A Variable Stiffness Artificial Muscle Material for Soft Robotics

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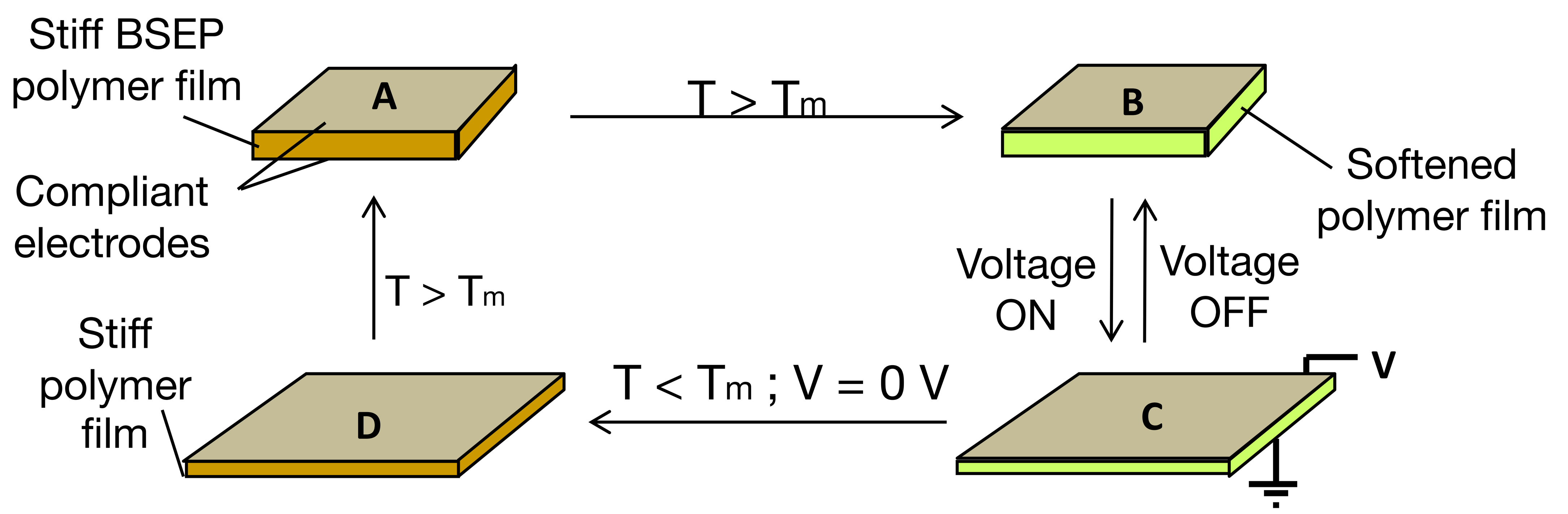
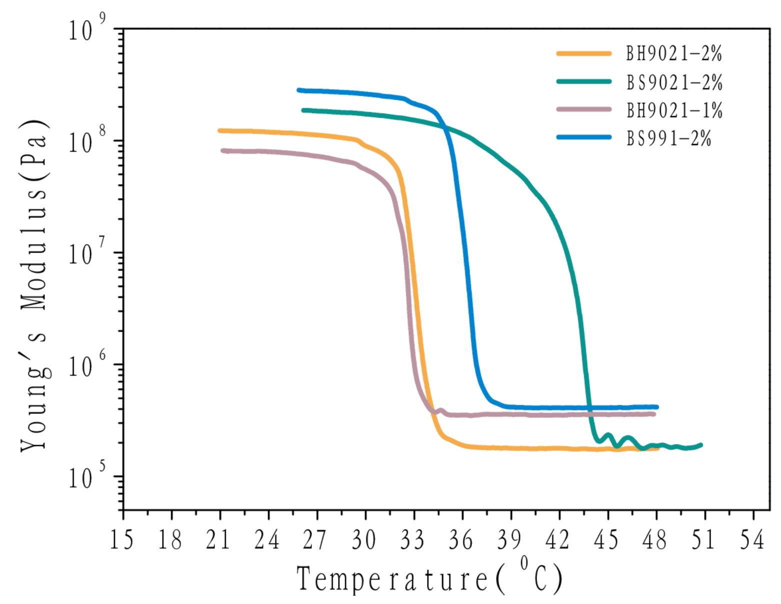
Bistable Electroactive Polymer (BSEP)

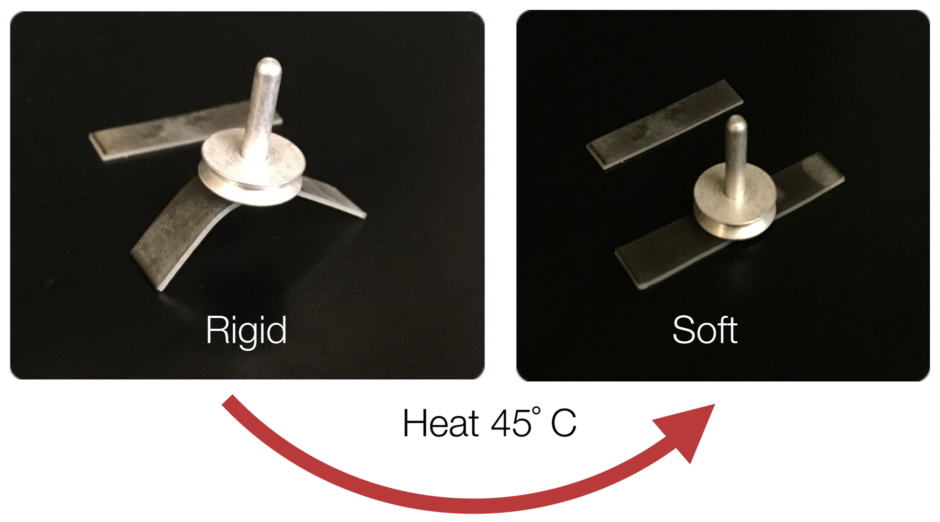
Combining shape memory properties via phase transition and the dielectric elastomer actuation, we have developed a bistable electroactive polymer (BSEP) that is rigid in ambient conditions and rubbery above the transition temperature at which large strain actuation can be achieved as a dielectric elastomer. The polymer is cooled below the transition temperature to “freeze” the actuated shape. This process is reversible.



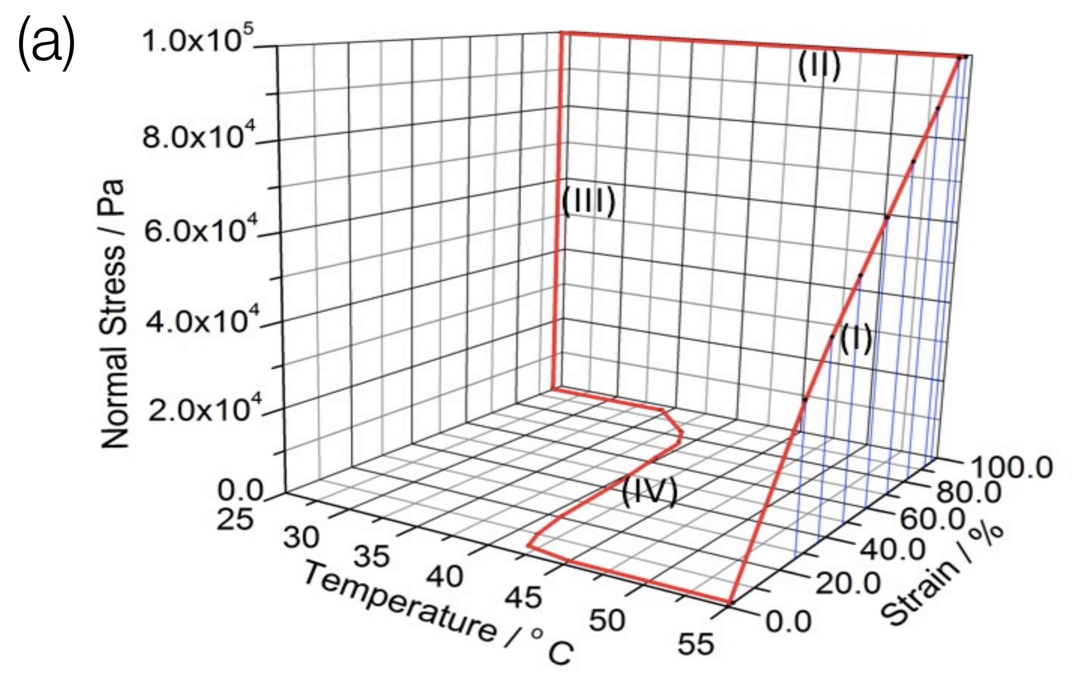
The BSEP can be actuated to any shape allowable by the maximum strain, reversibly and repeatedly. Other elastomers such as silicone, have fast actuation, but low strain, whereas, materials such as VHB are capable of high strain, but actuation speed is compromised. BSEP has been demonstrated to have fast actuation and is capable of high strains.

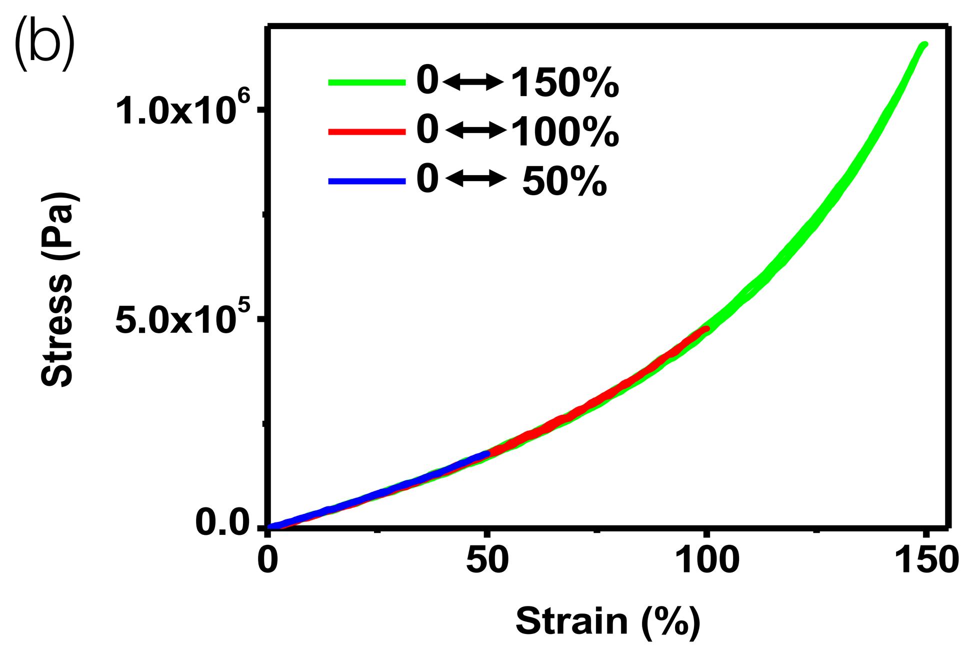


By using two different cross-linkers and varying lengths of alkyl chains, we can tune the phase transition to the application.



The rigid polymer is shown holding a weight. After the BSEP is heated above a 45 ˚C, the material softens.

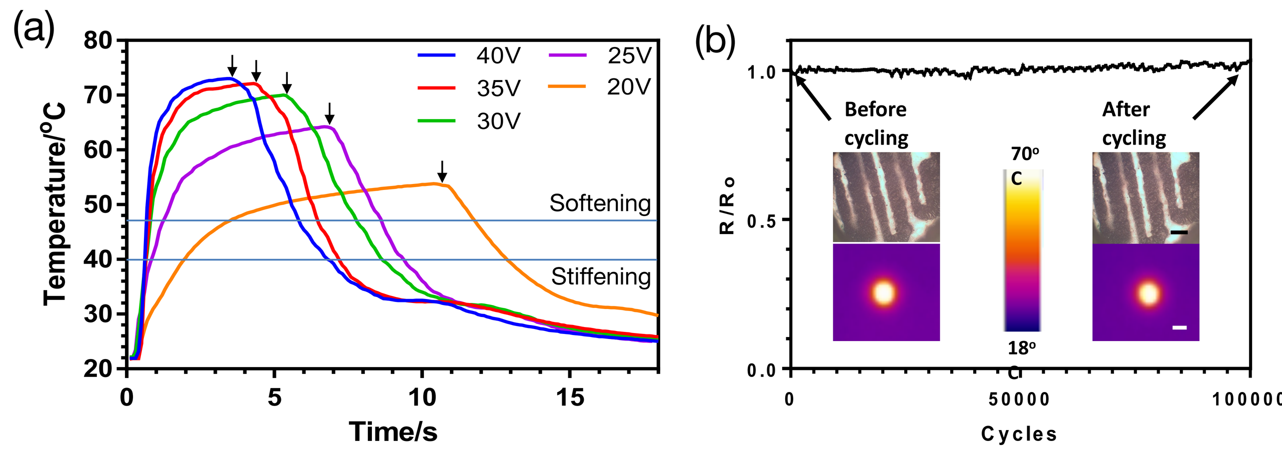




(a) Temperature–strain–stress diagram for a BS60 film. At 55°C (I), the polymer is rubbery. After the strain increases to 100%, the polymer is cooled to room temperature (II). At this point, the stress is released (III), but the strain remains at 100%. When the temperature is increased back up to 55°C (IV), the strain is released. (b) Cyclic tensile loading-unloading tests of BS80-AA5 under different stretch ratios with a strain rate of 0.01/s. The material can reach up to 150% with no hysteresis.

Compliant Heating Electrode

CNTs are used as a compliant heating electrode material due to its high thermal stability and ability to form percolation networks

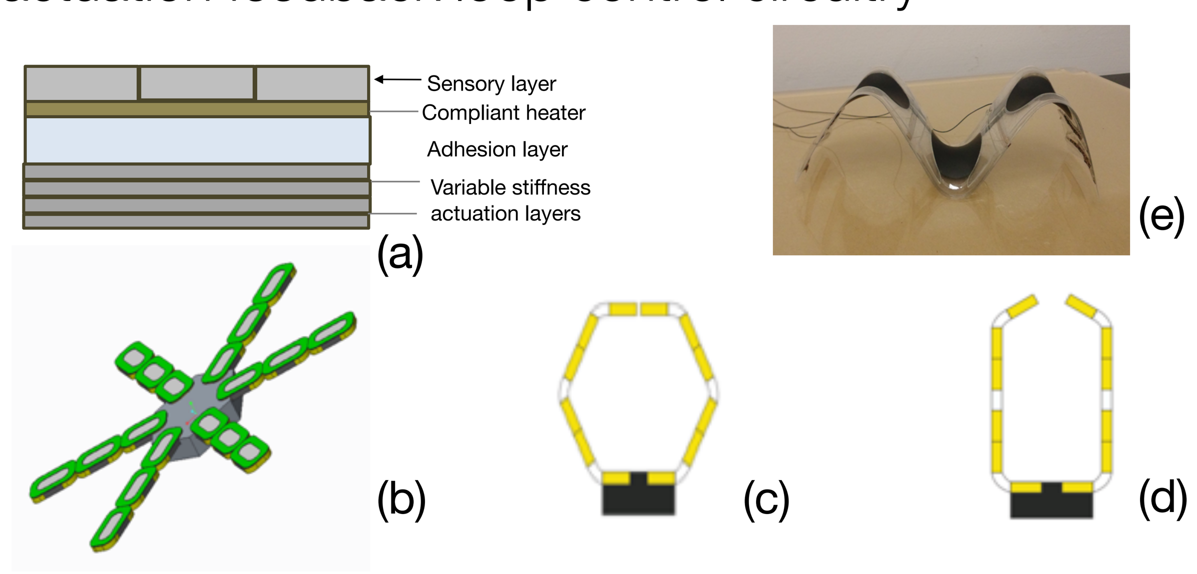


(a) Temperature profiles of serpentine-CNT electrode under different voltage supplied. As the voltage increases, the heating rate increases (b) Lifetime cyclic testing with 100% area expansion

Dextrous Manipulator

Soft robotics

Soft grippers and manipulators can be fabricated using BSEP, compliant electrode materials and sensing-actuation feedback loop control circuitry



(a) Cross-section of an individual finger (b) 3D model of 18 rotary joint actuator. (c) Illustrations of deformed structure showing two 3-joint actuators iterated together to form a closed grip. (d) The same actuators could an also maintain a small gap (e) A multi-segmented actuator is shown contorting its conformation

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