Master's Thesis Engineering Technology

2022-2023

Optimizing ultrasonic spray coating for depositing a superhydrophobic coating with PVDF and nanoparticles

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Introduction

In industry, manufactured products are furnished with coatings that confer positive attributes upon the product. Typically, an **air spray system**, such as an air spray gun, is employed to administer a coating. The procedure entails subjecting the liquid coating to a gas of high pressure, generally ranging between 15 and 50 psi. This results in the coating being expelled from the apparatus at a high velocity. Subsequently, upon exiting the device, the coating experiences deceleration due to air resistance, leading to the formation of small droplets that eventually lead to a mist before settling on the substrate. If the coating only contains **PVDF** a maximum contact angle of **± 100°** is obtained with good adhesion, making the surface hydrophobic.

Problem

The use of an air spray system results in a suboptimal outcome, as only 25-50% of the dispersed coating liquid effectively reaches the intended substrate, leading to an unwanted **increase in material cost**. This inefficiency is primarily due to the imprecise direction of the coating onto the substrate and the occurrence of bounce-back. The latter happens when droplets land on the substrate too quickly, bouncing off the surface and generating environmental waste. Furthermore, this method generates **droplets of varying sizes**, ranging from 0 to 130 µm. **PVDF falls short of achieving superhydrophobic properties** (>150°). Consequently, the absence of a self-purifying effect on the surface layer leads to the accumulation of impurities. Moreover, increasing the contact angle should be accompanied without a major loss of adhesion.

Objective

In order to achieve a uniformly coated surface that fulfills the requirements for **superhydrophobicity**, characterized by a minimum water contact angle of 150°, it is crucial to conduct research focused on enhancing this contact angle through the **incorporation of silica particles** within the coating. This will be achieved by utilizing an **ultrasonic spray system** for the deposition of these particles. Various types of silica particles are being considered as part of this research.. Moreover, it is essential for the final coating to demonstrate long-term **durability** in tape tests. Additionally, the coating should effectively **prevent the accumulation of impurities** when subjected to rinsing with demineralized water.

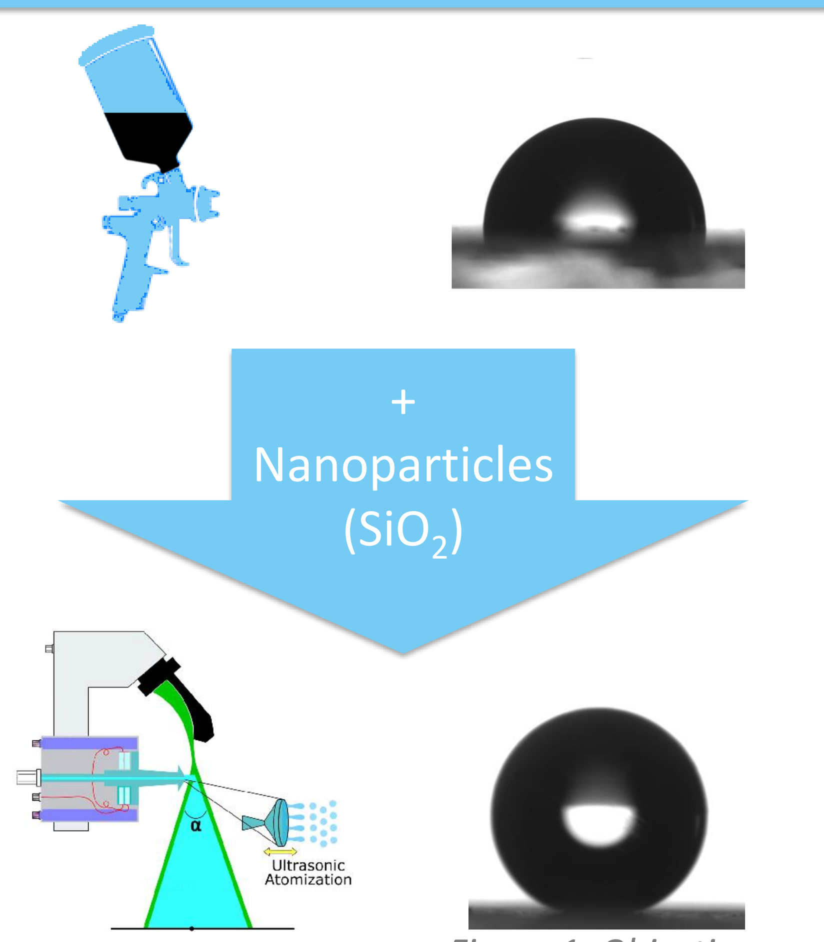

Figure 1: Objective

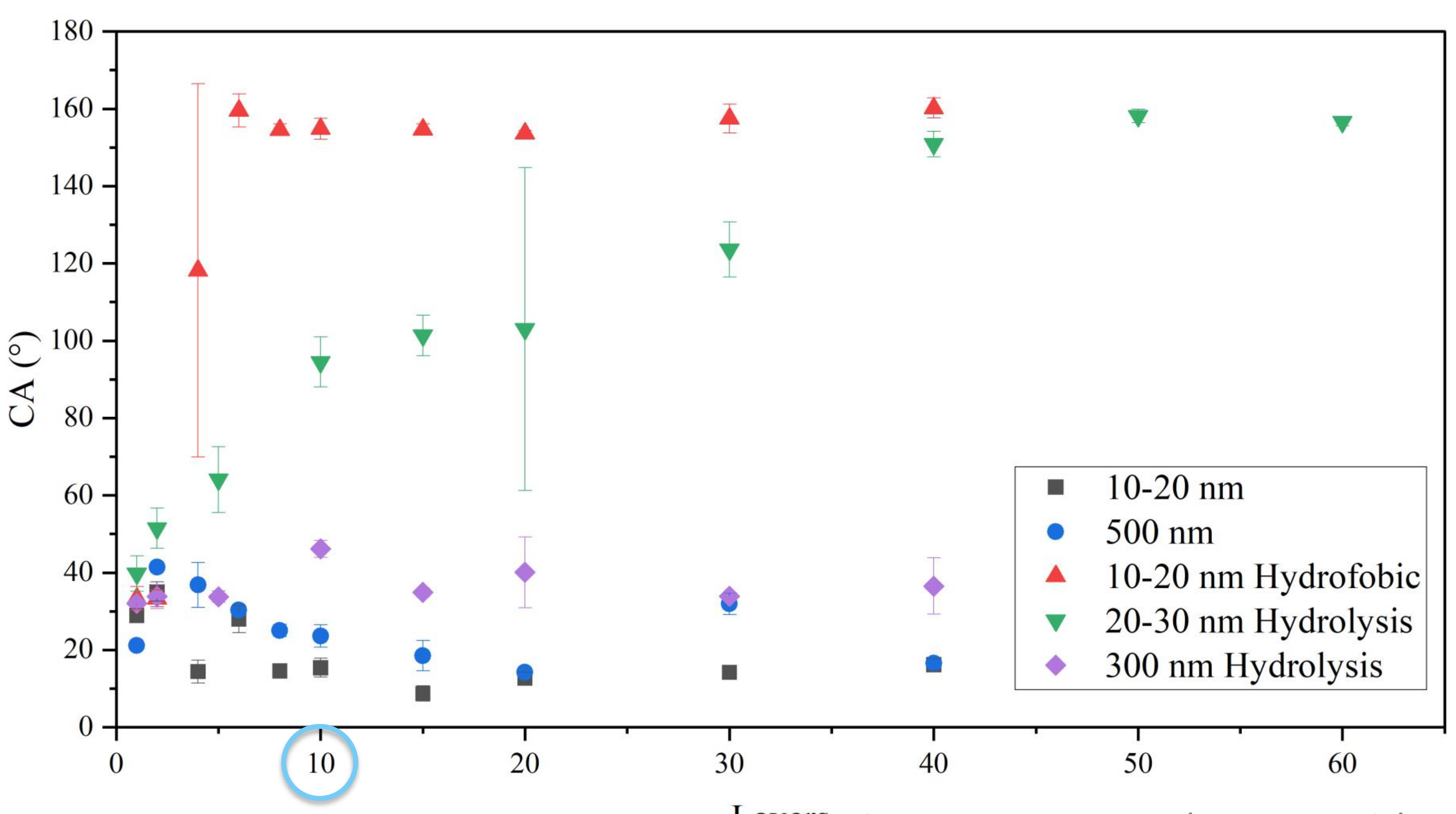

Figure 2: Contact angle nanoparticles

Method

The contact angle is increased by implementing nanoparticles. Nanoparticles are materials with at least one dimension in the range of 1-100 nm. An alternative definition proposes that nanomaterials exhibit a specific surface area to volume ratio equal to or greater than 60 m^2/cm^3. These particles differentiate them from their bulk equivalents and individual ions composing the material.

Figure 3: Droplet on PVDF mixed NP by Dieter Reenaers

The various SiO_2 nanoparticles are evaluated on their hydrophobic properties. The particles that are investigated in this research are 10-20 nm SiO_2, 500 nm SiO_2, 10-20 nm SiO_2 made hydrophobic, 20-30 nm SiO_2 hydrolysis formed and 300 nm SiO_2 hydrolysis formed. Their contact angle is visualized in figure 2 for a concentration of 1 g/l on glass substrates and exhibit poor adhesion. The 10-20 nm SiO_2 made hydrophobic have the most promising results and will be used in different stacking layers (Table 1) on glass to create an adhesive superhydrophobic coating. Hereby, it is worth noting that in the diagram, the blue colour corresponds to the PVDF component, while the red colour signifies the presence of 10-20 nm SiO2 made hydrophobic nanoparticles.

SEM-images

These SEM –images were taken of 10 spray passes with a concentration of 1 g/l nanoparticles with a zoom of 10,000x.

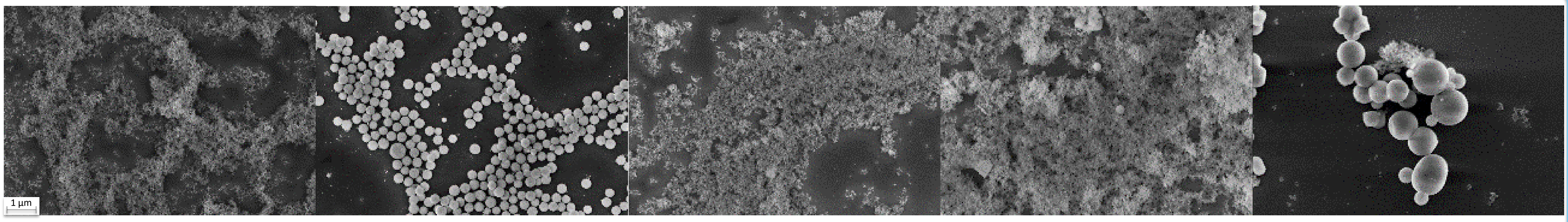

Figure 4: SEM 10kx by Jan D'Haen

Results

Table 1: Summary results

	PVDF	Nanoparticles	PVDF & nanoparticles	PVDF mixed nanoparticles	PVDF & PVDF mixed nanoparticles
Content	PVDF		PVDF		PVDF
Contact angle	± 100°	± 160°	± 150°	± 155°	± 155°
Self cleaning	82%	95%	100%	99%	98%

Conclusion

The use of nanoparticles has demonstrated the capability to significantly enhance the contact angle up to a maximum of 160°. However, the nanoparticles alone exhibit poor adhesion properties. To overcome this limitation, the incorporation of PVDF has shown promise in improving adhesion on glass. Nevertheless, this approach can be cost-prohibitive due to the higher concentration of nanoparticles needed. Alternatively, it has been discovered that employing a layered approach, which involves incorporating a PVDF layer in combination with a layer comprised of mixed nanoparticles and PVDF, demonstrates comparable properties to the NP-PVDF mixture. The self-cleaning tests revealed that PVDF exhibits the poorest self-cleaning performance, even worse than purified glass, primarily to its surface roughness. On the other hand, all the other coatings subjected to testing demonstrated highly favourable characteristics, effectively eliminating at least 98% of the applied graphite.

The selection of the appropriate approach depends on the specific requirements of the application at hand, as well as the cost constraints involved. Careful consideration should be given to strike a balance between achieving desired properties and managing expenses effectively. For future research, it is advisable to explore the adhesion properties of the coatings, followed by conducting tests on substrates characterized by rougher surfaces. This approach would provide valuable insights into the performance and suitability of the coatings under more challenging conditions.

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[1] S. Slegers, M. Linzas, J. Drijkoningen, J. D'Haen, N. Reddy, and W. Deferme, "Surface Roughness Reduction of Additive Manufactured Products by Applying a Functional Coating Using Ultrasonic Spray Coating," *Coatings*, vol. 7, no. 12, p. 208, Nov. 2017, doi: 10.3390/coatings7120208.