

# 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

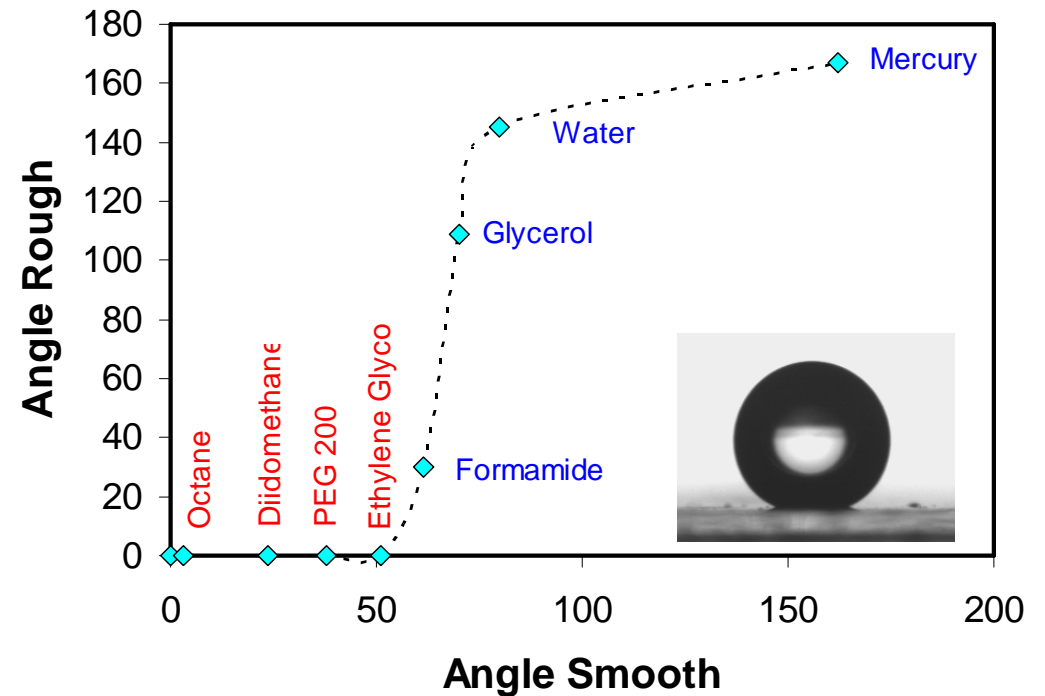
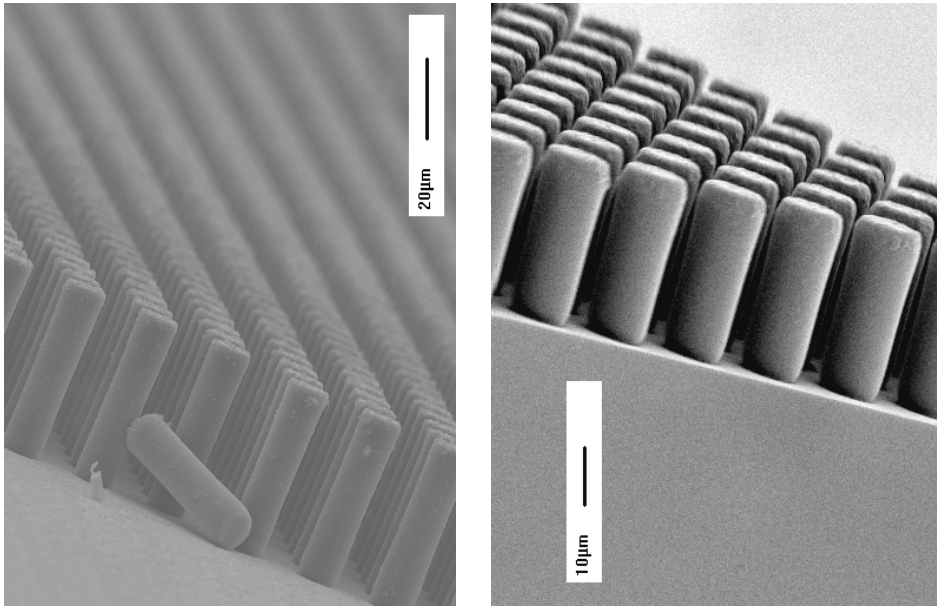
## Multidisciplinary People

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  $\mu\text{m}$ , smooth and straight walls, aspect ratios up to  $\sim 4$

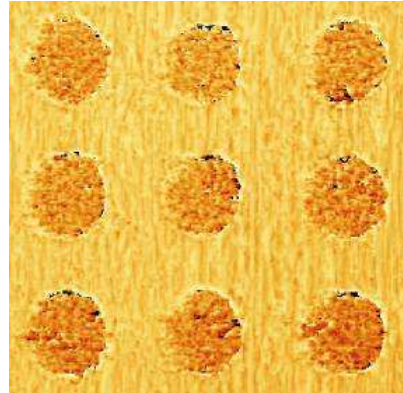
# Electroplated Textured Surfaces

## Fractal growth

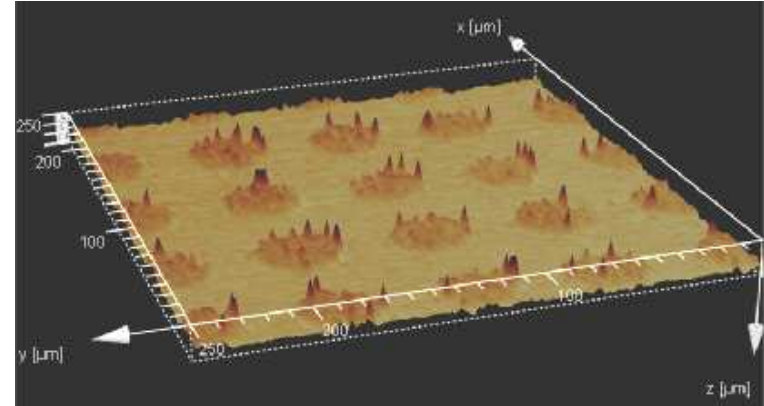


*Base Cu electroplated surface*

## Electroplating through a mask

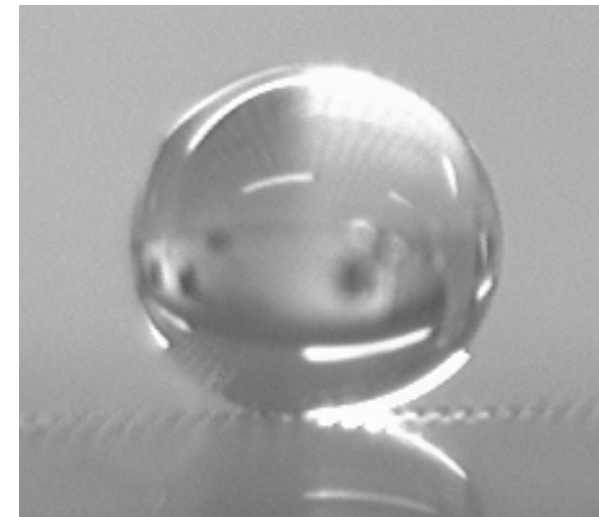
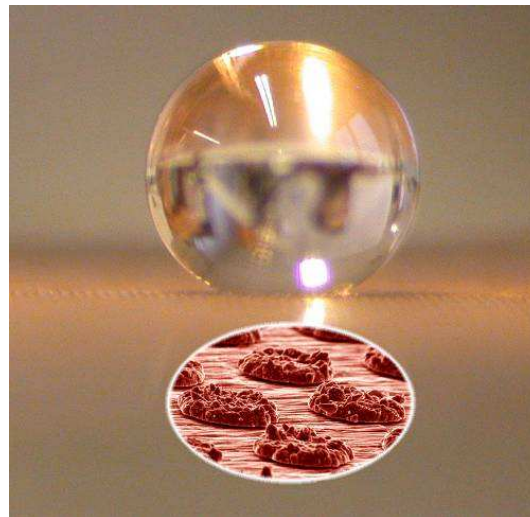
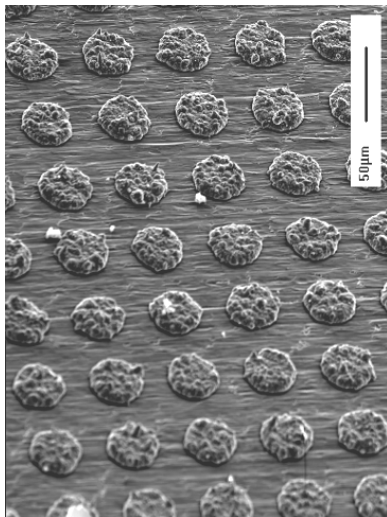


*Confocal image of a 30 $\mu\text{m}$  textured electroplated Cu*



*3D view of a electroplated copper sample*

## Double length scale "Chocolate chip cookies"



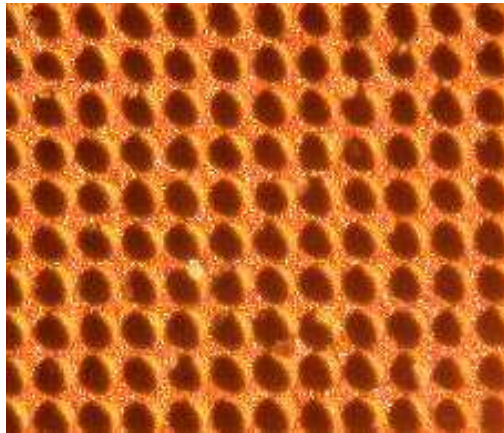
### References

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

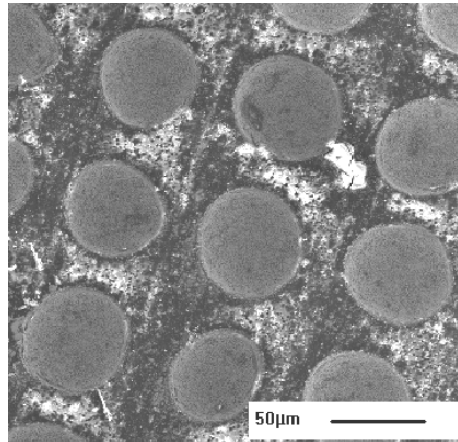
Shirtcliffe, *et al*, *Adv. Mater.* 16 (2004) 1929-1932.

# Etching of Copper Surfaces

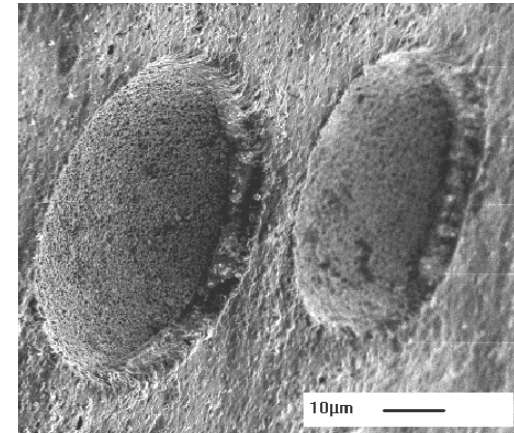
Etching using PCB Techniques – Simple and Effective



*Copper sample etched through a 30 μm pattern*

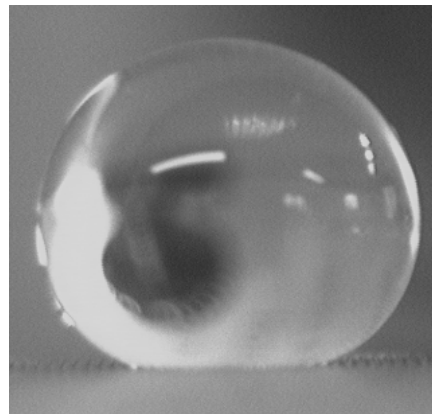


*SEM picture of the pattern of the etched copper surface*

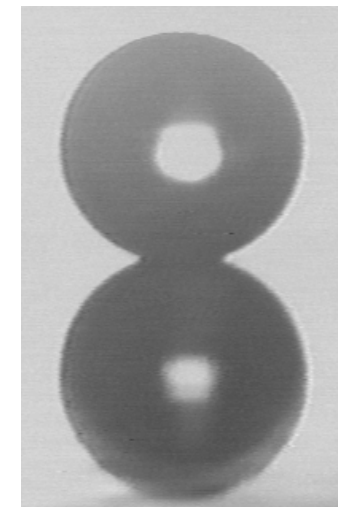
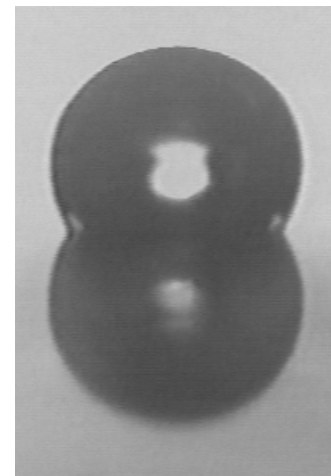


*SEM picture of an etched hole in copper sample*

30 μm and 40 μm Patterns

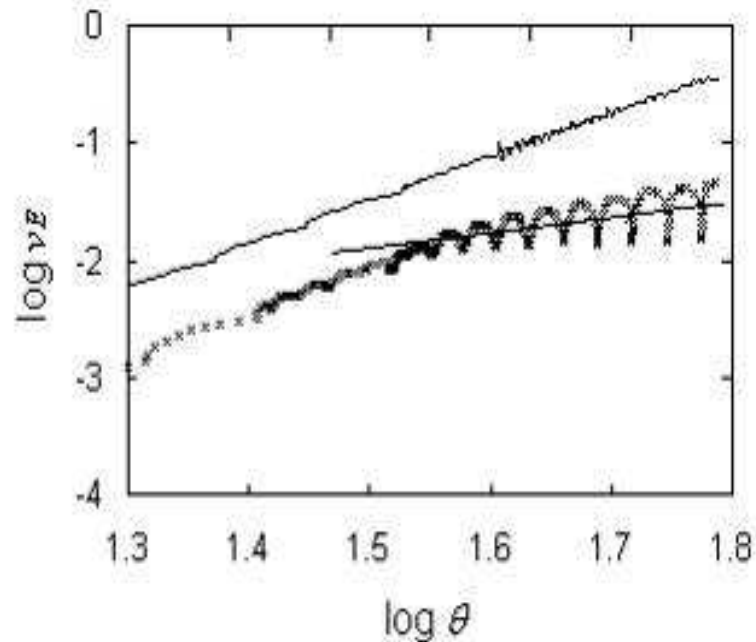


*40 μm pattern with Grangers*



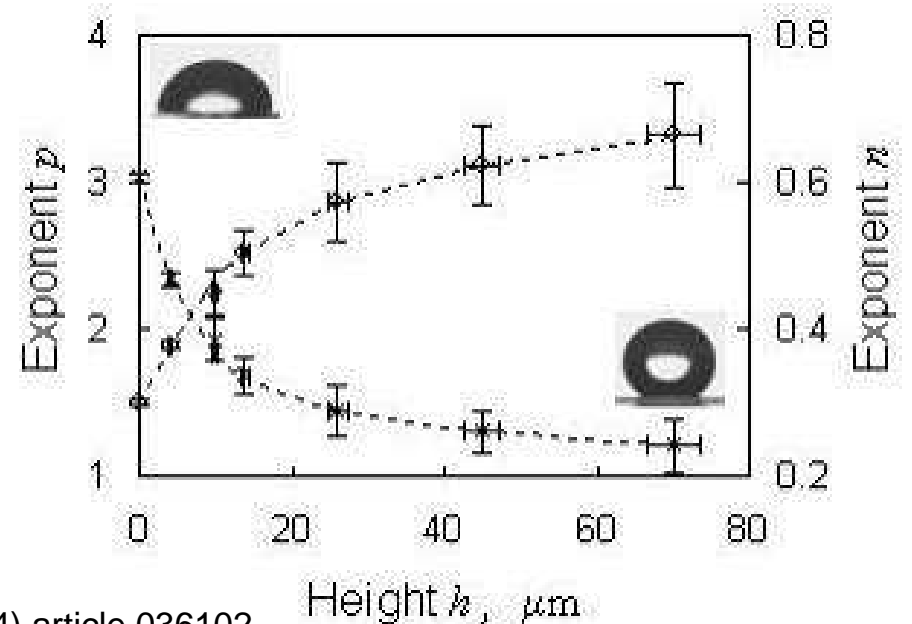
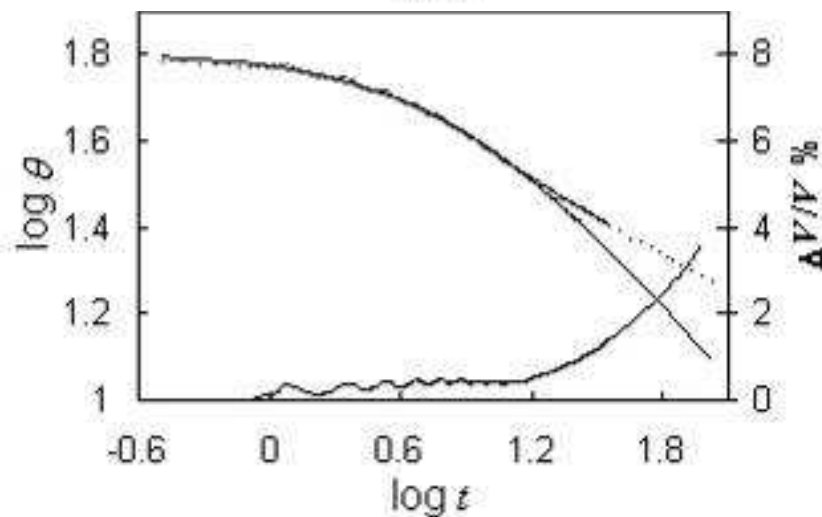
# Superwetting Data Set on Pillars

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



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

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

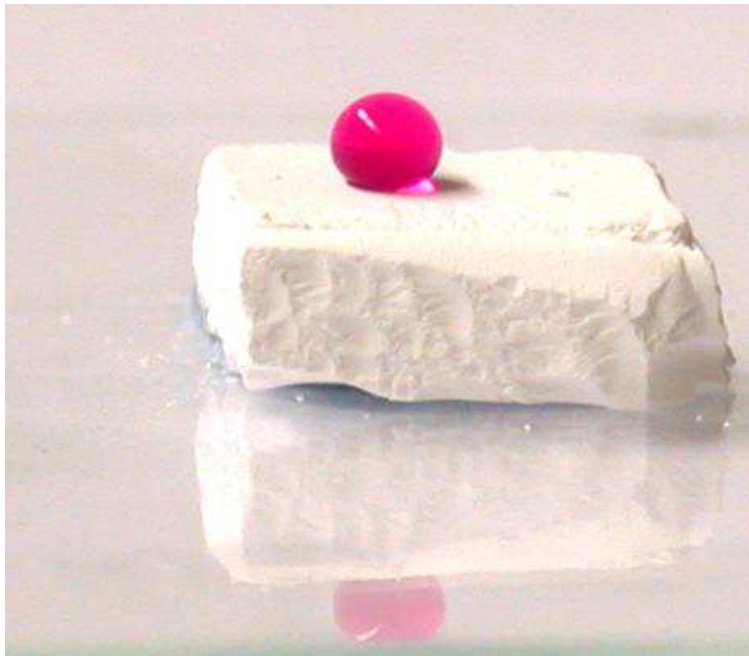


References

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



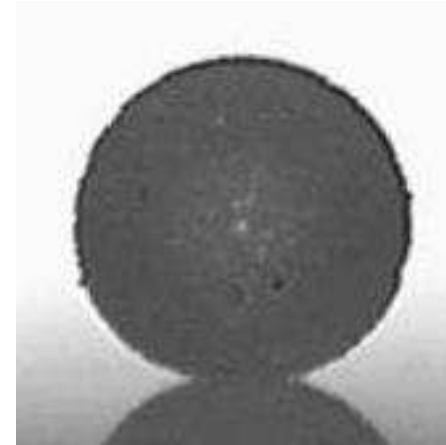
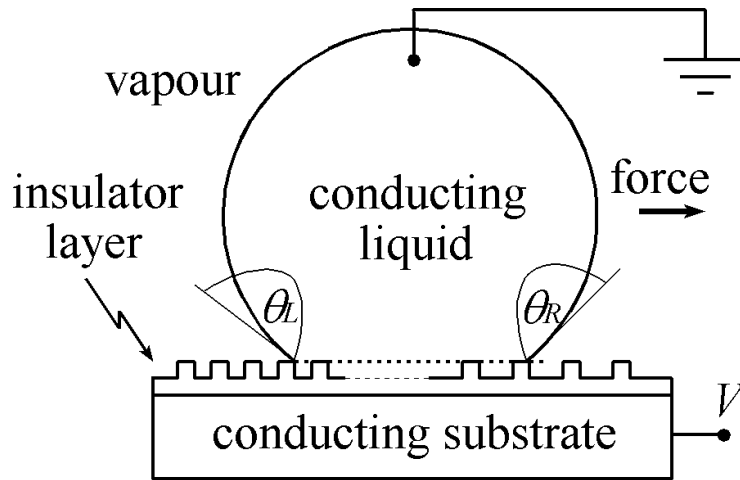
Foam heated  
(and cooled)  
prior to droplet  
deposition

## References

Shirtcliffe, *et al*, *Langmuir* 19 (2003) 5626-5631

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

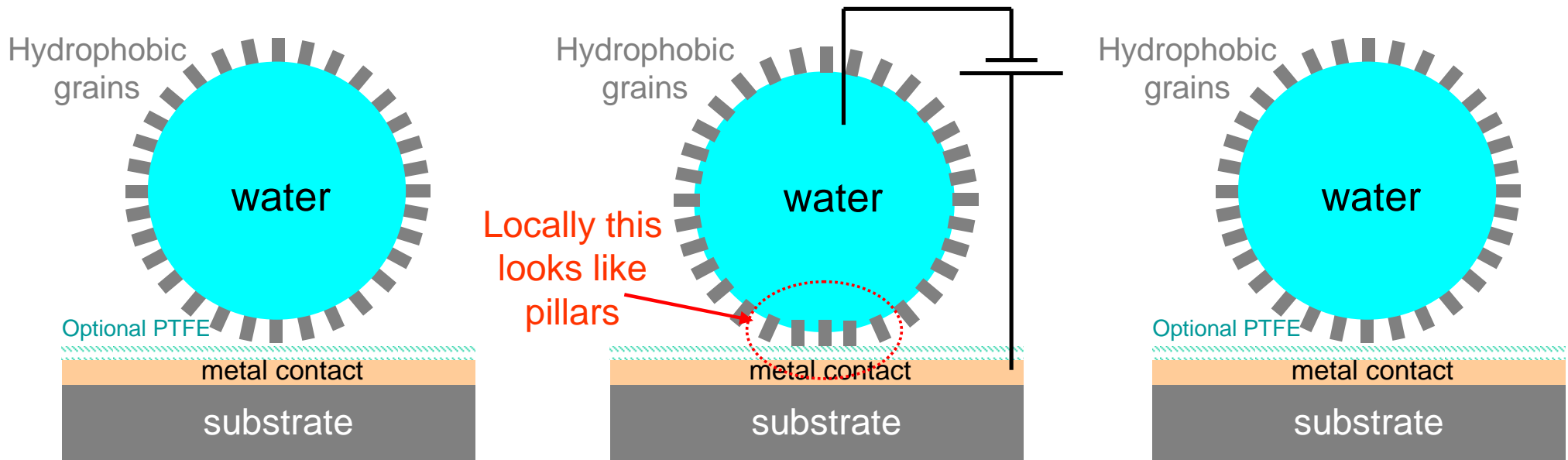
# Electrowetting & Liquid Marbles



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**

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Research Council

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# Size Data (Lycopodium)

