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The Effect of Layering Superhydrophobic Coating On Its Transmittance, Durability and Self-Cleaning Properties

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Abstract: Two superhydrophobic solution were prepared onto the glass slides which were S Nano hydrophobic liquid repellent and DPRO super hydrophobic glass coating by using wipe method which the best option that can be used to apply on the glass substrate of the solar panel. The coated glass slides were characterized using Field Emission Scanning Electron Microscopy (FESEM), contact angle meter and UV-Vis spectrophotometer. Based on the characterization, all coatings show hydrophobic properties and the transmittance value is above 80% allowing light to pass through the glass. The water contact angle were in the range of 111º to 117 º while DPRO super hydrophobic glass coating was in range of 107 º to 108 º. For further characterization, the samples were tested for their durability through sandpaper abrasion. The coatings also shows that it was able to self-clean washed out all of the kaolin powder that lies on its path. The water contact angle of the coatings was analysed again by using in order to find out the coatings' durability. Based on the findings, both solution shows little changes after the sand paper abrasion test. However, the S Nano hydrophobic solution shows a slightly higher water contact angle showing a better hydrophobic property.

Keywords: Characterization Of Superhydrophobic Solution, Field Emission Scanning Electron Microscopy, Contact Angle Meter, UV-Vis Spectrophotometer

1. Introduction

Inspiration on a developing a technology for humankind benefits in their daily basis which comes from living things' characteristic or advantages, or from nature itself, in order to overcome their environment difficulties is not unusual nowadays. Superhydrophobic coating is also well-known to be related with living things.

For examples, the lotus leaf holds a huge secret in repelling the water by having few main characteristics, which the water that drops onto it will roll down with slight lifting due to its water contact angles. It is because the arrangement of micro or nanostructured of lotus leaf, and also low surface energy has contributed to the reason behind the non-wettability of the following living thing

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(Wang et al., 2009). This feature has open up a path for the researchers in attempts to study how to synthesize the surface structures and produces a superhydrophobic coating that can be used to clean up the solid surfaces from contamination such as dirt and dust on the surface of solar panel. This include manipulating the surface to mimic the surface of the hydrophobic surfaces found in nature.

There are a lot of research that has been conducted regarding the superhydrophobic coatings on the solar panel. The methods that have been used to exhibit the superhydrophobic characteristic on the surfaces are sol-gel method, spraying method, chemical etching, dip-coating or solution immersion method, spin coating method, dual layers method, chemical vapor deposition and calcination method (Rodríguez et al., 1989). All of the methods have their own advantages to be used to synthesise the substrate’s surface, while some has their specific conditions to be used to carry out the task.

This research attempts to analyse the ready-made superhydrophobic solutions. In particular, this research will be focused on the application for solar panel, hence the balance between the transmittance of the superhydrophobic coating and the ability for it to roll dirt will be the crucial to determine its suitability for the application. The durability of the coatings were tested with experiment of sandpaper abrasion.

2. Materials and Methods

Two sample which were S Nano hydrophobic liquid repellent and of DPRO super hydrophobic glass coating and were prepared on the glass slides using wipe method. The samples were characterized by Field Emission Scanning electron microscope, contact angle meter and UV-Vis spectrophotometer in order to study the surface morphology, the water contact angle of the coatings and the rate of transmittance of UV rays.

2.1 Chemicals and Apparatus

The ready-made solutions that used to prepare the samples were S Nano hydrophobic liquid repellent and of DPRO super hydrophobic glass coating. furthermore, the apparatus and chemical that used Decon 90, microfiber cloth, bulb blower, beaker, tweezer, and distilled water.

2.2 Methods

The glass slides were first cleaned by using Decon 90. First, clean all the glass slides with tissue. Then, mix decon 90 with distilled water in a beaker with a ratio of ¼ : 1. The cleaned glass slide was immersed into the solution for 3 minutes. Next, the glass slide was taken out with a tweezer and cleaned with tissue and washed under running water. After that, the glass slide was immersed into a beaker contained distilled water for a minute. Lastly, the glass slide was taken out with tweezer and cleaned with tissue and bulb blower. The procedures were repeated for other glass slides.

The samples were prepared by wipe method. Use bulb blower to remove any dust on the cleaned glass slide to ensure its cleanness. Put the glass slide onto the prepared container to hold the glass slide. Sprayed/dripped the solution corresponding to their suitable method. Then, wipe the solution onto the placed glass slide until the water droplet of the solution was dried. Let the coated glass slide to dried in room temperature for two days. Repeat the following steps above for both solutions respectively to their assigned layers. Meanwhile, the surface morphology of the samples was studied using field emission scanning electron microscope. The transmittance of the samples was determined by using UV-Vis spectrophotometer and the water contact angle of the sample were analysed by using contact angle meter and later on were used again to determine the durability of the samples.

Since the solar panel are left at the open, there will be a lot of small grains of sand that carried by the wind will hit it and causing some damages to the coatings. Thus, this experiment is tested further by undergo the coated glass slides with sandpaper abrasion test. The method of sandpaper abrasion test is by placing the glass substrate that are loaded with 40 g weight and will be placed on the sandpaper with numbers of grit which is 800 grit silicon carbide sandpaper and move at a constant speed for 10 cm. The samples were then characterized again to see the effect of the test onto the characteristics of the coating.

3. Results and Discussion

The transmittance is defined as the ratio of the light passing through to the substrate and the light that has been reflected. In other words, transmittance is the capability of the amount of light to passes through a transparent material. Thus, it is important to find out the transparency of the coated glass slides in order to determine the effectiveness of coatings to let the light passing through especially when applied on solar panel, which the rate of transmittance playing an important part in the efficiency of solar panel to produce energy. Thus, to observe the transmittance of the coatings, Ultraviolet-visible (UV–Vis) spectrophotometer is being used to find out the transparency of the coatings. Figure 1 and Figure 2 Below were the results that been obtained from both types of solutions used on the coated slides. The results also included with a data of clean glass slide to show the rate of transmittance clearer.

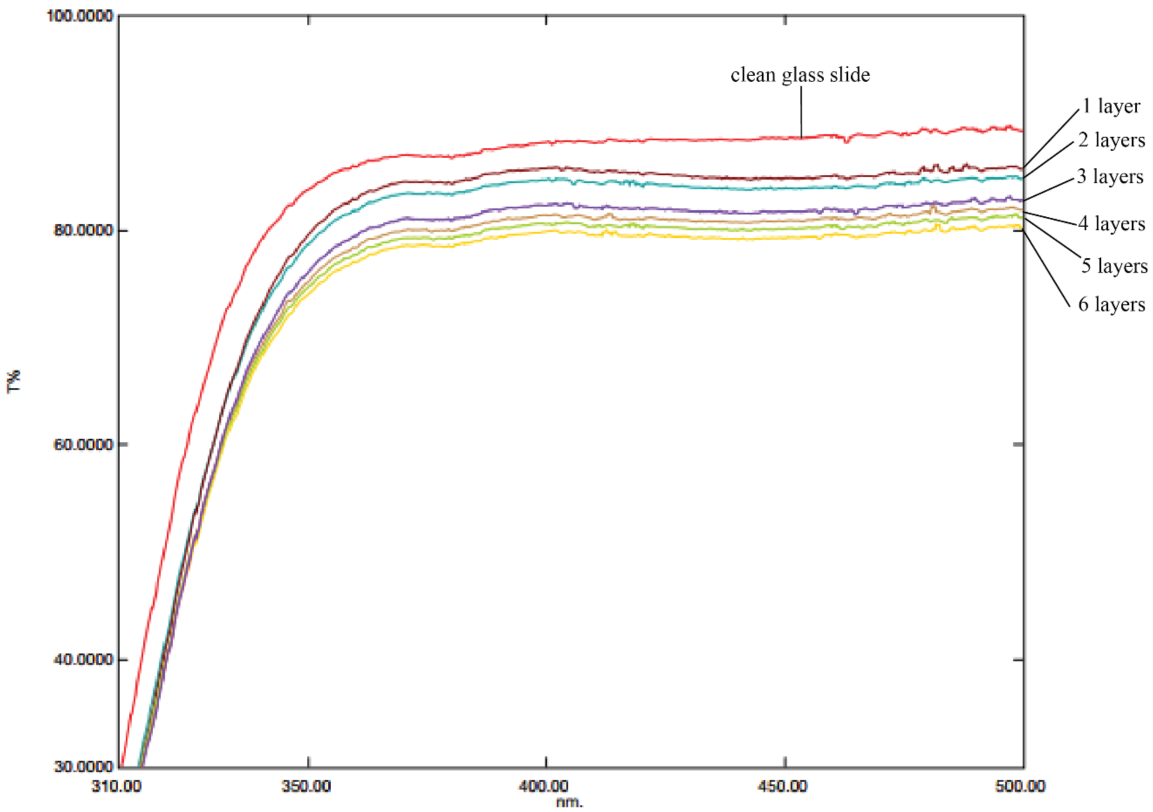

Figure 1: UV-Vis spectrophotometer results for DPRO Super Hydrophobic Glass Coating Ceramic Window Coating solutions' coated glass slides.

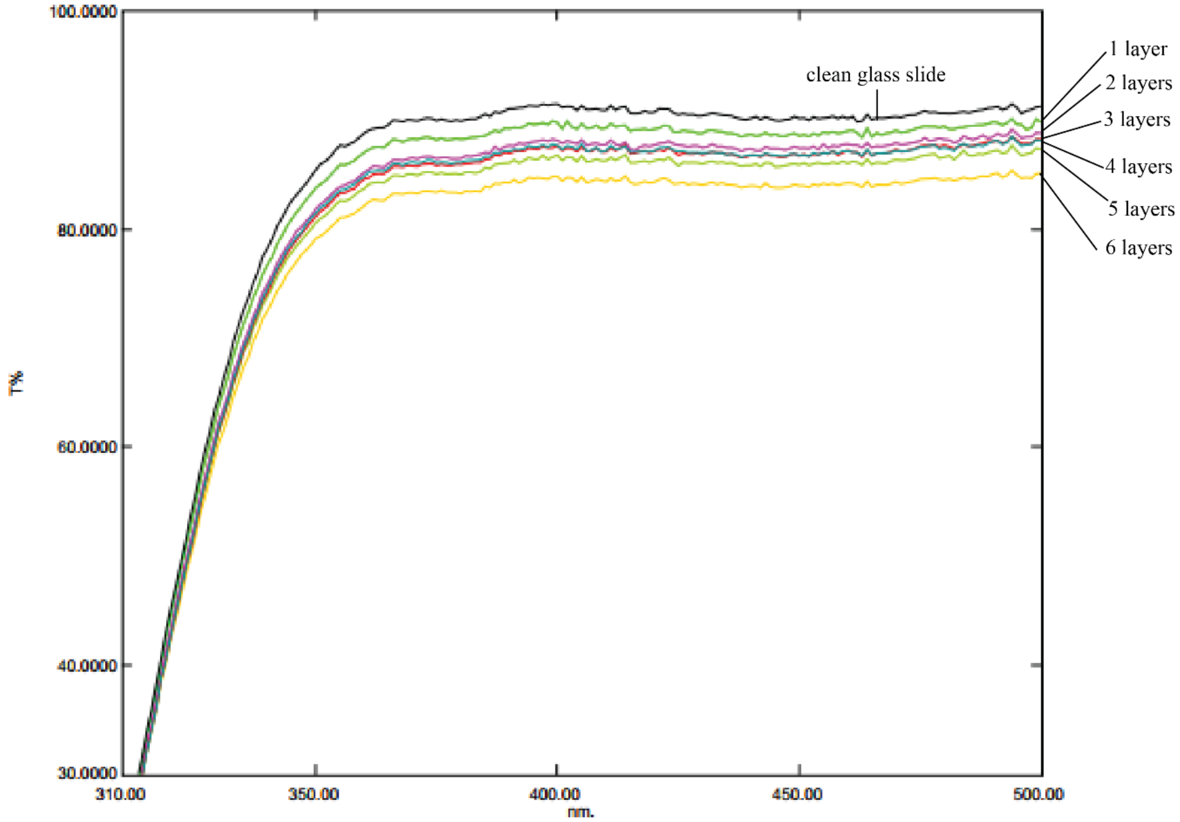

Figure 2: UV-Vis spectrophotometer results for S Nano Hydrophobic Liquid Repellent solutions' coated glass slides.

The presence of UV radiations is important since solar panels are made up of photovoltaic cells, which respond to UV rays to electric. Each cell is made up of silicon-conduction materials, which are extremely reactive to sunlight. The protons from the sun's rays allow electrons to escape from the silicon atoms, generating electricity.

As we can see from the results obtained above both coatings have ultraviolet (UV) light resistance since the UV-VIS spectrophotometer uses ultraviolet light to determine the absorbency or transmittance of a substance. The rate of transmittance of the coatings can be differentiate with the presence of clean glass slide which can be seen in each data above.

The data that obtained in both solutions shows decreased rate of transmittance of UV light as the number of layering increases. The differences of rate of transmittance between clean glass slides and coating is bigger at data of DPRO super hydrophobic glass coating than at the data of S Nano hydrophobic liquid repellent. This following observation can be stated as the of DPRO super hydrophobic glass coating has lower rate of transmittance that S Nano hydrophobic liquid repellent.

Figure 3, 4, 5 and 6 shows the images obtained by field emission scanning electron microscope (FESEM) at different magnifications which confirms the rough and porous microstructure that are originated from the accumulated silica nanoparticles.

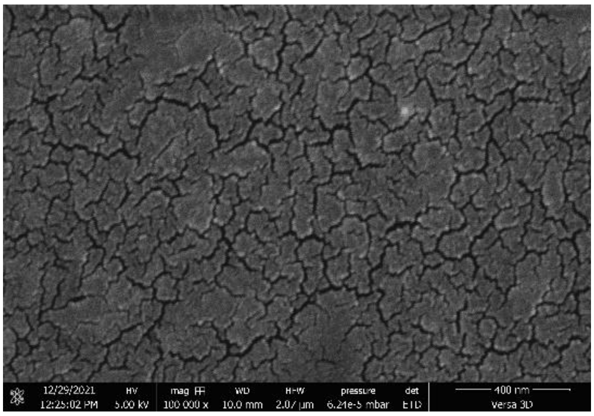

Figure 3: a surface morphology of S Nano hydrophobic liquid repellent at 100000x of magnification

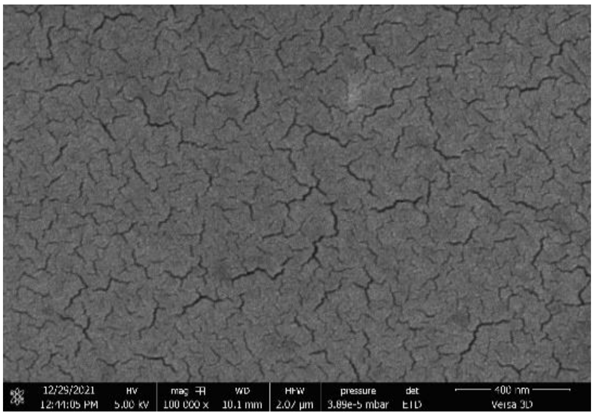

Figure 4: a surface morphology of DPRO super hydrophobic glass coating 100000x of magnification

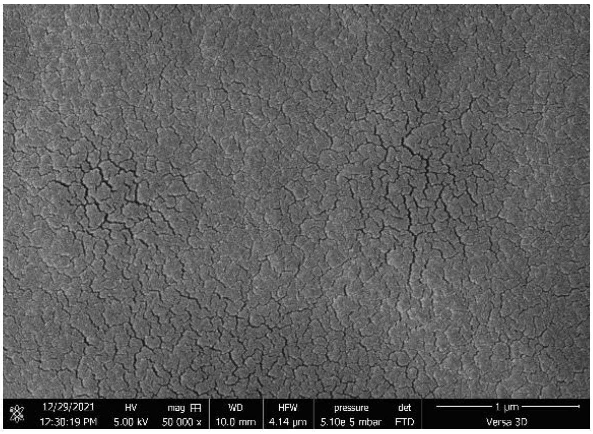

Figure 5: a surface morphology of S Nano hydrophobic liquid repellent at 50 000x of magnification.

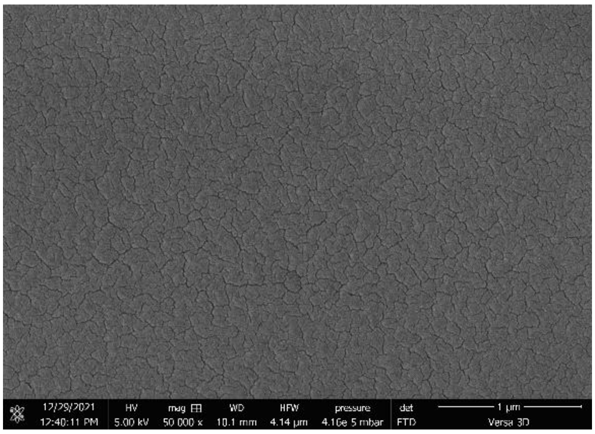

Figure 6: a surface morphology of DPRO super hydrophobic glass coating at 50 000x of magnification.

Based on the images that obtained above, both of the coatings have proven the rough and porousness microstructure, but from figure 3 and figure 4, it can be seen that S Nano hydrophobic liquid repellent has rougher surface than DPRO super hydrophobic glass coating. The trapped air between the rough microstructure and been pressure that exerted by the weight of water droplet that cause the extreme non–wettability of the superhydrophobic silica coatings. Both coatings have almost the same morphology, but the differences can be seen where S Nano hydrophobic liquid repellent has wide and long “air pocket” while DPRO super hydrophobic glass coating has thin and small “air pocket” which this discovery led to the differences of the value obtained for the water contact angle.

This following “air pocket” is one of the most crucial characteristics of a hydrophobic surface. This statement is supported with a model that are still used nowadays which is Cassie-Baxter model. Cassie-Baxter model stated that as a water droplet has fall onto the surface, the water droplet stays on the hierarchical structures, where the trapped are will causing the adhesion of water droplet with the surface decreased.

As for figure 7 and 8, were the images of water contact angle, respectively to their coating. In order to obtain an accurate reading of water droplet’s contact angles, the amount of testing was conducted and recorded for three times on the random positions on the glass slide respectively, and the mean were used as the final value for water contact angle by using contact angle meter

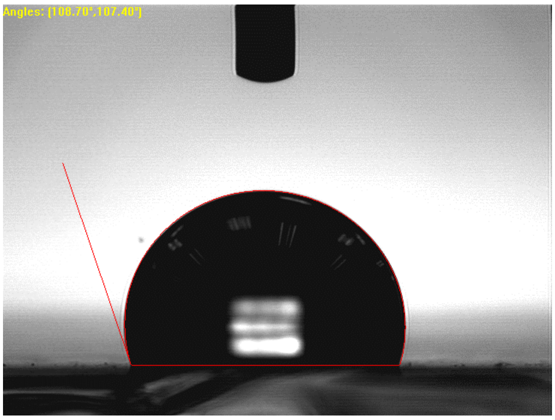

Figure 7: an image of water contact angle of DPRO super hydrophobic glass coating for four (4) layers of coatings.

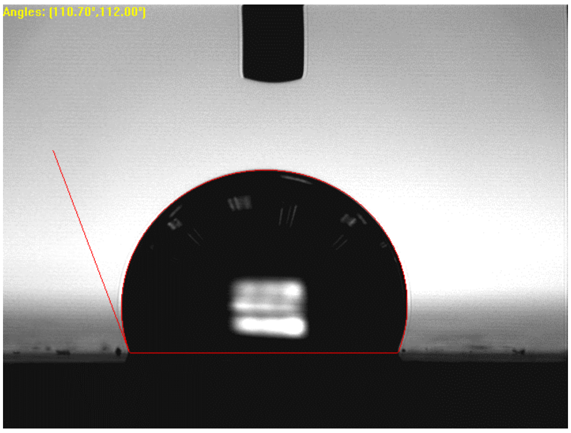

Figure :8 an image of water contact angle for S Nano hydrophobic liquid repellent for four (4) layers of coatings.

Table 1: The water contact angle obtained from the coated glass slides.

Type of solution	Number of layers	1^{ST} measurement / °	2^{ND} measurement / °	3^{RD} measurement / °	Mean of final reading / °
DPRO super hydrophobic glass coating	2	104.50	109.50	107.40	107.13
	4	106.70	108.70	106.30	107.23
	6	106.20	109.80	106.80	107.60
S Nano Hydrophobic Liquid Repellent	2	118.20	118.60	111.70	116.17
	4	106.40	110.70	116.20	111.10
	6	115.80	114.90	113.70	114.80

Based on the table above, we can see that the results that has been obtained from the experiment were above 90°. Referred from Table 1, it is safe to say that both types of solutions can be classified as hydrophobic. As for the effect of layering, the mean of the measurement for the water contact angle for each prepared layer shows an increase for both the DPRO super hydrophobic glass coating and as for the S Nano hydrophobic liquid repellent. However, there is a decrease in the transmittance as the layers increases as shown earlier in the UV-Vis spectroscopy result.

The reason of the non-uniformed data that has been obtained for S Nano Hydrophobic Liquid Repellent may be due to the unevenness of the coating applied on the slides thus reduced the effectiveness of the coating to act onto the water droplet.

Figure 9, 10 and 11 shows the images of the self-cleaning test. The powder was used to see the effect of superhydrophobic was kaolin that has a characteristic of hydrophilic. A water has been pushed out from a syringe easily washed away all the kaolin powder that lying on its path which proving the effectiveness of self-cleaning properties of the hydrophobic coating.

Figure 9: an image of clean glass slides

Figure 10: an image of glass slide coated DPRO super hydrophobic glass coating

Figure 11: an image of glass slide coated with S Nano hydrophobic liquid repellent

Based on the results that has been obtained above, at the path of the water droplet, it can be seen that there are remained kaolin on the clean glass slide whereas for both coated glass slides, the are no remaining on the coated glass slides, after flowing the water with a syringe. From here, it is clearly can be seen that the effect of superhydrophobic is acting onto the water. Since the surface of the coated surface contain air pocket due to the surface's morphology of the coating, the water droplet will strengthen the hydrophobicity due to the state of the water droplet that sit to a certain degree on the trapped air and cause the adhesion of water droplet with the surface reduced.

3.1 Durability test

After the sandpaper abrasion, the samples were analysed again to see the effect of the abrasion on the characteristic of the coating. From the naked eye observation, there are some tiny grain of black sands has stick onto the surface of the coating and some tiny straight lines has appeared on the coating when the glass slide was faced toward a source of light such as sunlight. Nonetheless these were only marks caused by the abrasion and can easily be blown away from the surface.

For the self-cleaning test, the self-cleaning properties were still observed with clean track for both of the solution. This can be observed in Figure 15 and 16.

Figure 15: an image of glass slide coated with DPRO super hydrophobic glass coating

Figure 16: an image of glass slide coated with S Nano hydrophobic liquid repellent

Contact angle test were repeated in order to find out the changes of water contact angle of the coating after undergoes the durability test. Figure 13 and 14 shows the contact angle measured for both of the coating solutions and Table 2 shows the values for different areas on the surface and the average mean value for the water contact angle.

Based on the table, the results that has been obtained from the experiment were still above 90º, as the samples are still in the hydrophobic region. As for the pattern of layering effect, the mean of the measurement for each prepared layer increased for the DPRO Super Hydrophobic Glass Coating Ceramic Coating and as for the S Nano Hydrophobic Liquid Repellent, the mean of the measurement is decreased at 4 coating layers and increased at 6 coating layers, which does not change the pattern of the data that can be seen from the table 1.

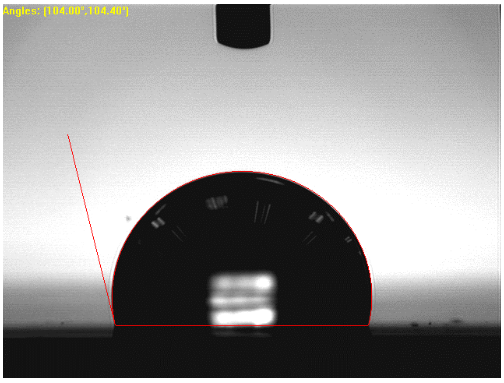

Figure 13: an image of water contact angle of DPRO super hydrophobic glass coating for four (4) layers of coatings.

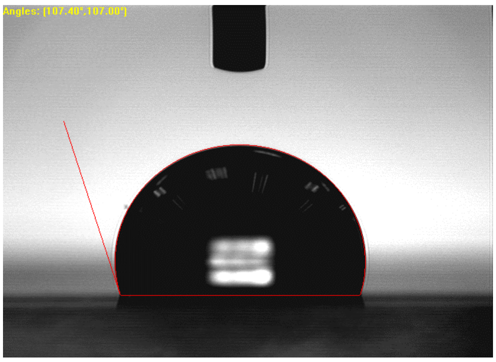

Figure 14: an image of water contact angle of S Nano hydrophobic liquid repellent for four (4) layers of coatings.

Table 2: The water contact angle obtained from the coated glass slides after samples undergo durability test

Type of solution	Number of layers	1ST measurement / º	2ND measurement / º	3RD measurement / º	Mean of final reading / º
DPRO super hydrophobic glass coating	2	103.30	101.70	102.80	102.16
	4	105.20	104.00	104.30	104.50
	6	108.50	107.10	103.70	106.43
S Nano Hydrophobic Liquid Repellent	2	107.60	108.30	111.40	109.10
	4	111.00	110.40	107.40	108.60
	6	113.30	116.40	116.80	115.50

4. Conclusion

The research intends to investigate the effect of layering superhydrophobic coating on its transparency, durability self-cleaning properties, classifications of surfaces, water contact angle and surface morphology between two solutions by using wipe method. Hence below are the comparison of the results obtained.

Both solutions have shown some satisfying results relating with the effectiveness of the solutions to maintain the durability and cleanliness of the glass slides which an indicator to applied onto the glass substrate that will be placed onto the solar panel. In the end, a decision must be made to choose the best solution that can be used to be applied on the glass substrate of the solar panel. From the result, it can be concluded that the best solution to be use is S Nano hydrophobic liquid repellent due to higher water contact angle, self-cleaning properties and high transparency.

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