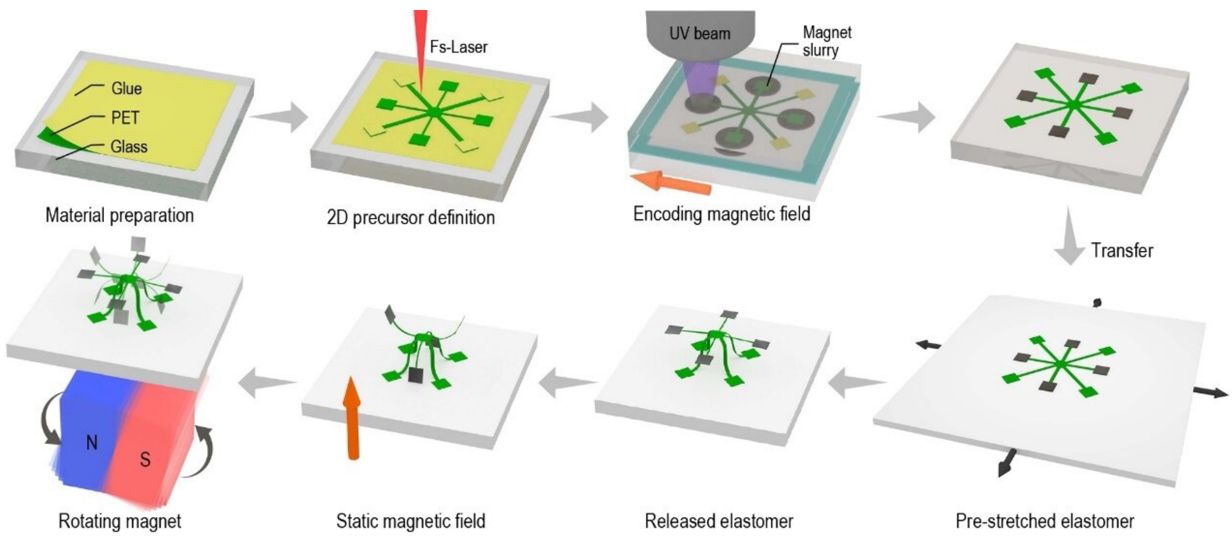
A high-order shape-morphing and high-frequency actuated 3D mesostructure with applications in multifunctional devices

November 16 2022



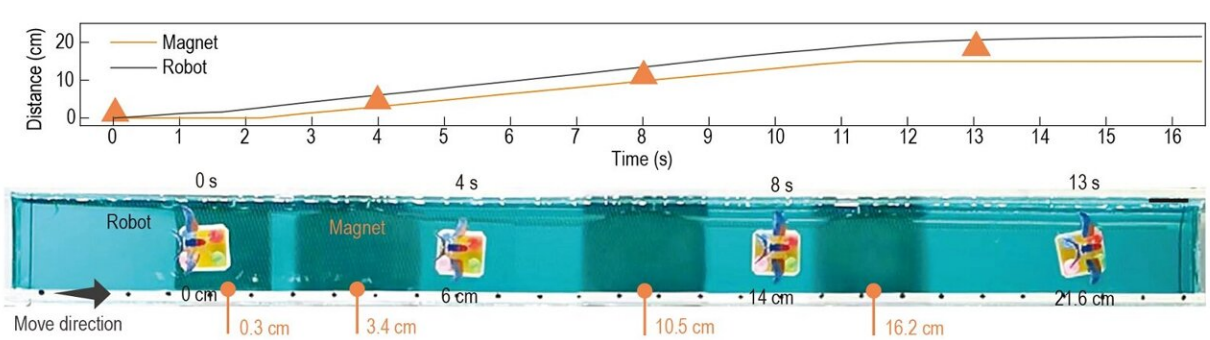
The 2D PET precursor is defined by femtosecond laser and the discrete magnetization profiles are patterned by UV curing of magnetic composite materials. The 2D precursor is then attached to a pre-stretched elastomer and assembled into 3D mesostructure after stress release. Under a static magnetic field, the METM demonstrates high-order deformation. Under a rotating magnetic field, the METM shows high-frequency actuation. Credit: Science China Press

Three-dimensional (3D) mesostructures, assembled from 2D patterned precursors through compressive force, are compatible with most advanced planar semiconductor technologies (e.g., photolithography), functional materials (e.g., monocrystalline silicon, plastic and metal) and length scales from macro to micro.

Endowing the 3D mesostructures with the ability of reconfiguration and multi-function enables their distinctive applications in robotics, microelectromechanical systems (MEMS), sensing and wireless communication. However, until now, the development of morphable 3D mesostructures with high-order (multi-degree of freedom) deformation and untethered high-frequency actuation remains challenging and deserves to be further studied.

Recently, a research group headed by Prof. Jiawen Li and Prof. Dong Wu from the Department of Precision Machinery and Precision Instrumentation, University of Science and Technology of China has reported a scheme of magnetically encoded transferable 3D mesostructure (METM) with high-order deformation and high-frequency actuation.

The METM uses polyethylene terephthalate (PET) film as a skeleton fabricated by femtosecond (fs) laser and discrete magnetic domains as actuation units defined by UV curing. This study was published recently in *National Science Review*.



A sliding robot with two magnetically coded wings is transferred onto four foam balls and floats on the water. A fast-rotating magnet beneath the water actuates the robot to flap its wings at high frequency. Due to the aerodynamic force exerted on the wings, the robot can move forward in a water channel. Credit: Science China Press

The distinctive features of the METM include:

(1) High-order deformation. The technique of magnetic encoding ensures that the orientations of magnetic domains on the METM are along designed 3D directions. Therefore, the METMs can realize high-order deformation under a static magnetic field, such as combining bending and twisting, hierarchical and multidirectional deformation in one configuration. A 3×3 array of conductive METMs is integrated into circuit devices for four-channel switchable color letter displays.

(2) High-frequency actuation. The METMs, using PET film as skeleton with modest structural modulus (~3 GPa), enable both high-frequency (~55 Hz) and large-deformation (~66.8%) actuation under alternating magnetic field. The high-frequency actuations of the METMs in air (underdamping) and in liquid (overdamping) are systematically studied by using both experimental verification and theoretical simulation.

(3) Applicable to multifunctional devices. Thanks to its transferable merit, the morphable METMs can be integrated onto the surfaces of many multifunctional devices. For example, the METM is transferred into a petri dish loaded with four-color equal-area water to become a liquid mixer, and also integrated into the circuits to realize the sequential flashlight. Additionally, the METMs can be transferred onto four foam balls and become a sliding robot, which can flap its wings and glide

forward actuated by a rotating magnet beneath.

More information: Rui Li et al, Magnetically encoded 3D mesostructure with high-order shape morphing and high-frequency actuation, *National Science Review* (2022). DOI: 10.1093/nsr/nwac163

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