A new microfluidic switch technique by controllably buckling Stimuli-responsive polyelectrolyte hydrogel thin layer

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Abstract:

Elastic mechanical instabilities in thin polymer films may present as different out-of-plane deformation modes including wrinkling, creasing, buckling, folding, and delamination. Elastic transformation can achieve the giant morphology change in very short time. Recent experimental and theoretical progress has provided a fundamental understanding on these instabilities in gel systems (Phys. Rev. Lett. **105**, 2010; Adv. Mater. **23**, 2011; Soft Matter **8**, 2012; Soft Matter **10**, 2013). Some applications incorporate buckled thin film structures into devices to fulfill certain purposes such as, to prevent device/structure failure during large deformations (Adv. Mater. **20**, 2008), to relieve surface/interfacial mechanical stress (Nature Nanotech. **1**, 2006), to yield novel strain sensing structures (Adv. Mater. **26**, 2014), or to improve the efficiency of solar cells.(Nat. Photonics **6**, 2012). In recent work, we have shown fast actuation of crease instability (< 1 sec) on the surfaces of thin ionic hydrogel layers at low electric voltages of 2 – 4 V (Adv. Mater. **25**, 2013) by constructing layer system.

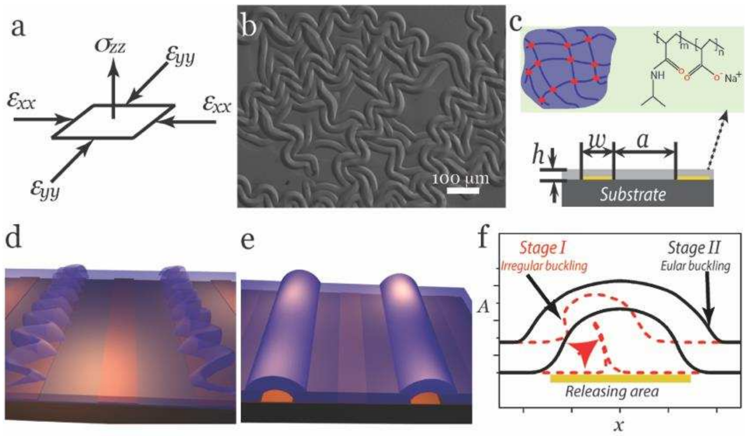

Fig.1 a) Stress state before buckling, b) buckling induced delamination stripes patterns, c) Structure design and PNIPAM gel, d) Electro-actuated irregular buckling blisters, and e) Euler buckling blisters, f) cross-sections of irregular buckling blister and Euler buckling.

In the current report, we describe the reversible electrically actuated delamination and buckling of a thermally responsive poly(N-isopropylacrylamide-co-sodium acrylate) (PNIPAM) polyelectrolyte gel layer on micro-patterned electrode surfaces. Through a two-step mechanism corresponding to electrochemically-triggered delamination at a first critical voltage, followed by gas bubble formation at a second critical voltage, we demonstrate that large out of plane displacements (up to 8 times the initial gel thickness) can be achieved, with rapid switching at modest triggering voltages (from – 3 to – 6 V). Using thermally triggered deswelling of the gel, we show that it is possible to return the gel to its initially flat and adherent state, enabling reproducible formation of buckled structures through multiple cycles of actuation. Our ambition is to investigate the actuated buckling instability and use it as passive valve for micro-fluidic application.