Enhancing Hydrophobicity: The Role of Additives in Emulsion-Based Coatings

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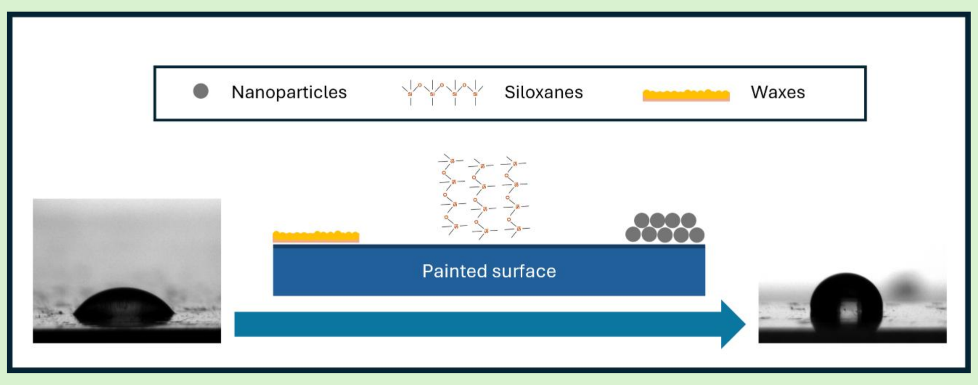
Introduction

Hydrophobic, and particularly superhydrophobic, surfaces have garnered significant industrial interest owing to their potential benefits in enhancing corrosion resistance, self-cleaning capability, anti-fogging, and anti-icing properties, thereby contributing to improved equipment durability and performance. Fluorinated compounds are commonly employed to fabricate such coatings due to their inherently low surface energy; however, their application is increasingly restricted owing to concerns related to bioaccumulation and toxicity.[1,2] Therefore, research has focused on exploring more environmentally friendly alternatives to impart hydrophobicity to coatings. Materials such as polydimethylsiloxane (PDMS), waxes, long-chain alkanes, carbon-based materials and nanoparticles have been investigated.[3]

In this study, various compounds, including waxes, siloxane-based molecules and nanoparticles, were incorporated into an acrylic emulsion to evaluate their effects on the hydrophobicity of coatings on metal and glass substrates.



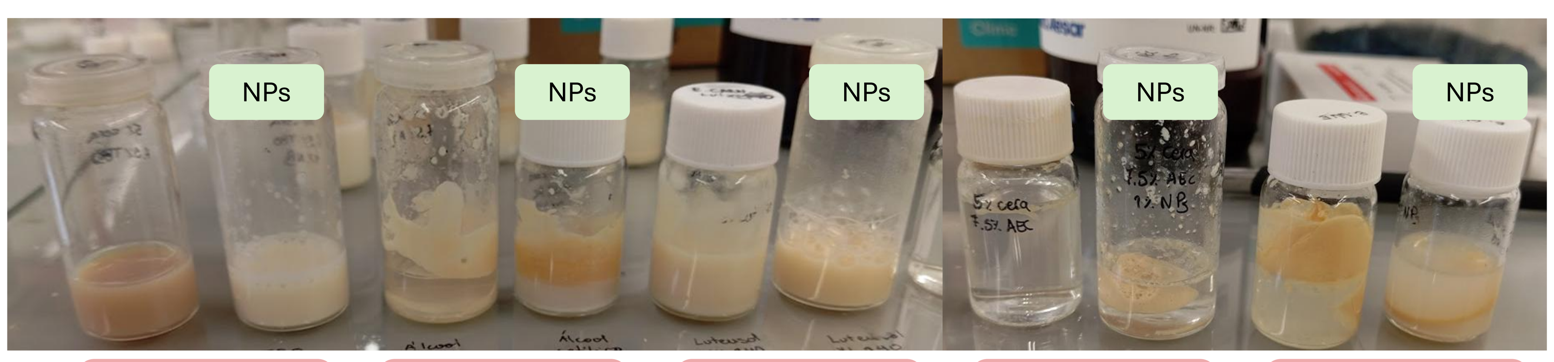
Methods

Different additives were prepared and added in distinct ways to two types of emulsions, type A and type B. The emulsions differ from each other in the monomers used.

Results

Effect of carnauba wax

- Carnauba wax was previously dispersed in a surfactant solution 7.5%, with and without SiO_2 nanoparticles (1%).



Tween 80 | Cetyl alcohol | Lutensol XL140 | Cetyl alcohol | Glycerol ethoxylate

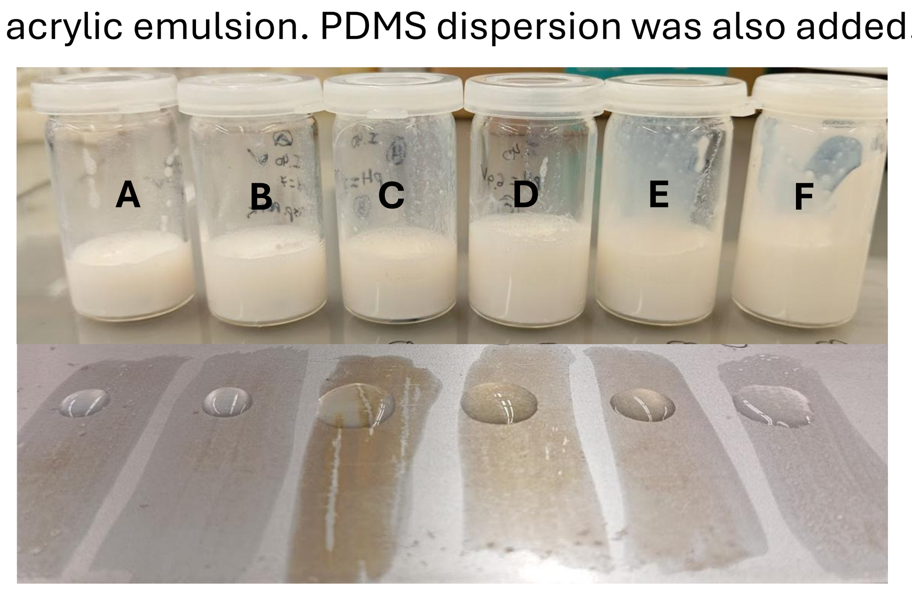
› With Tween 80 (T80) and Lutensol, occurred dispersion of wax, but NPs precipitated.

- Carnauba wax was dispersed in a Tween 80 (T80) solution, increasing concentration, with and without SiO_2 nanoparticles.

1% T80 | 1% T80 + 1% SiO_2 NPs | 1.5% T80 ✓ | 2.5% T80 ✓ | 5% T80 + 1% SiO_2-HDMTS | 0.5% T80 0.5% Cetyl alcohol | 0.5% T80 0.5% Cetyl alcohol 1%SiO_2 NPs

› A minimum of Tween 80 (1.5% w/w) is necessary to disperse carnauba wax.

- Hydrophobic effect was studied adding the best dispersion of carnauba wax to an acrylic emulsion. PDMS dispersion was also added.



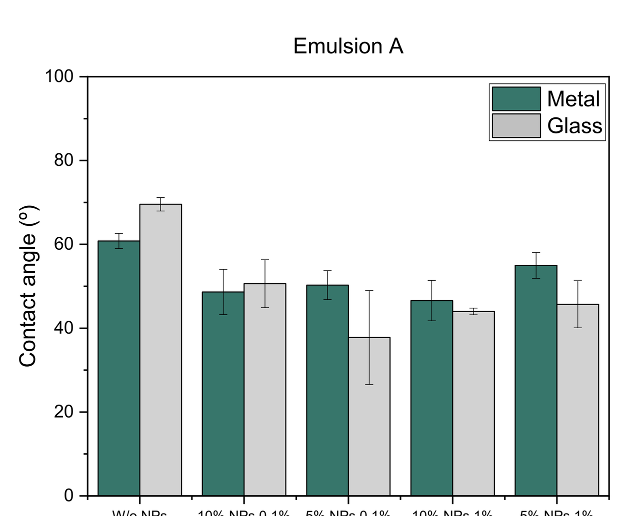
A – Acrylic emulsion
B – Emulsion + Dispersion PDMS
C – Emulsion + Dispersion Wax in 5% T80
D – Emulsion + Dispersion Wax in 5% T80 and 1% SiO_2
E – Emulsion + Dispersion Wax in 2.5% T80
F – Emulsion + Dispersion Wax in 1.5% T80

› Besides inherent hydrophobic effect of carnauba wax, with the dispersion and introduction in an acrylic emulsion, hydrophobic effect was not shown.
› PDMS dispersion seemed the best option to increase the contact angle of the acrylic emulsion.

Effect of hydrophobic nanoparticles

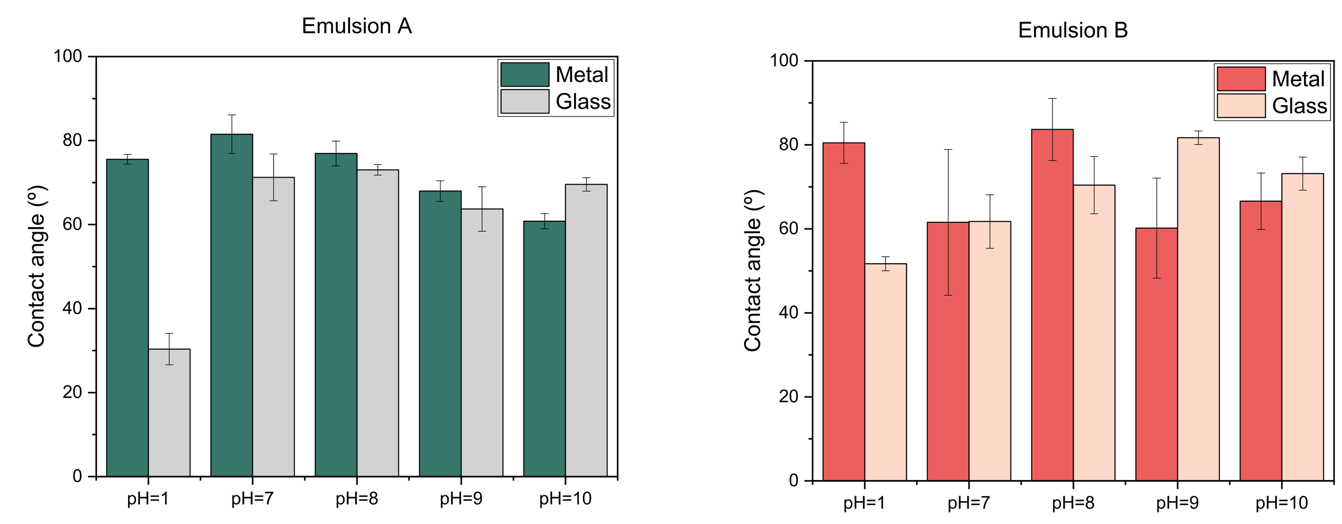
- Hydrophobic NPs were added directly in the acrylic emulsion and dispersed using high-speed equipment, but NPs precipitated.
- Thus, NPs were previously dispersed in a surfactant solution, and this dispersion was added to the acrylic emulsion.

› The addition of NPS previously dispersed in a surfactant solution did not increase the hydrophobicity of the emulsion.

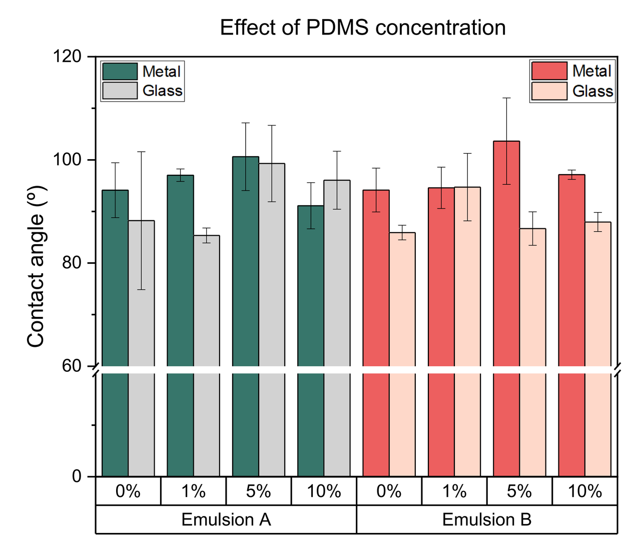


Effect of PDMS and siloxane-based compounds

- Two types of acrylic emulsions were used for tests, type A and type, B. Emulsions have the following contact angles, in metal and glass substrates, at different pH.

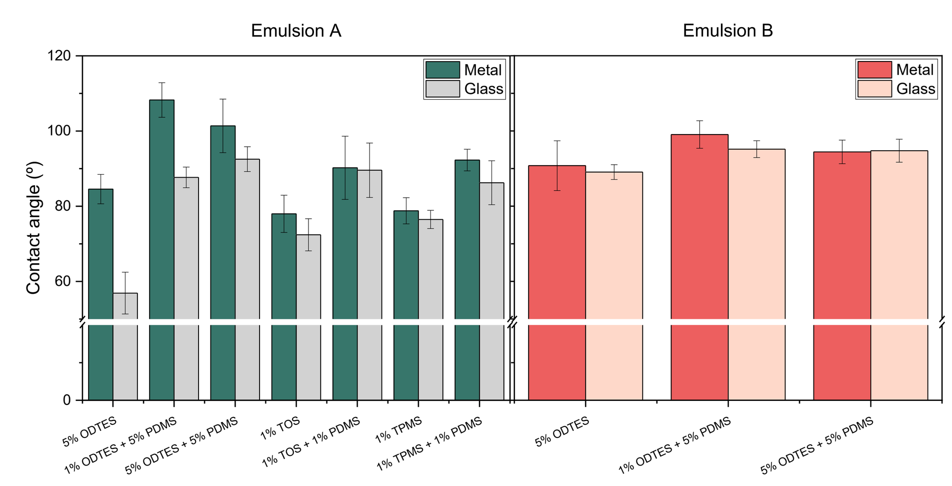


- PDMS was added directly in different concentrations (w/w) to the emulsions at pH=8:

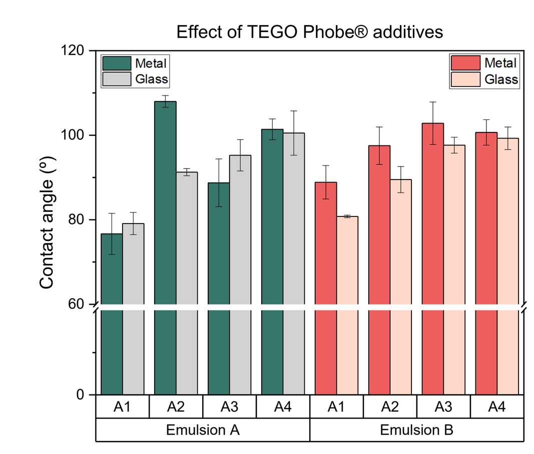


› Contact angle increased with 1 or 5% PDMS. Above 10% of PDMS, contact angle did not increase and phase separation was observed.

- PDMS were mixed with other siloxane compounds, including commercial additives TEGO Phobe:



TOS – Triethoxy(octyl)silane; TPMS – Trimethoxypropylsilane; ODTES - Octadecyltriethoxysilane

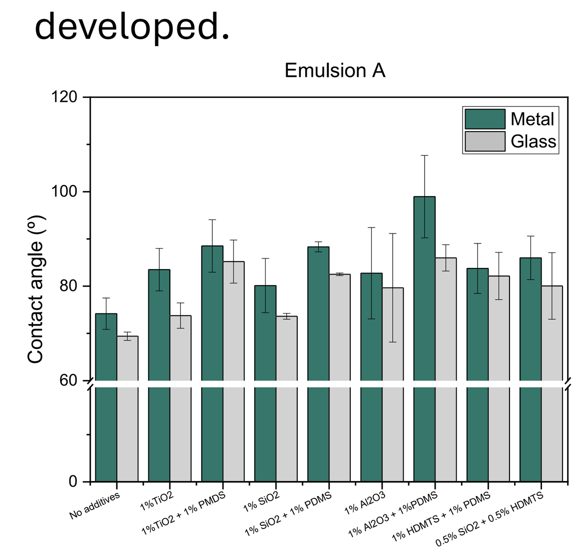


A1 – 8% TEGO Phobe 1659; A2 – 8% TEGO Phobe 1659 + 5% PDMS; A3 – 10% TEGO Phobe 6600; A4 – 10% TEGO Phobe 6600 + 5% PDMS

› Combinations with PDMS and additives showed higher contact angle than only additives in the emulsions.
› Some hydrophobic additives, decreased the contact angle of the emulsions.

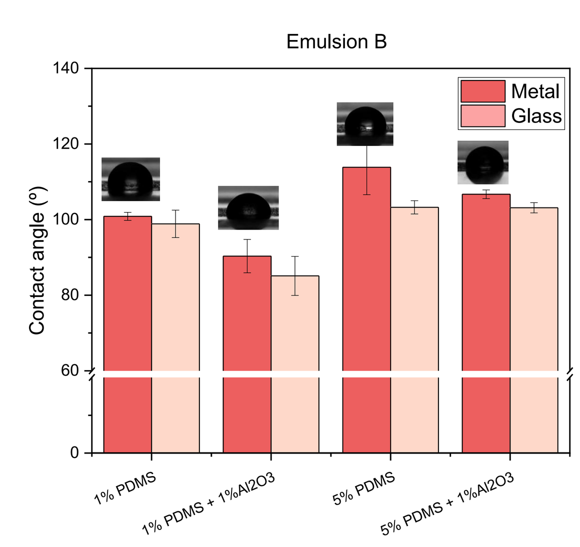
Effect of hydrophobic nanoparticles + PDMS

- Combinations between PDMS with hydrophilic and hydrophobic nanoparticles were developed.



› Hydrophilic nanoparticles were easier to disperse in acrylic emulsions.
› Some synergistic interactions were observed between PDMS and NPs.
› Higher contact angle in glass, but low adhesion in the substrate.
› Best combination was with PDMS and Al_2O_3 nanoparticles.

- After, the best combinations with PDMS and NPs were tested in emulsion B.



› PDMS seemed to have a greater effect in contact angle, than NPs.
› Yet, these combinations all showed a hydrophobic effect (θ>90º)

Conclusions

- Acrylic emulsions can show high contact angle (above 80º).
- These contact angles can increase to a hydrophobicity region with some additives.
- Among some siloxane-based compounds, PDMS is the best candidate to improve hydrophobicity.
- Synergistic interactions between some hydrophilic NPs and other siloxane compounds increase contact angle of aqueous emulsions.

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