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Shape-shifting 3D protein microstructures with programmable directionality via quantitative nanoscale stiffness modulation

Mian Rong Lee
Nanyang Technological University, Singapore

The ability to shape-shift in response to a stimulus increases an organism's survivability in nature. Similarly, man-made dynamic and responsive "smart" microtechnology is crucial for the advancement of human technology. Here, 10–30 µm shape-changing 3D BSA protein hydrogel microstructures are fabricated with dynamic, quantitative, directional, and angle-resolved bending via two-photon photolithography. The controlled directional responsiveness is achieved by spatially controlling the cross-linking density of BSA at a nanometer lengthscale. Atomic force microscopy measurements of Young's moduli of structures indicate that increasing the laser writing distance at the z-axis from 100–500 nm decreases the modulus of the structure. Hence, through nanoscale modulation of the laser writing z-layer distance at the nanoscale, control over the cross-linking density is possible, allowing for the swelling extent of the microstructures to be quantified and controlled with high precision. This method of segmented moduli is applied within a single microstructure for the design of shape-shifting microstructures that exhibit stimulus-induced chirality, as well as for the fabrication of a free-standing 3D microtrap which is able to open and close in response to a pH change.

Biography

Mian Rong Lee is a final year graduate student from Nanyang Technological University, Singapore. Working with two-photon lasers, she has created protein-based shape-shifting materials, stimuli-responsive actuators and ventured into the direct metal writing of patterned SERS substrates and metamaterials.

mianrong37@gmail.com

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