategy for assembling self-cleaning hydrophobic surfaces on the solar panel.

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1. Introduction

Various designs of antireflective (AR) coatings are implemented extensively in a wide variety of optical systems to enhance the efficiency and power output such as photovoltaic (PV) devices; light emitting diodes; architectural windows; lenses and high-power laser systems etc. [1]. The use of PV devices is fast spreading decentralized energy harvesting sources due to the ability to convert directly the solar energy into electrical energy [2-4]. The PV panels are deployed outdoor and exposed to the open environment, therefore the dust accumulation, bird-droppings and water-stains (salts) [5-8] tends to haul on the panel surface and significantly disturb the solar performance and cause degradation of the solar PV systems efficiency. The accumulation of dust due to adhesion and retention, block incident photons from reaching the PV cells and thus reduces the output electrical power. In addition, the atmospheric humidity also increases the energy requirement through surface tension which keeps the particles on the PV module. The adhesion to the module surface increases as the cohesion forces between particles [9-12]. In order to overcome the decrease in efficiency of installed PV panels and losses due to the dirt and dust accumulation on the panels, the appropriate and regular cleaning process is required [13]. Thus, regular cleaning of solar modules is essential and therefore different cleaning techniques have been developed such as electrodynamics screen, water and mixture of surfactants. In electrodynamics screen technique, a very thin or transparent cover is embedded over the solar panel [14-16] where a set of cyclical voltage is applied to the wires which creates an electrostatic force wave that travels across to the surface of the panel [17]. In addition, the most durable technique to clean the PV modules is using water [18]. Fixed nozzles and a sliding set of nozzles attached with a sliding brush or a rotating brush is used to remove sticky or muddy particles [17]. The brushing methods are driven by the machine that is designed just like windscreen-wiper and by increasing the water pressure and moving the water nozzles along the length of the PV panels especially for the large solar farms that tend to be scarce of using clean water, making it expensive. Besides that, a mixture of surfactant is also used to clean and remove dust that sticks on the cells and can preserve the cells efficiency at a constant level. The surfactant removes the negatively charged particles by repulsion

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between the sand particles and the surfactant droplets which are capable of removing the sand particles and cleaning the glass surface [19, 20]. Regular supply of water and surfactant is required, in order to keep the PV panels clean. Although combination of water and surfactant technique is the best way to clean the PV panels, it is very costly and absolutely not worth because the PV panels need to be cleans often to reduce the losses of efficiency of the solar panels especially in the areas that contain high pollutions.

Therefore, another approach that involves deposition of nano-films based on hydrophobic or hydrophilic material possess self-cleaning characteristic on the surface of PV panels to maintain the efficiency of PV panels. To reduce the frequency of cleaning cycle and keep the solar panel surface clean, an anti-reflection hydrophobic coating with self-cleaning characteristics is grown on the top surface of the PV panel. The micro or nanostructures surfaces combined with the low surface energy materials exhibit water contact angle larger than 90° which repels off the water from the surfaces [21, 22]. The self-cleaning characteristics are very important in industrial application as it can be used to prevent the snow adhesion [23-25], antifogging [26-28], lossless liquid transfer and self-cleaning especially in PV applications [21, 29-31]. Zhang et. al [32] have grown poly (tetrafluoroethylene) (PTFE) super-hydrophobic surfaces by changing the density of the fibrous crystals. Huanjung et. al [33] presented a dip-coating method to fabricate super-hydrophobic coating on the heterogeneous wood surfaces using PDMS and silica nanoparticles. The present study focuses to deposit thin film hydrophobic coatings on a soda-lime glass using wiping method and deposited films are tested using rain droplet simulator and characterized in context of transmittance and reflection.

2. Experimental section

2.1 Preparation and deposition of hydrophobic coating

The soda lime glass substrates (5 x 5 cm) were cleaned prior to deposition by isopropanol ($(CH_3)_2CHOH$) followed by deionized water (DI-H_2O) in an ultrasonic bath operated at 40°C and 100Hz. Then, the substrates were dried by nitrogen dryer. After cleaning, the hydrophobic solution was deposited on the substrates by wiping method. The hydrophobic solution of $37.6\ \mu l$ was dropped on the substrate and the liquid droplet was wiped and spread uniformly using a microfiber cloth without any lint on the glass. The coated glass substrates were dried for 180 minutes at room temperature.

2.2 Performance test

After deposition of the hydrophobic coating on the glass substrate, the performance test was conducted to measure the durability of deposited thin film coatings using rain droplet simulator. The rain droplet simulator contained holding assembly with small water tubes attached to water pump to simulate rain, moveable platforms with various angles adjustments and sand tube to sprinkle dust particles. The substrates coated with hydrophobic solution and uncoated substrates were placed onto the platform of the rain droplet simulator right under the water tubes and sand tube. The water was dripped from the water tubes followed by the sprinkling of sand on samples in two different approaches as Method 1 and Method 2. In Method 1, the samples were sprinkled first with sand particles then simulated with the rain water and dried for 24h. Whereas, in Method 2, the samples were simulated with rain water first and then sprinkled with sand particles and dried for 24h. These two methods were repeated with the different platform angles as to 0°, 15° and 30° during rain droplet simulations.

2.4 Characterization

Transmittance and reflectance measurements before and after the running performance test were conducted for spectral range between 200 nm – 1200 nm using Cary 5000 UV-Vis-NIR Spectrophotometer. The wettability of deposited coatings was characterized with a commercial contact angle system (DataPhysics, OCA 20) at ambient temperature using $1\ \mu l$ water droplet as the indicator.

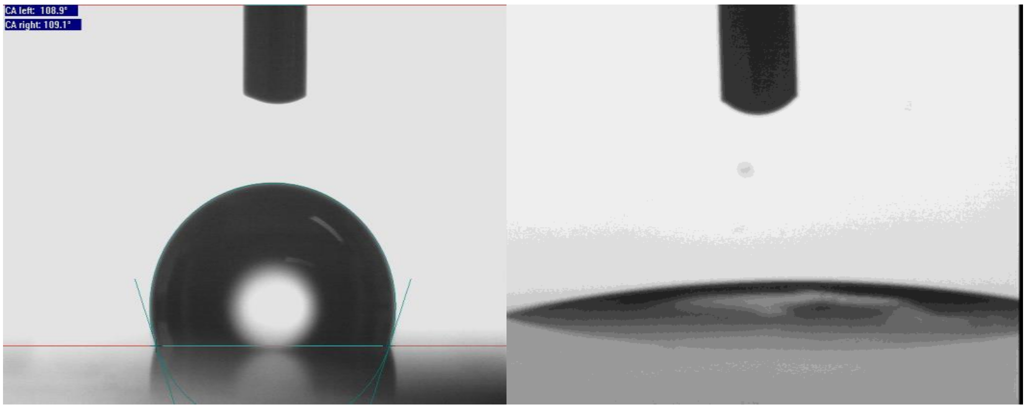
3. Results and discussions

3.1 Contact angle measurements

Fig. 1 shows the contact angle measurements of the coated and uncoated soda-lime glass substrates and the reference contact angle measurements are given in Table 1. A large difference between contact angles are observed for two coated and uncoated samples. The water dropped onto the coated glass tends to shape up into a small sphere form due to high water contact angle while the water dropped on the uncoated glass possess hydrophilic form.

Table 1. Reference contact angle of coated glass and uncoated glass.

Glass Samples	**Contact Angles (degrees)**
Coated glass	110.49°
Uncoated glass	13.24°



(a) *(b)*

Fig. 1. Water contact angle of a) coated glass and b) uncoated glass.

3.2 Performance test

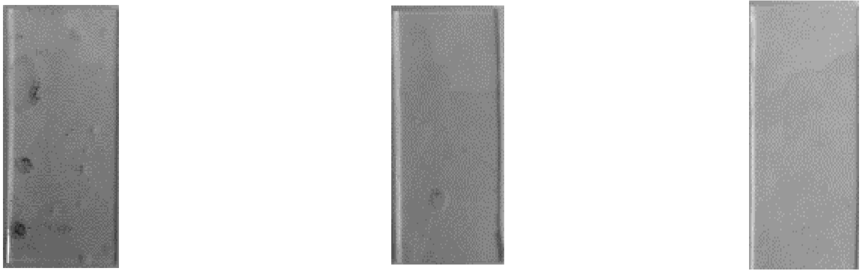
Performance test is conducted on both samples (with and without hydrophobic coating) using rain droplet simulator for 3 different platform angles. Table 2 shows snapshots of samples after being subjected to the performance test under rain drop simulator and dried for 24h followed by Method 1 for platform angle 0°, 15°and 30°. The snapshots in Table 2 shows that the sand particles are adhered more on the surface of the uncoated glass as compared to the surface of the hydrophobic coated glass meanwhile least sand particles stick on the glass samples coated with hydrophobic solution for platform's angle 30°. As the sand particles are sprinkled first on the coated glass followed by rain water dropped on the coated glass, the water droplets washes away the surface along with the sand particles due to the high roughness and weak attraction forces between the water and coated glass surfaces. However, the sand particles are accumulated on uncoated glass sample for platform angle 0° and 15° due to the strong attraction between the water molecules and the uncoated glass surface.

Table 2. Snapshots of coated and uncoated samples after being subjected to the performance test under rain drop simulator followed by Method 1 for platform angle 0°, 15° and 30°

Platform Angle

0° 15° 30°

Coated Samples



Uncoated Samples

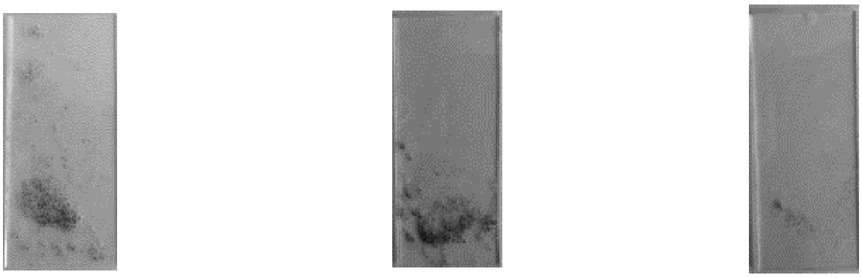


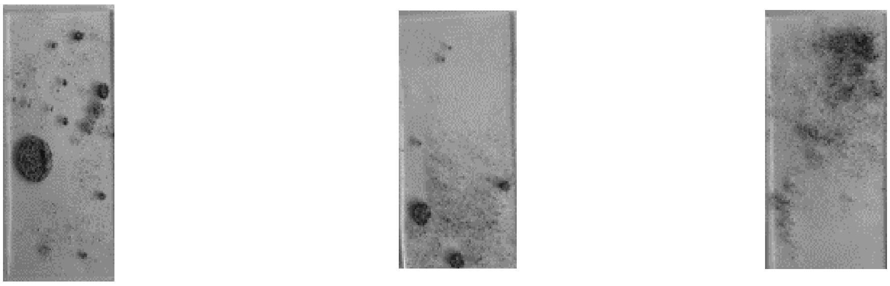
Table 3 shows the snapshots of coated and uncoated samples simulated by the rain drop test followed by Method 2 (the rain drops are showered first followed by sand particles sprinkling). More sand particles are stick to surface of each sample (coated and uncoated substrate) for all angles as compared to results as given in Table2. It is clearly seen that the uncoated samples contain more sand particles as compared to coated glass. The existence of water on the substrate surface before the sand particles are sprinkled hold together the sand particles on substrate surface.

Table 3. Snapshots of coated and uncoated samples after being subjected to the performance test under rain drop simulator followed by Method 2 for platform angle 0 °, 15 °and 30 °.

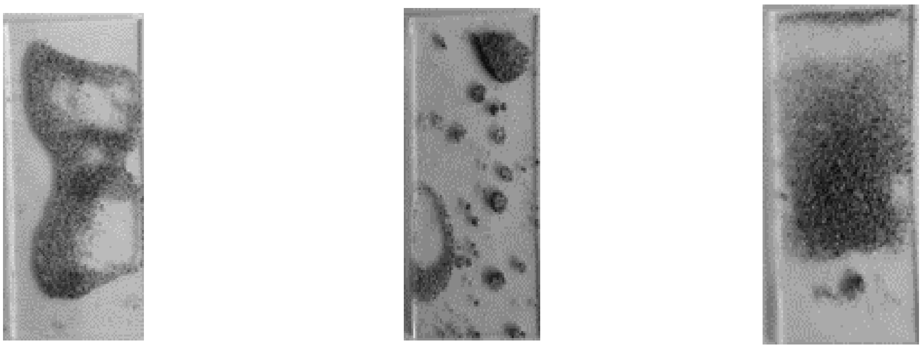
Platform Angle

0° 15° 30°

Coated Samples



Uncoated Samples



3.3 Transmittance and reflectance

Table 4. Transmittance and reflectance of glass samples before conducting the performance test.

Samples	**Transmittance (%)**	**Reflectance (%)**
Coated Glass	93.00	7.00
Uncoated Glass	91.00	9.00

The measured values of transmittance and reflectance of coated and uncoated glass samples after subjected to rain droplet simulator are listed in Table 4. The transmittance and reflectance are measured using UV-VIS Spectrophotometer operating wavelength 550 nm. The coated glass sample shows the high transmittance and low reflectance as compared to the uncoated glass sample, which infers that the hydrophobic coating maintain the transmission by allowing more radiation to transmit through the top layer of the glass. Table 5 presents the transmittance measurements of the coated and uncoated samples after being subjected to rain drop simulation test followed by Method 1 and Method 2.

Table 5. Transmittance measurements of coated and uncoated samples after subjected to rain droplet simulator.

Transmittance (%)						
Platform Angle	**0**		**15**		**30**	
Simulating Method	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
Coated Glass	90.97	79.56	91.77	85.99	91.98	87.75
Uncoated Glass	75.06	86.86	82.13	85.06	91.96	75.29

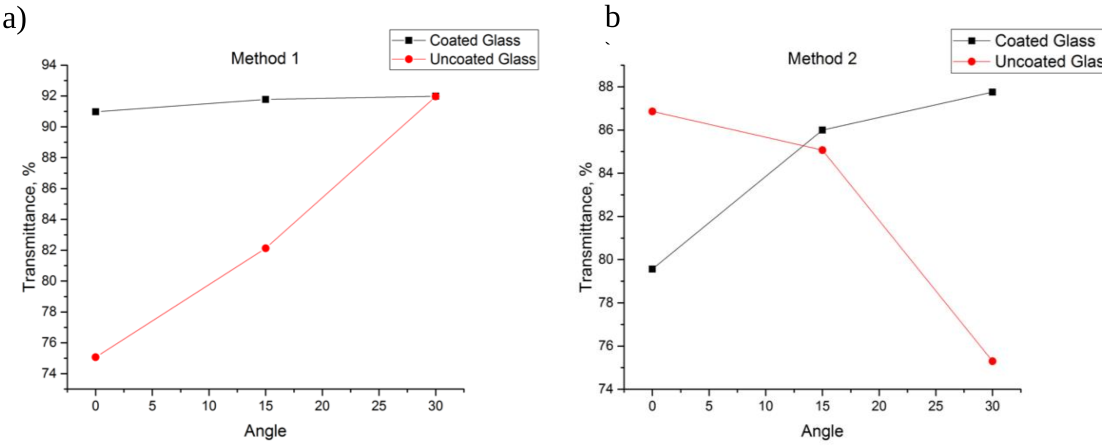


Fig. 2. Transmittance of coated and uncoated sample after subjected to performance test by a) Method 1 and b) Method 2.

Fig. 2 shows the transmittance percentage of coated and uncoated samples at three different angles subjected to performance test by Method 1 and Method 2 measured by UV-VIS Spectrophotometer at 550 nm. The hydrophobic coated glass in Method 1 have shown the highest transmittance as compared to the uncoated glass samples as shown in Fig. 2a. High value for transmittance is observed for inclination angle 30°, as the water is easier to roll off and washed away the sand particles from the surface. Meanwhile in Method 2, the transmittance of a coated glass is high for platform angle 30° due to the low energy surface of the coating which repelled the water and washed the dust particles. However, in case of uncoated glass samples, the sand particles tend to stick on the surface after being sprinkled on the glass due to the attraction forces from the left over water on glass surface.

Table 6. Reflectance measurements of coated and uncoated samples after subjected to rain droplet simulator.

Reflectance (%)						
Platform Angle	0		15		30	
Simulating Method	**Method 1**	**Method 2**	**Method 1**	**Method 2**	**Method 1**	**Method 2**
Coated Glass	8.81	10.73	8.15	9.06	7.94	8.99
Uncoated Glass	9.72	9.62	8.73	8.63	8.58	9.64

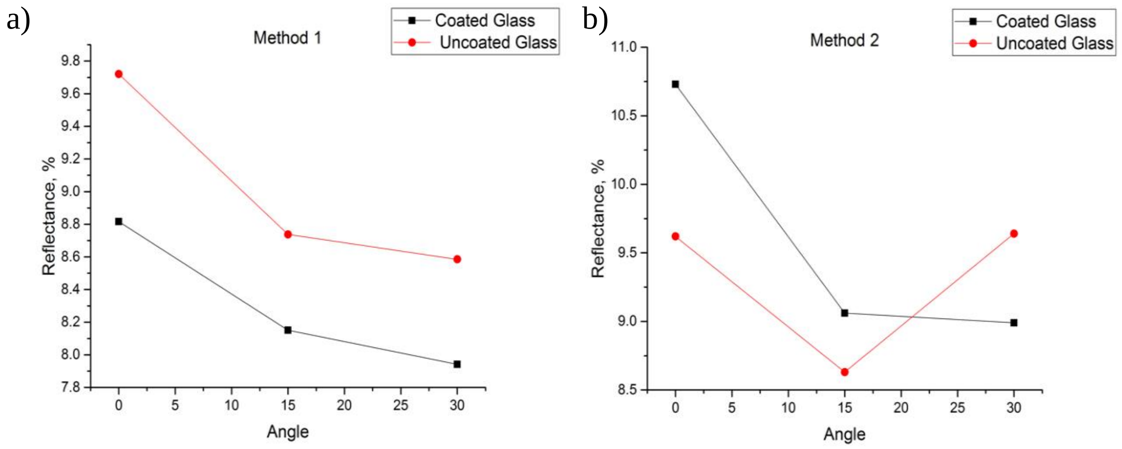


Fig. 3. Reflectance after the performance test for a) Method 1 and b) Method 2.

Fig. 3 shows the reflectance of coated and uncoated glass samples after being subjected to the rain droplet simulator performance test followed by Method 1 and Method 2. The reflectance of the samples is decreased as the platform angle is raised from 0° to 30°. The sand particles are washed away with water at higher platform angle, particularly for the Method 1. On the other hand, the high values for reflectance are observed for both coated and uncoated samples for Method 2 for low inclination angle. The lower values of the reflectance are obtained for the coated glass at higher inclination angle 30°, where water washes the sand particles from the glass substrate surface.

4. Conclusions

In this study, the self-cleaning hydrophobic coatings are deposited by applying simple wiping method. The deposited coating specify typical surface roughness and low surface energy which concede hydrophobicity such as high-water contact angle, self-cleaning capability and high transmittance.

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