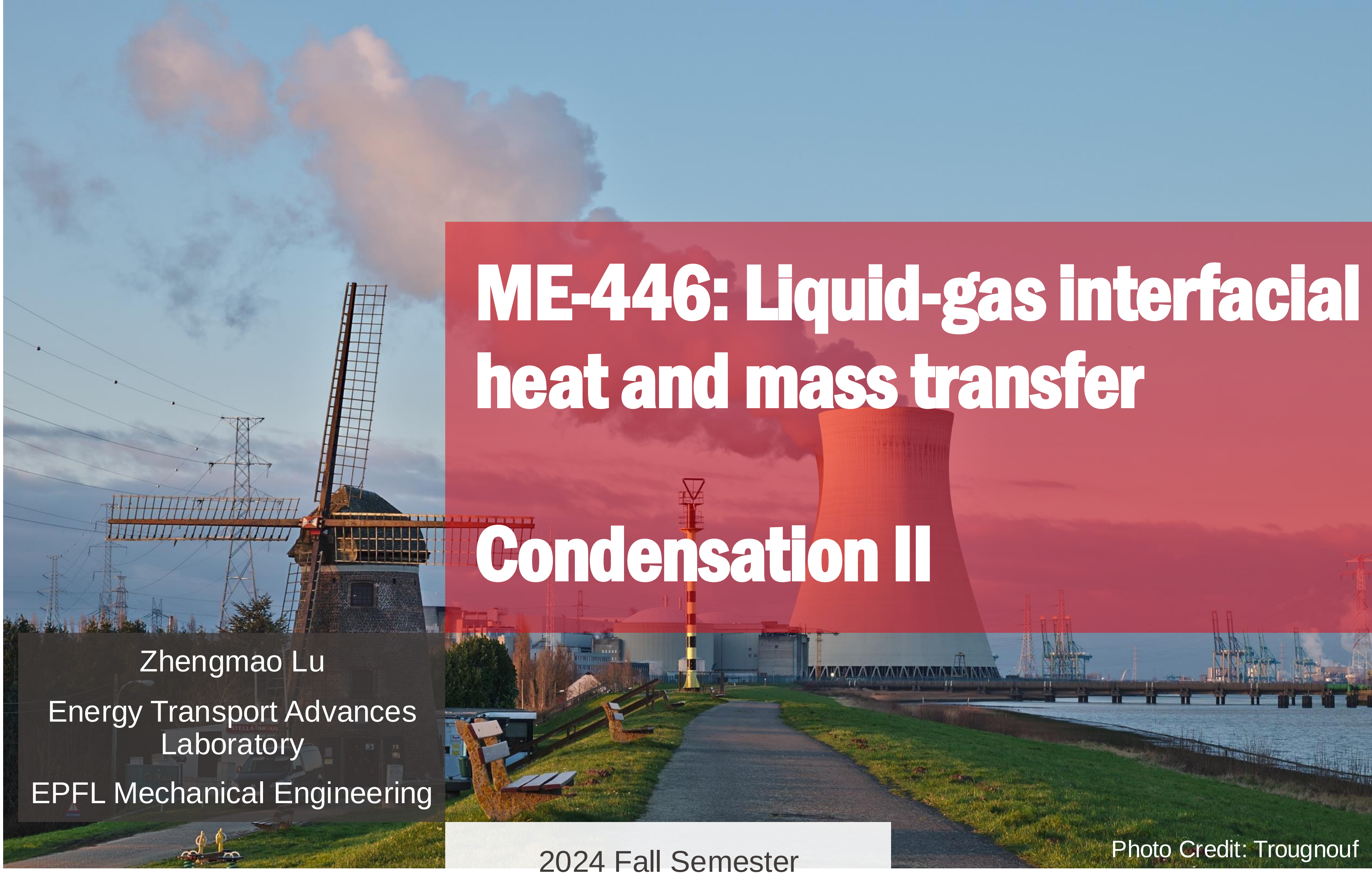
EPFL

ETA-Lab
Energy Transport Advances



ME-446: Liquid-gas interfacial heat and mass transfer

Condensation II

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Energy Transport Advances Laboratory

EPFL Mechanical Engineering

2024 Fall Semester

Photo Credit: Trougnouf

Last Time

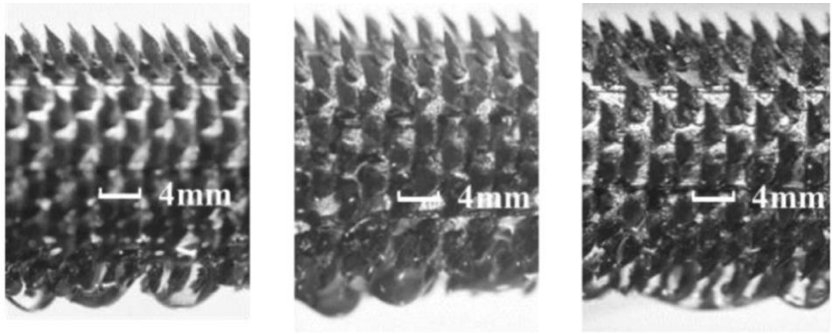
- Nucleation in condensation
- Rose’s analysis of dropwise condensation
- Nusselt’s analysis of filmwise condensation

Intended Learning Objective Today

- Typical condensation enhancement strategies
- Jumping-droplet condensation
- Condensation enhancement for low surface tension fluids

Condensation Enhancement

Finned Tube Condenser



Gu *et al.*, *International Journal of Heat and Mass Transfer* 2020

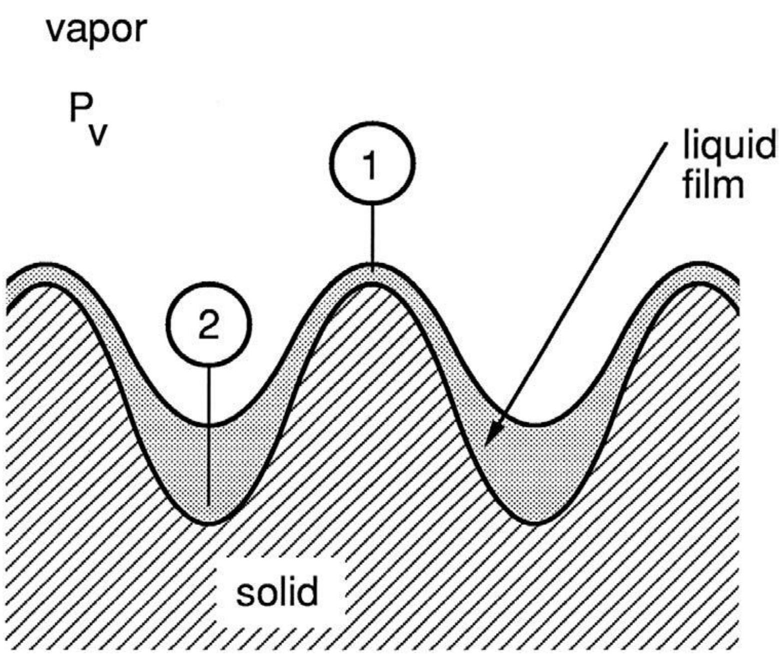
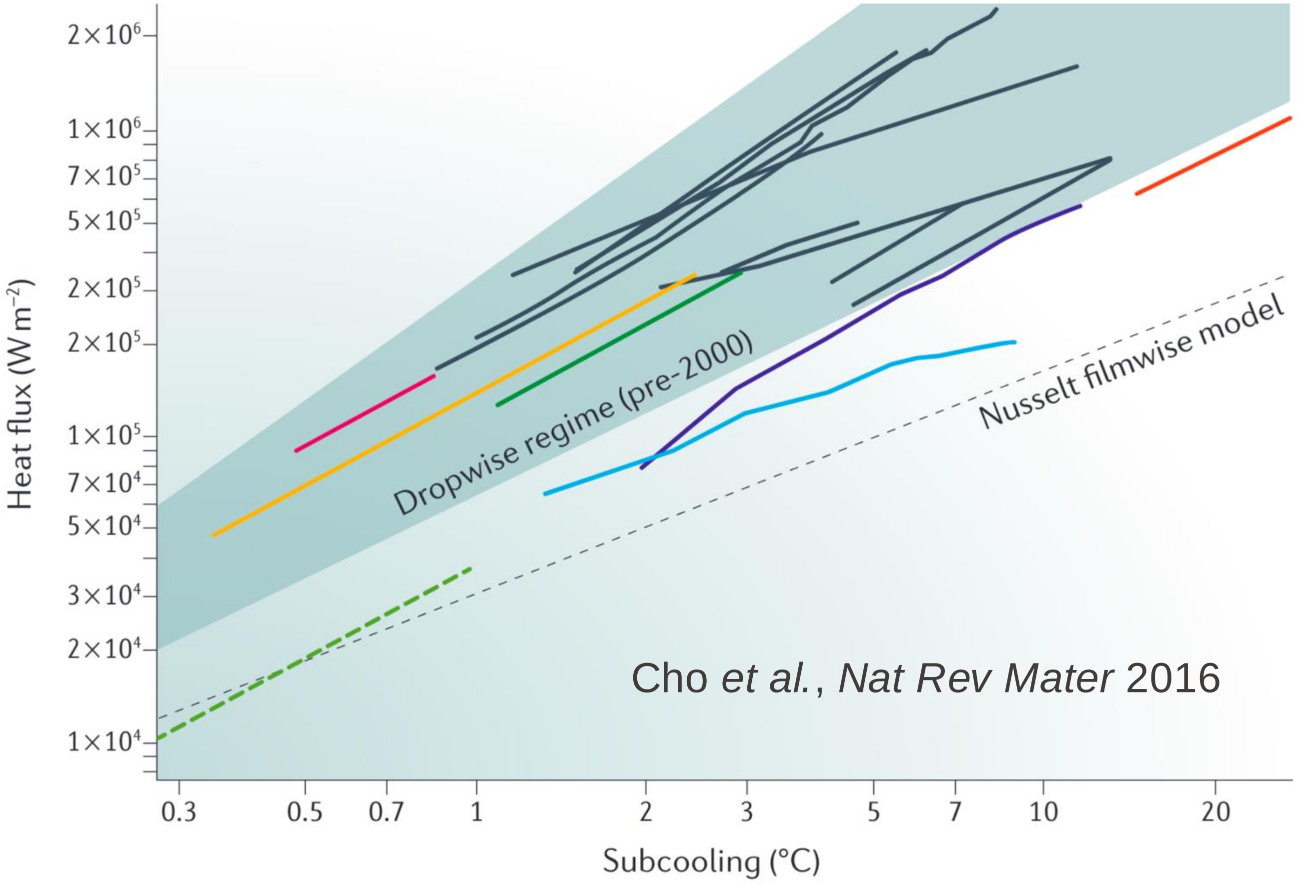
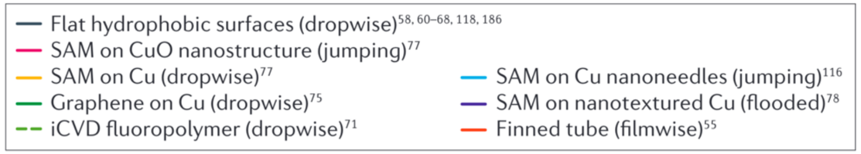


FIGURE 9.26 in Carey

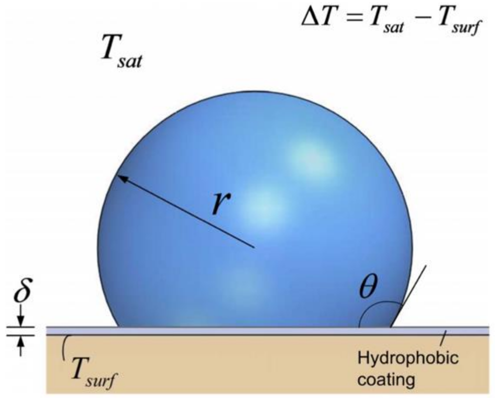
Condensation Enhancement



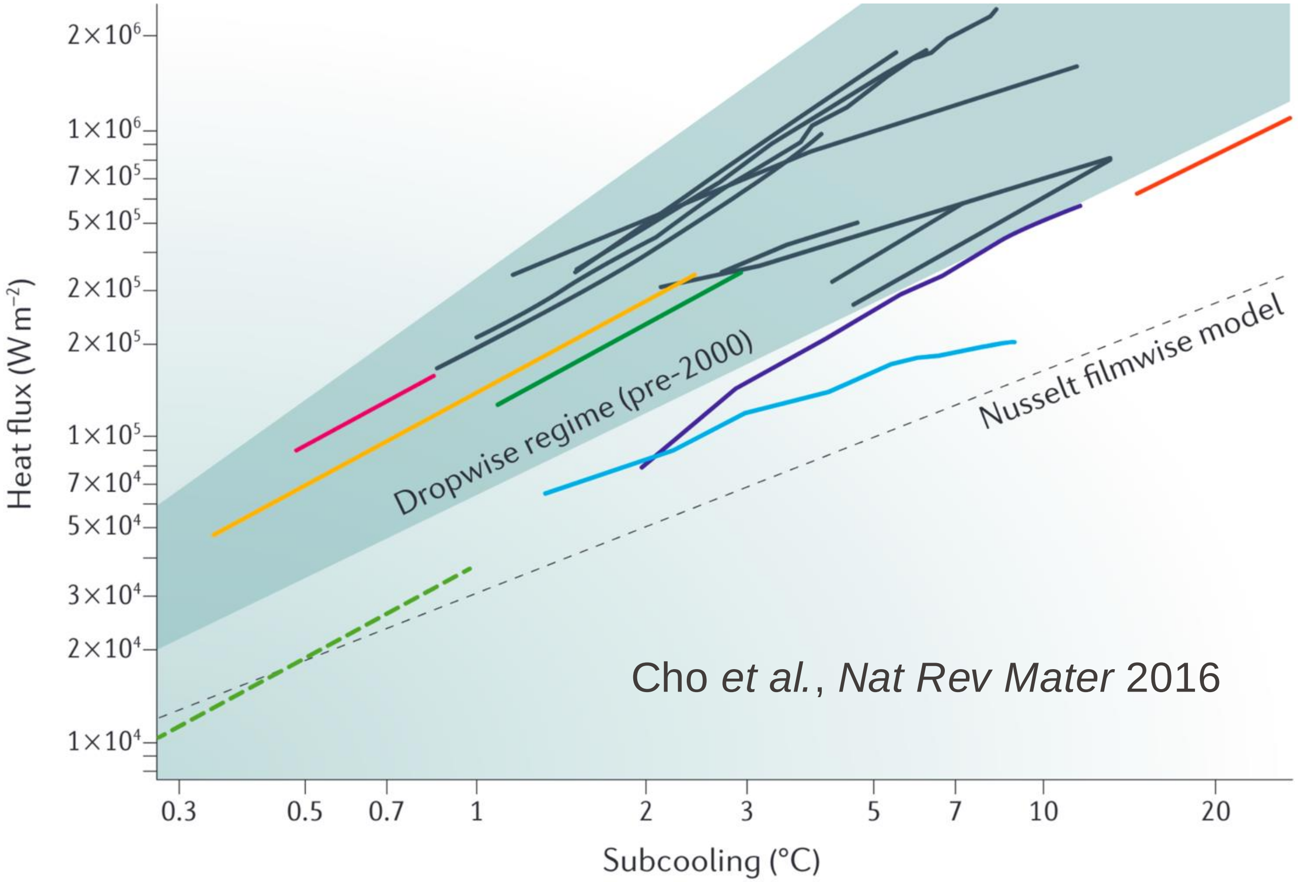
Cho *et al.*, *Nat Rev Mater* 2016



Flat Hydrophobic Coating

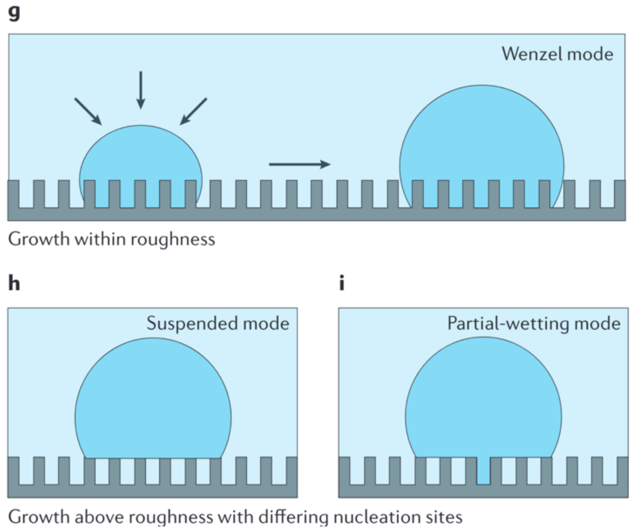


Condensation Enhancement

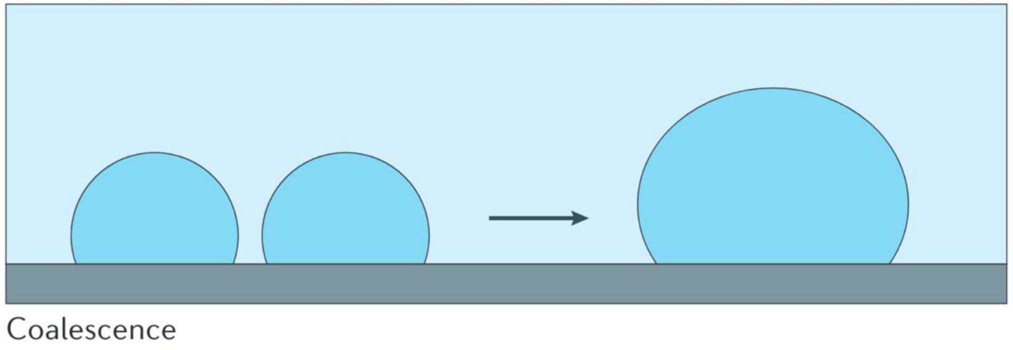


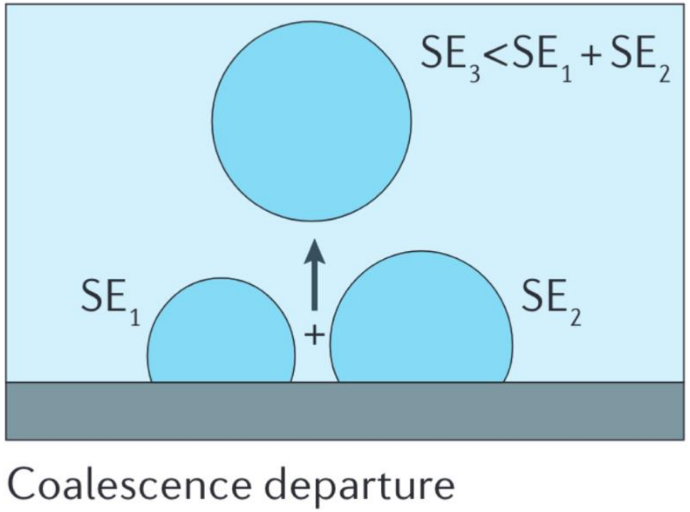
Cho *et al.*, *Nat Rev Mater* 2016

Surface Structure + Hydrophobic Coating



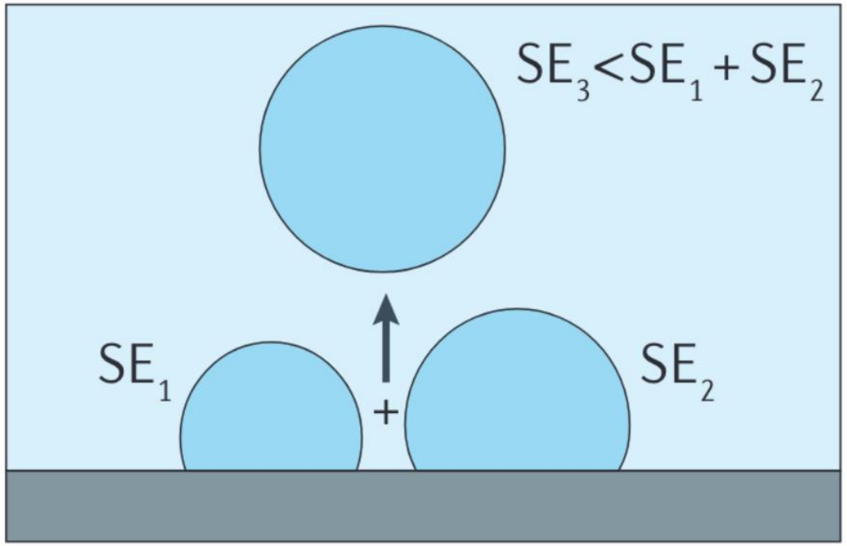
Jumping Droplet Condensation





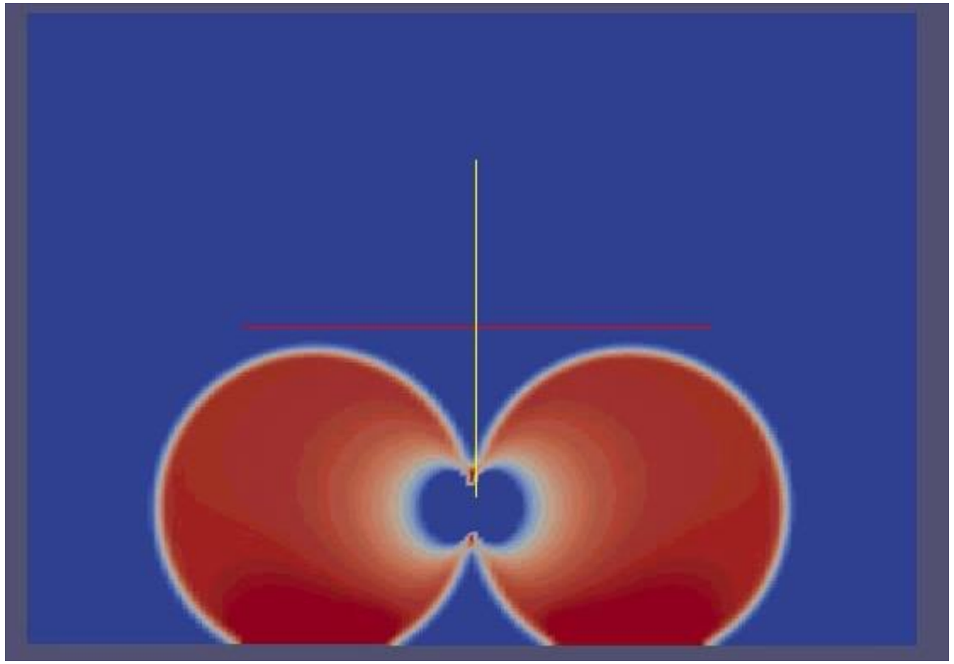
https://doi.org/10.1103/PhysRevLett.103.184501

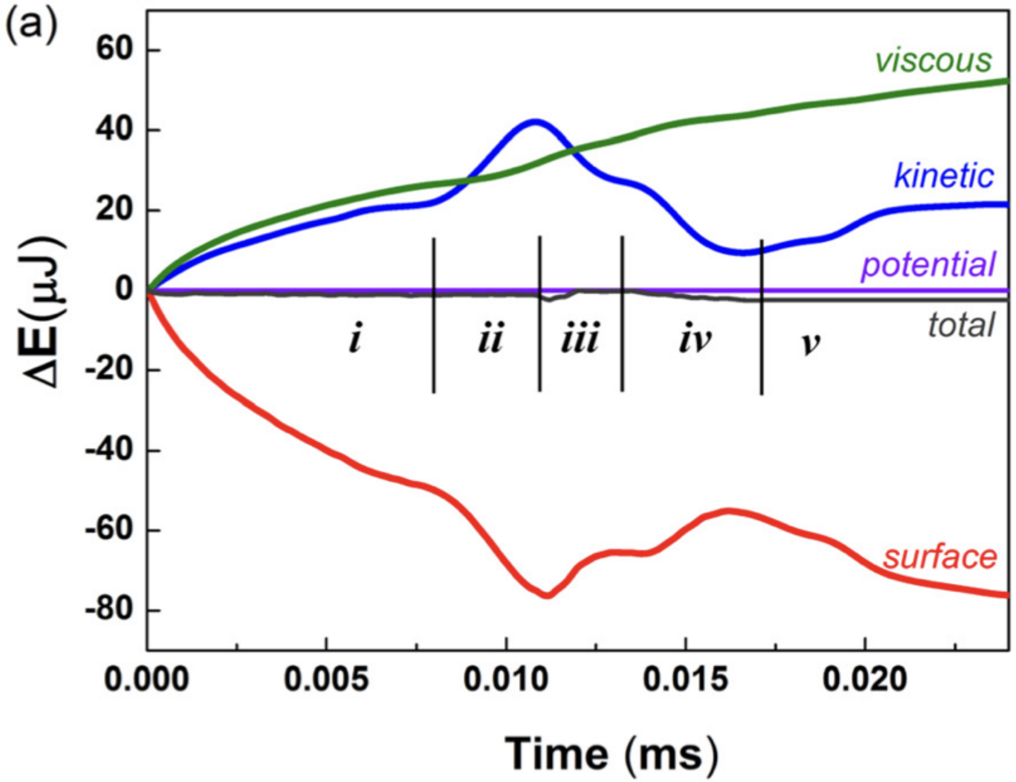
Jumping Droplet Condensation



Coalescence departure

Jumping Droplet Condensation





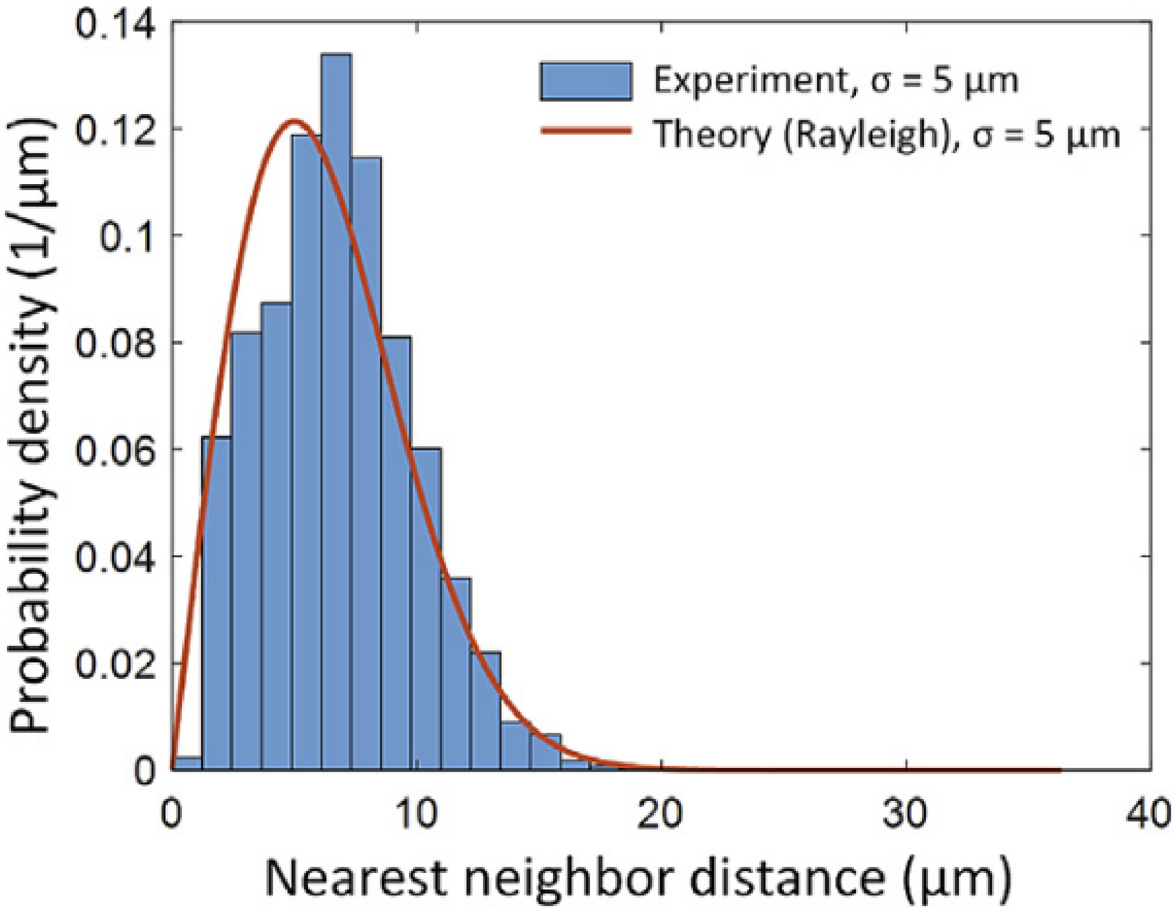
Appl. Phys. Lett. 103, 161601 (2013)

Distribution of Droplet Radii in Dropwise Condensation

- Probability density function

$$A(r) = \frac{r^{-2/3}}{3r_{max}^{1/3}} \qquad r_{max} = K_3\sqrt{\frac{\sigma}{\rho g}} \qquad \text{for } r_e < r \leq r_{max}$$

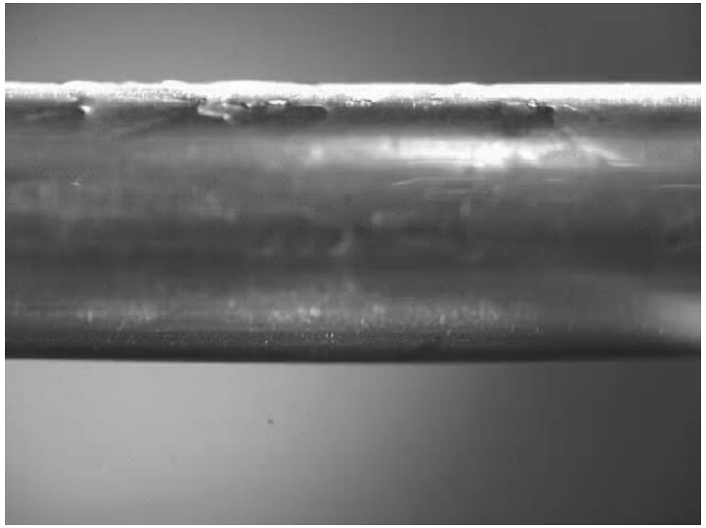
Distribution for Jumping Droplet Condensation



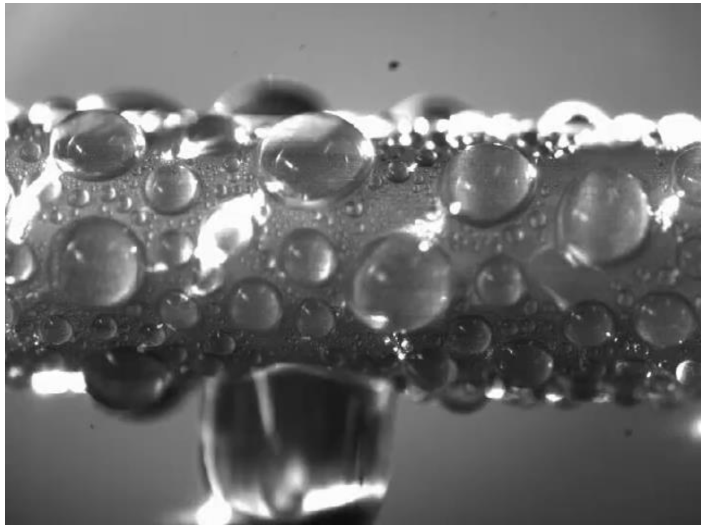
Since contacting neighboring droplet will cause jumping removal, droplet radius should be around half the nearest neighbor distance

Different Condensation Mode

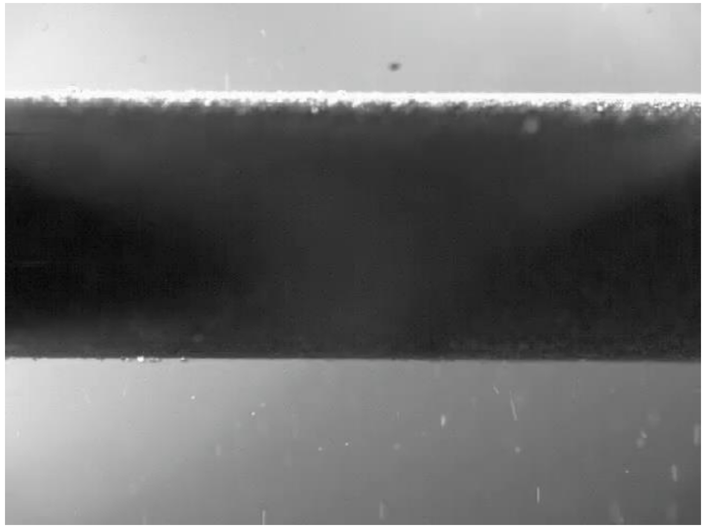
Superhydrophobic surface



Filmwise condensation



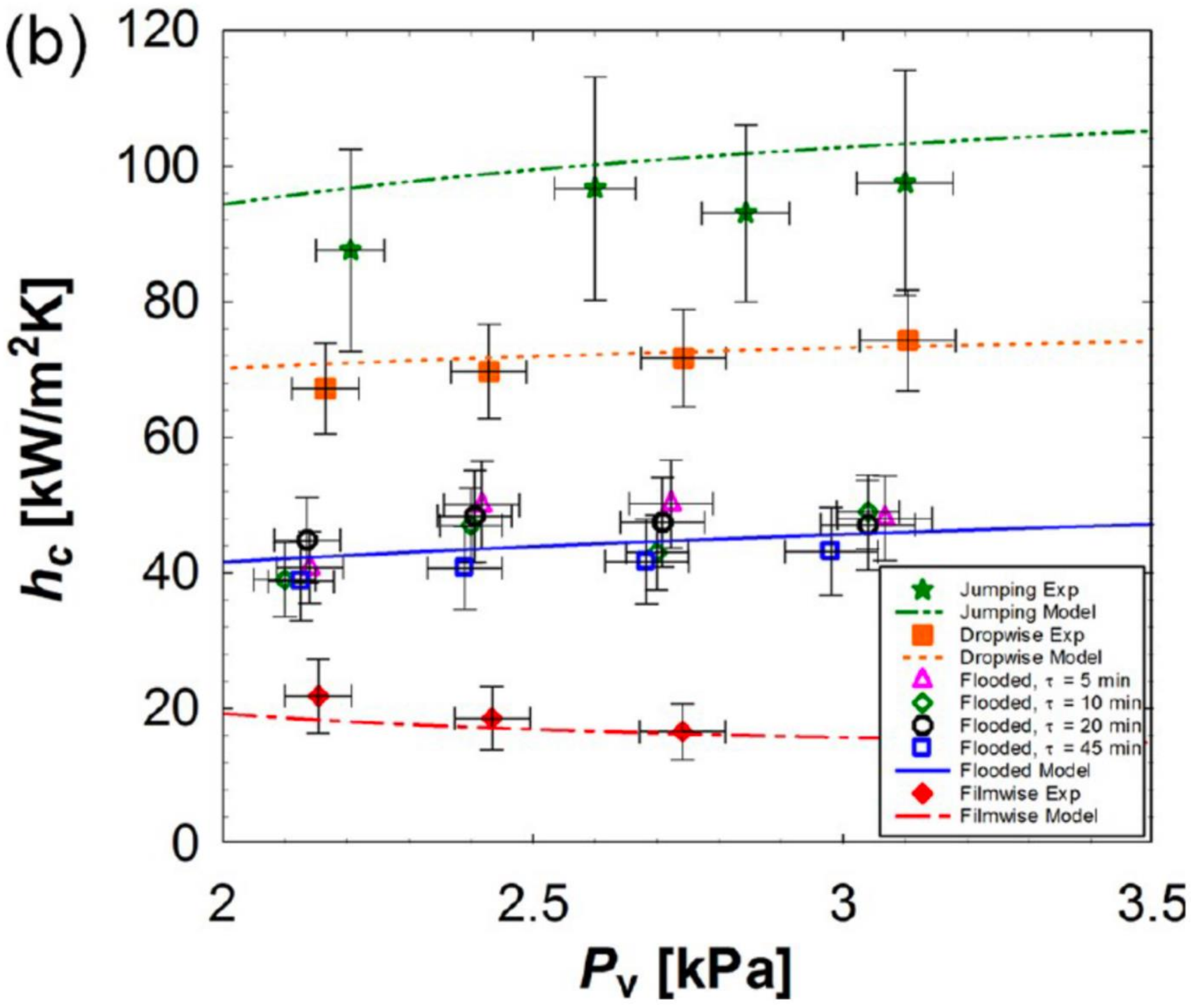
Dropwise condensation



Jumping-droplet condensation

Miljkovic *et al.*, *Nano Lett.* (2013)

Heat Transfer Enhancement



Jumping-droplet

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Dropwise

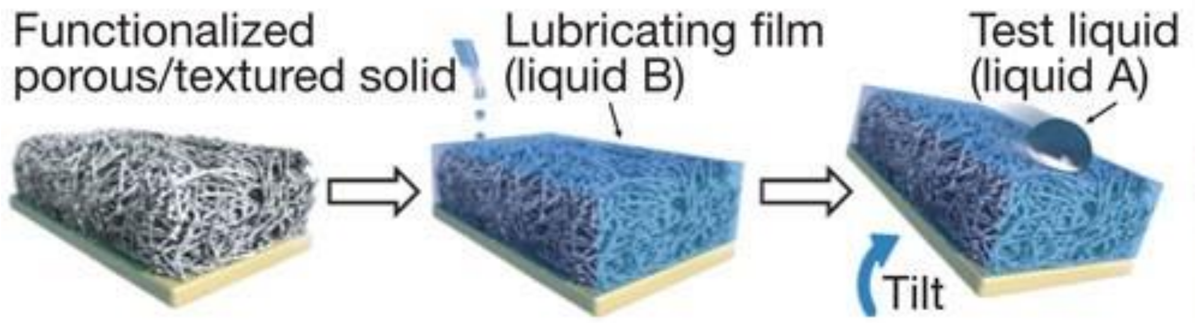
>

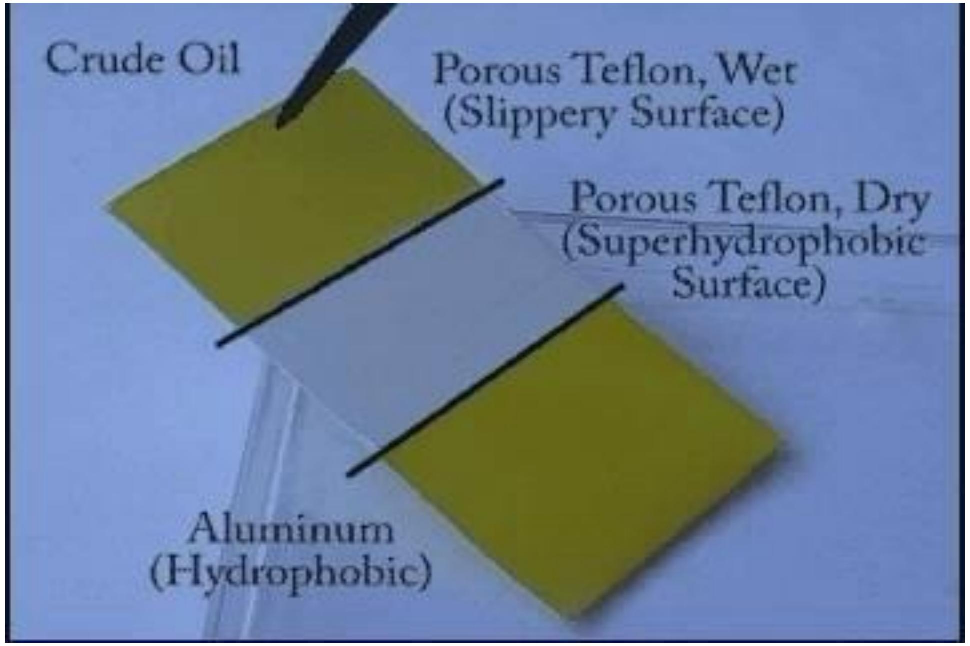
Filmwise

Nano Lett. 2013, 13, 179−187

How About Low Surface Tension Fluids

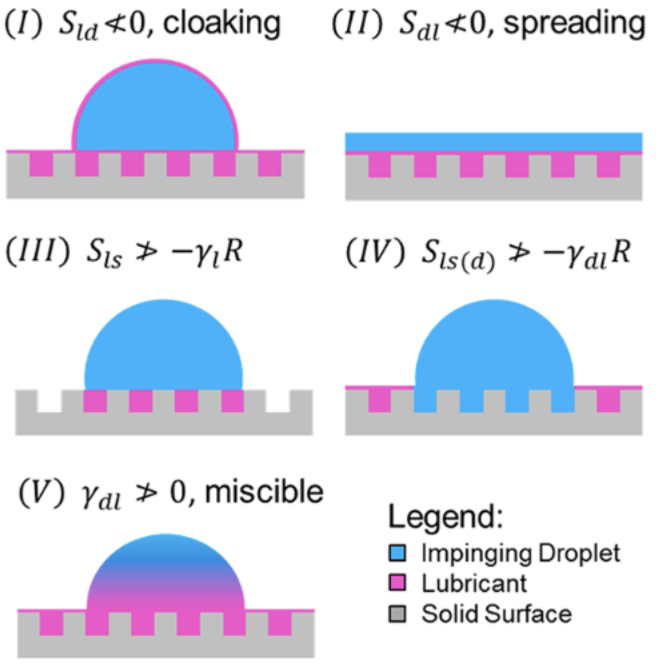
Lubricant Infused Surface (LIS)





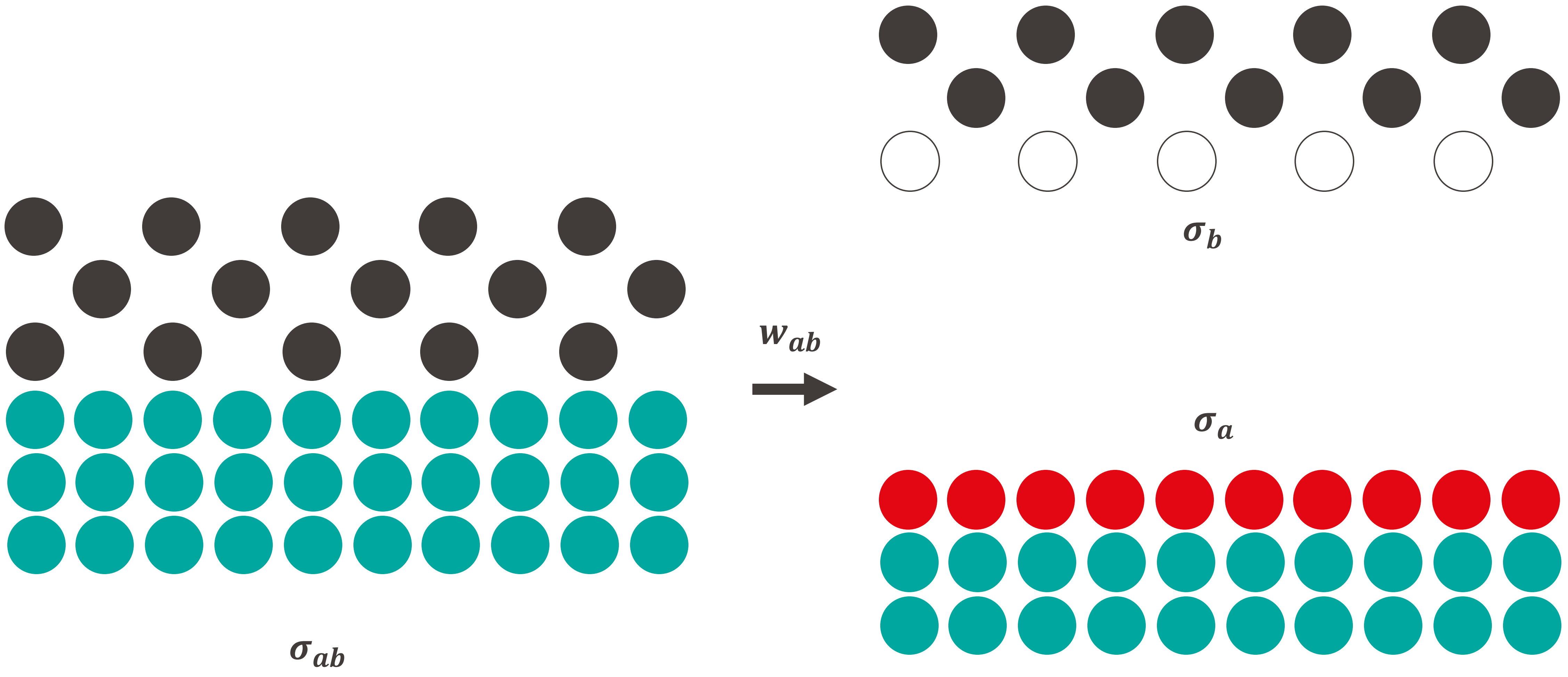
Nature volume 477, pages 443–447 (2011)

How to Design LIS



ACS Appl. Mater. Interfaces2017, 9, 42383−42392

From Week 2



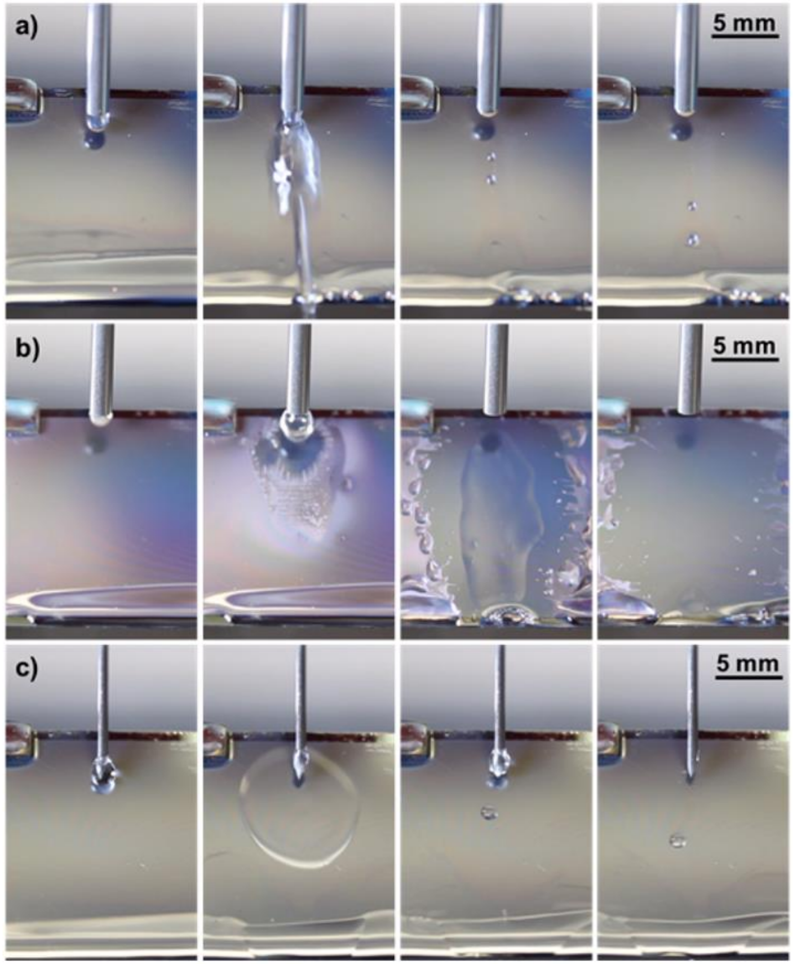
$$\sigma_{ab} = \sigma_a + \sigma_b - w_{ab}$$

w_{ab} depends on intermolecular interactions

van Oss, Chaudhury, and Good (vOCG Model)

Langmuir 1992,8, 2877-2879

How to Design LIS



Diiodomethane (CH_2I_2) dropped onto a LIS of methanol infused in SiO2pillar

Methanol dropped onto a LIS of diiodomethane infused in SiO2pillar

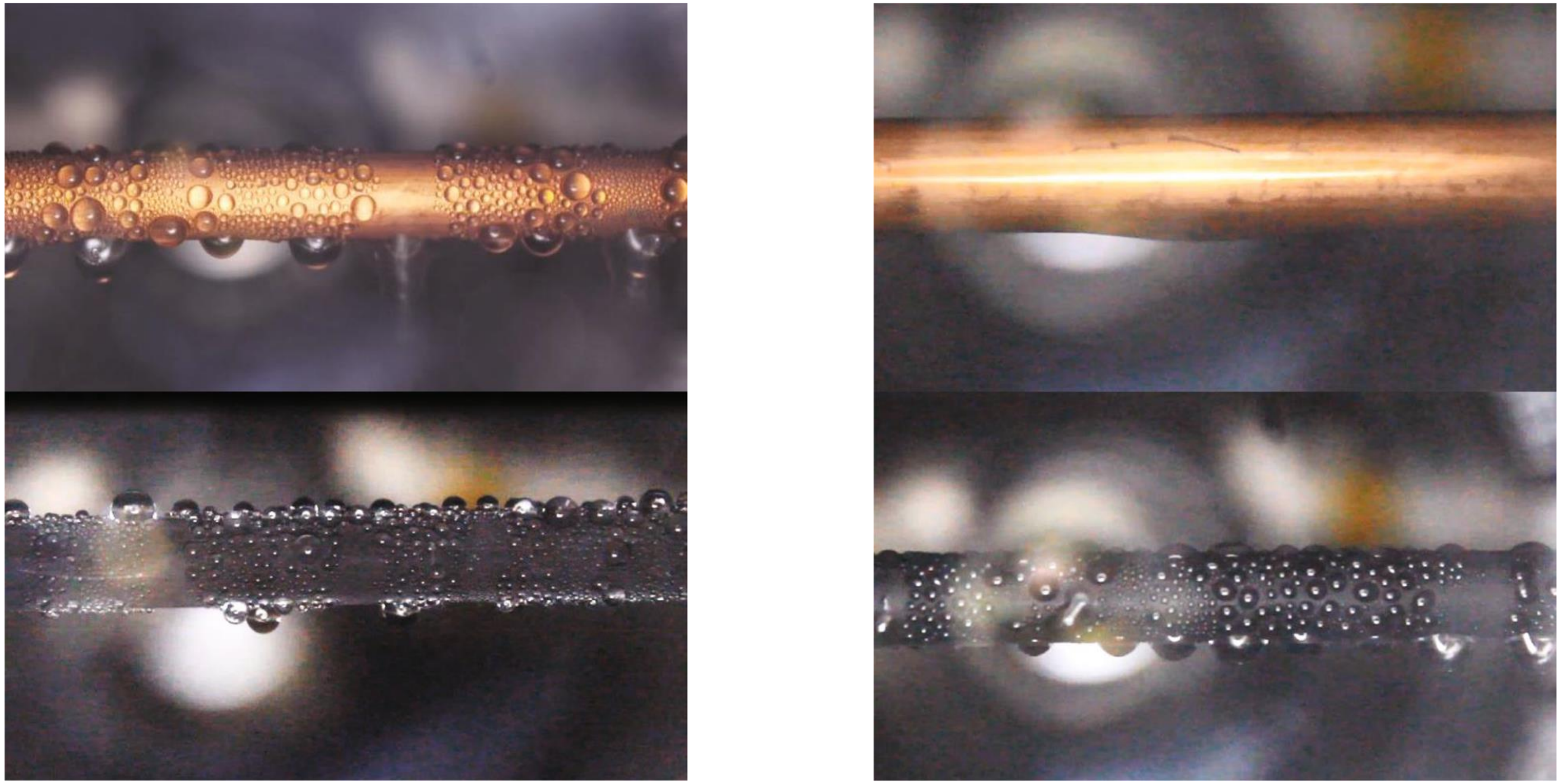
Heptane dropped onto a LIS of methanol infused in SiO2pillars

Condensation Experiment

Water (72 mN/m) | Toluene (28 mN/m)

Regular hydrophobic

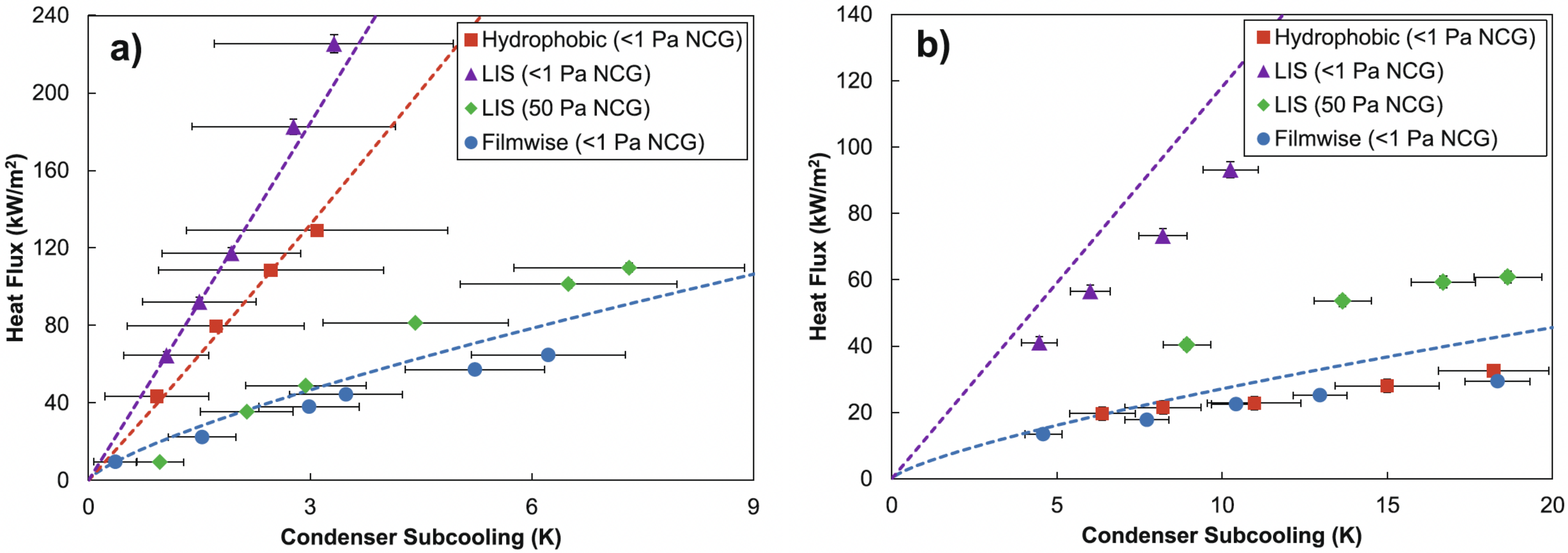
LIS



Heat Transfer Enhancement

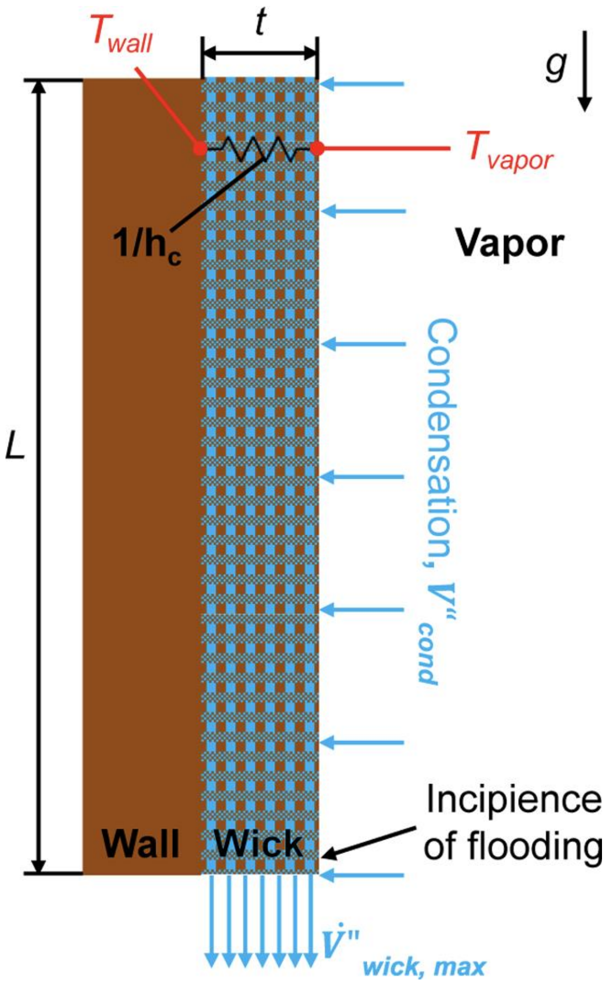
Water (72 mN/m)

Toluene (28 mN/m)



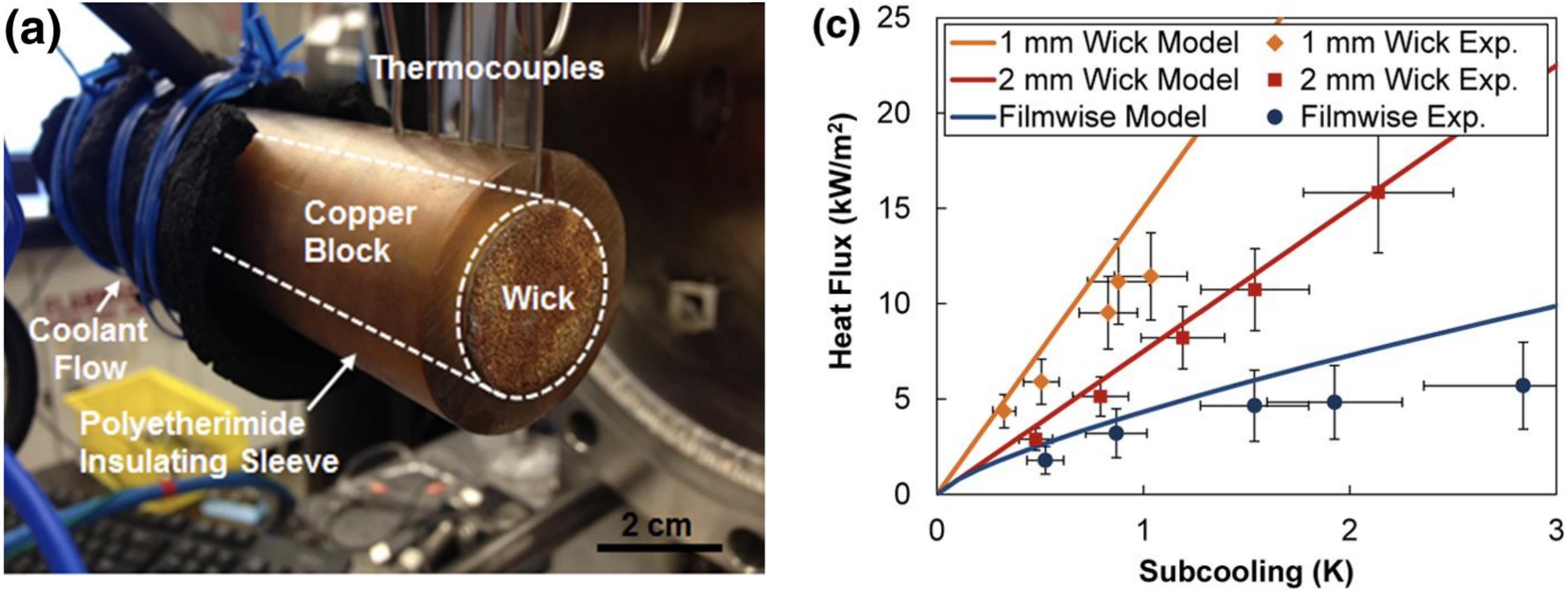
Preston, D.J. et al. Sci Rep 8, 540 (2018)

Wicking Condensation



Langmuir 2018, 34, 4658−4664

Experimental Results



Langmuir 2018, 34, 4658−4664