Electronic Supplementary Information

Functional Graphene Springs for Responsive Actuation

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Experimental Section

Fabrication of GFS: For preparation of GF, 8 mg/mL aqueous graphene oxide (GO) suspension was injected into the glass pipeline and was then baked in an oven at 230 °C for 2 h after sealing up the two ends of the pipeline as we reported previously.[1, 2] The GFS was fabricated by wrapping the as-prepared wet GF around the cylindrical objects, followed by annealing it under 500 °C in tubular furnace. The magnetic GF was prepared by mixing Fe_3O_4 nanoparticles (20 nm) with 8 mg/mL GO suspension under ultrasonication (weight ratio of Fe_3O_4/GO = 1:10), followed by hydrothermal process within pipelines as mentioned above for in-situ incorporation of Fe_3O_4 nanoparticles into the interlayers of graphene sheets. Accordingly, magnetic GFS was fabricated by wrapping the wet Fe_3O_4/GF around the cylindrical objects, followed by annealing it under 500 °C in tubular furnace.

Characterizations: The whole stretching process of GFS was recorded by a digital video camera recorder. The length change was obtained by analysis of the video. The morphology and X-ray energy disperse spectra (EDS) of the samples was examined by scanning electron

microscope (SEM, JSM-7001F). The electric character of GFS was measured by using CHI 660D electrochemical workstation. Mechanical property test of GFS was conducted with an AGS-X material testing system (SHIMADZU).

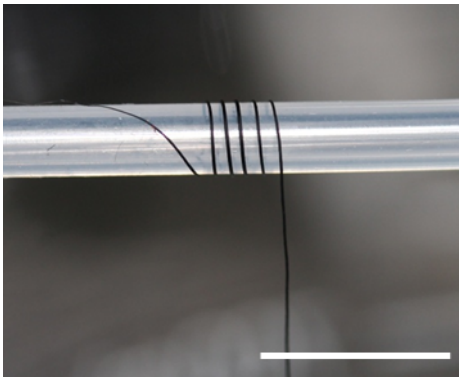

Fig. S1 Photo of wet GF winding around the glass rod. Scale bar: 1 cm.

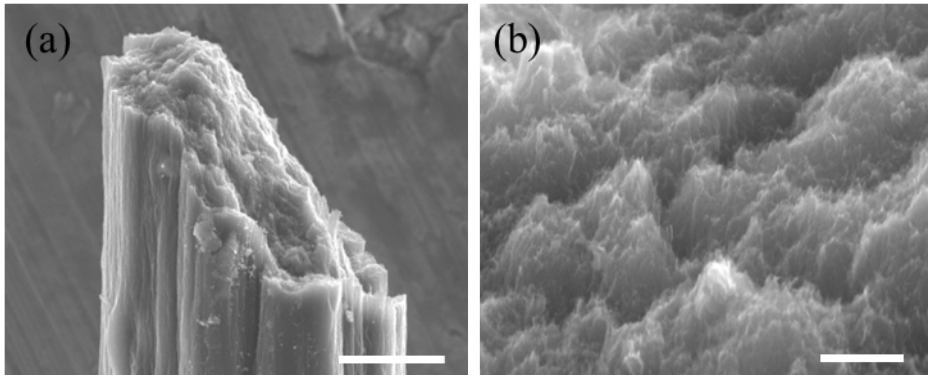

Fig. S2 SEM images of the cross-section (a) of a GFS and the enlarged view (b). Scale bars: a, 10 μm; b, 1 μm.

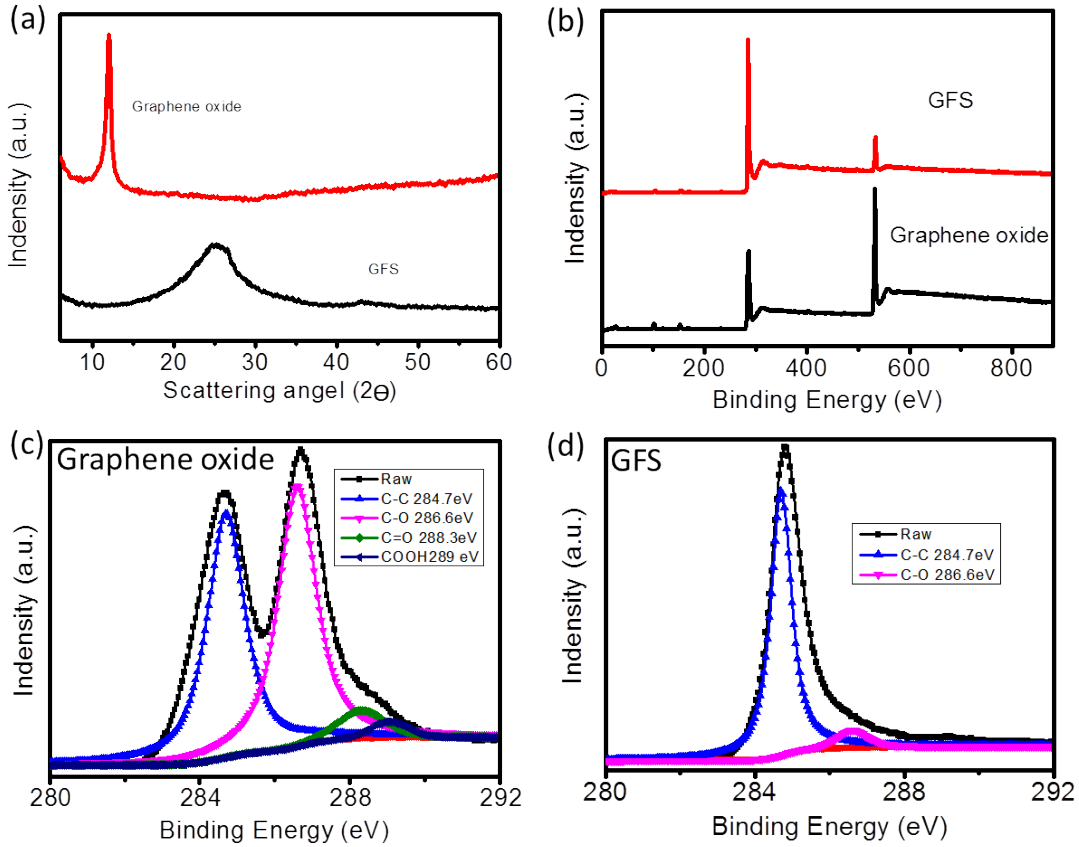

Fig. S3 (a) X-ray diffraction (XRD) patterns of graphene oxide (GO) and GFS. The typical diffraction peak of GO at approximately 11° has completely disappeared for GFS. (b) X-ray photoelectron spectroscopy (XPS) of GO and GFS. (c) and (d) The C1s spectrum of GO and GFS. The O/C atomic ratio is roughly 1:9, which is largely lower than that in GO (1:2). The C1s spectrum of the original GO reveals four types of carbon containing bond: C=C/C–C (284.7eV), C–O (286.6eV), C=O (288.3eV), and O–C–O (289.0eV). However, for GFS, the C–C bonds become dominant. The results indicated that the oxygen containing groups of GFS had been removed significantly compared to GO.

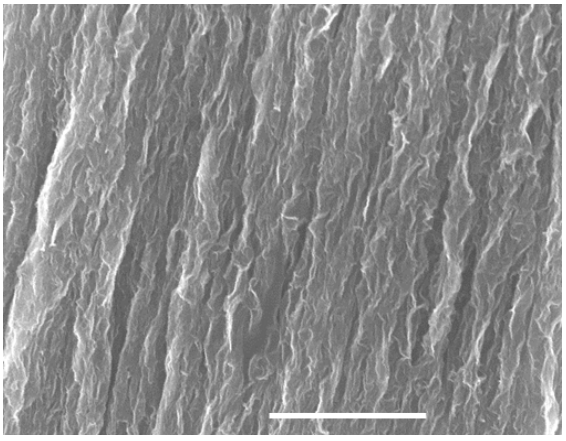

Fig. S4 SEM image of GFS surface after mechanical testing. Scale bar: 2μm.

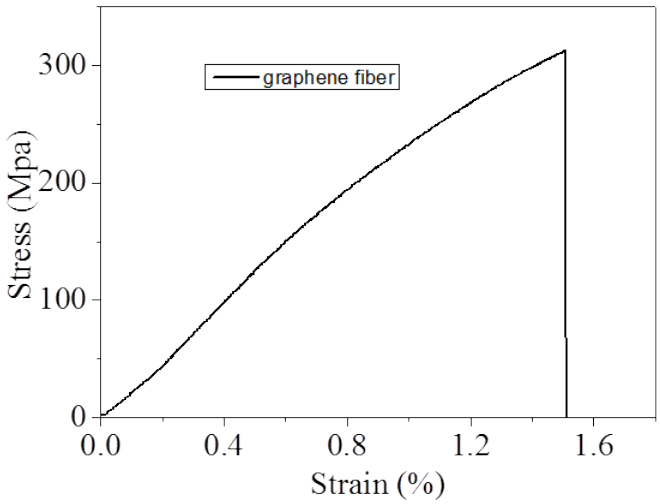

Fig. S5 Stress-strain curve of graphene fiber.

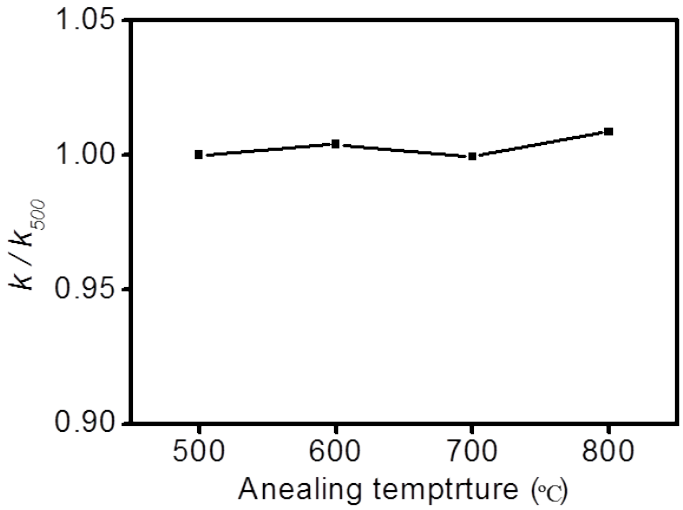

Fig. S6 This ratio of elasticity coefficient (k) change of GFS after different tempreture annealing. k_{500} stands for the elasticity coefficient of GFS after anneling under 500°C.

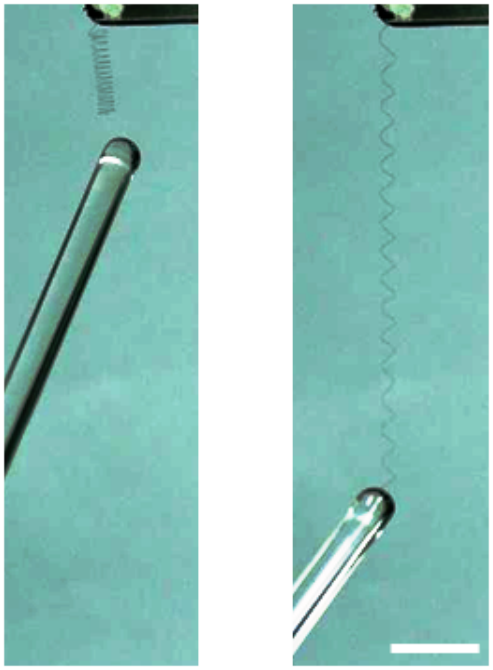

Fig. S7 Photos of GFS (left) and stretched (right) by a static electricity-charged glass rod. Scale bar: 1cm.

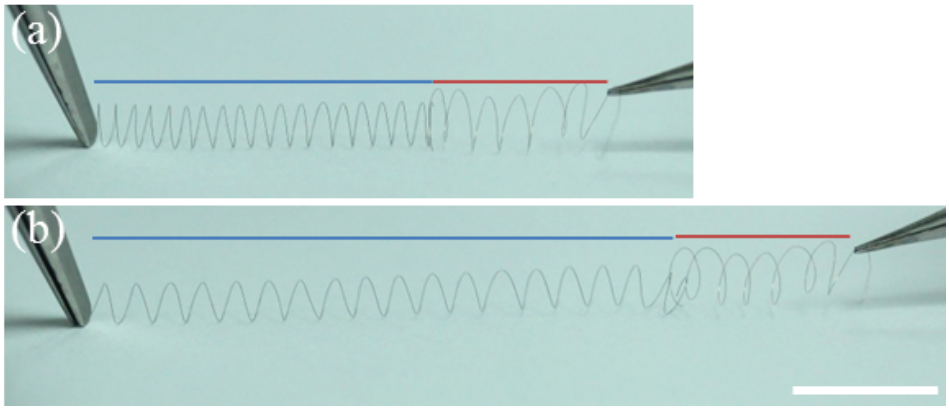

Fig. S8 (a) Photos of GFS (left) and the copper spring (right) which have the same fiber diameter. (b) GFS stretched up to 200% of its original length when copper spring had no length change. Scale bar: 1 cm.

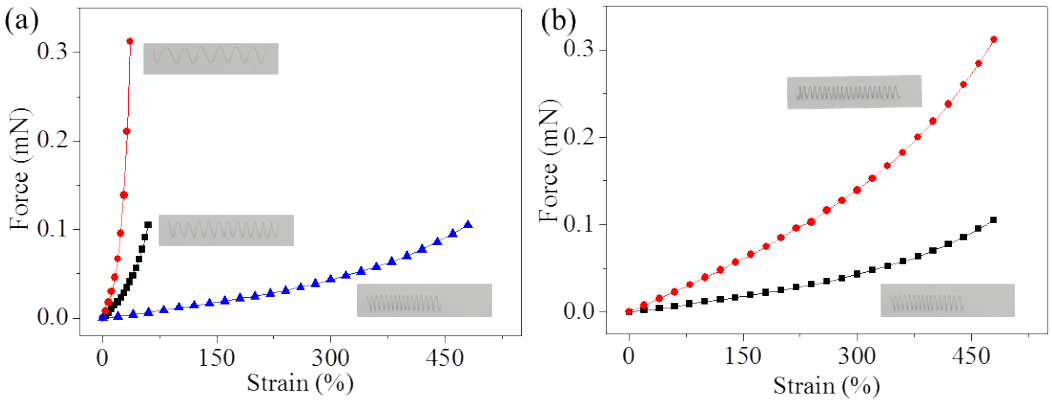

Fig. S9 Force-strain curves of different spring with different loops distance (*l*) and spring diameter (*D*). From up to down, (a) *l* = 3mm, 2mm, 1mm, (b) *D* = 2mm, 3mm. respectively.

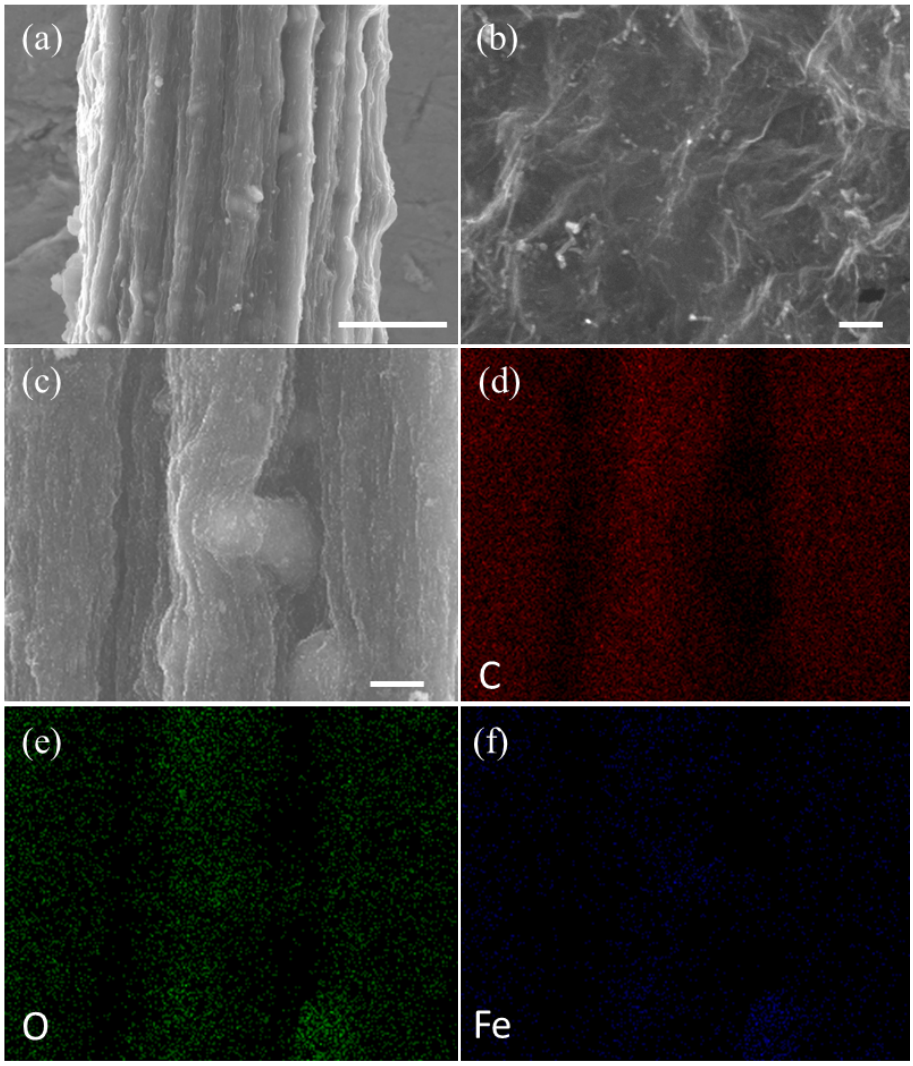

Fig. S10 The surface (a, c) and cross-sectional (b) SEM images of Fe_3O_4-GFS, respectively. (d–f) C, O, Fe elemental mappings of (c) determined by EDS.

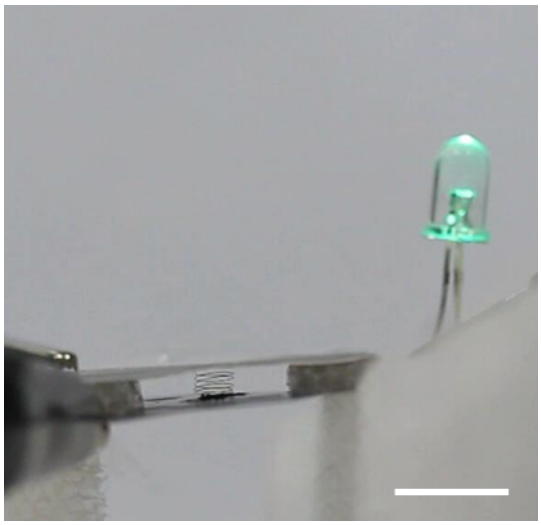

Fig. S11 Photo of Fe_3O_4-GFS switch at on state. Scale bar: 1cm.

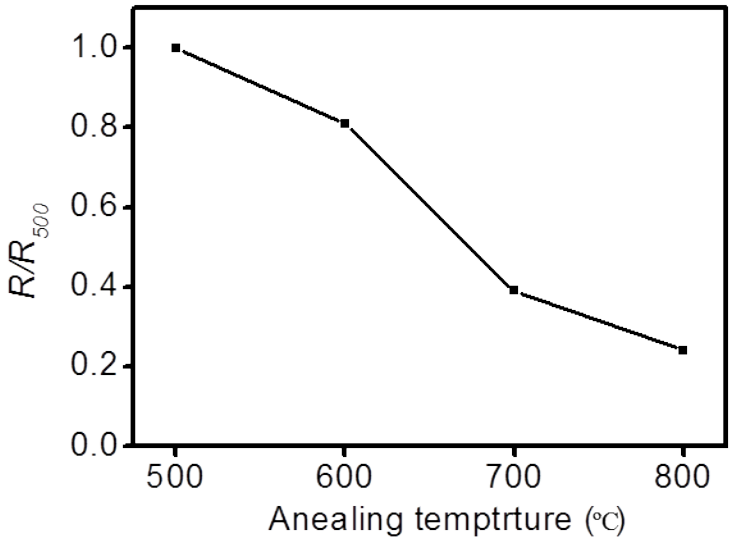

Fig. S12 The relative electrical resistance change (R/R_{500}) of Fe_3O_4-GFS after different tempreture annealing. R_{500} is the initial resistance of GFS after 500°C annealing. The results indicat the reduced electrical resistance of GFS under higher annealing tempreture.

Supporting Movie Caption:

Movie S1. The stretching behavior of a GFS under electrostatic field.

Movie S2. The magnet actived Fe_3O_4-GFS switch.

[s1] Z. L. Dong, C. C. Jiang, H. H. Cheng, Y. Zhao, G. Q. Shi, L. Jiang, L. T. Qu, *Adv. Mater.,* **2012**, *24*, 1856–1861.

[s2] C. G. Hu, Y. Zhao, H. H. Cheng, Y. Wang, Z. L. Dong, C. C. Jiang, X. Q. Zhai, L. Jiang, L. T. Qu, *Nano Lett.,* **2012**, *12*, 5879–5884.