Application of Shape Memory Polymers in Wettability Transition on Superomniphobic Surfaces

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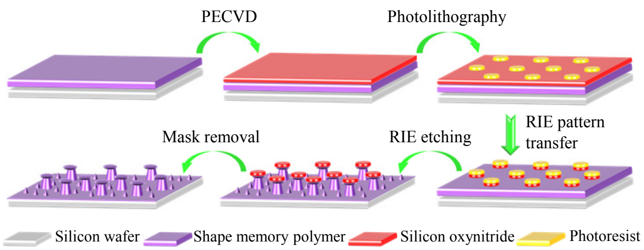
Introduction

- **Superomniphobic surfaces** are extremely repellent to virtually all liquids-aqueous or organic, acids or bases or solvents, Newtonian/non-Newtonian.
- There are no reports that combine superomniphobicity and shape memory effect to systematically design superomniphobic surfaces with metamorphic textures (i.e., textures that transform their morphology in response to an external stimulus).

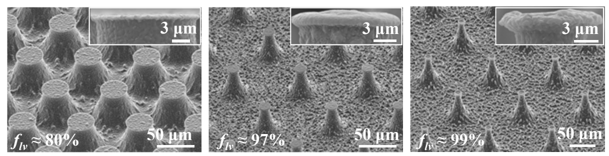
Wetting Transitions on Superomniphobic Surfaces:

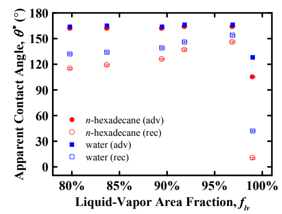
- We designed and fabricated the first-ever ***Metamorphic Superomniphobic (MorphS) Surfaces*** using a thermo-responsive shape memory polymer (SMP).
- The ***wetting transitions*** on our MorphS surfaces are solely due to transformations in morphology of the texture.
- We envision that our robust MorphS surfaces with reversible wetting transitions will have a wide range of applications including *rewritable liquid patterns, controlled drug release systems, liquid–liquid separation membranes, lab-on-a-chip devices, and biosensors.*

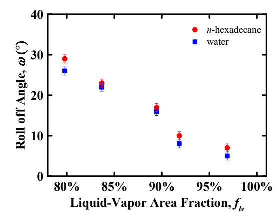


1. Deposition of shape memory polymer via spin coating and post-curing.
2. Deposition of silicon oxynitride layer through PECVD.
3. Fabrication of hexagonal patterns of photoresist columns via photolithography.
4. Transfer of the hexagonal patterns into the silicon oxinitride layer via reactive ion etching (RIE).
5. Fabrication of the shape memory polymer pillars using O_2 RIE.
6. Removal of the silicon oxynitride layer using hydrofluoric acid.
7. Modification of the surface chemistry of the shape memory pillars with heptadecafluoro-1,1,2,2-tetrahydrodecyl trichlorosilane

Wettability of MorphS Surfaces



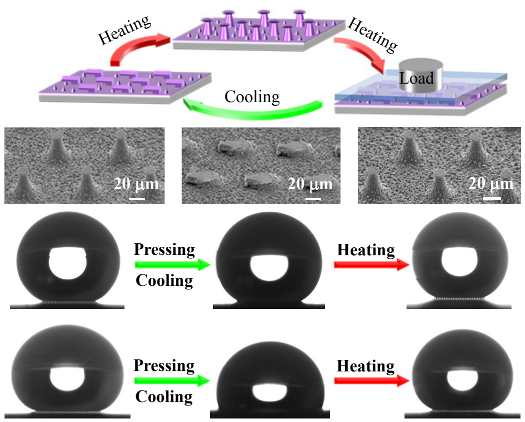




For a surface composed of a hexagonal array of mushroom-like pillars, the apparent contact angle can be determined using the Cassie–Baxter relation as:

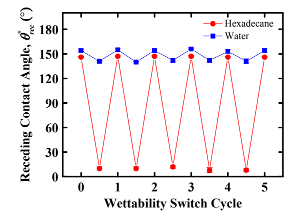
$$\cos\theta^* = f_{sl}\cos\theta - f_{lv} \approx \left[\frac{\pi}{2\sqrt{3}\left\{1+\left(\frac{D}{R}\right)\right\}^2}\right]\cos\theta - \left[1-\frac{\pi}{2\sqrt{3}\left\{1+\left(\frac{D}{R}\right)\right\}^2}\right]$$

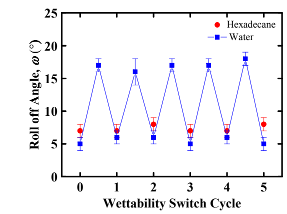
Morphology Transformation of MorphS Surfaces



- **Transformation:** Heat the *mushroom-like pillar texture* above the glass transition temperature ($T_g \approx 60$°C), press it ($P \approx 10$ MPa) and then cool it down to room temperature to obtain the collapsed pillar texture.
- **Recovery:** Heat the *collapsed pillar texture* above the glass transition temperature to recover the mushroom-like pillar texture.

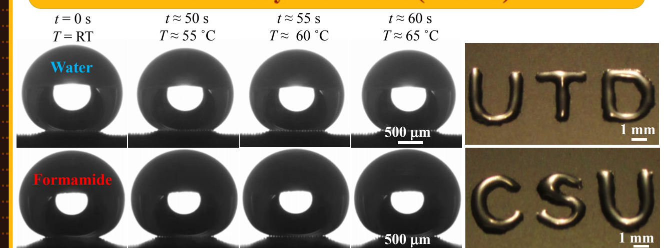
Cyclic Wettability Transition (Ex Situ)





- The ***mushroom-like pillar texture*** has re-entrant texture and D/R is very high (4.4). So, droplets of water and n-hexadecane adopt the Cassie-Baxter state (i.e., *superhydrophobic* and *superoleophobic*)
- The ***collapsed pillar texture*** does not have re-entrant texture and D/R is low (1.6). So, droplets of water adopt the Cassie-Baxter state (i.e., *superhydrophobic*), while droplets of n-hexadecane adopt Wenzel state (i.e., *not superoleophobic*)

Wettability Transition (In Situ)



Upon heating the ***collapsed pillar texture*** while a droplet of **water** (γ_{lv} = 72 mN m^{-1}, ρ = 1000 kg m^{-3} and boiling point = 100°C) or a droplet of **formamide** (γ_{lv} = 58.2 mN m^{-1}, ρ = 1130 kg m^{-3} and boiling point = 210 °C) is in continuous contact with the texture, the morphology transforms into the mushroom-pillar texture which results in an in situ transition of the droplets from a high adhesion Cassie-Baxter state to a low adhesion Cassie-Baxter state.

Publication

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