

Shape Memory and Recovery Mechanism in Hard Magnetic Soft Materials

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Abstract

Hard-magnetic soft materials (HMSMs), which combine soft polymer matrices with hard-magnetic particles, have emerged as versatile materials capable of achieving complex deformations under magnetic fields. This work aims to provide a comprehensive understanding of the non-thermal shape memory and recovery mechanisms in HMSMs. By developing a theoretical model, we interpret the transfer of shape information between different field quantities, such as the remnant magnetization vectors and the magnetic forces. The two-dimensional thin beam model developed here implies that the two-way interaction between magnetization patterns and mechanical deformations is the key for the shape memory effect in HMSMs. Experiments also validate the theoretical model and the proposed mechanism for shape memory. This study offers valuable insights into the control of shape memory effects in HMSMs and presents opportunities for advancements in soft robotics, secure data storage, and responsive materials. Furthermore, the idea is combined with the flexoelectret effect, the bending of electrets produces electrical signals, and extended to giant magnetoelectric (ME) rubbers. We also show that the snap-through instability provides a mechanical way of enhancing the output electrical current in ME rubbers, whose conversion efficiency is insensitive to the frequency of applied magnetic field. Our experiments indicate that the snapping ME rubber is able to light LED array even at 1Hz external magnetic field of $\sim 400\text{Oe}$.

Keywords:

Magnetoactive materials shape memory effect snap-through instability magnetoelectric effect energy harvesting