Hierarchical micro/nano structures for enhanced self-cleaning applications

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The idea of observing, understanding and learning new concepts from the properties present in nature is called 'biomimetics' and has recently been gaining increasing interest. These particular properties are created through designed surfaces containing structural features in the micro- or nano-metre scale. Superhydrophobicity is a clear example, which describes a phenomenon where water cannot wet the surface it rests on. Such extreme non-wetting effect is observed on the surfaces of the lotus leaves. It is recognized that the superhydrophobicity of these surfaces is due to their unique hierarchical surface structure.[1]

Hierarchical structures form air pocket, leading to the smallest contact area of a water droplet, resulting in the reduction of contact angle hysteresis and, consequently, lowering adhesion.[1, 2]

In this paper we present a flexible and adaptable fabrication method to create complex hierarchical structures over inherently hydrophobic resist materials. We have tested these surfaces for their superhydrophobic behavior and successfully verified their self-cleaning properties.

Nanoimprint Lithography (NIL)[3] is a good alternative towards conventional lithographic methods mainly due to its hybrid nature, low cost, high throughput and flexibility for use with different substrate materials. The process we developed to realize hierarchical micro/nano structures over a large area in a cost

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effective manner is described in Figure 1. First large micropillar structures were patterned in Ormostamp material which was spin coated on a Silicon substrate and patterned by UV light assisted NIL. The 500 nm nanopillars were then transferred onto the micro structured pillars by reverse NIL[5]. The resulting hierarchical structures were successfully replicated in PDMS, which in turn was used as the master stamp to directly pattern in a low surface energy resist. Feasibility studies of utilizing the produced hierarchical master stamps in a nano-injection molding process and furthermore in a continuous roll-to-roll nanoimprint process are ongoing.

Figure 2 shows tilted view SEM images of the nano features printed on the micro pillar structures and the corresponding water contact angle value. The hierarchical structures where realized in mr-XNIL26 SF (Commercial resist from *Micro Resist Technology GmbH)*. The contact angle of a planar surface printed with this resist is 100 ^{0}, i.e., it is inherently hydrophobic, which means that it does not need any additional chemical treatment to reduce its wetting. The water contact angle (WCA) of the micro pillars is 145 ^{0} and the corresponding WCA of the nano pillars is 140 ^{0}. The threshold for superhydrophobicity is 150^{o} [1], this indicates that with the above results, one level of structures is not sufficient to achieve the desired self-cleaning effect. However, with these complex 3D structures we achieved a water contact angle of **166 ^{0}** and a contact angle hysteresis about **5-7^{0}** by direct structuring the surface and without any further (post) chemical treatment. To the best of our knowledge, this is the highest WCA values observed on inherently hydrophobic material.

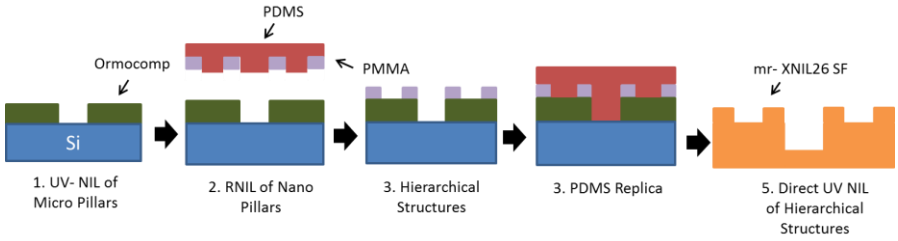

Figure 1: Schematic of the fabrication approach followed to develop the 3D hierarchical surfaces.

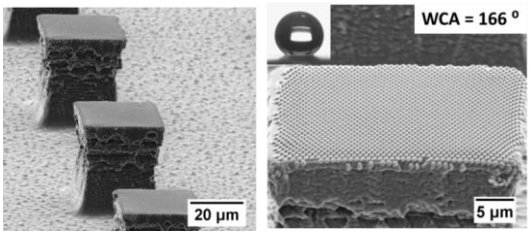

Figure 2: Tilted view SEM images of the square pillars with the hexagonal pillar structure on the top and it water contact angle value. The square pillar pattern has a width of 40 µm and a height of 40 µm (left). The hexagonal pattern has a diameter of 500 nm, 750 nm pitch and a height of 700 nm (right).

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