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High Energy Density Shape Memory Polymers Using Strain-Induced Supramolecular Nanostructures

Researchers at Stanford have reported the first high energy density shape memory polymer based on the formation of strain-induced supramolecular nanostructures, which immobilize stretched chains to store entropic energy. Record high amounts of energy can be stored (19.6 MJ/m3 or 17.9 J/g), **six times higher than the best previously reported**, while maintaining near 100% shape fixity and recovery. Shape memory polymers (SMPS) are promising materials in many emerging applications such as soft robotics, deployable hinges or space structures, sealants and smart biomedical sutures, due to their excellent shape recovery and other properties. However, practical application is limited by poor energy densities (1 MJ/m3). Achieving high energy density SMPs that simultaneously possess high recovery stress and large recoverable strain poses a significant challenge. The Stanford team's solution is a novel shape memory mechanism based on the formation of strain-induced supramolecular structures by polymer chains with dynamic bonds. Under strain, the polymer chains align into stable and hierarchically organized supramolecular nanostructures, trapping the stretched polymer chains in a highly elongated state. Upon heating, the dynamic bonds break and stretched chains contract to their initial disordered state.

Stage of Development
First report of a shape memory polymer based on supramolecular nanostructures that achieves record-high energy density of 19.6 MJ/m3 with shape fixity and recovery above 90%. Optimization work is ongoing.

Applications

- Soft actuators

- Soft robotics
- Artificial muscle
- Virtual reality motion generation
- Responsive surfaces
- Stretchable and wearable electronics

Advantages

- Simple one-pot synthesis at low cost ($5/kg for raw materials)
- Single-component and solution soluble
- Excellent shape memory properties and high energy density
- Competitive with existing technologies on key metrics (e.g., recovery stress, recovery strain, energy density)

Publications

- Cooper, Christopher B., et al. "High Energy Density Shape Memory Polymers Using Strain-Induced Supramolecular Nanostructures." *ACS central science* 7.10 (2021): 1657-1667.

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