An instant multi-responsive porous polymer actuator driven by solvent molecule sorption

Abstract

Fast actuation speed, large-shape deformation and robust responsiveness are critical to synthetic soft actuators. A simultaneous optimization of all these aspects without trade-offs remains unresolved. Here we describe porous polymer actuators that bend in response to acetone vapour (24 kPa, 20 C) at a speed of an order of magnitude faster than the state-ofthe-art, coupled with a large-scale locomotion. They are meanwhile multi-responsive towards a variety of organic vapours in both the dry and wet states, thus distinctive from the traditional gel actuation systems that become inactive when dried. The actuator is easy-tomake and survives even after hydrothermal processing (200 C, 24 h) and pressing-pressure (100 MPa) treatments. In addition, the beneficial responsiveness is transferable, being able to turn 'inert' objects into actuators through surface coating. This advanced actuator arises from the unique combination of porous morphology, gradient structure and the interaction between solvent molecules and actuator materials.

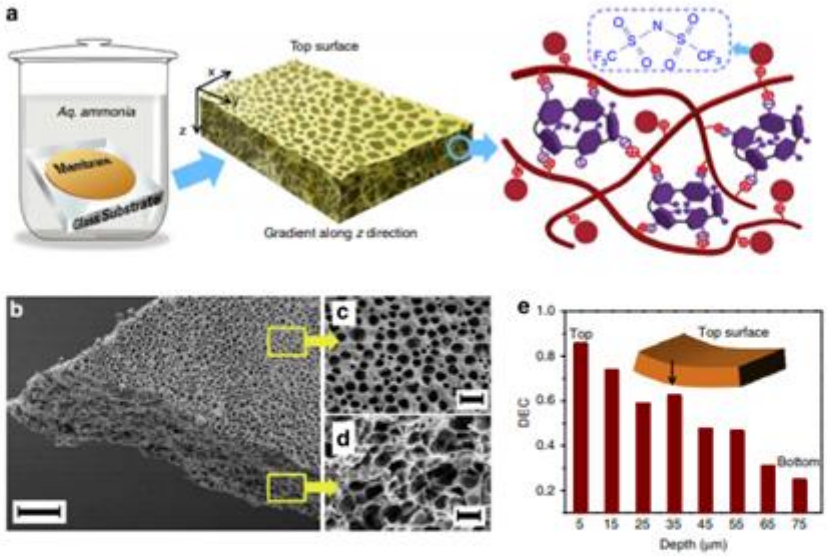

Figure 1 | Design concept and structure characterizations of the membrane actuator. (**a**) A scheme illustrating the preparation route (left), porous morphology (middle) and the chemical structure (right) of the $PILTf_2N$/C-pillar[5]arene membrane actuator. On the right: the red line and purple ring represent $PILTf_2N$ polymer chains and C-pillar[5]arene molecules, respectively; this cartoon schematises the electrostatic complexation between the imidazolium cations on $PILTf_2N$ and the carboxylate anions on C-pillar[5]arene molecules. (**b**–**d**) SEMmorphologies of the membrane actuator: general view (**b**, scale bar (black), 30 μm); top surface (**c**, scale bar, 3 μm); and cross-section (**d**, scale bar: 1 μm); (**e**) the structural gradient of the DEC along the membrane cross-section (top-down direction). The DEC of the membrane is defined as the ratio of the imidazolium units that have electrostatically complexed with COO^- groups (on C-pillar[5]arene) to the overall amount of imidazolium units (Supplementary Fig. 3). Experimentally, DEC values at different locations of the membrane are determined by the sulphur content at different locations of the membrane cross-section (Supplementary Fig. 4).