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Fabrication of Superhydrophobic Modified-Polyurethane Coatings for Outdoor Insulators

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Abstract **-** This study proposes a novel coating to enhance the reliability of electrical transmission systems. Environmental contamination of outdoor insulation surfaces leads to the puncture of insulators and heavy loss due to power outage in the transmission line. The water droplet on superhydrophobic coatings can pick up dirt particles and remove contamination from the surface of insulators due to the easy cleaning property of these coatings. Fabricated superhydrophobic coating in this paper has contact angles higher than 150° and CAH (Contact Angle Hysteresis) less than 10 degrees. This coating indicated good rubbing durability and there was not any contamination on the surface of coating after immersion in polluted water by Kaolin.

Keywords: Insulators, Nanosilica, Organosilane, Polyurethane, Superhydrophobic Coating.

1. Introduction

During wet days, environmental contaminants such as costal salt water and cement dust found in industrial settings on outdoor insulators can reduce the reliability of electric transmission systems. Different technologies have been employed in the industry to mitigate the surface of insulators. Room Temperature Vulcanized (RTV) silicone rubber coating that has good dielectric and chemical property and can retain water hydrophobicity has indicated better performance than other methods [1-2].In spite of the significant properties of these coatings, they cannot prevent the accumulation of dust and cannot reduce ice adhesion on surfaces. Also, RTV silicone rubber has high cost and its processing is difficult because of its sensitivity to moisture [3].

Superhydrophobic coatings that have contact angles higher than 150° and CAH less than 10° can eliminate contaminations much more effectively due to their easy cleaning property. Water droplets on these surfaces can pick up dirt particles. The combination of nano/micro structure with low surface energy material is needed for making a superhydrophobic surface. RTV silicone rubber superhydrophobic coatings have been recently fabricated [4-6]. Seyedmehdi et al. [5] made RTV superhydrophobic coating from nanosilica, ATH (aluminum trihydroxide) and hydrophobic fluoric particles. The final coating indicated contact angle higher than 150° and sliding angle less than 5°. Farzaneh et al. [6] prepared RTV superhydrophobic coating from nano titanium dioxide that had contact angles higher than 150° and CAH less than 8°. Formulated silicone rubber superhydrophobic coatings still have a high cost and processing problem due to the usage of RTV silicone rubber. This study demonstrates the development of superhydrophobic modified-polyurethane coating by organosilane that has contact angle higher than 150°, CAH less than 10°, low cost and easy processing.

2. Materials and Methods

Superhydrophobic modified-polyurethane coating was made from Polyol (Desmophen A870, Covestro), Nanosilica (Aerosil RX-50, Degussa), Organosilane (Silmer Q20, Siltech), Hardener (Desmodure N-75, Covestro) and solvents. The concentration of nanosilica was 2, 4, 6, 8 and 10wt% in each formulation, respectively. Also, the concentration of organosilane was kept at 1wt% in all formulations. The used organosilane includes methoxy groups which are hydrolyzed and will be reacted with the hydroxyl group on nanosilica surfaces. The hydrolysis reaction of the methoxy group can be catalyzed using an acid (PH: 4). Polyol and hardener used in this study have been utilized for industrial paints and have lower cost compared with RTV silicone rubber.

For preparing superhydrophobic coatings, two different solutions were prepared. The first solution contained nanosilica and ethanol while the second solution included organosilane, ethanol and distilled water. The resin, ethanol and water were mixed in a different container in order to hydrolyze initially the organosilane. Then, solution 2 was added to solution 1 to form solution 3. The mixture of polyol, hardener and solvent is added to solution 3 and the final coating is applied on ceramic tile (7.5x3.5cm) by a spray gun. The coated substrate was then heat treated at 100º C for 30 min.

Contact angle and CAH were employed to directly assess the hydrophobicity of coatings. CAH indicates droplet mobility on a surface and is the difference between maximum (from advancing process) and minimum (from receding process) contact angles [7]. The CAH of three different points on the coatings were measured and their averages were reported. The mechanical durability of the coatings was evaluated by sandpaper (400 grids). In this method, the surface was moved in one direction (horizontal) on sandpaper while a pressure (~3,450 Pa) was applied normal to the superhydrophobic coating. The surface was slowly dragged on the sandpaper [8]. To evaluate the accumulation of dust on the surface of superhydrophobic coatings, a small insulator (half coated) was immersed in polluted water by Kaolin (10wt %).

3. Results and Discussion

The results of wetting tests, rubbing durability and dust contamination are discussed in this section. The wetting test confirmed that the fabricated coating is superhydrophobic. The durability test showed the level of robustness of coating against mechanical rubbing and the polluted water test indicated that superhydophobic coating could remove dust from the surface of outdoor insulators.

Figure 1 shows the advancing and receding contact angles for water plotted against nanosilica concentrations. This indicates that the CAH of coatings will be reduced by increasing nanosilica. There are not many significant differences between the CAH of coatings with nanosilica concentration higher than 8. Hence, we can conclude that the minimum required nanosilica concentration to obtain desired surface roughness is when nanosilica concentration is ≥ 8. The water drops on coatings with CAH less than 10 degrees can easily roll off from the surface [6].

The results of mechanical durability tests are shown, in Figure 2 (in this graph only CAH was employed to compare the wettability). This test was performed on coatings that have advancing contact angles higher than 145º. The changes in the CAH of coatings with nanosilica ≥ 8 are at a level that can be considered acceptable for a tough sand paper mechanical durability test. Only superhydrophobic coatings (CAH less than 10 degrees) could pass this test.

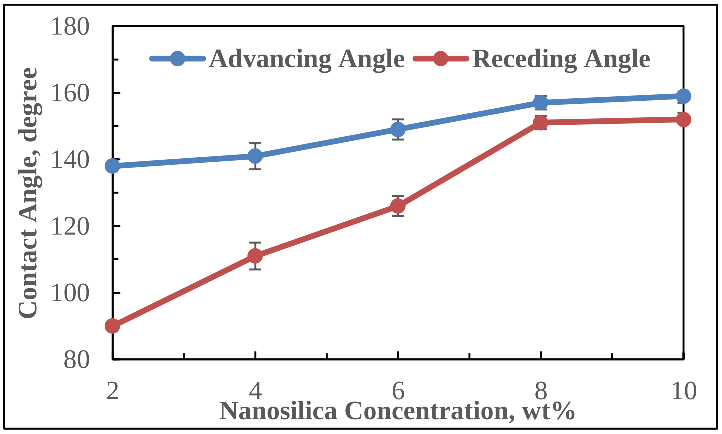

Fig. 1: Advancing and receding contact angles versus nanosilica concentration.

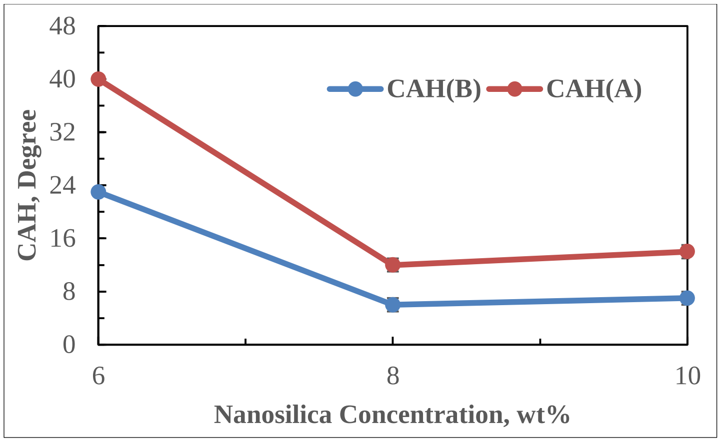

Fig. 2: CAH for coated samples versus nanosilica concentration (legends (A) means After; (B) means Before).

Figure 3 indicates the insulator that was removed from polluted water by kaolin (only coating with 8wt% nanosilica utilized in this test). The left side of the insulator was coated by the superhydrophobic coating (the coating is semi-transparent) and the right side was not coated. As it can be seen, the non-coated side was covered by contaminants while there was not anything on the side coated by superhydrophobic coatings.

4. Conclusion

A method was developed to fabricate modified-polyuretahne superhydrophobic coating to prevent the accumulation of dust on outdoor insulators. Increasing the nanosilica concentration could raise the contact angle of the final coating. The best CAH was attained at 8wt% nanosilica. Also, superhydrophobic coating with CAH less than 10 degrees could pass mechanical durability. There was not any contamination on the insulator coated by superhydrophobic coating when it was immersed in the polluted water. The results of this study showed that superhydrophobic polyurethane coating is a good candidate for the coating of outdoor insulators. However, the UV durability and electrical properties of these coatings should be evaluated in the next step of this research.

Fig. 3: The insulator that was immersed in the polluted water.

References

[1] E. A. Cherney and R. S. Gourer, “RTV silicone rubber coatings for outdoor insulator,” *IEEE Trans. Dielectr. Electr.Insul.*, vol. 5, pp. 605-609, 1999.
[2] R. Hackam, “Low-Molecular weight silicone fluid in RTV silicone rubber coatings,” *IEEE Trans. Dielect. Elect. Insul*, vol. 6, no. 1, pp. 84-94, 1999.
[3] J. Li, L. Fan and C. Wong, “Insulator coating and method for forming same,” U.S. Patent 7 722 951, May 25, 2010.

[4] M. Ma and R.M. Hill, “Superhydrophobic surfaces,” *Curr. Opin. Colloid Interface Sci*., vol.11, pp. 193-201, 2006.

[5] S. A. Seyedmehdi, J. Zhu, H. Zhang, "Superhydrophobic RTV silicone rubber insulator coatings," *Appl. Surf. Sci*, vol. 258, pp. 2972-2976, 2012.

[6] M. Farzaneh, S. A. Kulinich and F. Arianpour, "Hydrophobic and ice-retarding properties of doped silicone rubber coatings," *Appl. Surf. Sci*, vol. 265, pp. 546-552, 2013.

[7] E. Bormashenko, Y. Bormashenko and G. Whyman, “Contact angle hysteresis on polymer substrates established with various experimental techniques,” *Langmuir*, vol. 24, pp. 4020-4032, 2008.

[8] Y. Xiu, Y.Liu and D. Hess, “Mechanically robust superhydrophobicity on hierarchically structured Si surfaces,” *Nanotechnol*., vol.21, pp. 155705-09, 2010.