Supporting Information

Magnetic Multimaterial Printing for Multimodal Shape Transformation with Tunable Properties and Shiftable Mechanical Behaviors

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Strain measurements of the active metamaterials.

Figure S3 illustrates the strain measurements of the chiral metamaterial in Figure 4. Figure S3a shows the undeformed configuration with initial dimensions of x_0 and y_0, and the blue dashed box indicates the outline of the undeformed metamaterial. In Figure S3b-e, the red dashed boxes depict the outlines of the deformed metamaterial. At 22°C, the structure realizes shear deformations under both upward and downward magnetic fields (Figure S3b,c). The deformations are not simple shear for both cases and thus are decoupled into biaxial deformation (from blue dashed box to black dashed box) and simple shear deformation (from black dashed box to red dashed box). Normal strains are then calculated as $\varepsilon_x = \Delta_x / x_0$ and $\varepsilon_y = \Delta_y / y_0$, where Δ_x and Δ_y are the elongation (positive) or contraction (negative) in the x-axis and y-axis directions, respectively. Shear strain γ is defined as the angle change with the counterclockwise direction as positive. As for the deformations at 90°C, there is no shear deformation under both upward and downward magnetic fields, and the metamaterial goes through biaxial deformation as shown by the red dashed box in Figure S3d,e.

Figure S4 illustrates the strain measurements of the hourglass metamaterial in Figure 5. Figure S4a shows the undeformed configuration with the initial length L_0 and initial height H_0 of the hourglass metamaterial, and the blue dashed box indicates the outline of the undeformed metamaterial. In Figure S4b-e, the red dashed boxes depict the outlines of the deformed metamaterial, where Δ_L and Δ_H are the elongation (positive) or contraction (negative) in the length and height directions, respectively. Normal strains are then calculated as $\varepsilon_L = \Delta_L / L_0$ and $\varepsilon_H = \Delta_H / H_0$. For the bending deformation in Figure S4e, we first use two arcs with different radii (R_1 and R_2) to fit the top and bottom edges of the deformed metamaterial. The nodes marked by the black stars in Figure S4e are used for the fitting. Then we use the average curvature of the two arcs to characterize the bending deformation. For the bent metamaterial in Figure S4e, the deformed length is calculated as the average length of the top and bottom arcs, and the deformed thickness is calculated as the average distance between the two arcs.

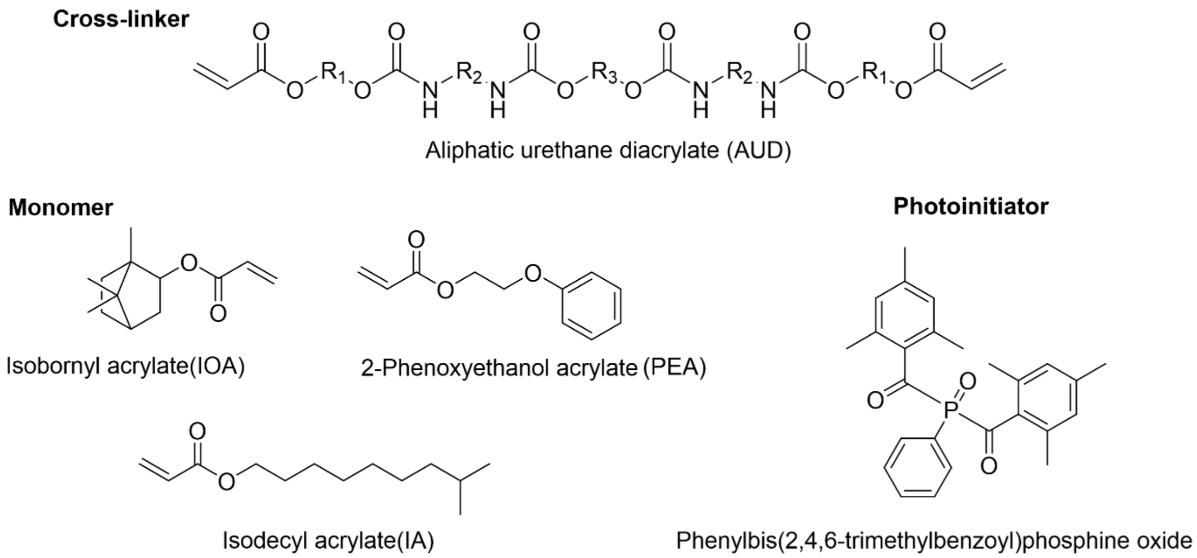

Figure S1. Chemical structures of the components in the resins.

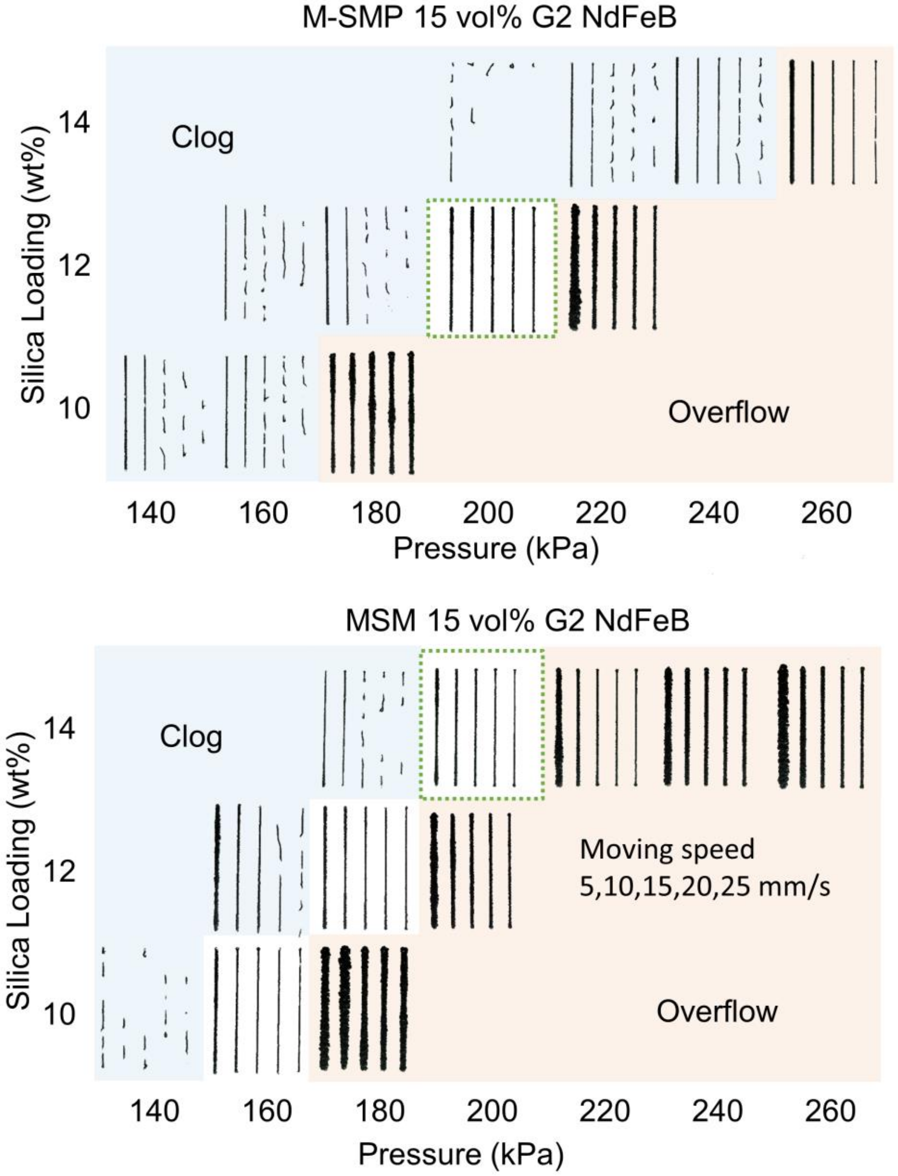

Figure S2. Enlarged Figure 2c. Effects of silica loading, printing pressure, and nozzle translation speed on the quality of the printed filament. Each grid shows five filaments printed at different nozzle translation speeds, which increase from 5 mm/s to 25 mm/s with a step of 5 mm/s from left to right.

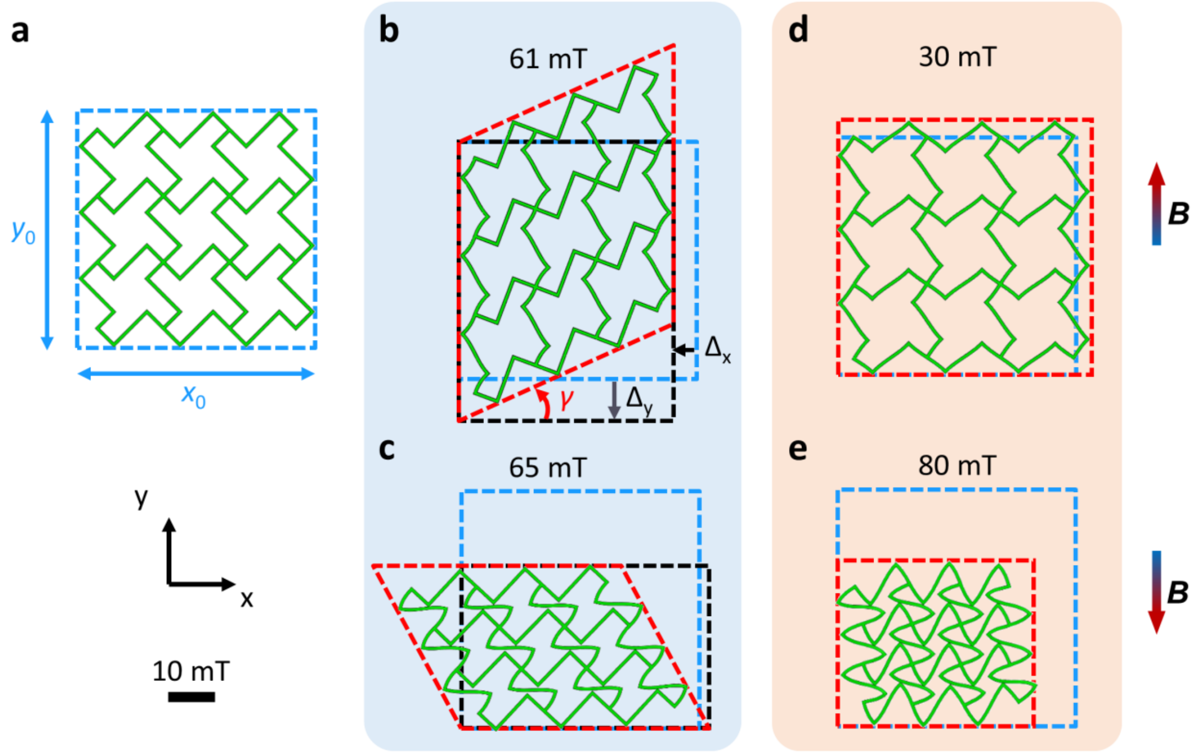

Figure S3. The strain measurements of the chiral metamaterial.

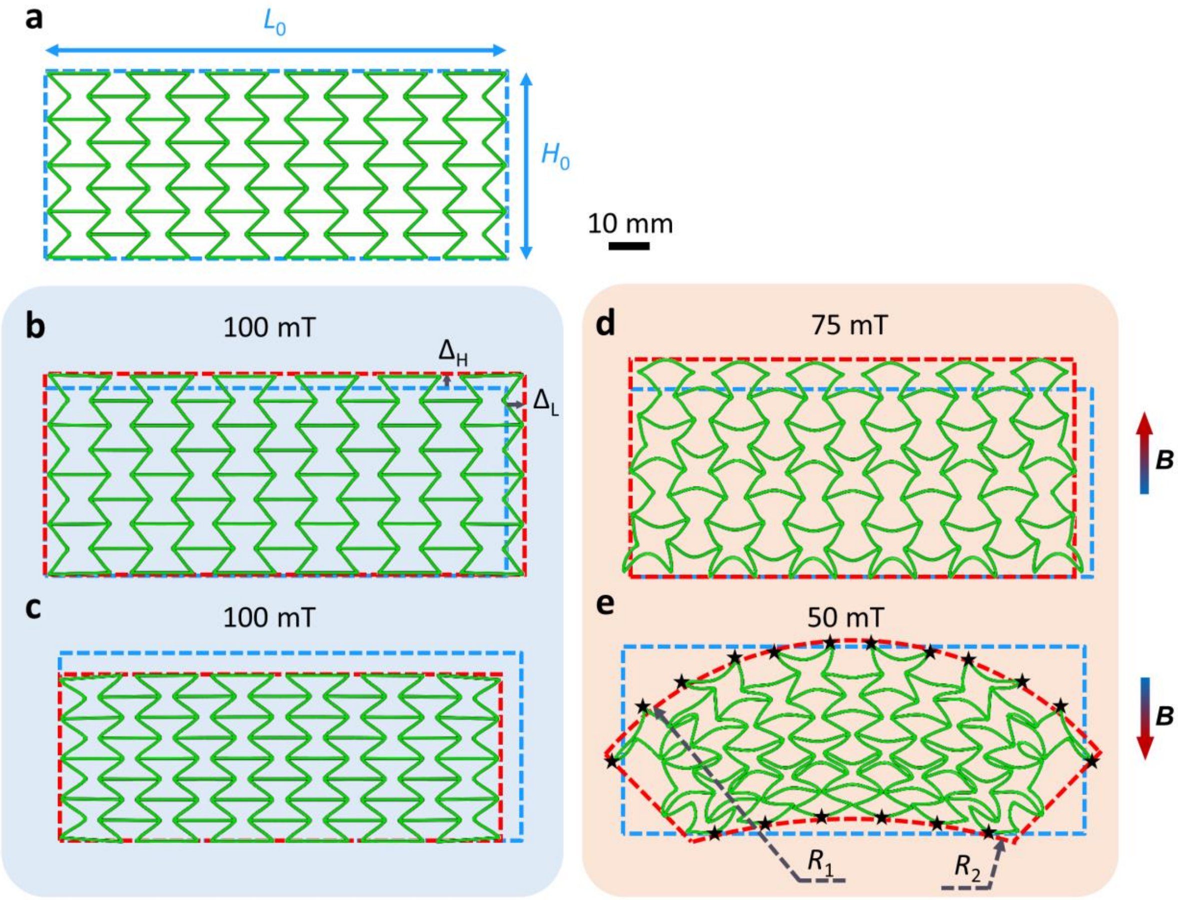

Figure S4. The strain measurements of the hourglass metamaterial.

Supporting Video Captions

Video S1. Multimodal pop-up structures (mp4).

Video S2. Active metamaterial with tunable properties and shiftable mechanical behaviors - a chiral design (mp4).

Video S3. Active metamaterial with tunable properties and shiftable mechanical behaviors - an hourglass design (mp4).