

Ceramic and Colloidal Processing

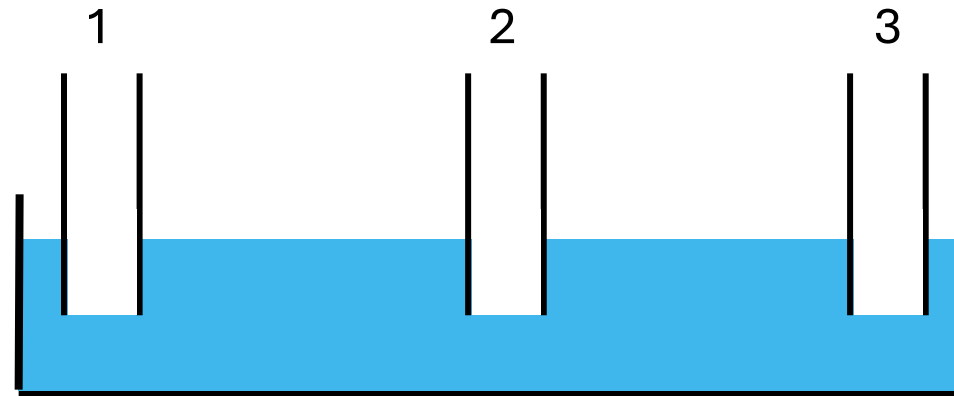
Surface Tension, Wettability and Hydrophobic Surfaces: Exercises

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Exercise 1: Capillary Rise in Capillaries with Different Wettabilities

Three identical capillaries with different wettabilities are dip in a water bath as shown in the schematic below. The contact angle of water θ_w on the inner capillaries surfaces are given as:

- Capillary 1: $\theta_{w1} = 164^\circ$
- Capillary 2: $\theta_{w2} = 90^\circ$
- Capillary 3: $\theta_{w3} = 27^\circ$

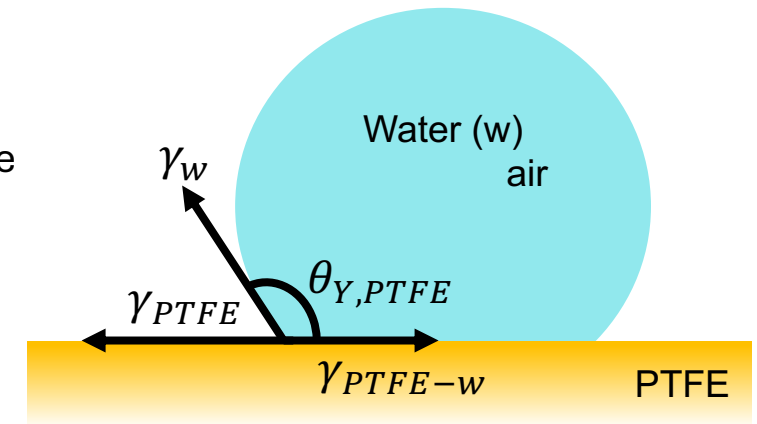


Question a) Qualitatively draw the water meniscus inside the three capillaries

Exercise 2: Young's Equation

A water droplet is placed on a smooth surface consisting of polytetrafluoroethylene (PTFE). With a goniometer we measure the contact angle $\theta_{Y,PTFE}$.

- Given:
 - Water surface tension: $\gamma_w = 0.072 \frac{N}{m}$
 - Surface tension of PTFE: $\gamma_{PTFE} = 0.020 \frac{N}{m}$
 - Young's contact angle of water on PTFE: $\theta_{Y,PTFE} = 115^\circ$



Question a) Calculate the interfacial tension between water and PTFE (γ_{PTFE-w})

Exercise 3: Surface Tension Estimation by Capillary Rise

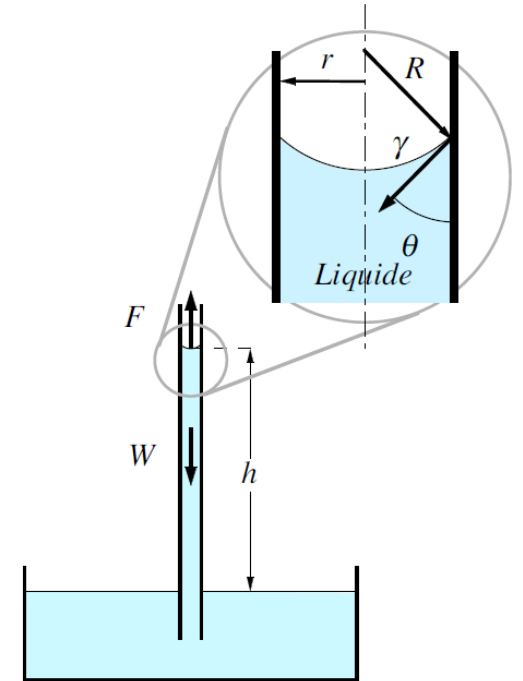
Using the capillary rise method, we want to experimentally estimate the surface tension of water. This is done in ambient conditions.

Given:

- Outer capillary diameter $d_{out} = 3 \text{ mm}$
- Wall thickness of capillary $t = 0.5 \text{ mm}$
- Water density $\rho_w = 1 \frac{\text{g}}{\text{cm}^3} = 1000 \frac{\text{Kg}}{\text{m}^3}$
- Gravitational acceleration $g = 9.81 \frac{\text{N}}{\text{Kg}}$
- Capillary rise $h = 14 \text{ mm} = 0.014 \text{ m}$
- Water contact angle with the inner capillary surface $\theta = 17^\circ$

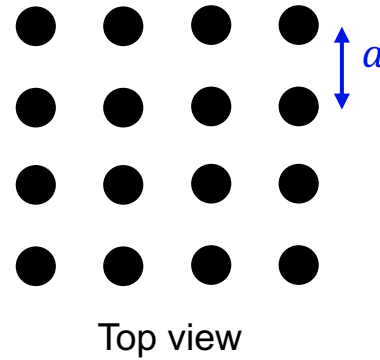
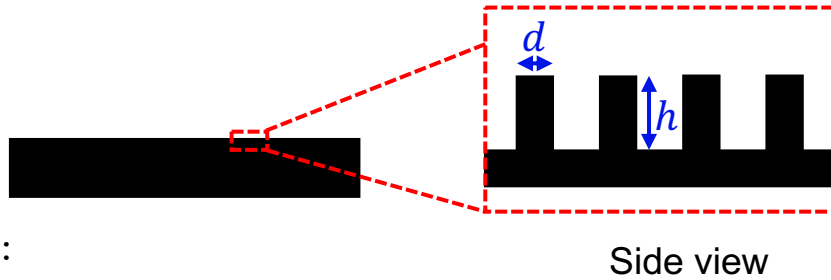
Question a) Calculate the water surface tension based on the aforementioned parameters

Question b) We repeat the same measurement using a capillary whose material on the inner surface has a different wettability. In this case the contact angle of water is $\theta = 40^\circ$. The geometry doesn't change. Does h increase, become smaller or remain unchanged? And why? (qualitative explanation).



Exercise 4: Wenzel and Cassie-Baxter States

Consider a rough PTFE surface consisting of circular micropillars arranged like in the schematic below:



$$f_R = \frac{\text{actual area}}{\text{projected (apparent) area}}$$



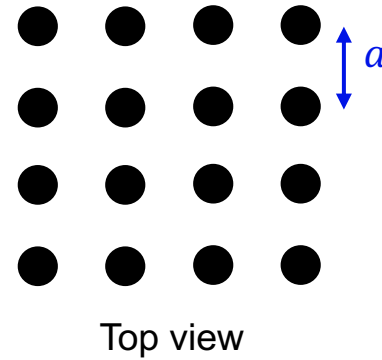
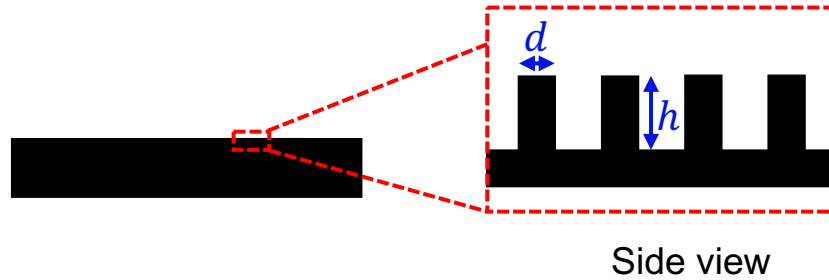
Given:

- Pillar height $h = 20 \mu\text{m}$
- Pillar diameter $d = 10 \mu\text{m}$
- Interpillar distance $a = 30 \mu\text{m}$

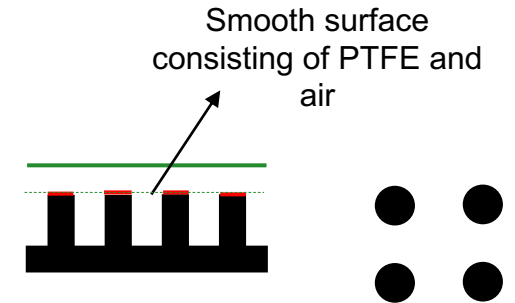
Question a) Calculate the roughness factor f_R of the surface (hint: simplify the problem by considering a single unit cell consisting of 4 pillars)

Exercise 4: Wenzel and Cassie-Baxter States

Consider the same surface made of PTFE from the previous slide. Consider its top surface as a smooth surface consisting of PTFE and air (dashed line).



$$\varphi_{PTFE} = \frac{A_{PTFE}}{A_{tot}}$$



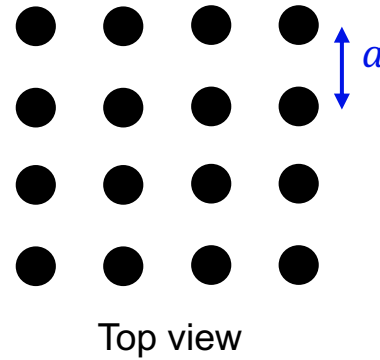
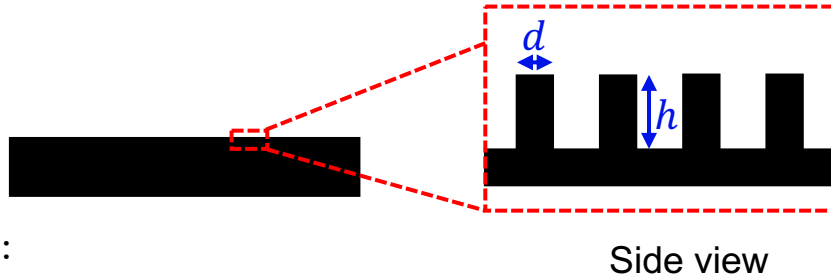
Given:

- Pillar height $h = 20 \mu m$
- Pillar diameter $d = 10 \mu m$
- Interpillar distance $a = 30 \mu m$

Question b) Calculate the fractional surface area occupied by PTFE φ_{PTFE} (hint: reduce problem to a single unit cell consisting of 4 pillars)

Exercise 4: Wenzel and Cassie-Baxter States

Consider the same surface made of PTFE from the previous slide.



$$\cos \theta_{Y,c} = \frac{\varphi_{PTFE} - 1}{f_R - \varphi_{PTFE}}$$

Given:

- Pillar height $h = 20 \mu m$
- Pillar diameter $d = 10 \mu m$
- Interpillar distance $a = 30 \mu m$

Question c) Using the results obtained in a) and b), calculate the critical Young's contact angle of the surface.

Question d) Assuming that the Young's contact angle of water on PTFE is $\theta_{Y,PTFE} = 115^\circ$, determine whether a water droplet placed on this surface will be in Wenzel or Cassie Baxter state.

