Bio-inspired Superhydrophobic Wax and Polyethylene Coatings

Lee-El Tanenbaum, Míriam Lorenzo and Jonah Garmaise
Mentored by Dr. Iryna Polishchuk and Prof. Boaz Pokroy

Department of Materials Science and Engineering and the Russell Berrie Nanotechnology Institute
Technion - Israel Institute of Technology, Haifa 32000, Israel

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Abstract

Superhydrophobicity is a highly desirable surface property and provides many opportunities for application in the modern world Superhydrophobicity is defined as a droplet of water maintaining a contact angle (CA) [1] of more than 150° and contact angle hysteresis [2] less than 5° [1]. In nature, many organisms such as the lotus leaf have natural strategies utilizing repellent wax coatings to maintain superhydrophobicity. In order to create a coating with superhydrophobic properties, both the structure and the chemistry components of the wax must be fabricated [2]. The chemical hydrophobicity of paraffin wax is intrinsic while the structural hydrophobicity is achieved by using micro and nano sized wax crystals layered hierarchically. Polyethylene, another promising material, also has intrinsically hydrophobic chemical properties, and during the fabrication process, it can gain the hierarchical structure required for the superhydrophobic surfaces.

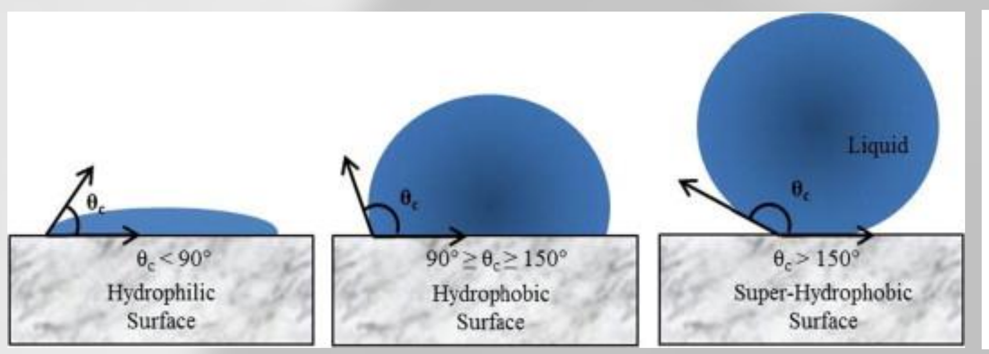


Figure 1: Contact angle

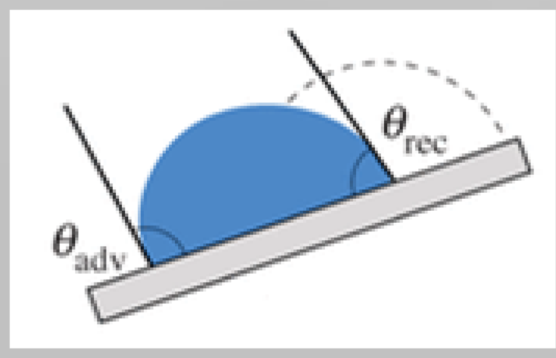
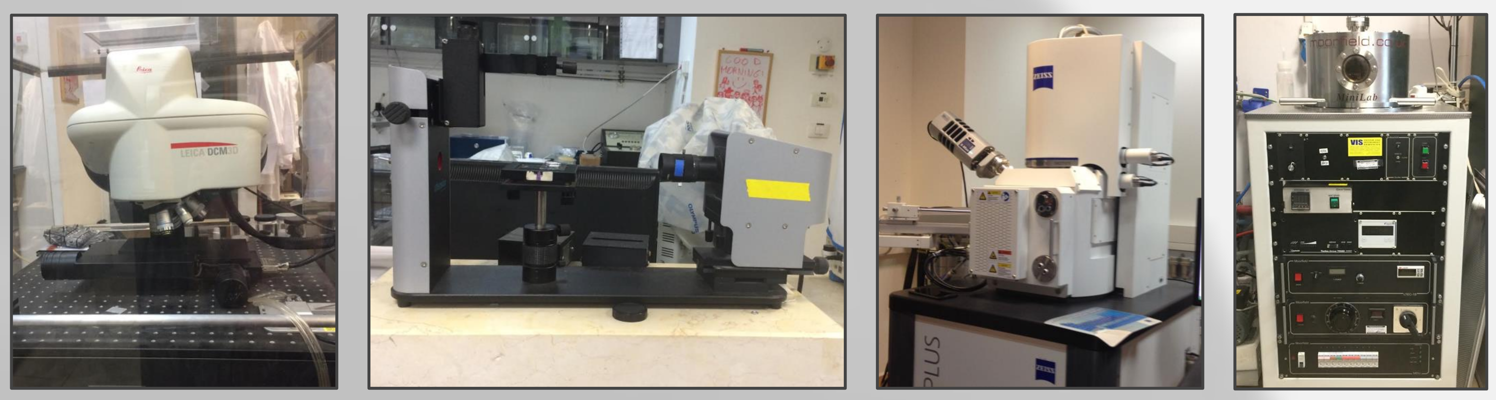


Figure 2: Hysteresis

Experimental

Materials: $C_{36}H_{74}$, $C_{50}H_{102}$ and $C_{24}F_{50}$ waxes were thermally evaporated [3] on various surfaces in order to fabricate superhydrophobic coatings. In addition, high density polyethylene (HDPE) coatings were fabricated on polymer surfaces with and without micro-texture.

Methods: In order to check the hydrophobicity of both wax and polyethylene surfaces, the contact angle (CA) of a drop of H_2O was measured using an optical tensiometer Attension Theta [3]. The LEICA DCM 3D confocal microscope [3] was used to study the roughness and topography of the obtained surfaces and the scanning electron microscope (SEM) [3] was then used to image fabricated surfaces on a micro and nanoscopic scale.



LEICA DCM 3D — Attension Theta Lite Tensiometer — SEM microscope — Thermal evaporator

Figure 3: Lab instruments used

Results & Discussion

WAX COATINGS $C_{36}H_{74}$ + $C_{50}H_{102}$ and $C_{24}F_{50}$

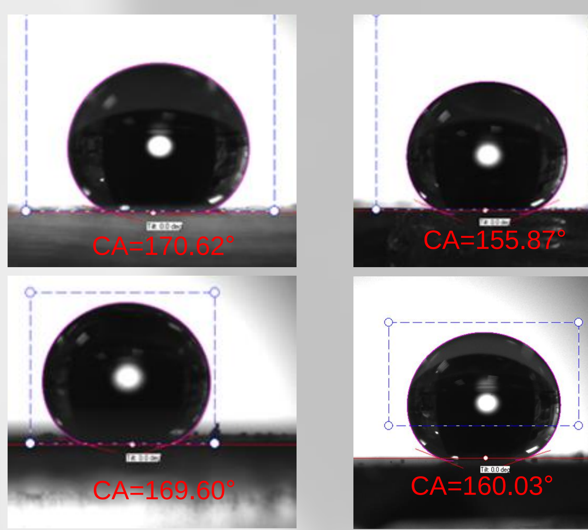


Figure 4: Contact Angles for $C_{36}H_{74}$ + $C_{50}H_{102}$ wax on a steel surface

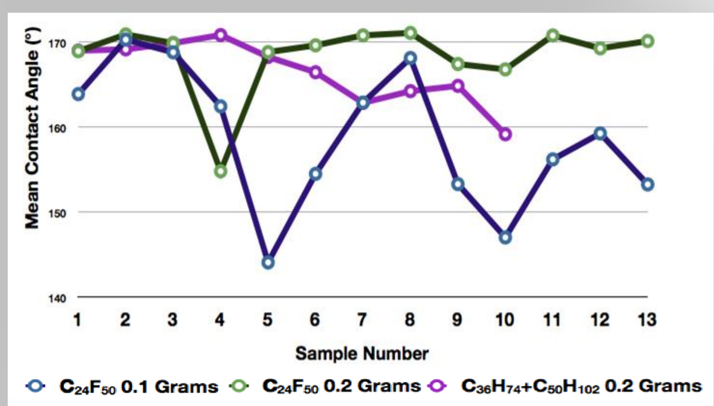


Figure 5: Comparison of CA of various wax coatings. $C_{24}F_{50}$ 0.2 grams demonstrates the highest CA. The $C_{36}H_{74}$ + $C_{50}H_{102}$ coating showed lower CA probably due to not accurate static CA measurements on highly superhydrophobic surface.

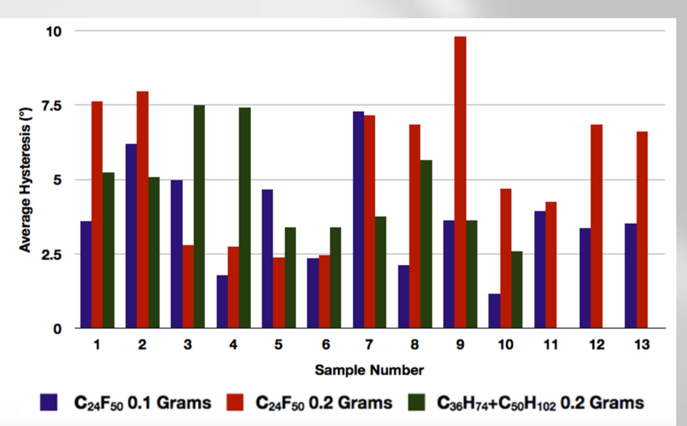


Figure 6: Average static CA hysteresis for different wax coatings. Most of the coatings have hysteresis less than 5°.

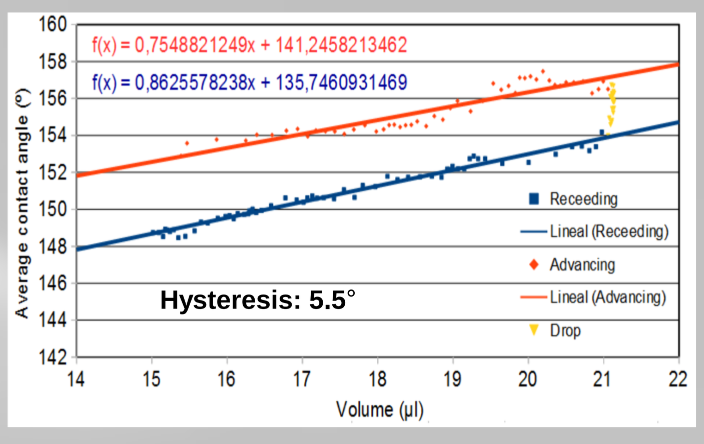


Figure 7: Hysteresis measurement for $C_{24}F_{50}$ wax coating on a steel surface. The extarcted value of hysteresis is almost 5°

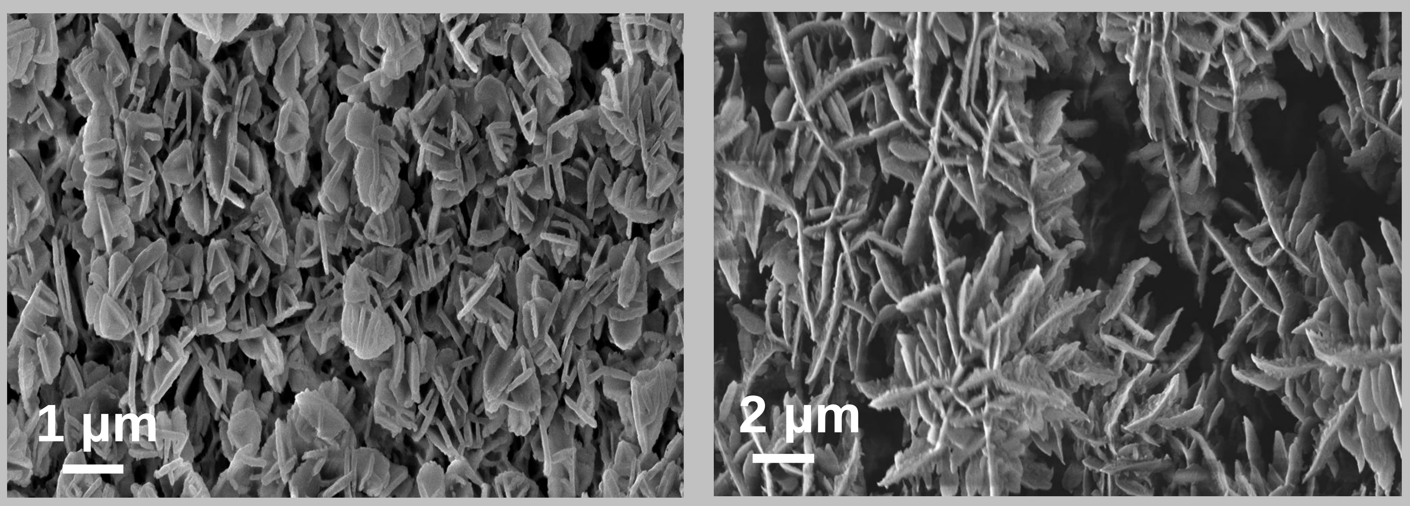


Figure 8: Surface structure obtained utilizing Scanning electron microscope (SEM). $C_{36}H_{74}$ + $C_{50}H_{102}$ wax on a steel surface and $C_{24}F_{50}$ wax on a steel surface. The $C_{24}F_{50}$ sample is a unary structure with micron sized crystals. The $C_{36}H_{74}$ + $C_{50}H_{102}$ is a hierarchical structure with micron crystals and nano crystals on top.

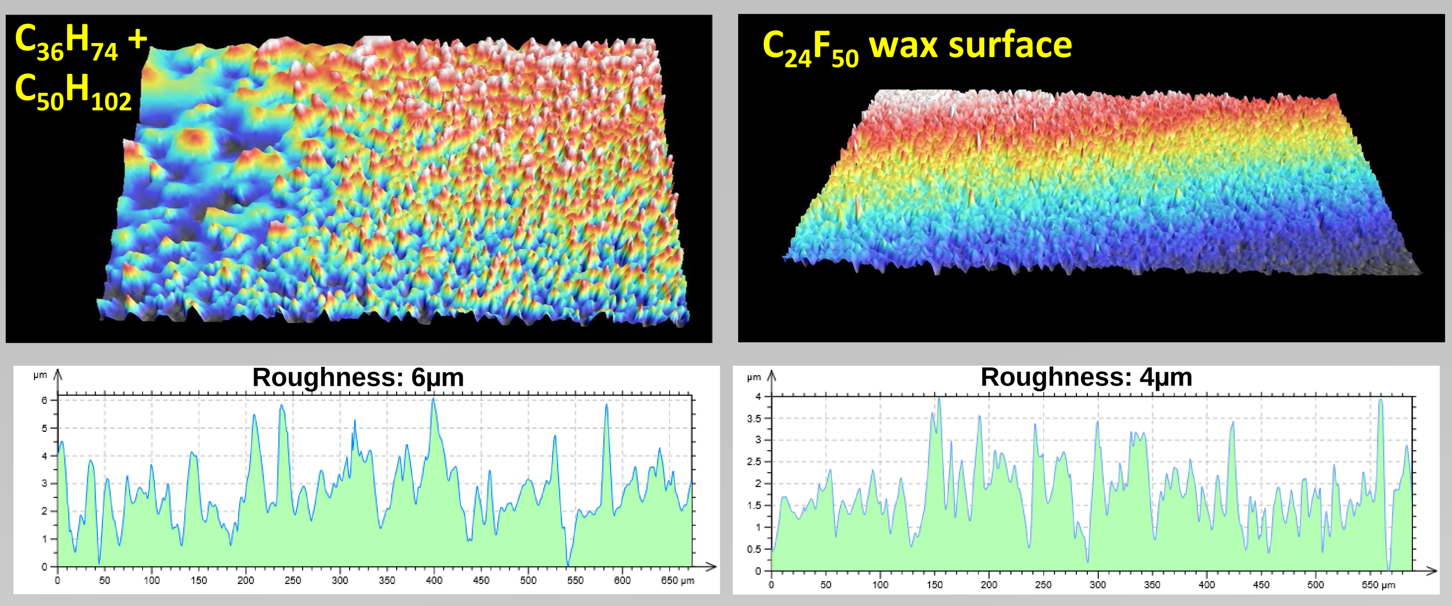


Figure 9: Confocal microscope analysis. 3D and profile view of wax steel surfaces. The $C_{36}H_{74}$ + $C_{50}H_{102}$ coating has a higher roughness as seen in the profile extraction.

POLYETHYLENE COATINGS

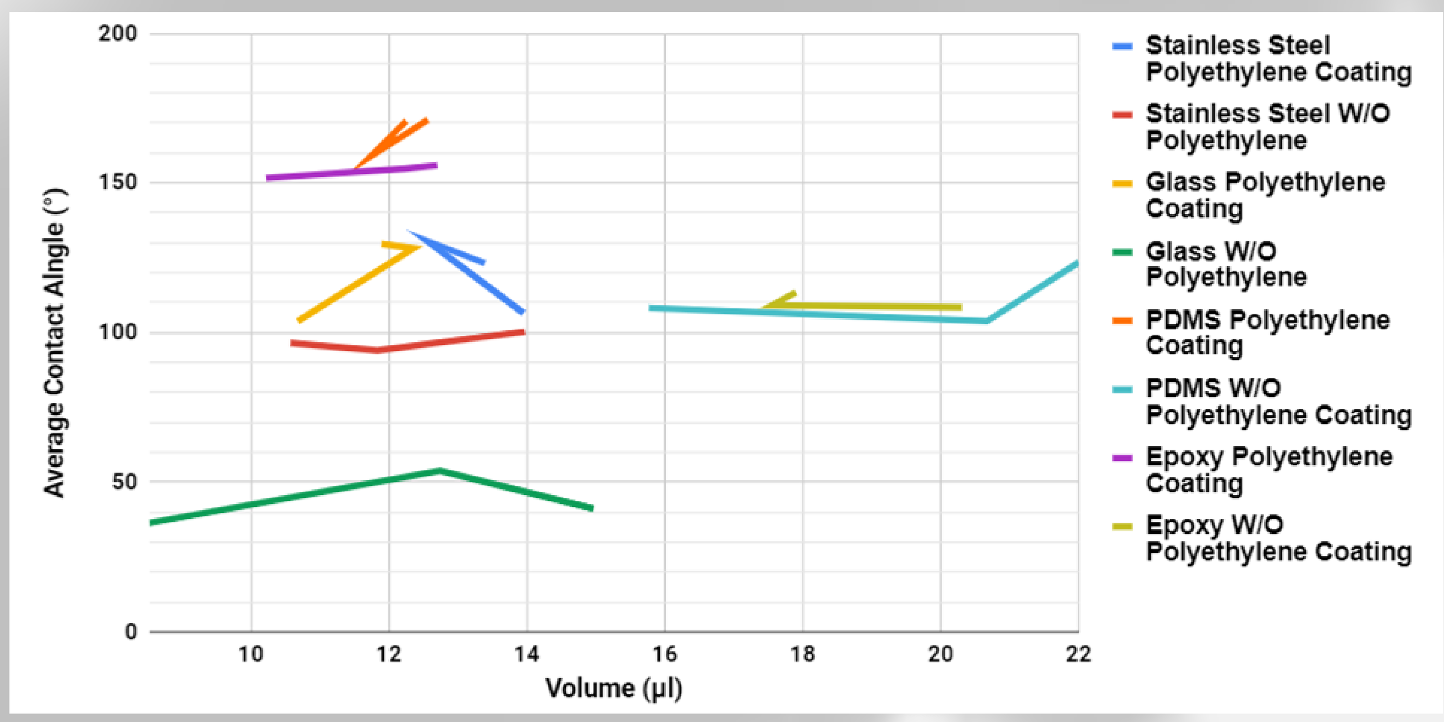


Figure 10: Contact angle for steel, glass, textured epoxy and PDMS substrates coated with polyethylene.

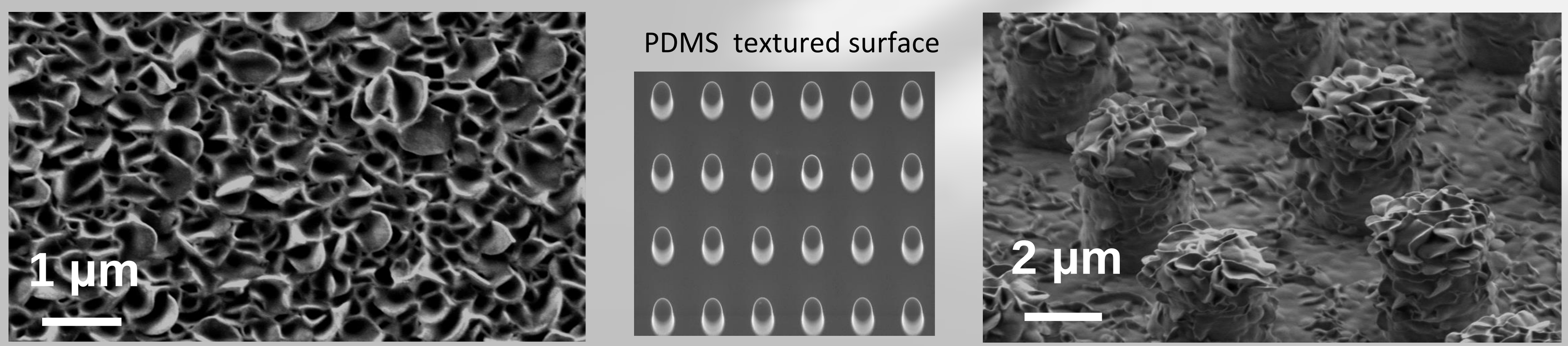


Figure 11: SEM images of the polyethylene coating on smooth glass surface (left) and textured polymer surface (right). The polyethylene coating provides the textured PDMS substrate the hierarchical structure. The PDMS pillars are micron sized, while the polyethylene layers on top create nanostructures.

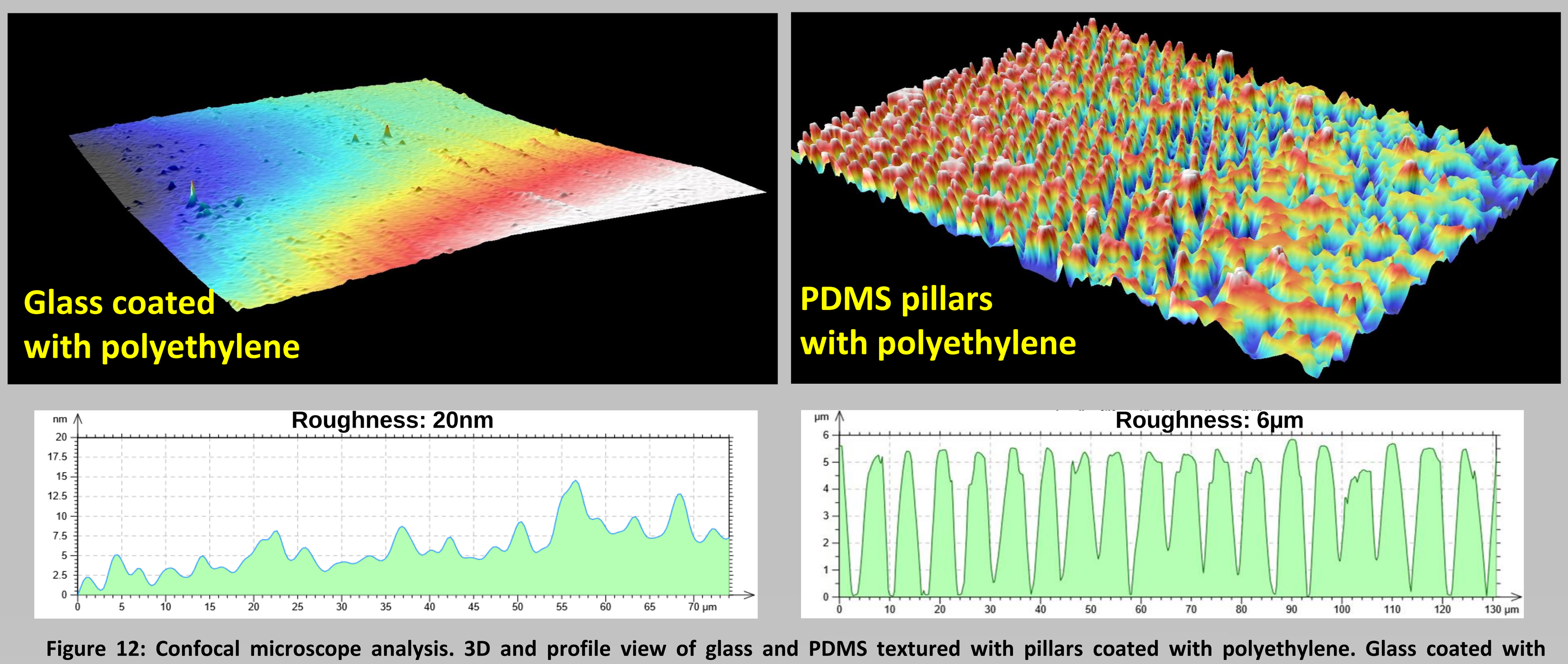


Figure 12: Confocal microscope analysis. 3D and profile view of glass and PDMS textured with pillars coated with polyethylene. Glass coated with polyethylene has a roughness of only 20nm while textured PDMS coated with polyethylene has a roughness of 6µm.

DISCUSSION

As we can see from comparing the contact angle (fig. 4, 5, 6, 7), wax coatings are mostly superhydrophobic. Moreover, the hierarchical structure (fig. 8) of the complex $C_{36}H_{74}$ + $C_{50}H_{102}$ wax coating renders the surface higher roughness (fig. 9) and therefore higher CA. We have also achieved this hierarchical structure on the surface of micro textured PDMS substrate coated with HDPE (fig. 11, 12), proving that, both roughness component of textured PDMS and chemical hydrophobicity of HDPE on their own contributed to superhydrophobic properties of the resulted surface (fig. 10). With the analysis of the experimental data it is shown that micro-structures, especially hierarchical ones, as well as the chemical properties of materials create superhydrophobic attributes.

References

[1] D Quere, Wetting and Roughness (2008).
[2] S Pechook and B Pokroy, Bioinspired hierarchical superhydrophobic structures formed by n-paraffin waxes of varying chain lengths (2013).

Acknowledgments

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