Ultrathin, fast, flexible silicon for optically controlled micro-robotic systems

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Abstract:

Micro-mechanical systems employed for autonomous small-scale machines should operate untethered. Current untethered systems predominantly use magnetic fields, acoustic excitation, or electric fields to achieve actuation and motion. An alternative for remote powering of micro-scale systems is optical excitation. Here, we present an opto-thermically actuated platform based on a bimorph of suspended PECVD films with mismatched thermal coefficients of expansion. By optimizing the stress engineering of the PECVD films, lithographic patterning, dry-etching, and vapor phase suspension, free-standing structures are obtained and released from the substrate. Pre-stress in the films results in initially curved geometries that can be actuated by temperature and/or illumination, allowing control of the bending angle of the flexible films over more than 270 degrees within a low-temperature range of 20-60 degrees Celsius. We have developed flexible micron-scale structures, including grippers, flowers, springs, and more complex three-dimensional structures capable of terrestrial locomotion for micro-robotic systems. Moreover, by optically modulating 200 μm long micro-robotic structures at frequencies of up to 100 kHz, we achieve remarkable speeds of over 100 body lengths per second. Through deliberate design of the robot structure and spatial illumination, controllable, directional locomotion is achieved. Integrating plasmonic structures such as gold disks to enhance the opto-thermic conversion efficiency and allow wavelength selectivity has been explored. Plasmonic structures on ultrathin silicon have demonstrated strong resonant absorption peaks at specific wavelengths, tuneable by their dimensions. The combination of our thin film platform with plasmonically enhanced optical control potentially paves the way towards CMOS-compatible untethered micro-mechanical actuation with wavelength-selective control.

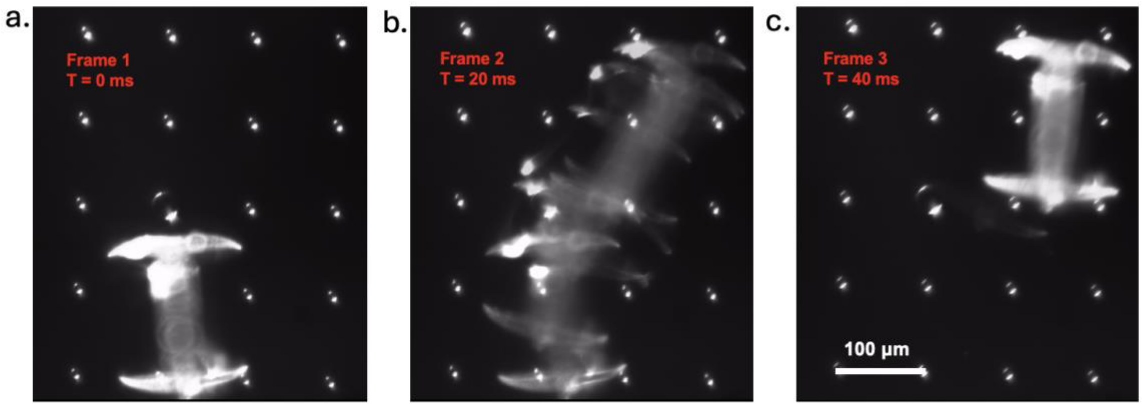

Figure 1*:* Micro robotic structure stood on a Si substrate with Au disk markers. a) Initial micro-robot position. b) Locomotion during modulated optical excitation at 200 Hz, captured within one video frame. The high-speed locomotion greater than the time resolution of the camera of 50 fps results in motion blur. c) Final micro-robot position.