Engineering Biomimetic Materials by Harnessing Mechanical Instability of High-Aspect-Ratio Polymer Pillar Arrays

Shu Yang
Department of Materials Science and Engineering
University of Pennsylvania

As beautifully exemplified by the remarkable mechanical properties of bone, the dazzling structural color of butterfly wings, the self-cleaning ability of the lotus leaf, and the dry adhesion in gecko foot hairs, biology provides an ideal inspiration for development of new functional hybrid materials. For example, mechanical instabilities in soft materials, precipitated by dewetting, swelling, and buckling during the production stage are often viewed as failure mechanisms that can interfere with the performance of devices. Nature, on the other hand, provides many examples of intrinsic, bottom-up effects from the phyllotactic growth of plants, to the pattern of animal stripes, and to fingerprints. In these systems, instabilities, packing constraints, and simple geometries drive the formation of delicate, detailed, and beautiful patterns.

Taking a cue from Nature, we are interested in exploiting mechanical instability on patterned polymer surfaces, which in turn, allowing for engineering complex, multi-functional structures. Specifically, we study (in)stability of polymer pillars, pattern evolution and transformation in 2D and 3D porous membranes due to osmotic pressure, capillary force and shape memory effect, respectively. In my talk, I will discuss several materials systems, including elastomeric poly(dimethylsiloxane) (PDMS), elastoplastic poly(2-hydroxy ethylmethacrylate) (PHEMA) based hydrogels that are responsive to environmental changes, and shape memory polymers (SMPs). In each system, we compare the experiments with theoretical modeling to elucidate the mechanism of mechanical instability and to tailor such instability through material design and packing constraints. Further, we study curvature directed self-assembly of nanoparticles and liquid crystal molecules. Finally, I will present their potential applications in reversibly tunable dry adhesion/wetting, sensors, tunable optical display and energy harvesting.