Learning from nature, we revealed that a super-hydrophobic surface needs the cooperation of micro- and nanostructures. Further studies have proved that the arrangement of micro/nano structure can directly affect the water movements. Based on the micro/nano structured interfaces with super-wettability, kinds of basic chemical reactions could be done within a small water drop. Under certain circumstances, a surface wettability can switch between superhydrophilicity and superhydrophobicity. We recently extended the cooperation concept into 1D system. Artificial ion channels with smart gating properties have been fabricated. The other one dimensional system is the artificial spider’s silk and cactus that can collect water from moist air.

KEYWORDS: Bio-inspired, Smart, Interfacial materials, Super-wettability

Learning from nature, we have built a series kinds of bio-inspired, smart, multiscale interfacial materials following the five-step strategy: selection of a unique property found in biology; understanding of the correlation between multiscale structure and macroscopic properties; design and synthesis of suitable target molecules; design of a two-way response using bistable states; construction of a binary cooperative complementary interface.

Starting from the superhydrophobic lotus leaves, we revealed that a super-hydrophobic surface with both a large CA and small sliding angle needs the cooperation of micro- and nanostructures. Further studies on other natural interfaces such as rice leaves, butterfly wings, water strider legs and mosquito eyes, have proved that the arrangement and orientation of micro and nano structure can directly affect the surface wettability and water movement trends. Recently, inspired by the self-cleaning fish scales underwater, we extended the three phase system from liquid/air/solid to the liquid/liquid/solid. The hydrophilic compositions together with the micro/nano structures endowing the fish scale with superoleophobicity underwater, which prevent them from pollution. By choosing hydrophilic hydrogel material and using the fish scales as templates, artificial fish scales have been fabricated, and the mechanical strength of the materials could be enhanced by integrating with nanoclay.

Based on the micro/nano structured interfaces with special wettability, kinds of basic chemical reactions could be done within a small water drop. Crystal arrays could also been prepared based on the superhydrophobic pillars.
Furthermore, since the superhydrophobic pillar-structured surfaces can generate direction-controlled liquid bridge arrays when placing an aqueous droplet upon the surfaces, no matter small molecule, polymer, silver NPs or microspheres can be arrayed in one direction along a long distance.

The four states of wettability (superhydrophilicity, superhydrophobicity, superoleophilicity and superoleophobicity) can switch between each other under certain circumstances by combination of surface micro- and nanostructures and surface modification of smart molecules. Besides the two dimensional interface, we recently extended the cooperation concept into the one dimensional system. The first example is bio-inspired artificial ion channel. Using shape controlled polymeric single nanochannel, whose ion transport properties are determined by the surface wettability, surface charge and the physical diameters, artificial ion channels with smart gating properties under external stimuli have been fabricated by integrating smart molecules into the nanochannels. These intelligent nanochannels could be used in energy-conversion system, such as photoelectric conversion system inspired by rhodopsin from retina or bR, and concentration-gradient-driven nanofluidic power source that mimic the function of the electric eels.

![Figure 2: Scheme of smart gating of micro/nanochannels. Centre: Smart gating of micro/nanochannel systems. Blue arrows represent the direction of fluid travel from the microchannel (the base side of the conical channel) to the nanochannel (the tip side of the conical channel). The two purple lines in the modified channel wall represent the functional molecules that can respond to external stimuli, which results in the changes of the surface properties, such as contact angle in the microchannel and the smart gating in the nanochannel. Surroundings: Typical structures and styles of responsive molecules (light-, thermo-, ions, etc.). With external stimuli, molecular changes may take place that include molecular configuration, molecular dipole, charge distribution, and atomic arrangement.](image)

The other one dimensional system is the artificial spider’s silk. In the moist morning, we always see small water drops hanging on the spider’s web. The energy of surface interaction and pressure differences induced by the periodic spindle knots on the spider’s silk can drive liquid drops in a specific direction that can collect water from moist air. Further, we prepared artificial spider’s silk based on dip-coating method. Droplets of water on the artificial spider’s silk behaved similarly to those on its biological counterparts.

After discovering the directional water collection ability of spider silk for the first time in the world, inspired by the cactus surviving in the most drought desert, we probed into the relationship of the structure-function of cactus (Opuntia microdasys) and found that the cactus had evolved a multi-structural and multi-functional integrated continuous fog collection system, which is superior to that found on the spider silk and can collect water more efficiently.

Learning from nature is a constant principle because nature provides us numerous mysterious properties that have developed over millions of years of evolution. Inspired by nature, the constructed smart multiscale interfacial materials system not only presents new knowledge, but also has great applications in various fields, such as self-cleaning glasses, superhydrophobic textile, water/oil separation, anti-biofouling interfaces, water collection system and also green printing technique.
Figure 3: Appearance and surface structures of the cactus. (a) Optical image of a plant of O. microdasys stem covered with well-distributed clusters of spines and trichomes. (b,c) Magnified optical images of a single cluster with spines growing from the trichomes in the top (b) and side (c) view. (d) SEM image of a single spine divided into three regions, the tip (e) with an apex angle (2a) and oriented barbs, the middle (f,g) with gradient grooves, and the base with belt-structured trichomes. (f,g) Magnified images of regions near the base and tip of the cactus spine, respectively. The microgrooves near the base are wider and sparser than those near the tip. (h) Magnified image of a single barb with an apex angle (2b) covering the tip of the spine (e). Scale bars, 5 cm (a), 500 mm (b,c), 100 mm (d), 20 mm (e–g) and 2 mm (h).

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REFERENCES

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