

How to overcome the uncertainties of polynomial fitting in contact angle determination?

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In the present work an easily implementable method is introduced for contact angle determination using sessile drops with a missing apex. Instead of fitting the drop-profile itself, the polynomial fitting is applied to the difference between the drop profile and the circumcircle, independently for both sides of the drop. The derivative value of this difference at the contact point is used to correct the slope obtained analytically from the circumcircle.

Keywords: Wetting; Contact angle; Sessile drop; Captive bubble; Polynomial fitting

The polynomial fitting to the profile of a sessile drop is widely used in those cases when the drop apex is not visible. The major disadvantage of this approach is that the resulted contact angle is highly sensitive to the applied polynomial order and the number of pixels to which the polynomial was fitted. In order to overcome these uncertainties, an easily implementable method was introduced.

Circumcircles are constructed independently for the left and right unperturbed parts of the profile. Polynomial is fitted to the vertical difference between the circumcircle and the profile, see Figure 1.

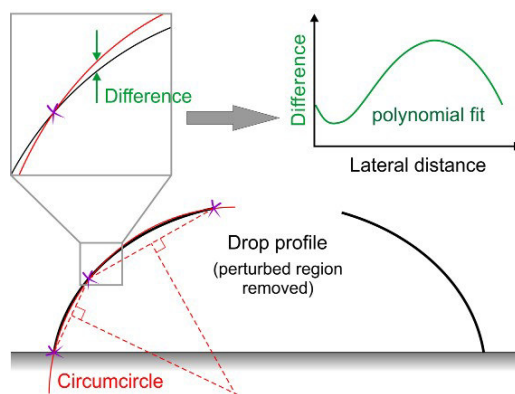


Figure 1. Schematics of the circumcircle and difference fitting method. Three points are selected from each arc: the endpoints and the point at the half of maximum height. Circumscribed circles that pass through these points are constructed independently and polynomial is fitted to the difference between the circle and the profile as a function of the lateral distance from the contact point.

The contact angle is calculated from the sum of the slope of the circumscribed circle and the polynomial curve at the three-phase contact point for each side. The derivative of the circumcircle at the contact point can be calculated analytically. The slope of the polynomial curve at the contact point does not change significantly with the contact angle or with the drop volume.

The method was validated in the contact angle range of 20°–150° with two different image resolutions (1280 × 1024 and 750 × 600 pixels) by comparing the results to the values calculated by the Young-Laplace fit (Figure 2). The accuracy of the method was found to be $\leq 0.6^\circ$ and it does not show significant dependence on the actual contact angle and on the resolution of the captured image. In comparison, the accuracy of the most sophisticated polynomial method is $\geq 1^\circ$.

Needle-in-drop measurements were carried out on a thermal SiO₂ surface for demonstration the capability of the present method (Figure 3). Two syringes were applied with different needle diameter and the determined contact angles were in good agreement considering their standard deviation.

The method improves the accuracy of the evaluation of the needle-in-drop measurements in sessile drop, captive bubble, electrowetting, and electrode wetting experiments.

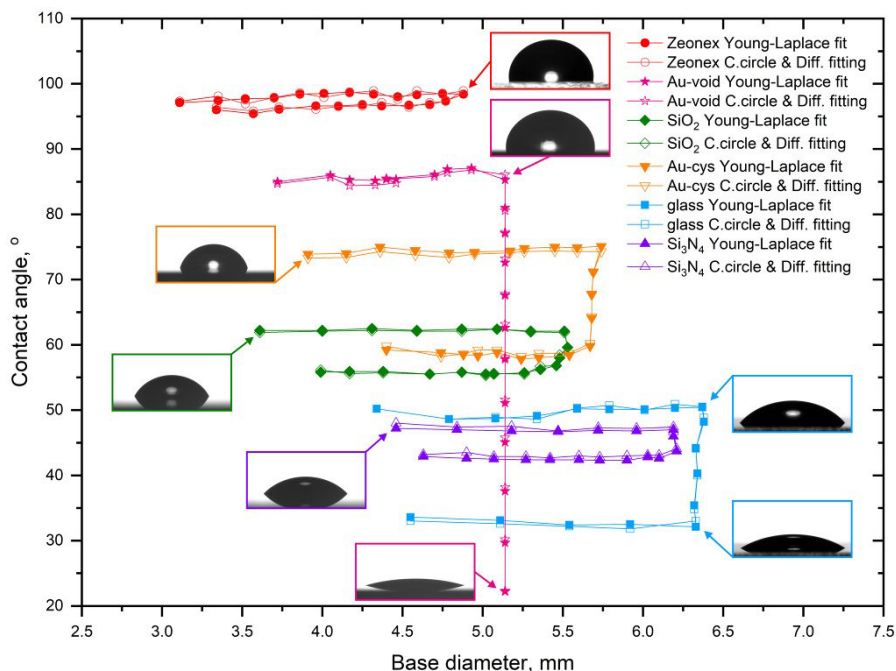


Figure 2. Contact angles as a function of the drop's base diameter. The values determined by the Young-Laplace fit are shown by filled markers. The hollow markers designate the values determined by the proposed circumcircle and differential fitting.

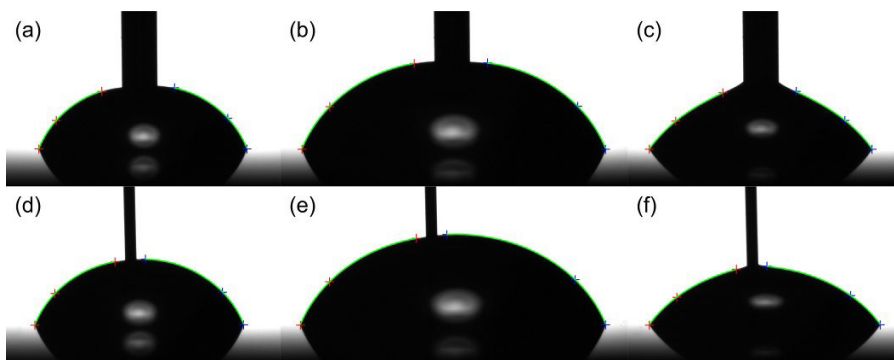


Figure 3. Evaluated images of water droplets with the volume of 10 μL (a,c,d,f) and 30 μL (b,e) captured in the advancing (a,b,d,e) and the receding phase (c,f). The measurements were carried out using two different needles with the diameter of 0.718 mm (a-c) and 0.235 mm (d-f). The red and blue crosses designate the points for the circumcircle construction, the green curves show the resulted profile after difference fitting.

References

- [1] E. Albert, B. Tegze, Z. Hajnal, D. Zámbo, D. P. Szekrényes, A. Deák, Z. Hórvölgyi, N. Nagy: Robust Contact Angle Determination for Needle-in-Drop Type Measurements, ACS Omega **4**, 2019, 18465-18471