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Ian Emge, Leslie Scheurer, Ryan Grant, Narasimha Prasad, Lisa Kelly, Bradley Arnold, Fow-Sen Choa, Brett Setera, N. B. Singh, "Surface characteristics of polymer nanocomposites," Proc. SPIE 11757, Smart Biomedical and Physiological Sensor Technology XVIII, 117570X (12 April 2021); doi: 10.1117/12.2585834

SPIE.

Event: SPIE Defense + Commercial Sensing, 2021, Online Only

Surface Characteristics of Polymer Nanocomposites

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ABSTRACT

The performance of optical and electronic detectors and sensors are affected by surface and bulk impurities. In some cases, nanoscale thin films are used as detectors and their life cycle is significantly decreased. In the case of conformal shapes, surfaces with different polishing, decoration and geometries exhibit unusual wetting and nucleation characteristics for impurities and this requires continuous attention for cleaning. The situation for space borne components and vehicles surfaces exposed to wetting liquids requires remote cleaning. In the present paper, we report the effect of surface topographies of substrates with nanoengineered titanium oxide and copper oxide nanoparticles embodied in polystyrene and study the effect of the composites to create different hydrophobic characteristics with great potential for detectors and sensors operating in ultra-violet and infrared regions.

1. BACKGROUND

There is a strong need to understand the fluid flow on surfaces decorated with complex geometries exhibiting unusual wetting properties. The surface of even a moderately hydrophobic material can become highly water repellent [1-3] when decorated with a pattern of microscopic pillars. These water repellent properties are known as the *lotus effect*, which was named after the water repellent and self-cleaning properties of leaves of the lotus plant as its surface is covered in these pillars. This term has been adapted to numerous technological products and more specifically for coatings. For ground and space borne vehicles surfaces that are exposed to a partially or fully wetting liquid, surfaces equipped with complex topographies display a rich variety of liquid interfacial morphologies. This paper reports the results of the effect of copper and titanium oxide nanoparticles on the lotus effect performance of a polymer. The contact angles were measured to determine this effect.

2. EXPERIMENTAL METHOD AND RESULTS

To prepare the polymer a 70/30 % mixture of polymethylmethacrylate (PMMA) to polystyrene (PS) was added to 70 mL of solvent. For the test performed, an average of 4.5 grams of PMMA and 2.2 g of Polystyrene was added to this 70ml of solvent. For the first batch of the polymer created toluene was used as the solvent, while later batches utilized tetrahydrofuran (THF) as the solvent.

To create the polymer the PMMA and PS were added to the solvent and mixed at 65 °C for 2 hours or until both the PMMA and PS were mixed fully and there was no visible PMMA or PS present in the solution for at least 15 minutes. This process was done by using a hot plate with a magnetic stir rod to heat and agitate the solution which was held in a glass beaker with a thermometer suspended into the solvent. After mixing, 20 mL of the polymer solution was poured into a smaller beaker and an oxide was introduced into the solvent. For the first 3 batches of polymer created, Titanium Oxide (TiO₂) was added and for the second 3 batches, Copper Oxide (CuO) was added to the polymer. On average, 0.05 grams of either titanium or copper oxide was added to 20 ml of the polymer solution.

Once the 0.05 grams of oxide were added to the solution, it was then left to stir for 2 hours to ensure that the oxide was thoroughly and evenly mixed throughout the solution. Once this was done, the solution was ready to be applied to the slides. This was done by using a spin coating machine with a custom 3D printed insert to hold the microscope slides.

To create the coated slides, 6 glass microscope slides were cleaned thoroughly to ensure the polymer would adhere well. Slides were placed one at a time into the holder and taped from the underside to hold it in place so that the top of the slide would be clean, unobstructed, and could be coated completely. 1 ml of solution was measured into a pipette and then applied to the slide so that it would cover as much of the top surface of the slide as possible. The slides were spin coated at 200 rpm for 18 seconds and then 2000 rpm for 90 seconds. This procedure was repeated three times for the polymer coating without any oxide and three times for the polymer coating with each oxide, producing nine total sample slides.

Each set of slides was treated in a different way: one set was left out to air dry, another was washed with 60 °C Cyclohexane and then left to air dry, and the last set of slides was annealed at 170°C. Once all the slides were treated, they were then left to sit overnight before testing was done.

After the slides were left to sit for a day, they were tested in a custom set up that consisted of a microscope connected to a laptop as shown in **Figure 1**. The microscope was set up so that it would view the edge of the glass slide and see the side view of a drop that was placed on the slide. An example microscope image can be seen in **Figure 2**. To help improve the image of the droplet a backlight was set up to shine through a piece of paper to diffuse the light around the droplet and improve the contrast. A mounted pipet was used to drop the test droplets on the slide so that a consistent height was achieved for testing.

Figure 1: Experimental set up of the microscope to measure the contact angles of the slides

10 microliters of water was measured into the pipet and the pipet was mounted 6 mm from the glass slide. The pipette was emptied onto the glass slide and a side view image of the slide was taken using the microscope. This process was repeated three times for each slide. The images [Figure 2] were converted into grayscale using *PhotoScape* software and analyzed using *ImageJ* software with an extension called *Drop Analysis* to measure the contact angles. The averages of the left and right contact angles were used as an overall result, as shown in **Tables 1** and **2**. The shape did not show any significant anisotropy [4] observed.

Figure 2: Image of a 10 microliter droplet on a treated slide

The data in Tables 1 and 2 show that there was no significant difference in the measured contact angle of any of the slides either with or without the oxides in them. However, among the three methods used to treat the slides, it was noted that the slides that were washed with cyclohexane did on average have a contact angle that was a few degrees higher than the rest. It should be noted that over all the hydrophobicity of the glass slides was greatly increased as the contact angle changed from an average of around 23 degrees for slides that were not treated to an average of around 73 to 90 degrees for the slides that were treated with the polymer.

ACKNOWLEDGMENTS

I would like to thank the NASA Langley Research Center for the opportunity to work with them as in intern on this research project. I would also like to extend a special thank you to Dr Narasimha Prasad from the NASA Langley Research Center, as well we as Dr N. B. Singh and Dr Bradley Arnold from UMBC for all their help, support, and guidance with the project as well.

3. SUMMARY

Effect of surface topographies of substrates with nanoengineered titanium oxide and copper oxide nanoparticles embodied in polystyrene are reported. A study to understand the effect of the composites to create different hydrophobic characteristics with great potential for detectors and sensors operating in ultra-violet and infrared regions was performed. This study is continuing to determine contact angle for other substrates as well.

Table 1: Average contact angles for different solvents based on TiO₂ composites

Solvent used in composite	Average contact angle (°)
Toluene	80.2
THF (air dried)	83.6
THF (treated with cyclohexane)	89.0

Table 2: Average contact angles for different solvents based CuO nanoparticle filled composites

Solvent used in composite	Average contact angle (°)
Toluene	93.9
THF (air dried)	82.5
THF (treated with cyclohexane)	88.5

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