Superhydrophobic Surfaces

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The Laboratory

Themes & Expertise

Wetting of surfaces

Sensors (QCM, SAW, etc)

Materials scientists

Physicists

Science

Wetting & topography

- new super-hydrophobic surfaces
- super-spreading, evaporation, liquid marbles, electrowetting, hydrophobic soil, slip boundary conditions

Multidisciplinary People

2 x Academics (Physicists)

3 x PhD Students (+ 2 others joint)

- All physicists by first degree

4 x Research fellows

- Electrochemist
- Applied physicist/acoustic waves
- Inorganic/protein chemist
- Materials synthesis (sol-gel)

Facilities

Surface fabrication

- Lithography, metal deposition
- Inorganic/materials lab

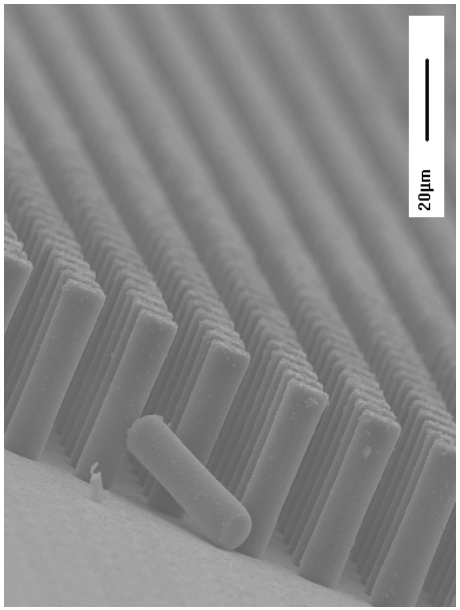
Surface characterisation

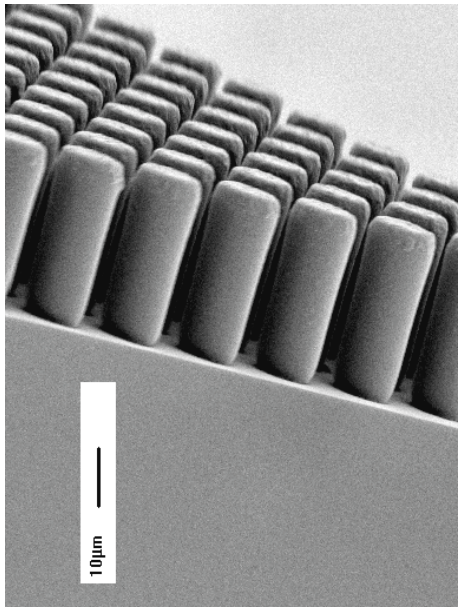
- SEM/TEM/Confocal microscopy
- Contact/non-contact profilometry

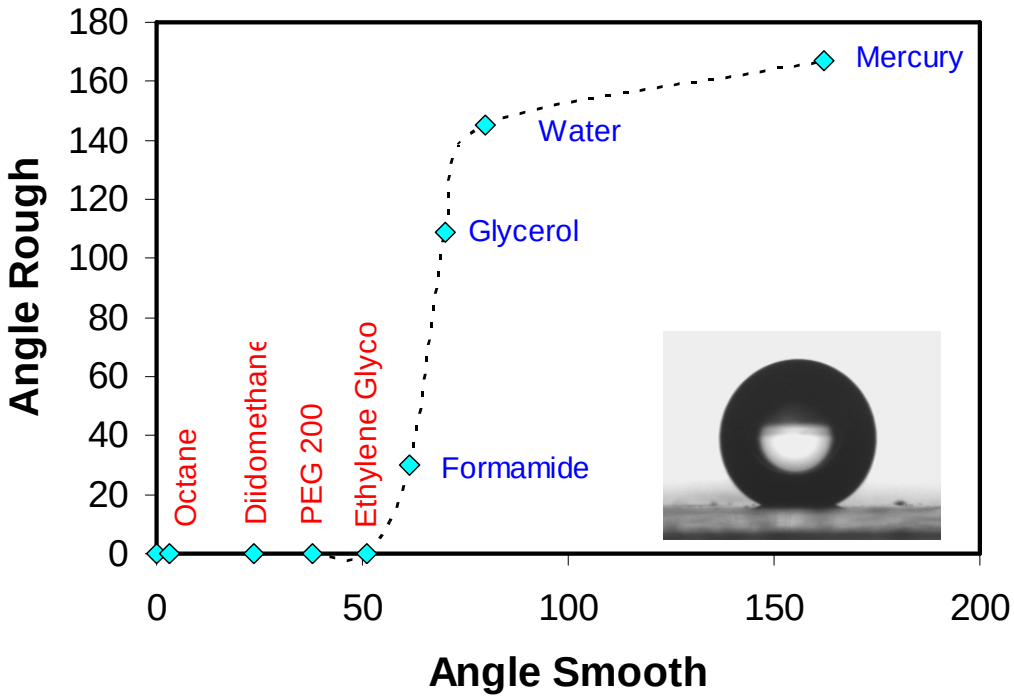
Instrumentation & measurement

- Krüss DSA, high speed camera
- kV supplies, RF Network analyzer, QCM

SU-8 Photoresist Pillars







SU-8 Photoresist

Model surfaces, tall structures to 45-75 µm, smooth and straight walls, aspect ratios up to ~ 4

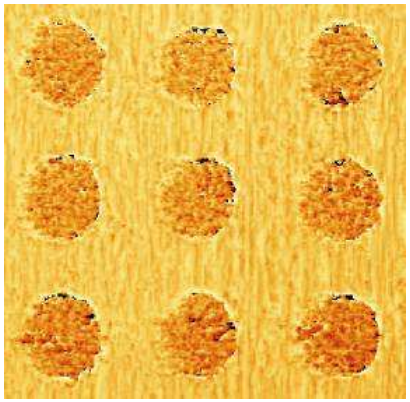
Reference Shirtcliffe, *et al*, J. Micromech. Microeng. 14 (2004) 1384-1389.

Electroplated Textured Surfaces

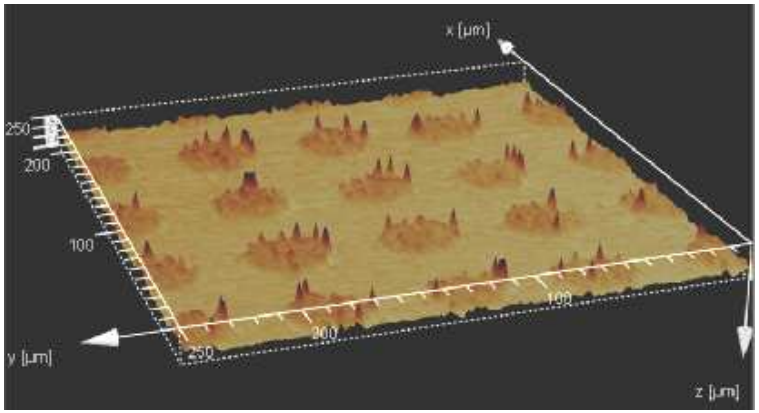
Fractal growth

Base Cu electroplated surface

Electroplating through a mask

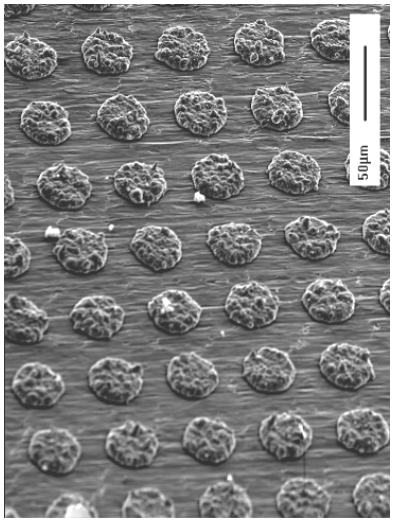


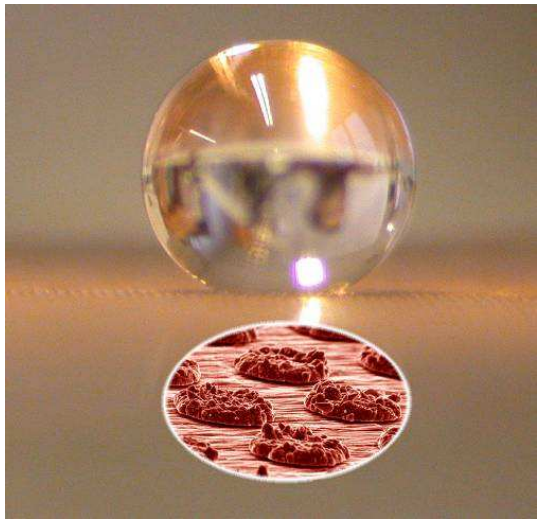
Confocal image of a 30µm textured electroplated Cu

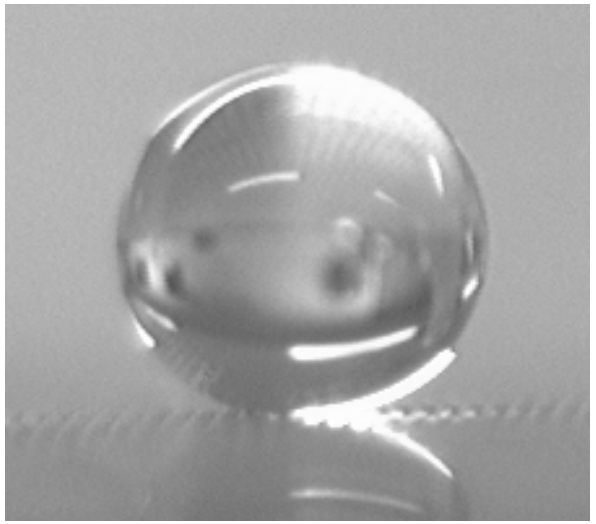


3D view of a electroplated copper sample

Double length scale“Chocolate chip cookies”







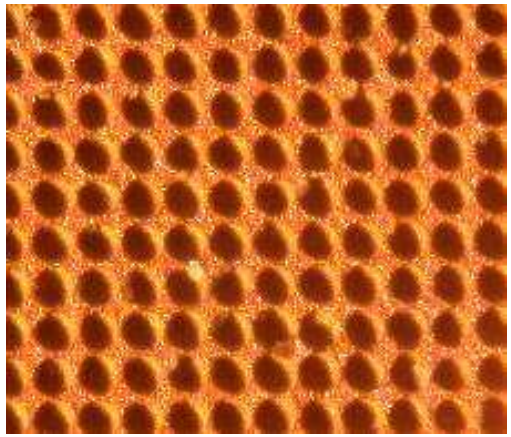
References

Shirtcliffe, *et al*, , Langmuir 21 (2005) 937-943.

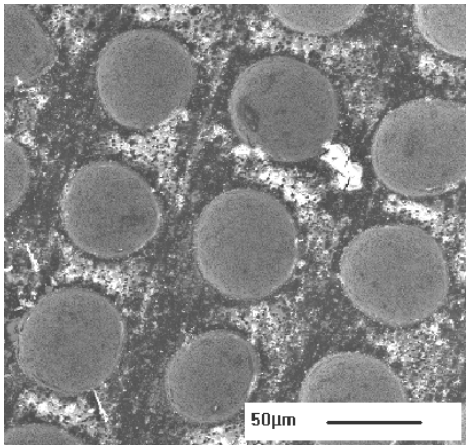
Shirtcliffe, *et al*, Adv. Maters. 16 (2004) 1929-1932.

Etching of Copper Surfaces

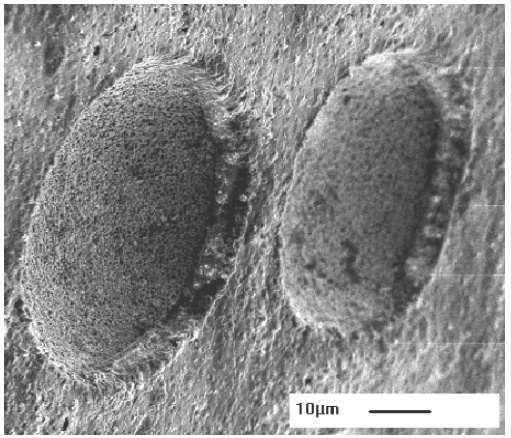
Etching using PCB Techniques – Simple and Effective



Copper sample etched through a 30 μm pattern

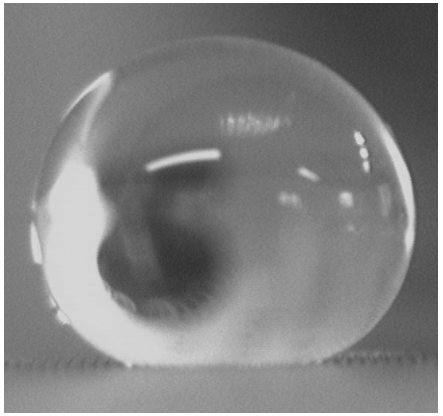


SEM picture of the pattern of the etched copper surface

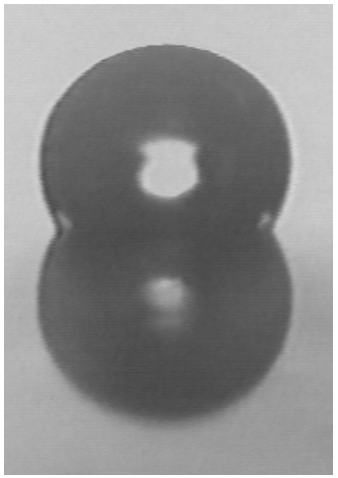


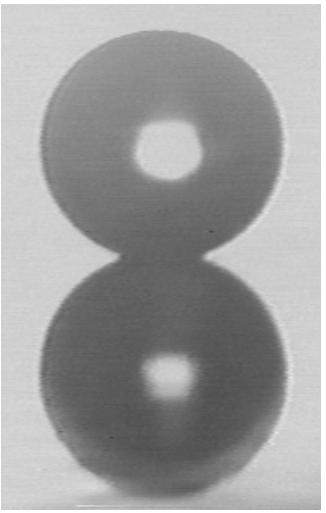
SEM picture of an etched hole in copper sample

30 μm and 40 μm Patterns



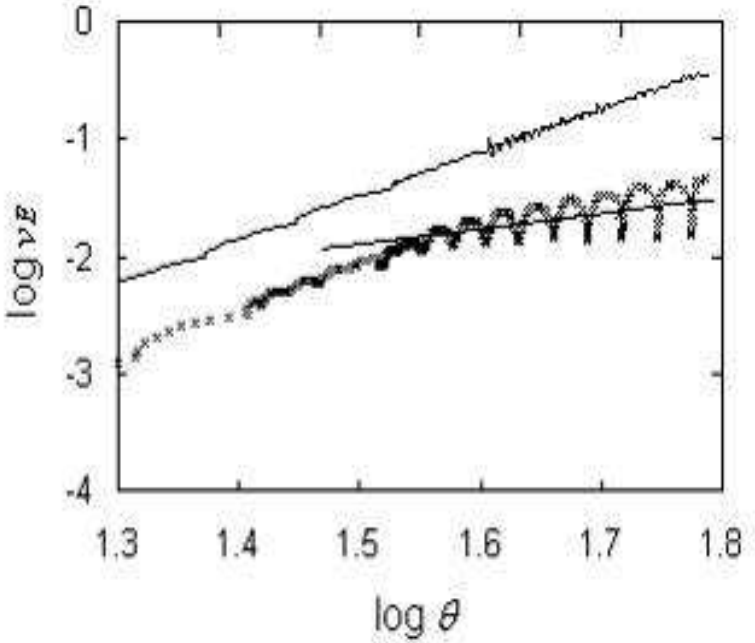
40μm pattern with Grangers





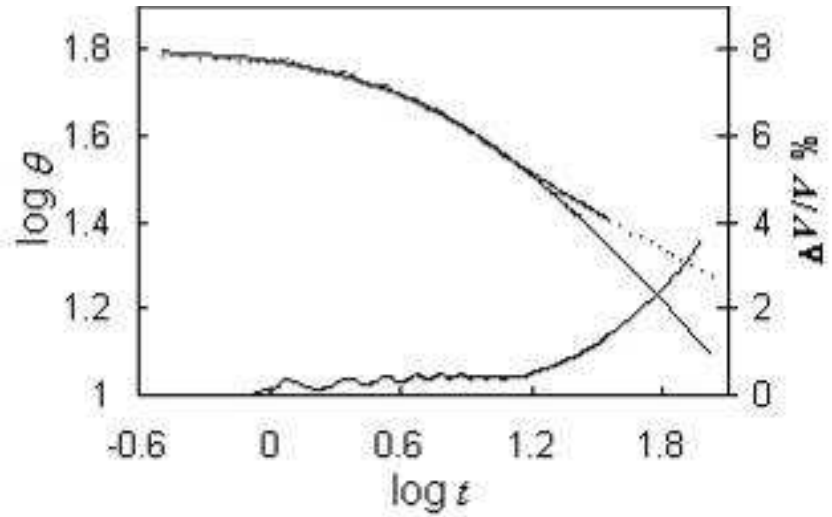
Superwetting Data Set on Pillars

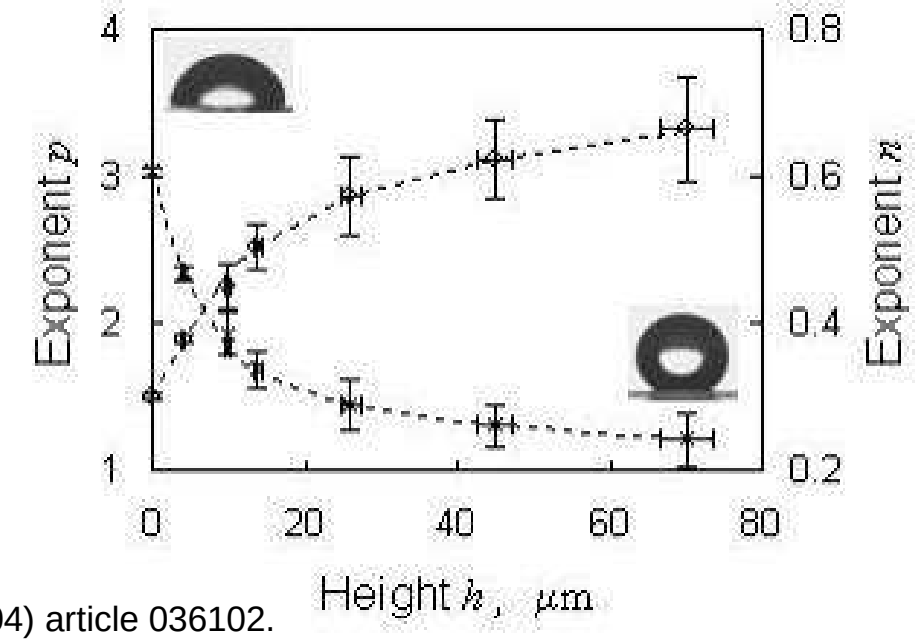
Tanner's Law exponents *p* and *n* (cubic to linear transition)



$$v_E \propto v^* \theta^p$$

$$\theta \propto \left(\frac{V^{1/3}}{v^*} \right)^n \frac{1}{(t + t_o)^n}$$

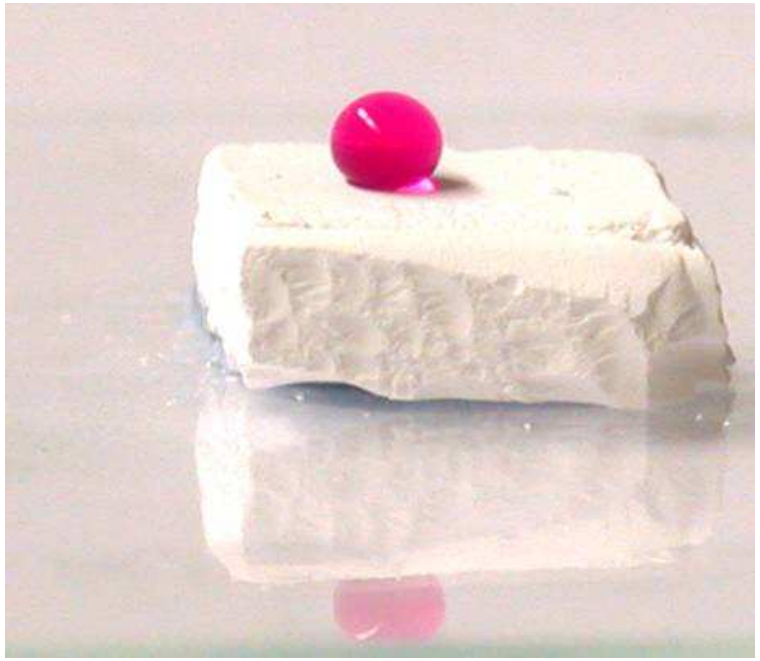




References McHale□, *et al*, Phys. Rev. Lett. 93, (2004) article 036102.

Superhydrophobic Sol-gels & Switching

1. Intrinsically superhydrophobic MTEOS sol-gel foam
2. Renewable surface by abrading
3. Switched to porous foam by heat cycle to change to hydrophilic

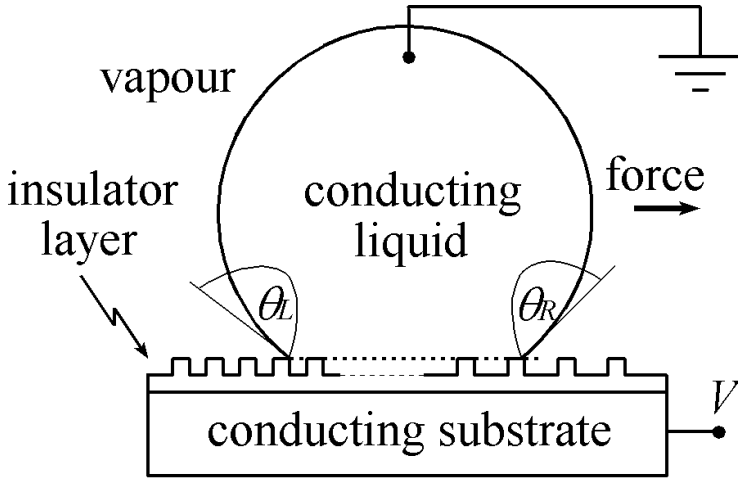


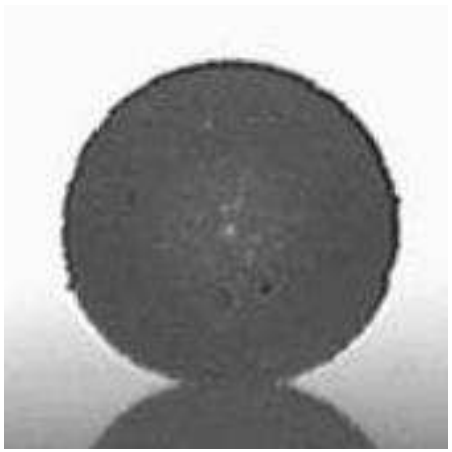
Foam heated (and cooled) prior to droplet deposition

References

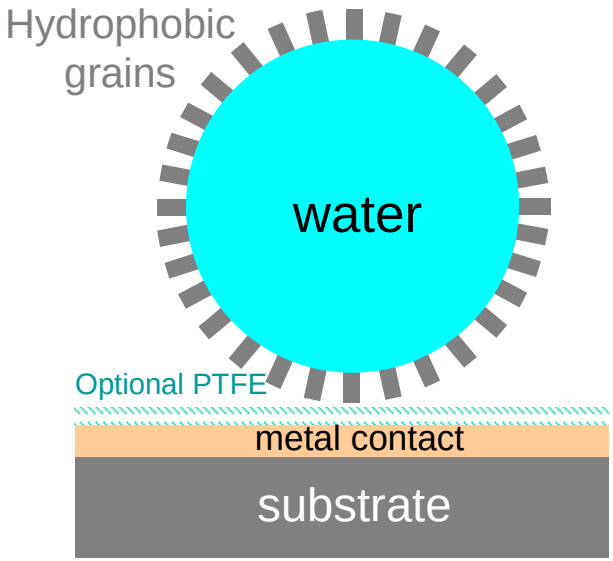
Shirtcliffe, *et al*, Langmuir 19 (2003) 5626-5631
Shirtcliffe *et al*, Chem. Comm. 25 (2005) 3135-3137 (also Nature News 20/7/05)

Electrowetting & Liquid Marbles

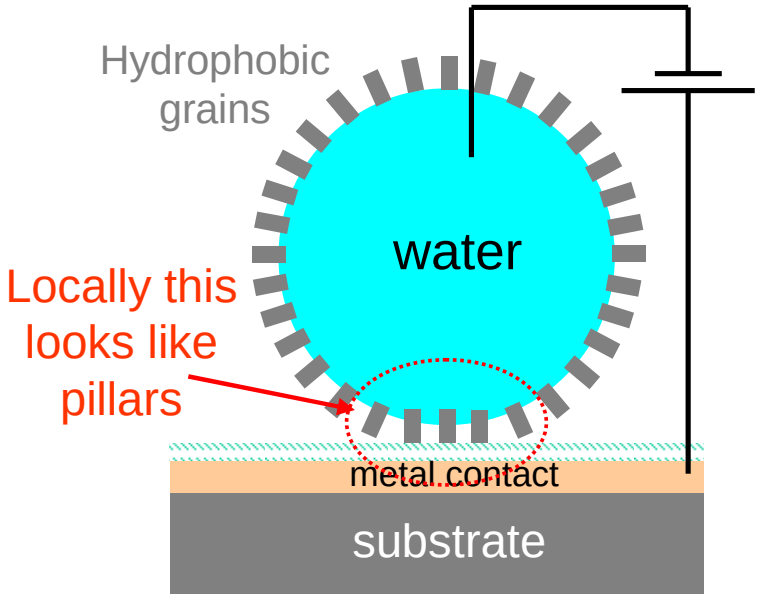




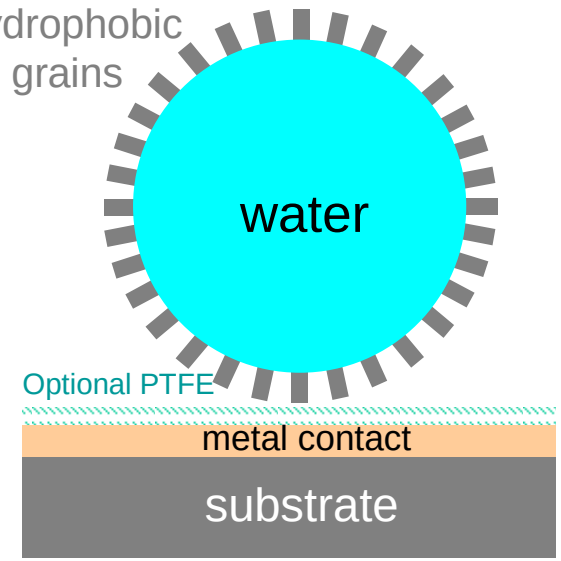
Initial Shape



Apply Voltage



Remove Voltage



References

Herbertson *et al*, Sens. Act. A. 130 (2006) 189-193.
McHale, *et al*, accepted by Langmuir (2006); Newton, *et al*, accepted by J. Phys. D. (2006).

Other Wetting Research

Slip Boundary Condition

- *The effect of superhydrophobic SU8 patterned surfaces on the response of the quartz crystal microbalance,* Sens. Act. A 123-24 (2005) 73-76.
- *Surface roughness and interfacial slip boundary condition for quartz crystal microbalances*, J. Appl. Phys. 95 (2004) 373-380.
- *Contact angle-based predictive model for slip at the solid-liquid interface of a transverse-shear mode acoustic wave device*, J. Appl. Phys. 94 (2003) 6201-6207.
- *Influence of viscoelasticity and interfacial slip on acoustic wave sensors*, J. Appl. Phys., 88 (2000) 7304-7312.

Novel Applications of Superhydrophobicity

- *A lichen protected by a superhydrophobic and breathable structure*, J. Plant Physiol. 163 (2006) 1193-1197
- *Plastron properties of a super-hydrophobic surface*, Appl. Phys. Lett. 89 Art 104600 (2006).

Theory of Wetting

- *Analysis of droplet evaporation on a super-hydrophobic surface*, Langmuir 21 (2005) 11053 - 11060.
- *Contact angle hysteresis on super-hydrophobic surfaces*, Langmuir 20 (2004) 10146-10149.
- *Frenkel's method and the dynamic wetting of planar heterogeneous surfaces*, Colloids and Surfaces, A206 (2002) 193-201.

Acoustic Wave Research

Biosensors

- *Layer guided-acoustic plate mode biosensors for monitoring MHC-peptide interactions*, Analyst 131 (2006) 892-894. (Note: Also selected to appear in RSC Chemical Biology Virtual Journal).
- *Pulse mode shear horizontal-surface acoustic wave (SH-SAW) system for liquid based sensing applications*, Biosens. Bioelectron. 19 (2004) 627-632.
- *Enantioselective detection of L-Serine*, Sens. Act. B: Chemical 89 (2003) 103-106.
- *Molecular imprinted polymer coated QCM for the detection of nandrolone*, Analyst, 127 (2002) 1024-1026.

Pollution Sensors

- *An EP-SAW for measurements of particulate matter in ambient air*, NDT & E, 20 (2005) 3-7.
- *Detection of polycyclic aromatic hydrocarbons using quartz crystal microbalances*, Anal. Chem. 75 (2003) 1573-1577.
- *Molecularly imprinted polymer coated quartz crystal microbalances for the detection of terpenes*, Anal. Chem., 73 (2001) 4225 –4228.

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  - *Drag reduction & slip at the solid-liquid interface*
  - *Electrowetting & superhydrophobic surfaces*
  - *Extreme soil water repellence*
  - *Superhydrophobic & superhydrophilic surfaces*
- NERC NER/J/S/2002/00662, NERC NEC003985/1 (SD)
  - *Advanced Fellowship* for Dr Stefan Doerr
  - *Fundamental controls on soil hydrophobic behaviour*

People

- PhDs, PDRAs, Other staff at NTU and external collaborators

EPSRC
Engineering and Physical Sciences Research Council

NOTTINGHAM TRENT UNIVERSITY

NATURAL ENVIRONMENT RESEARCH COUNCIL

Size Data (Lycopodium)