Flexible Magnetic Composites for Light-Controlled Actuation and Interfaces

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Introduction

Actuators are components used to move a mechanical system or perform shape morphing, in response to certain stimuli. Among various mechanisms to induce mechanical deformation, light has distinguishing advantages of wireless control, and the capability of high-resolution and localized stimulation. Current photomechanical systems are mainly based on liquid crystal, optical gradient force, shape memory polymers, or inequivalent expansion of gradient materials. The actuating direction mostly depends on incident light direction or material gradient direction. Most optomechanical devices can perform simple movement such as bending, twisting, or expansion with simple light modulation, and achieve complex movement like folding, walking, swimming, or waving only with complex light patterning or structured design. There are many occasions, however, where these modulations cannot be satisfied, and the versatility is limited by the design.

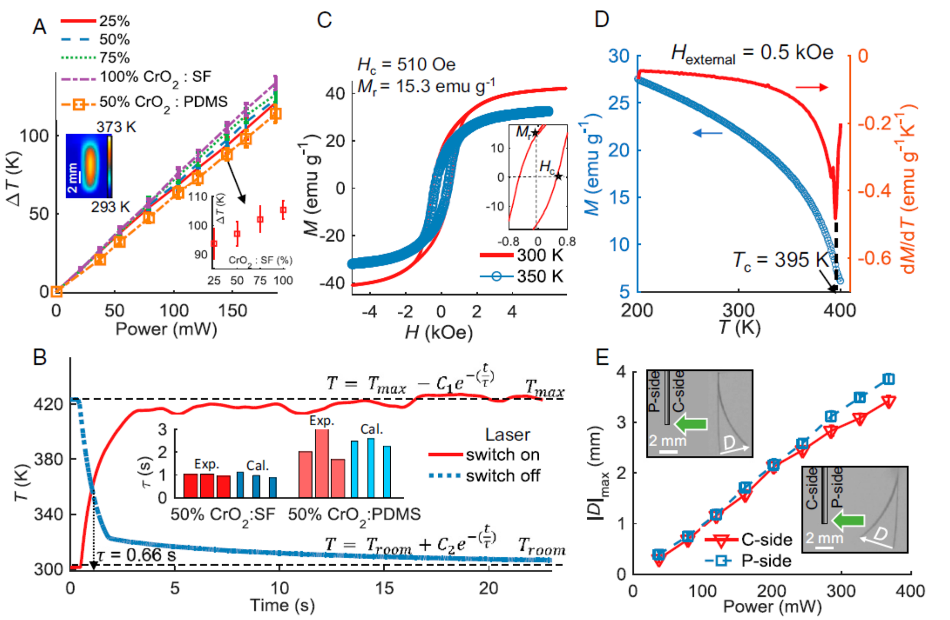

Figure: Photothermal responses and thermal-demagnetization properties. (A) Average temperature rise of magnetic silk-CrO_2 film with different loading percentages (25, 50, 75, 100%) and 50% magnetic PDMS strip under different laser powers. (B) Heating and cooling curve of a 50% magnetic SF film strip under 186-mW laser illumination. (Inset) Bar graph is experimental (thick bars) and calculated (thin bars) τ values for three 50% magnetic SF and three 50% magnetic PDMS strips with laser power 37 mW. (C) Hysteretic magnetization of pretreated CrO_2 powder at 300 and 350 K. (Inset) Curve at 300 K around zero magnetic field. (D) Magnetization of pretreated CrO_2 powder from 200 to 400 K (blue) and the first derivative of *M(T)* (red). (E) The maximum displacement of the tip of a 50% magnetic PDMS strip for laser illumination on both sides.

Results and Discussion

The interaction between light and matter has been long explored, leading to insights based on the modulation and control of electrons and/or photons within a material. An opportunity exists in optomechanics, where the conversion of radiation into material strain and actuation is currently induced at the molecular level in liquid crystal systems, or at the micro-electromechanical systems (MEMS) device scale, producing limited potential strain energy (or force) in light-driven systems. We present here flexible material composites incorporating CrO_2 that, when illuminated, are capable of macroscale motion, through the interplay of optically absorptive elements and low Curie temperature magnetic materials. These composites can be formed into films, sponges, monoliths, and hydrogels, and can be actuated with light at desired locations. Light-actuated elastomeric composites for gripping and releasing, heliotactic motion, light-driven propulsion, and rotation are demonstrated as examples of the versatility of this approach.

We introduce here light-responsive magnetic composites by incorporating CrO_2 in multiple flexible, elastomeric, and mechanically robust, durable materials. Optically induced demagnetization provides multiple opportunities for wireless actuation, shape morphing, and deformation in response to light in easy-to-use formats. Because of their polymorphic nature along with their flexibility and high failure strain, biopolymers and elastomers are used as magnetically inert host material matrices for ferromagnetic dopants.

References

[1] Li, M. *et al.*, Proceedings of the National Academy of Sciences **115**, 8121 (2018).