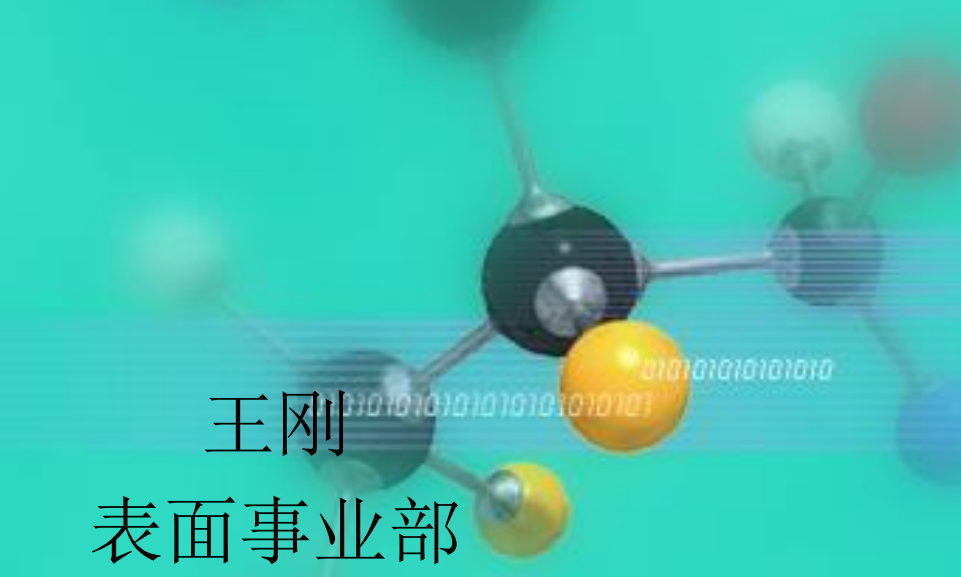


超疏水表面的黏附性

王刚

表面事业部



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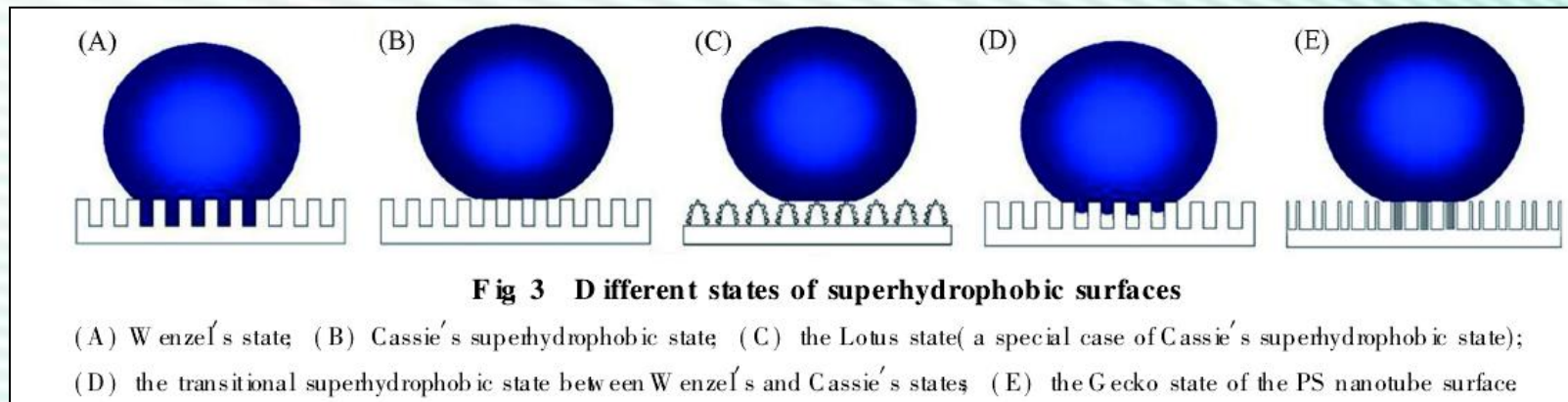
*展望



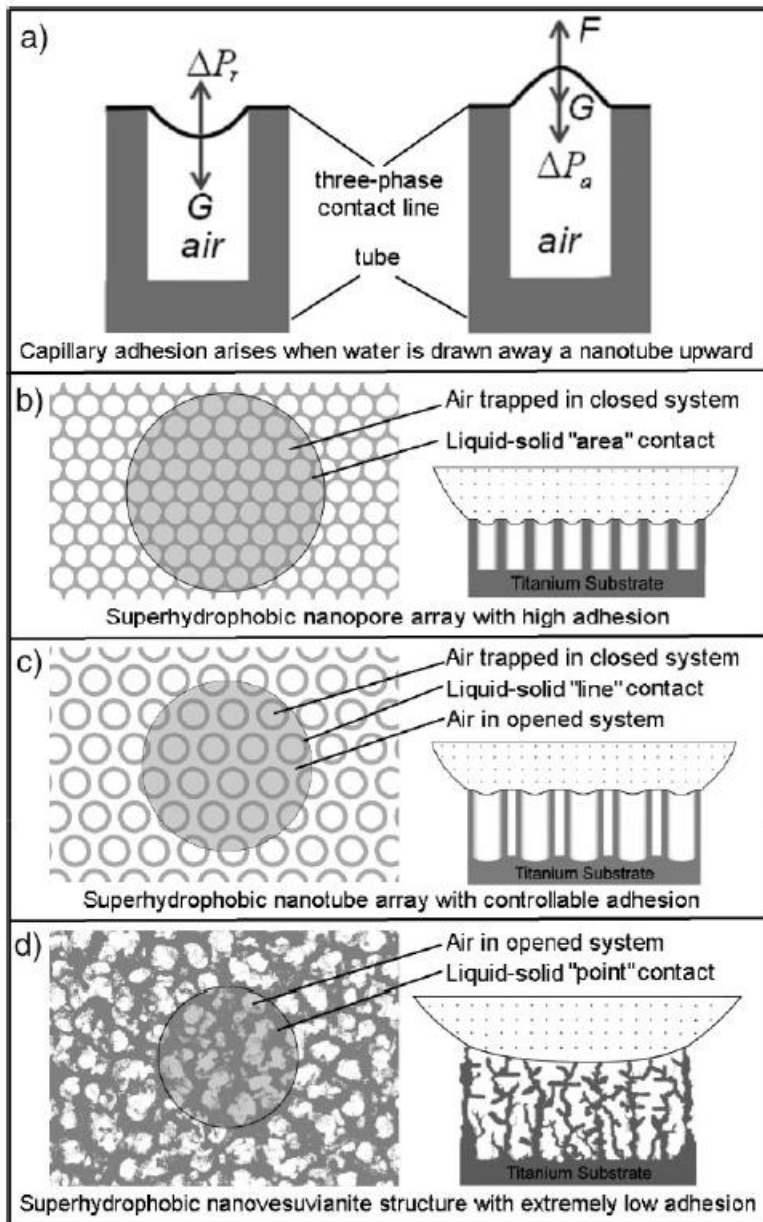
引言

超疏水表面

水滴静态接触角大于 150° 的固体表面为超疏水表面，结合接触角滞后的不同将超疏水表面状态分为Wenzel状态、Cassie状态、Lotus状态、Wenzel与Cassie的过渡状态以及Gecko状态5种。



Herminghaus认为，分级结构能够使任何材料构成的表面都变得不可浸润，即使是亲水材料，此时表面的微结构可以使水滴浮在表面，这也是一种Wenzel与Cassie过渡的状态。



超疏水多孔纳米结构的表面黏附力受两个关键性因素控制：

(1) 纳米结构几何表观形貌，它们通过固/液接触方式（“面接触”、“线接触”、“点接触”）实现微尺度下范德华引力的调控；

(2) 密闭毛细孔与开放毛细孔的比例，改变毛细孔径尺度和密度可实现微尺度下毛细作用力的调控，而改变毛细孔长度可实现对液/固分离前密闭的气相体积及负压大小的调控。



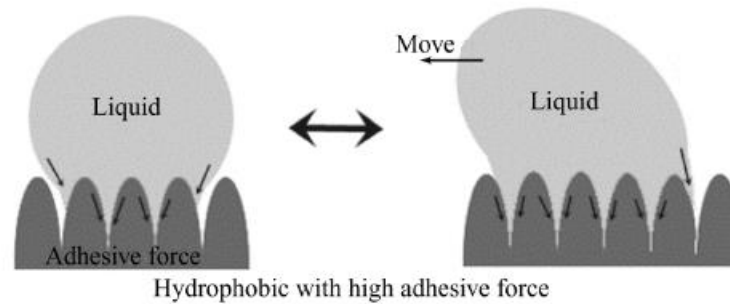


图 1 球状微阵列润湿过程^[20]

Fig. 1 Spherical microarray wetting process^[20]

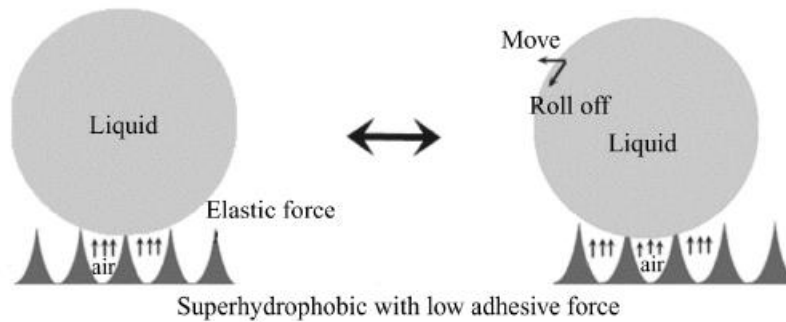
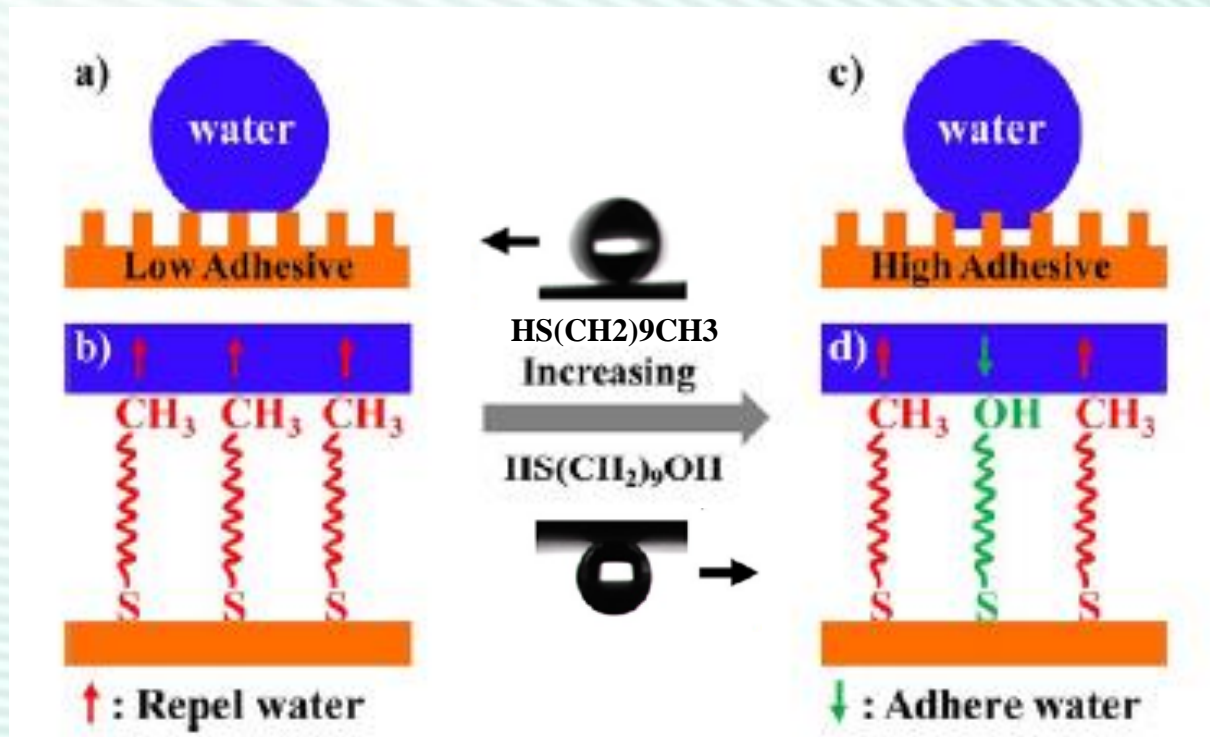
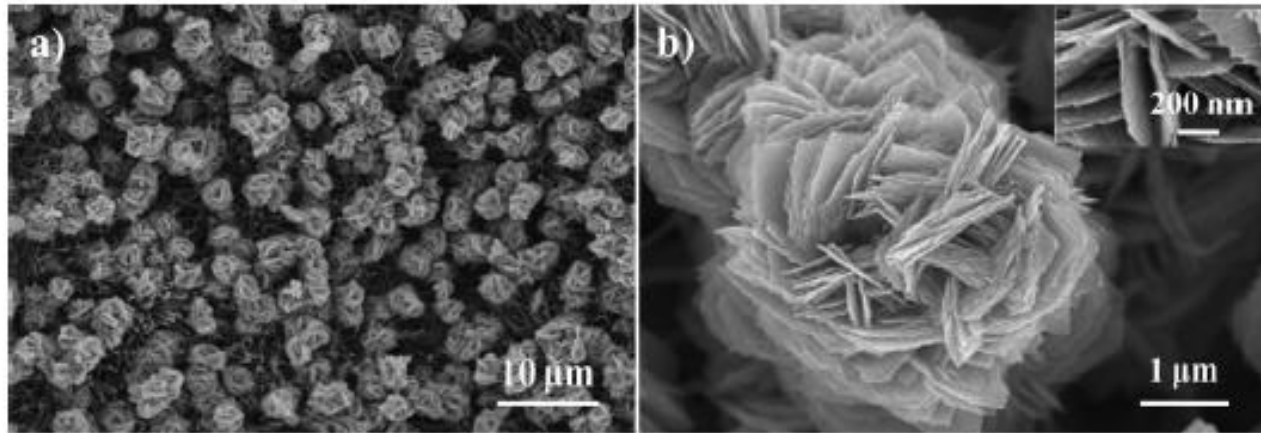
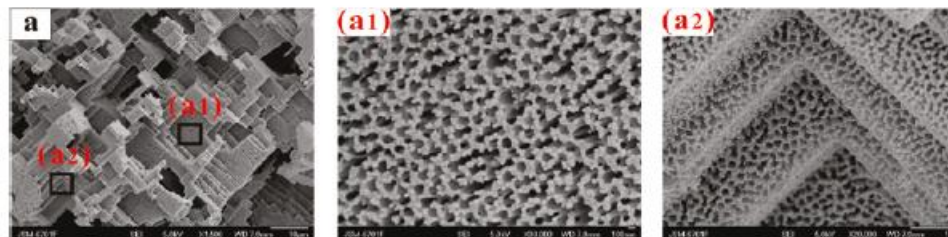
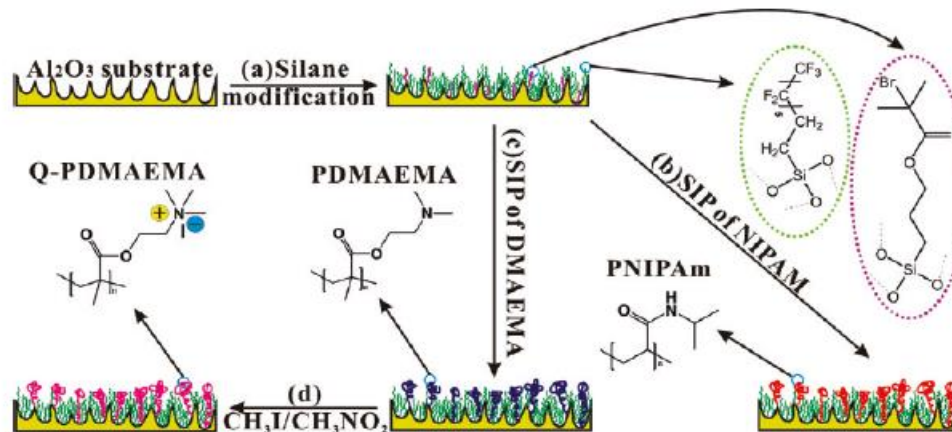
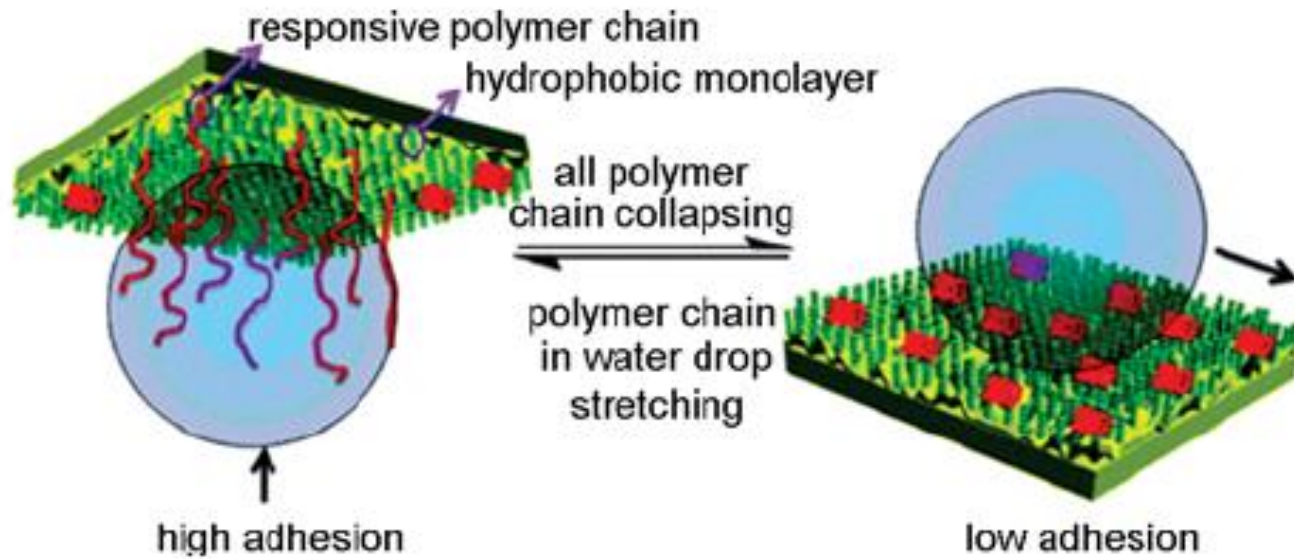


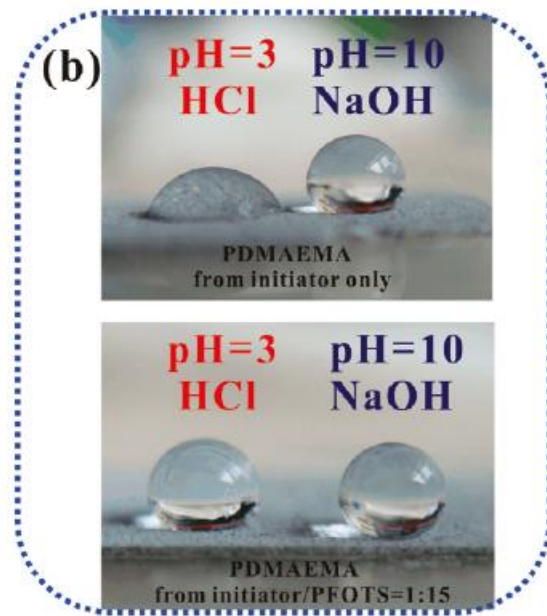
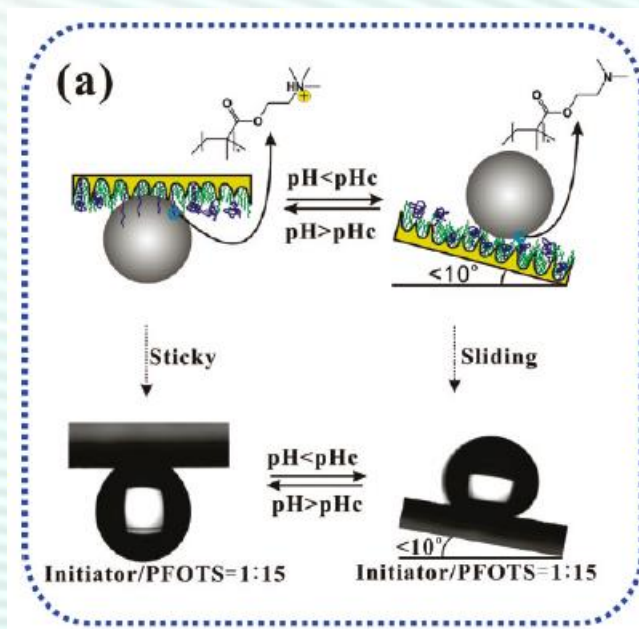
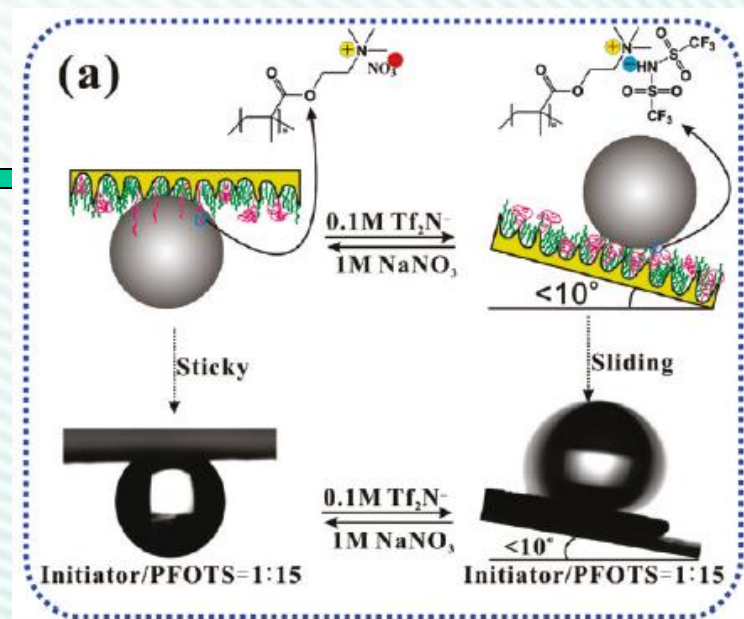
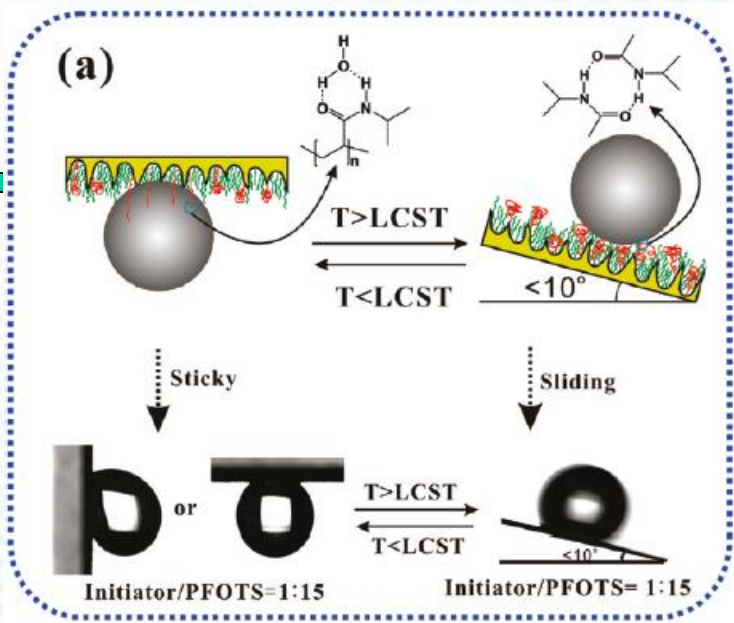
图 2 碗状微阵列润湿过程^[20]

Fig. 2 Bowl microarray wetting process^[20]

表面形貌是影响固体表面润湿性和黏附性的关键因素之一。表面形貌对表面黏附力大小的影响主要分为两点：
 一是水滴与表面的浸润接触面积。
 二是水滴与表面间封存的空气量。







Self-Cleaning

- 石油管道的输送
- 具有超疏水表面的管道，具有减阻性
- 具有自洁性的表面材料防水和防污处理
- 生物医学工程材料用于微量注射器针尖，可以完全消除昂贵的药品在针尖上的黏附及由此带来的对针尖的污染

Corrosion resistance

- 材料防腐蚀远洋轮船，可以达到防污、防腐的效果

Transparent & anti-reflection

- 室外天线上，可以防积雪

Anti-freezing



Self-Cleaning

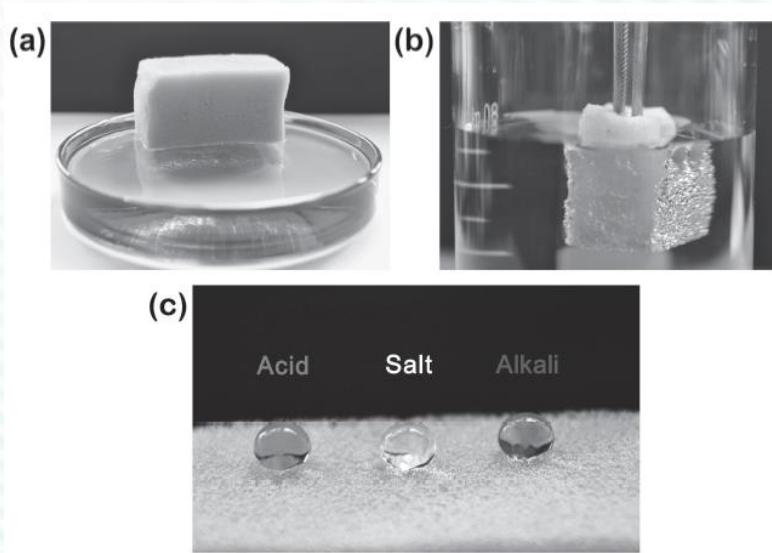
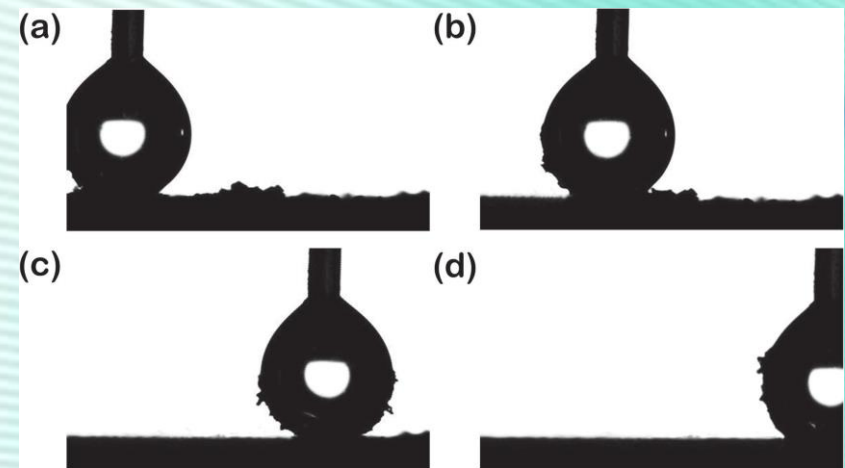
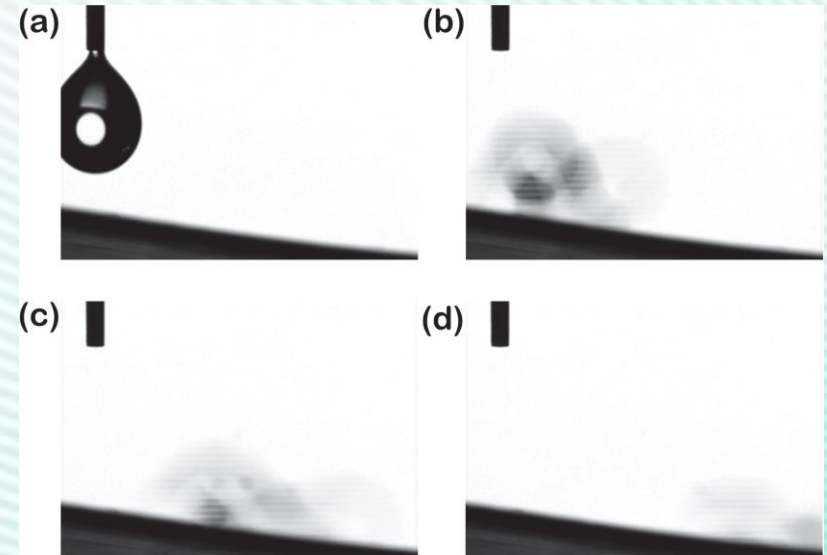
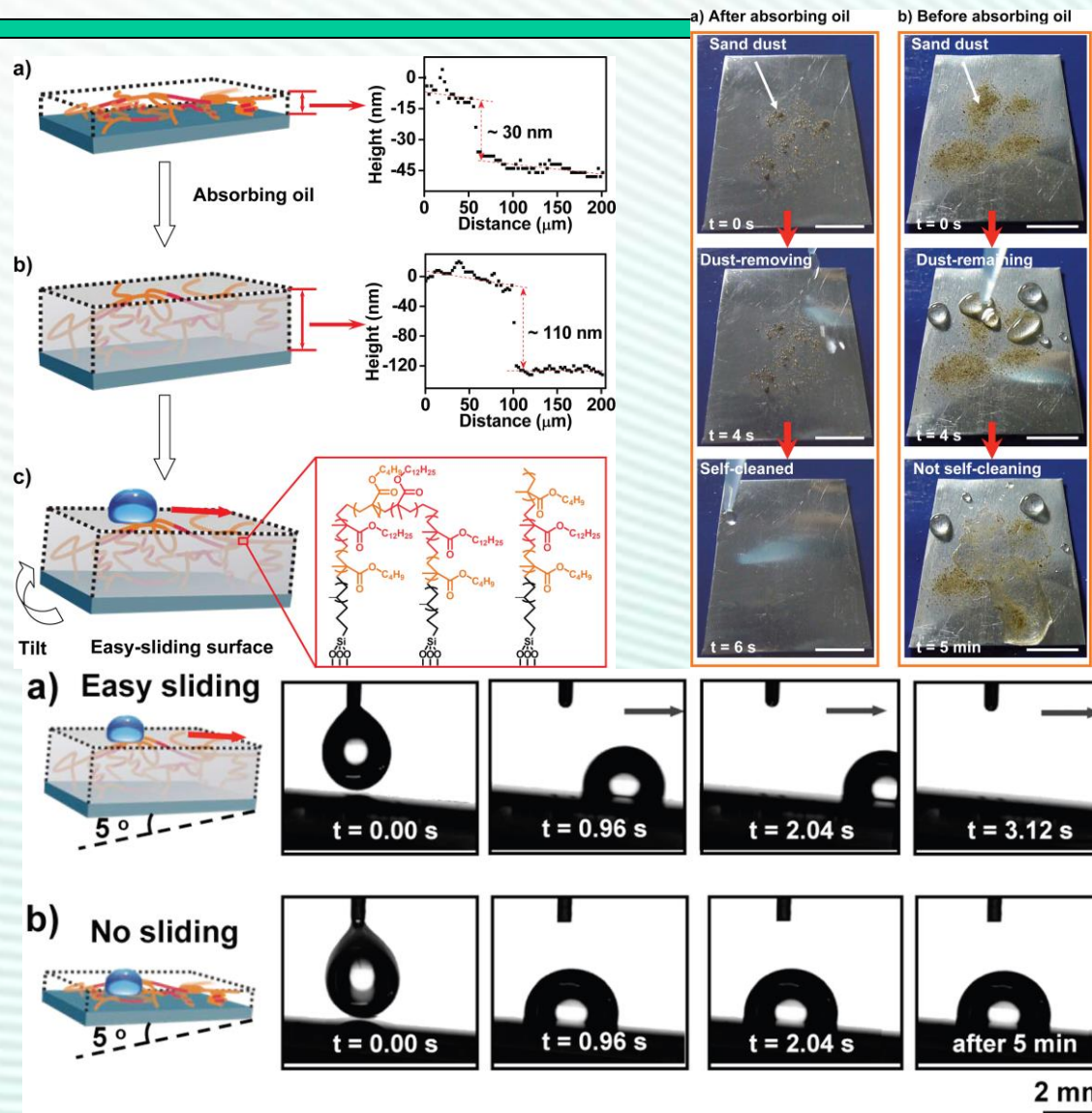


Figure 3. a) Optical image of the as-prepared polyurethane foam floated on water owing to its superhydrophobicity and light weight. b) Digital image of the superhydrophobic foam immersed in water by an external force, exhibiting a silver mirror-like surface due to the surrounded air bubbles. c) Optical image of aqueous hydrochloric acid (left, pH = 1), NaCl (middle, pH = 7), and NaOH (right, pH = 14) solution droplets with spherical shapes on the resultant polyurethane foam, demonstrating stable wettability towards different corrosive liquids.

- 1、接触角为 155°
- 2、较小的滚动角小于 5°

Self-Cleaning的关键是什么？





liquid transportation

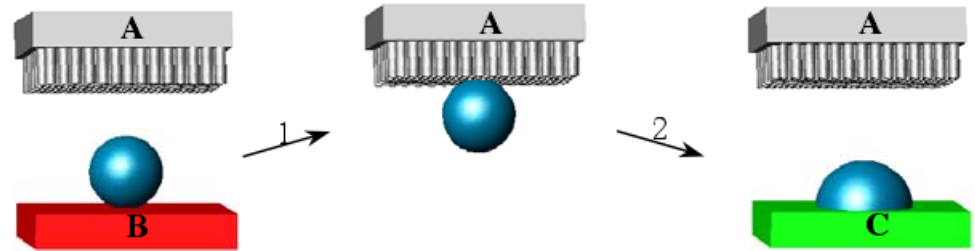
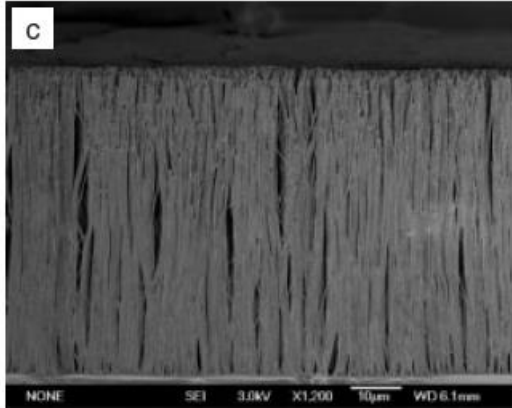
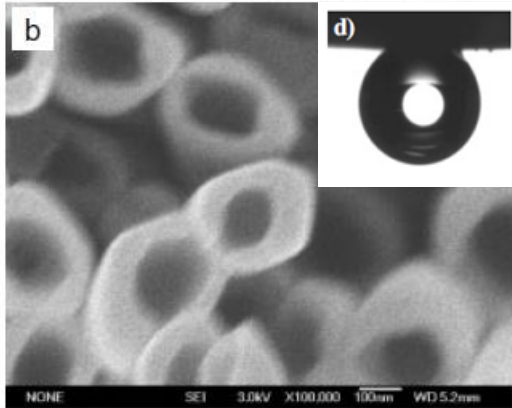
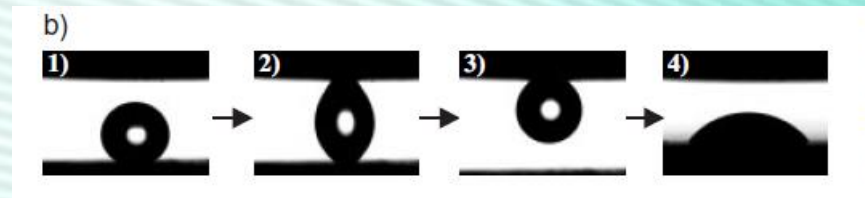
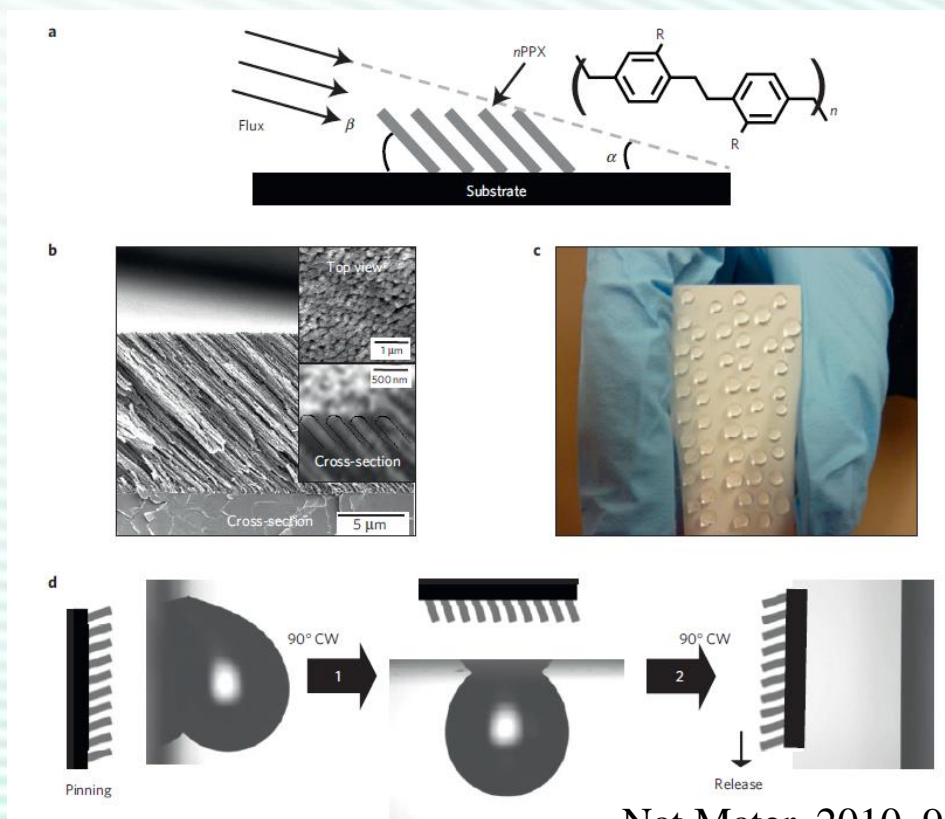
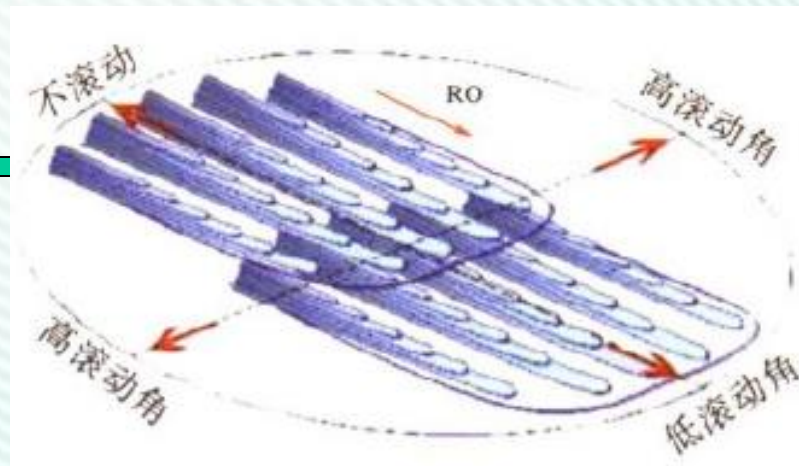
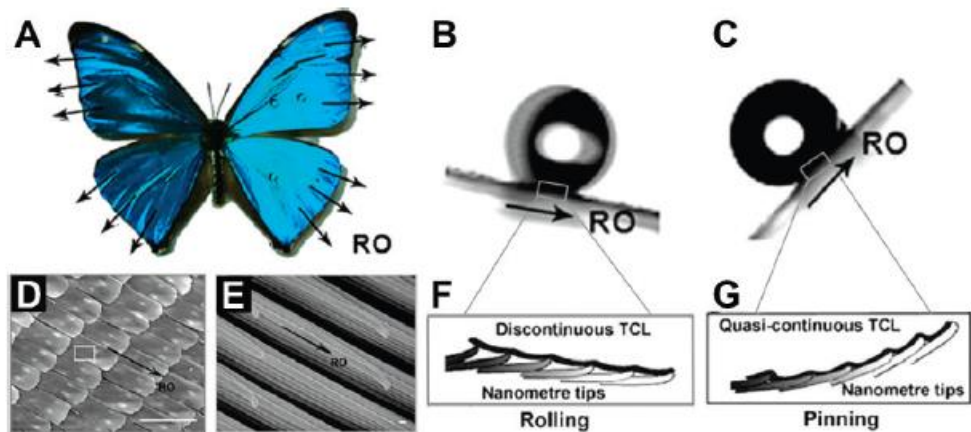


Figure 2-14. Schematic models of the possible application of the as-prepared aligned PS nanotube films in micro-sample analysis.



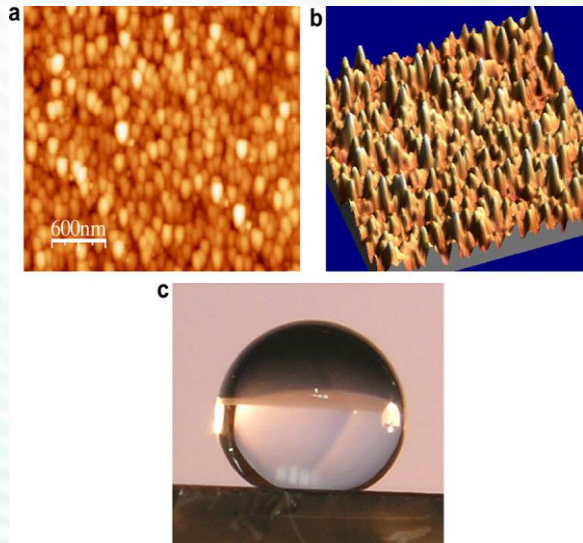
Adv Mater, 2005, 17: 1977–1981

2005 年，金美花等人受到壁虎脚底大量纳米结构刚毛产生高黏附力的启发，利用模板覆盖法首次制备出超疏水性且具有高黏附性的阵列聚苯乙烯纳米管膜，它可以在微量水滴从超疏水表面到普通亲水表面的传输上起到“机械手”的作用。每平方毫米超过6000000根纳米管。



一种由与基体成一定角度的聚对苯撑二甲基纳米棒阵列组成的纳米膜，该膜层具有显著的各向异性液滴黏附行为，能够简易通过气相技术制备得到并运用于微量液滴的运输。

Anti-Icing



$$\Delta G_c = \frac{4\pi}{3} \left[\frac{2\sigma_{vl}}{\rho_l R_w T \ln(p/p_{sl})} \right]^2 \sigma_{vl} f(\theta)$$

where

$$f(\theta) = \frac{1}{4} (2 + \cos \theta) (1 - \cos \theta)^2$$

- 1、超疏水表面能够延迟霜在冷表面的形成
- 2、超疏水表面霜在液滴定向生长

Int J Heat Mass Tran, 2008, 51: 5975–5982

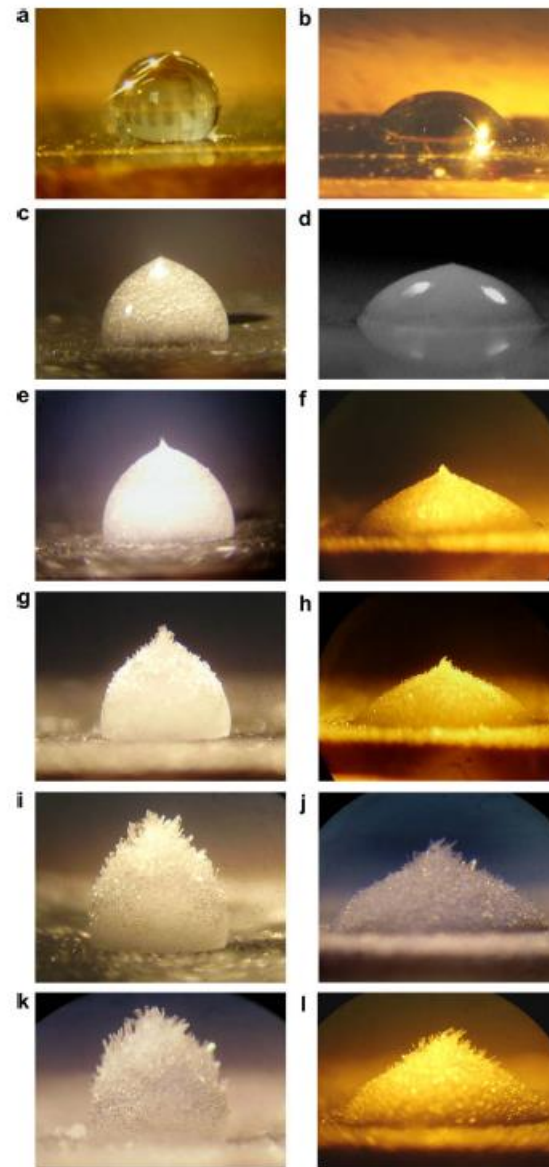
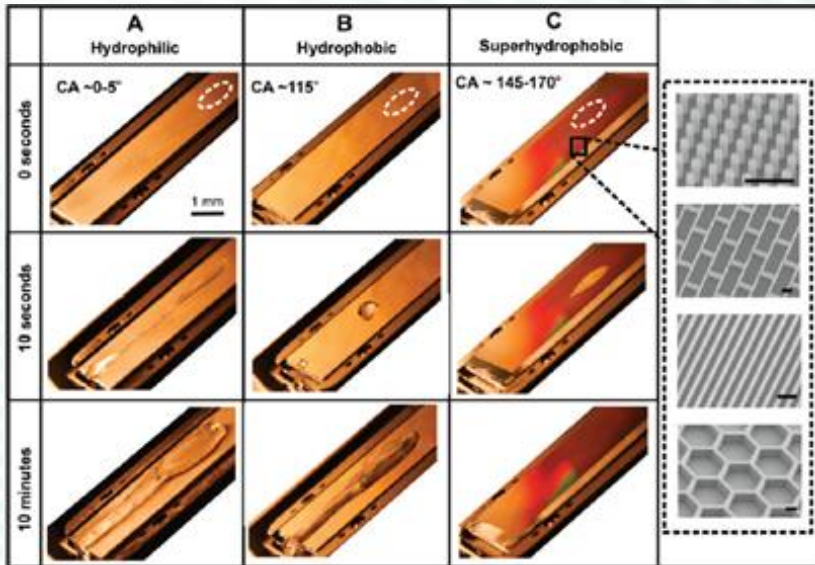
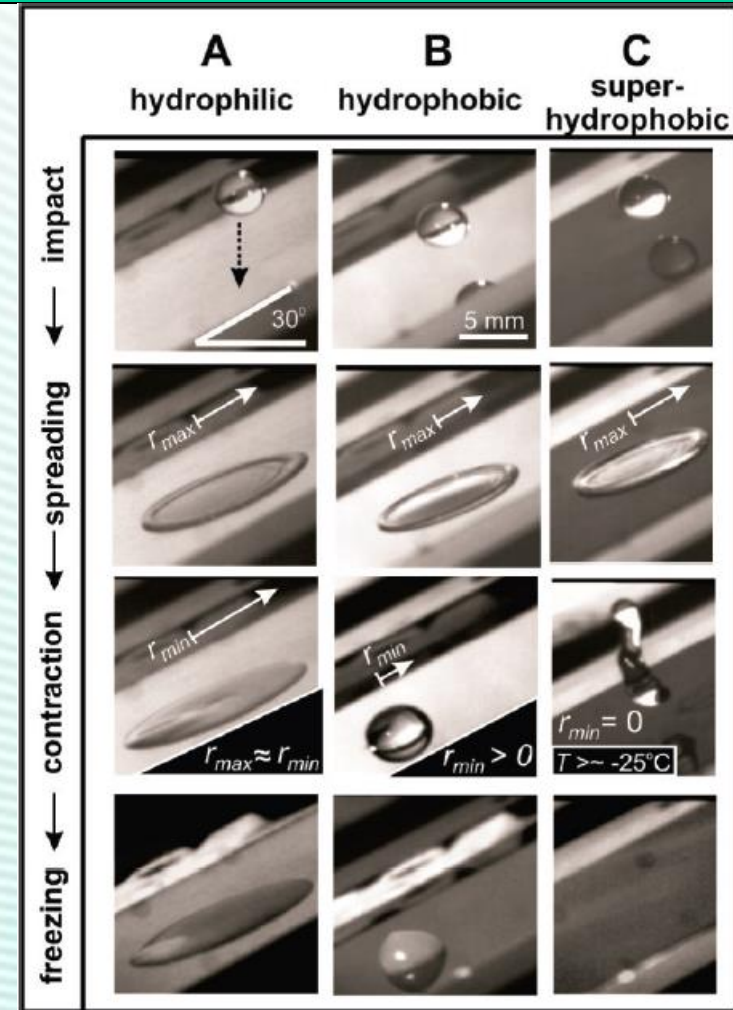


Fig. 6. Formation of frost crystals on two frozen water droplets surfaces on both the super-hydrophobic and the copper surface ($T_w = -10.4^\circ\text{C}$, $\phi = 42\%$, $T_{\infty} = 17.5^\circ\text{C}$). (a) Before cooling; water droplet on the super-hydrophobic surface; (b) before cooling; water droplet on the copper surface; (c) 45.0 s, super-hydrophobic surface; (d) 44.0 s, copper surface; (e) 55.5 s, super-hydrophobic surface; (f) 58.5 s, copper surface; (g) 97.0 s, super-hydrophobic surface; (h) 98.5 s, copper surface; (i) 21.99 s, super-hydrophobic surface; (j) 21.86 s, copper surface; (k) 30.25 s, super-hydrophobic surface; (l) 30.90 s, copper surface.



These results suggest that the design of nano- and microstructured materials that induce complete retraction of impacting water droplets before ice nucleation occurs may prove to be an effective strategy to prevent ice formation.

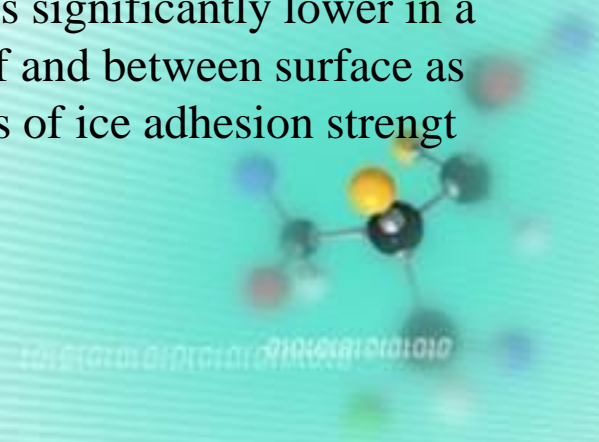


Superhydrophobic Surfaces: Are They Really Ice-Repellent?

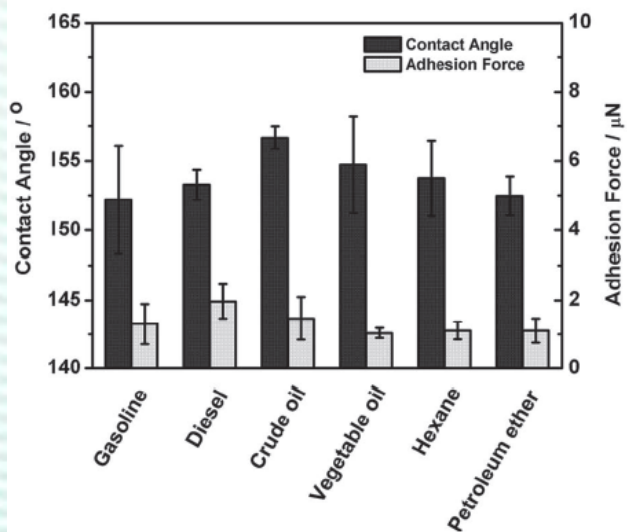
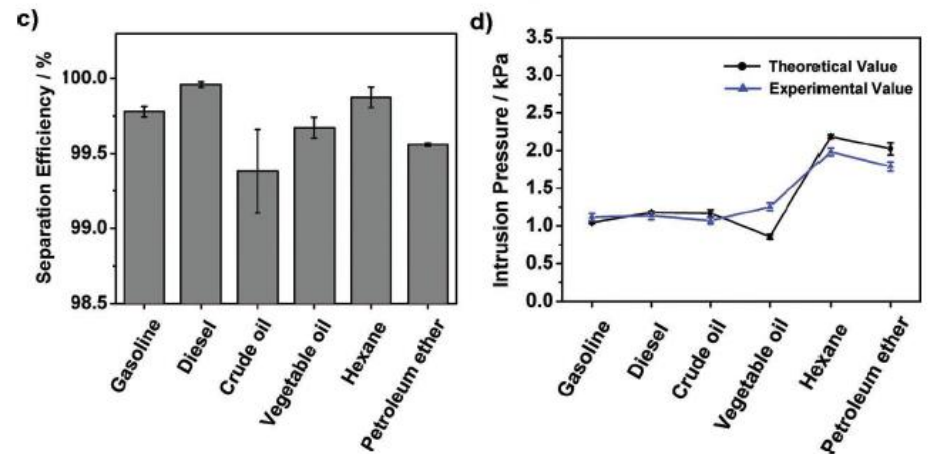
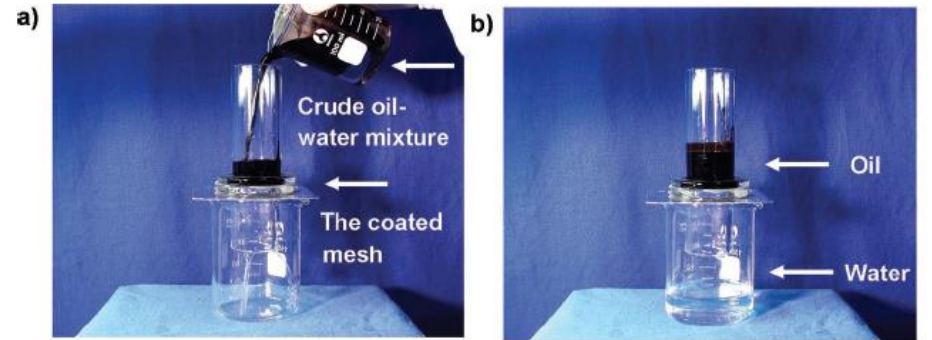
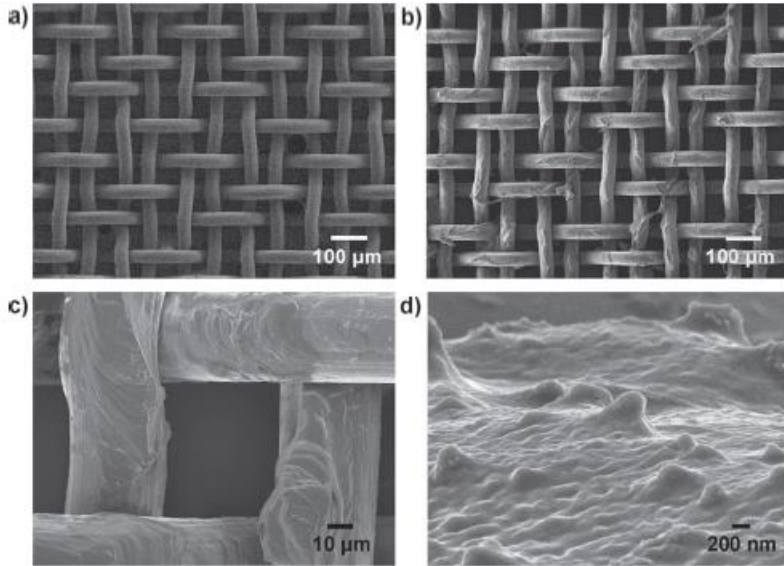
The ice-repellent properties of the materials deteriorate during icing/deicing cycles, as surface asperities appear to be gradually damaged

The anti-icing efficiency of superhydrophobic surfaces is significantly lower in a humid atmosphere, as water condensation both on top of and between surface asperities takes place, leading to significantly larger values of ice adhesion strength.

Langmuir 2011, 27(1), 25–29



Oil/Water Separation



展望

- * 以往的研究报道在制备材料的选择上存在着很大的局限性,而且许多方法涉及到特定的设备、苛刻的条件和较长的研究周期,难以制备大面积的超疏水表面.
- * 低成本地批量制备具有优异超疏水性能的表面(高接触角;超高或超低滚动角)、与基材高的结合强度、优异的耐酸碱介质性能、良好的耐高低温及长期稳定性能,为超疏水有机涂层材料的工程应用奠定了科学和技术基础,并有效应用于各个方面,这是该领域研究的一个最终目标.
- * 其次,从实际应用角度考虑,现有的超疏水表面的强度和持久性差,使得这种表面在许多场合的应用受到限制.表面的微结构因机械强度差导致材料被破坏或超疏水性变差.如何利用简单有效的方法构建具有可自我修复能力的超疏水膜层,从而获得性能持久优异的超疏水性界面材料也是当前研究的一大热点.
- * 此外,从理论分析的角度考虑,对于表面微结构的几何形貌、尺寸以及尤其表面化学成分与表面浸润性,是与滞后直接联系的黏滯力定量测试及研究还有待深入.

谢谢观赏