360° Contact Angles of Water Droplets on Micrometric Ramps, Pyramids and Staggered Cuboid Surfaces at varying Wettability

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Introduction

The apparent contact angle of a static droplet on a surface is often used to characterize the surface wettability. However, on regularly structured surfaces, this value can depend on the azimuthal angle of the measurement. We report the azimuthal variation of the apparent contact angle of a gently deposited sessile droplet on various regularly structured PMMA surfaces featuring stacked arrays of ramps in two sizes, pyramids and staggered cuboids. We also modify the surface wettability of the samples using plasma polymerization, thus applying a PTFE-like coating to the surfaces. We show how this results in both an increase of the apparent contact angle and in a reduction of its azimuthal variation.

Material and methods

We used diffuse backlight imaging to measure the apparent contact angle of water droplets on Polymethylmethacrylate (PMMA) samples. The surfaces were manufactured using hot embossing after 3D direct laser writing. The investigated structures can be seen in figure 1. Details on the hot embossing process and a similar 2D laser writing process were previously described by Foltyn et al. [1].

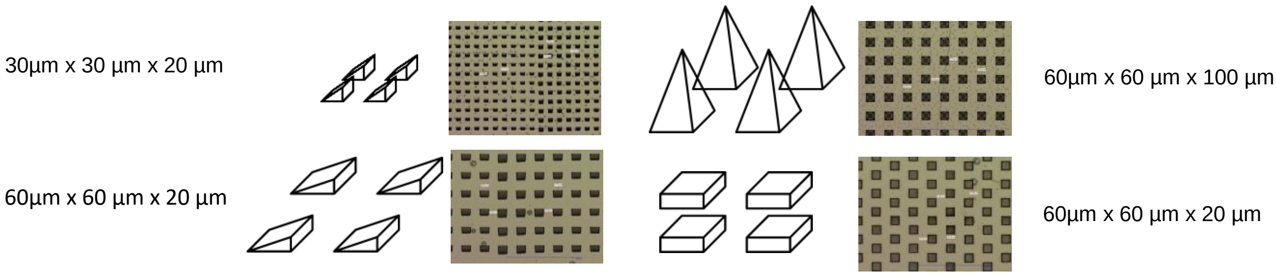

Figure 1. Surface structures

For the determination of the contact angles, we used the DataPhysics Optical Contour Analysis device modified by Foltyn [2]. In it, the dispensing tip and surface are contained in a chamber, which fixes the relative humidity to 98%. The windows in the optical path are heated to avoid condensation, which would interfere with the optical measurements. The samples are placed on a rotating platform to allow for the measurement of the contact angle from all sides. The droplets are set to 5 µL and are deposited onto the surface using a needle. Before rotating the surface the droplets are given 2 minutes to settle to their final position. The rotation stage is connected to the camera and a picture is taken in 1° increments. Figure 2 shows the experimental setup and details on the evaluation method can be found in the work of Foltyn et al. [3]. However, we used the DataPhysics software to analyze the contact angles.

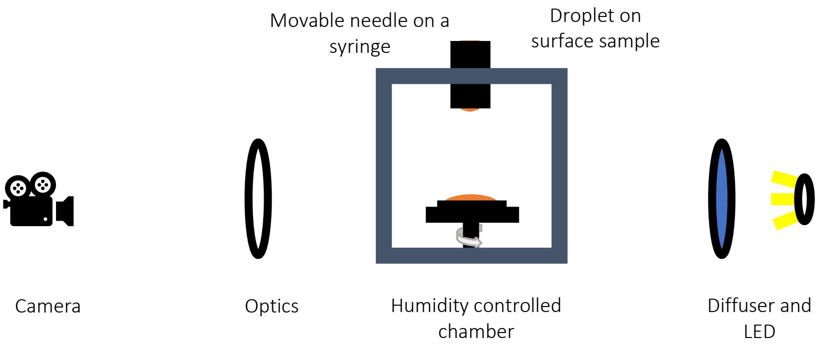

Figure 2. Experimental setup

The surface chemistry was modified by adding a nanometric PTFE-like layer through plasma polymerization. On flat untreated PMMA surfaces, the theoretical contact angle is 68°, while on a polymerized surface it is 120° [1].

Results and Discussion

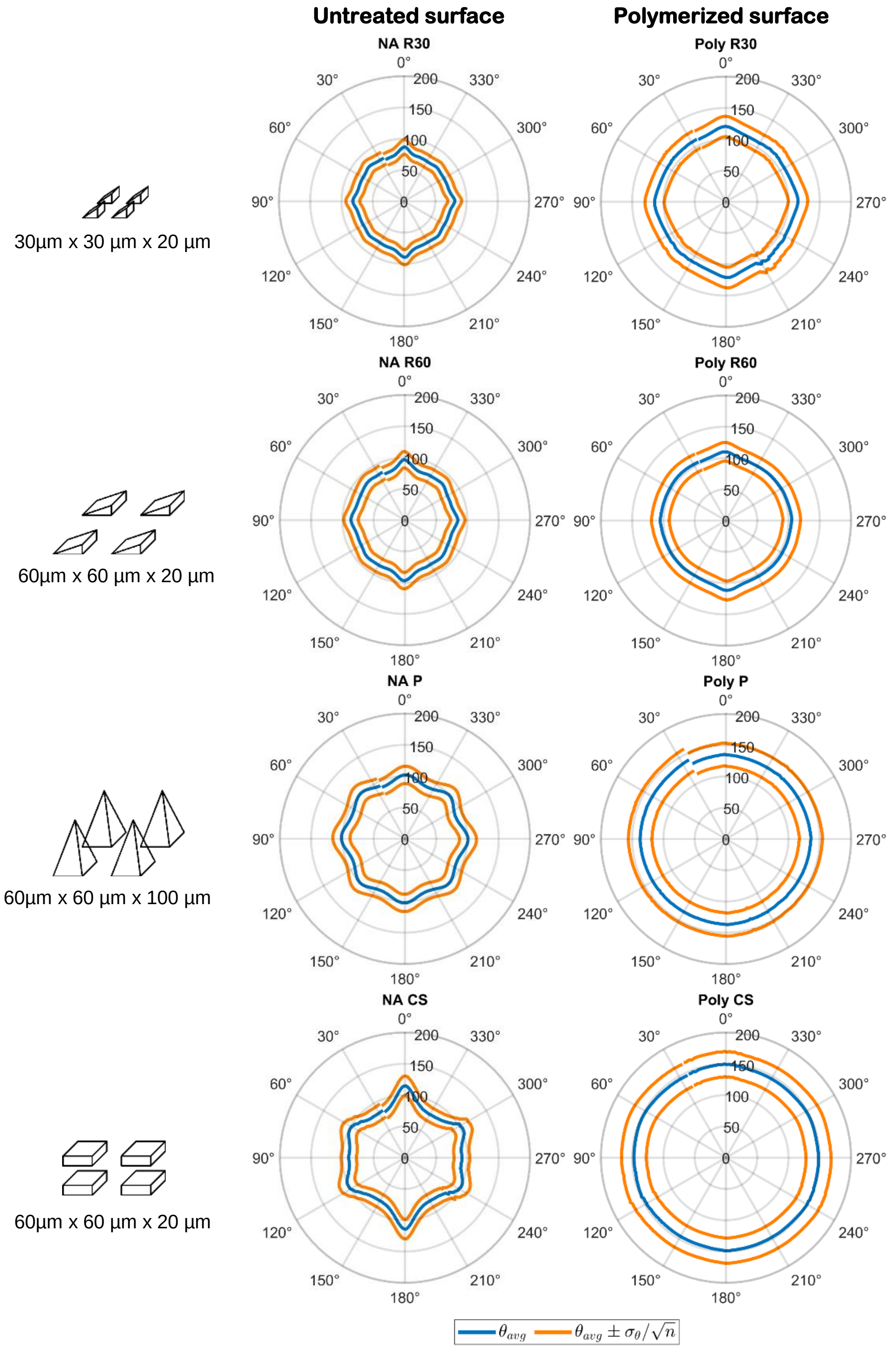

Figure 3. Selected results for the contact angle

Our results show how the variation of the apparent contact angle on non-cuboid and staggered cuboid structured surfaces over the azimuthal angle varies depending on the structure shape, size, arrangement and the surface chemistry. Figure 3 shows how for untreated surfaces the strongest dependence of the apparent contact angle on the azimuthal angle can be found for the staggered cuboids, whereas the strongest variation on polymerized surfaces is observed for the smaller structures. However, for all polymerized surfaces the effect of the azimuthal angle is smaller than for the untreated cases. The pyramids feature an almost 4-axis symmetry, while the staggered cuboids only shows symmetry along one axis.

The apparent contact angle reported here corresponds to the average of the measured contact angle on the right and left sides. In the future, the determination of the contact angle will be performed for each side separately to account for the anisotropy of the ramp structures. Additionally, the samples will be used for droplet impact experiments and specifically investigated for the differences between these structures and the cuboid structures previously investigated by Foltyn [1].

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References

[1] Foltyn, P., Guttmann, M., Schneider, M., Fest-Santini, S., Wildenschild, D., and Weigand, B.: Fabrication and evaluation methods of microstructured surfaces for droplet impact experiments. Droplet Interactions and Spray Processes. Springer International Publishing, 2020, pp. 71–86.

[2] Foltyn, P., Droplet collisions with dry solid surfaces with variable wettability and topography. PhD thesis, 2022

[3] Foltyn, P., Restle, F., and Weigand, B.: 360 evaluation of projected contact angles of static droplets on structured surfaces. Droplet Impact Phenomena & Spray Investigations (DIPSI), Bergamo, Italy. 2019