Wetting paradoxes for re-entrant structures: droplet morphology in the straight C-shaped channels

*Zhang, C.[1] and Kornev, K.G.[2]

[1]PhD Candidate, Department of Materials Science and Engineering, Clemson University;

[2]Professor, Department of Materials Science and Engineering, Clemson University

kkornev@clemson.edu; https://cecas.clemson.edu/kornevlab/

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Abstract:

Research objectives

The objective of this research is to provide the physical basis for design of multifunctional surfaces with controlled wettability for a broad range of applications in protective ceramics, microfluidics and textiles.

Methodology

In this research, C-shaped channels with different opening angles were fabricated through reverse molding with polydimethylsiloxane on the wax mold with embedded capillary tubes. The surfaces of the channels were modified through silanization to achieve different wettability. X-Ray micro computed- tomography (Micro CT) was used to image the 3D morphology of liquid droplets in the C-shaped channels. Based on the experimental observation, a mathematical model was constructed to study the conditions to form describe wetting/non-wetting transitions.

Results

By varying the opening angle of the C-shaped channels and contact angle between the liquid and the channel surface, two distinguishable droplet morphologies, clam-shell and column, were observed as indicators of wetting/dewetting transition in the channels. It was found that the clam-shell droplet morphology (dewetting) tends to form at the small angles of channel opening and large liquid/solid contact angles. Surprisingly dewetting occurs even when the liquid/solid contact angle is smaller than 90°; the drop does not spread over the channel but forms a clam-shell. On the other hand, the drop spread to form a column at the large angles of channel opening and small liquid/solid contact angles. Paradoxically, when the liquid/solid contact angle even larger than 90°, the column still can be formed at the large enough angles of channel opening. A phase diagram was constructed to describe this wetting/dewetting transition and compared with the experimental results, as shown in Figure 1.

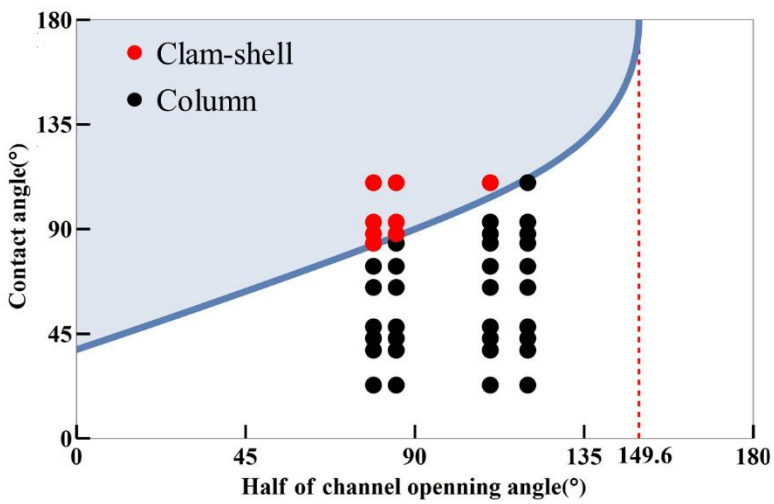

Figure 1. Phase diagram describing the wetting/dewetting (column(white) – clam-shell (grey)) transition droplets in C-shaped channels: The red and black dots are the experimental data.

Conclusions and potential future research

In this research, the phase diagram describing the wetting/dewetting transition of droplets in C-shaped channels was theoretically calculated and compared with experimental data. A new level of understanding of the wetting phenomena on structured substrates will offer a basis for design of multifunctional surfaces with controlled wettability.