Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting information

Pristine graphene oxide film-based contactless actuators driven by electrostatic force

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Experimental section

Materials

Graphite flakes (~325 mesh particle size), and sulfuric acid (H_2SO_4, 99.999%), hydrochloric acid (HCl, 37%) were purchased from Sigma-Aldrich. Hydrogen peroxide solution (H_2O_2, 30 wt. % in H_2O), potassium permanganate ($KMnO_4$, 99%), and Petri dishes (polystyrene) were obtained from Alfa Aesar. Deionized water was used throughout the experiment.

Synthesis of GO film

For preparation of GO film, 50 mL of 0.9 mg/mL GO suspension which was prepared by an improved Hummers method[S1] was poured into a glass Petri dish with a diameter of 9.5 cm and a depth of 1.6 cm, and incubated at 50 °C for 24 h. The GO film was carefully peeled off from the glass dish. The resulted GO film was maintained in an atmosphere environment before use.

Testing of electrostatic induction actuation behaviors

In order to test the electrostatic induction actuation behavior of GO film, the resulting GO film was cut into small strips (length 18.6 mm, width 2.0 mm). Then, a GO strip was attached on the surface of a sticker, followed by covering with a plastic Petri dish (polystyrene) with a diameter of 3.4 cm and a depth of 0.9 cm. Different objects were close to the surface of the dish from top to bottom, which resulted in the bending of GO strip with the movement of different objects.

Characterization

The morphology of GO film was characterized by scanning electron microscope (SEM, JSM-6360) and scanning probe microscope (Nanoscope IIIa Dimension 3100, Bruker). X-ray diffraction (XRD) patterns were recorded on Shimadzu XRD-6000 diffractometer. Fourier transform infrared (FTIR) spectroscopy was carried out on a spectrometer (IR Prestige-21, Shimadzu) in the 400-4000 cm^{-1} frequency range. Raman spectra were conducted under ambient condition using a 633 Raman system (WITec CRM200) with 532 nm laser excitation. The surface charges were determined by a Faraday cup connected to a high precision electrometer (Keithley 6514).

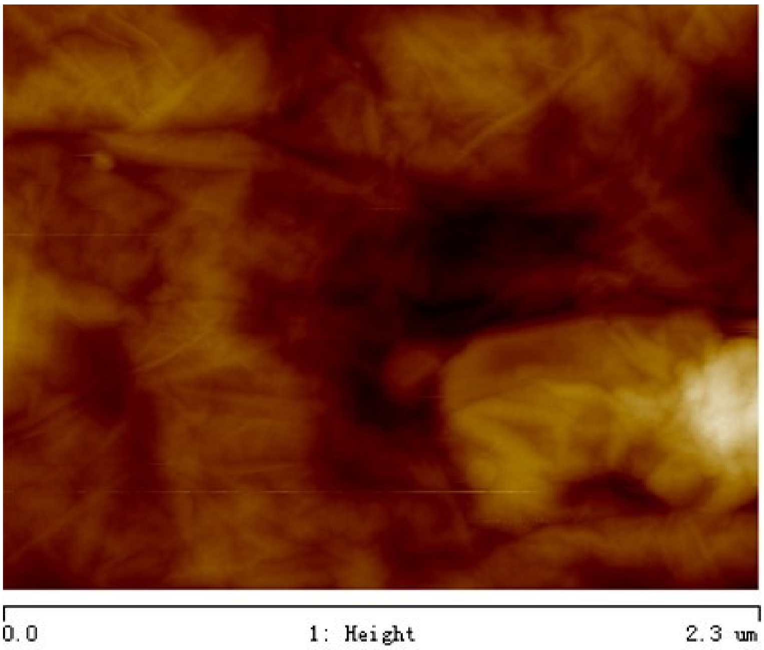

Fig. S1 AFM image of the obtained GO film.

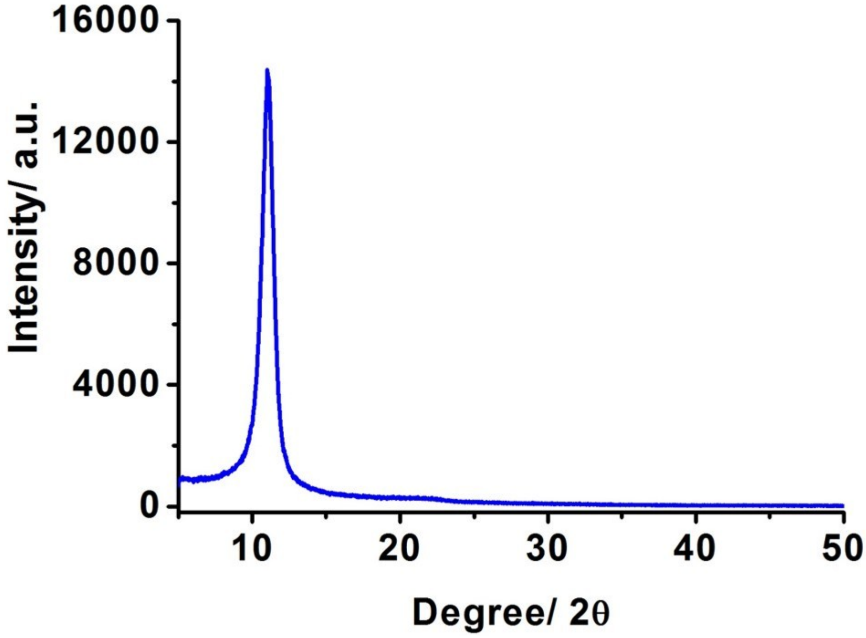

Fig. S2 XRD pattern of the obtained GO film.

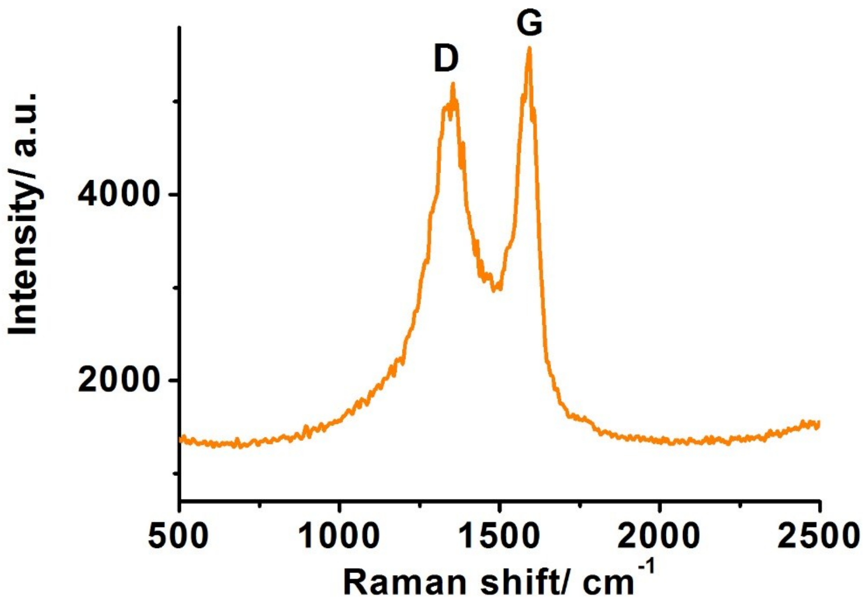

Fig. S3 Raman spectrum of the obtained GO film.

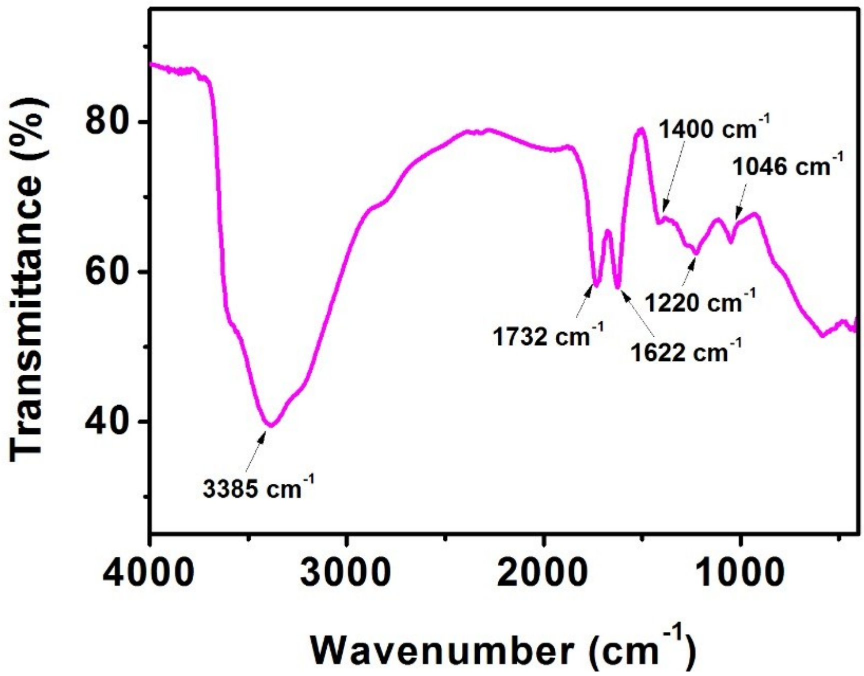

Fig. S4 FTIR spectrum of the obtained GO film.

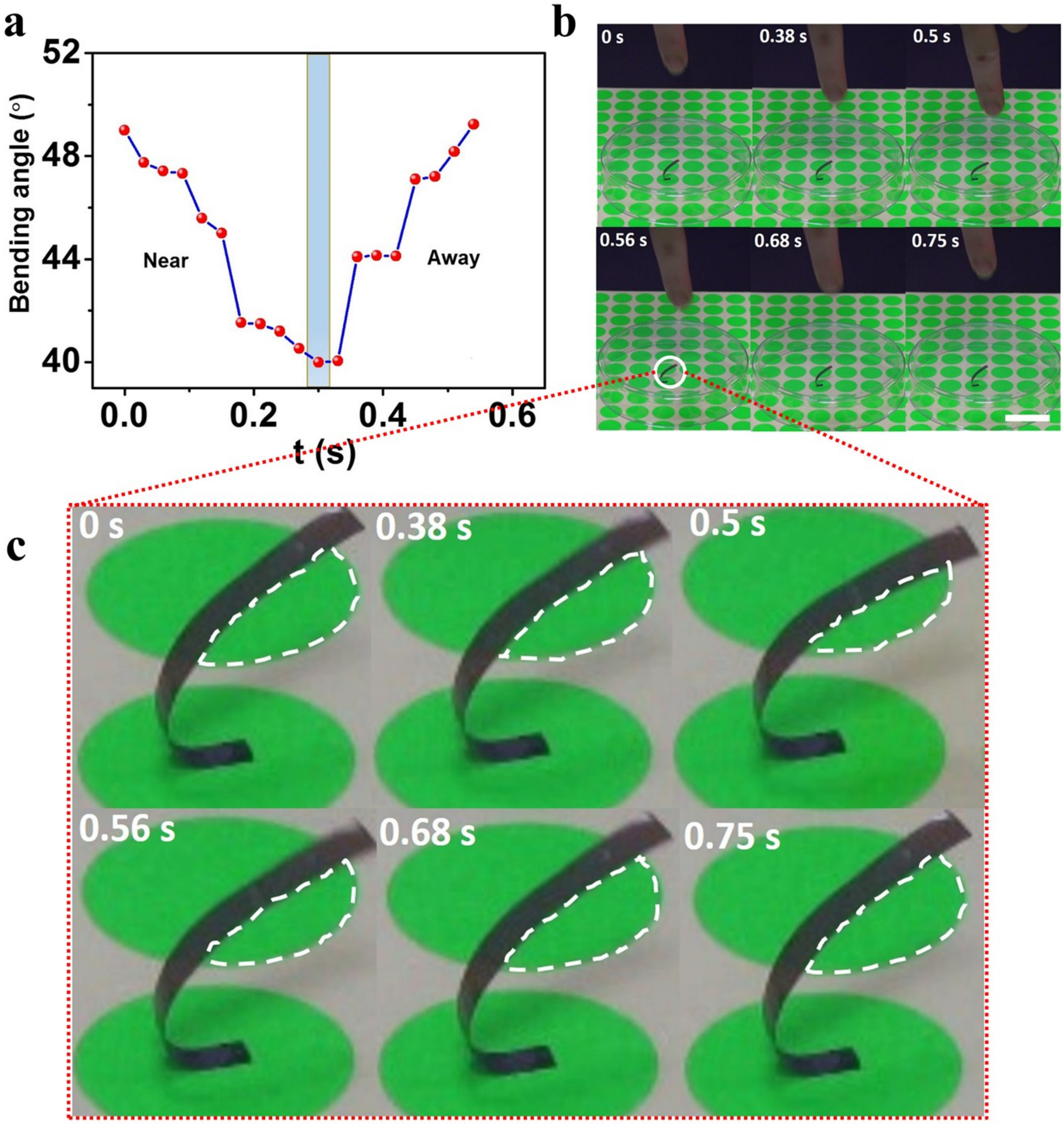

Fig. S5 Human finger induced actuation process of GO film-based actuator. (a) Bending angle plotted as a function of time. (b, c) Optical images and their local magnification of the Human finger induced actuation process of GO film-based actuator.

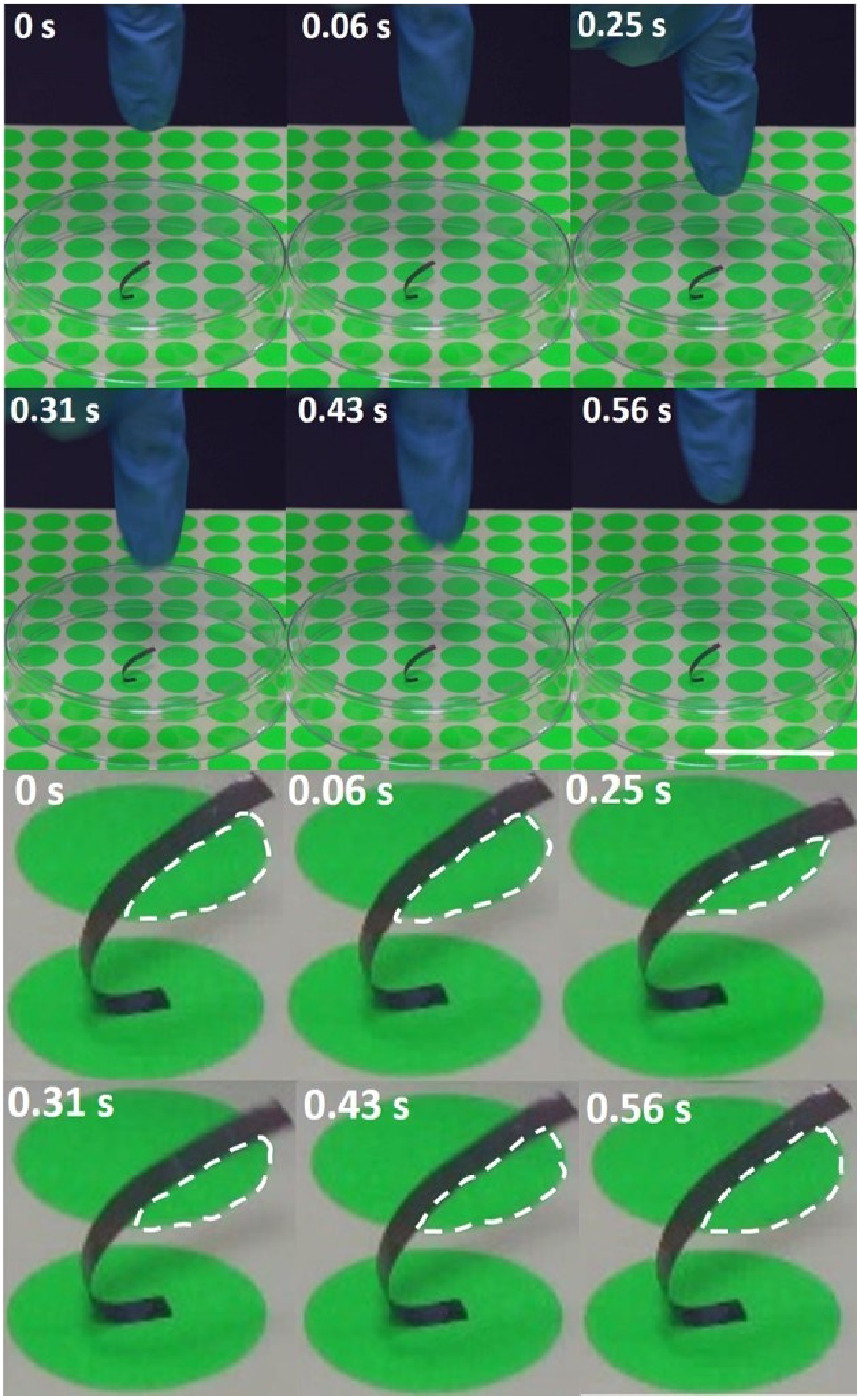

Fig. S6 Optical images and their local magnification of the human finger covered by laboratory glove induced actuation process of GO film-based actuator (scale bar, 4 cm).

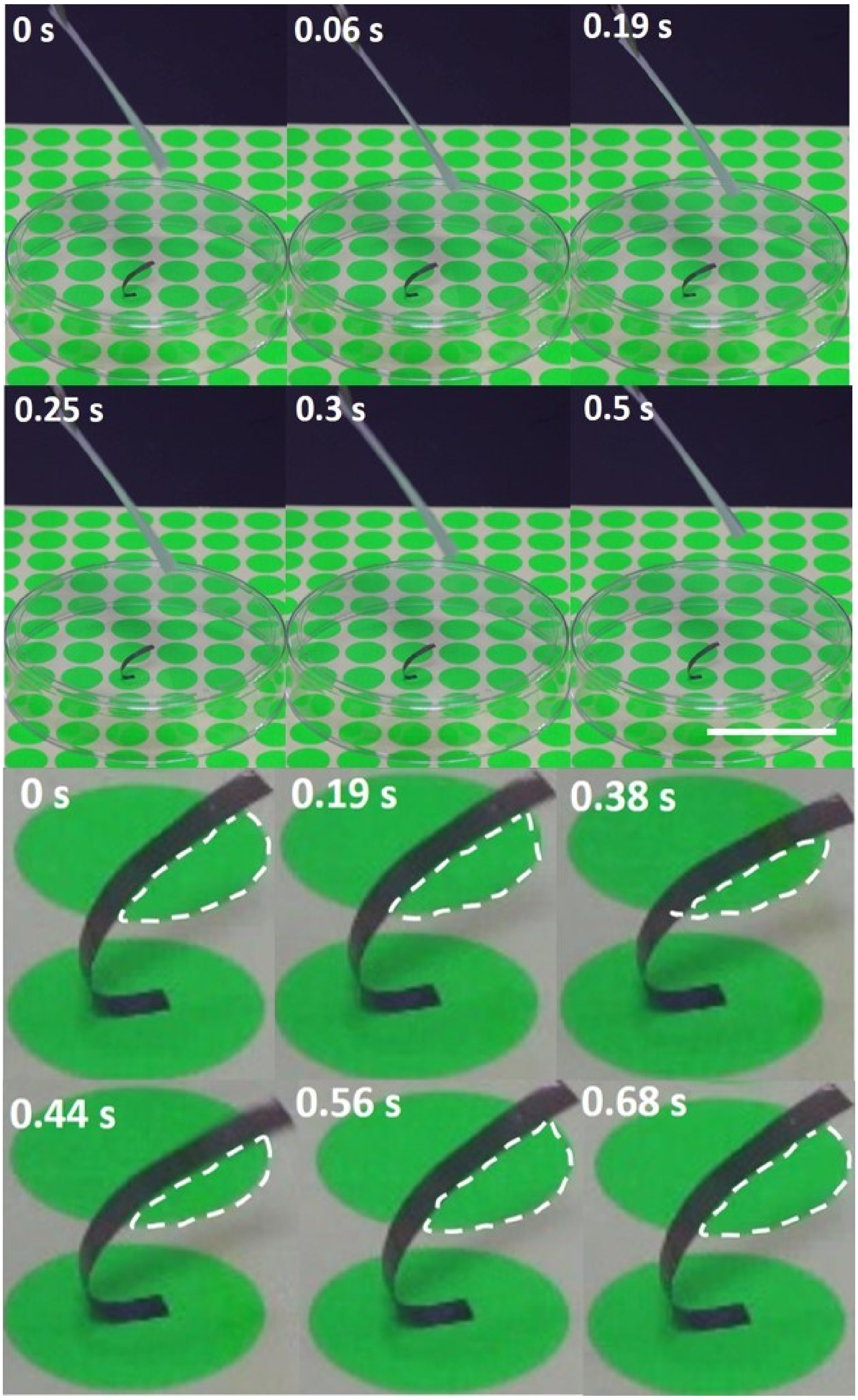

Fig. S7 Optical images and their local magnification of the weighing paper induced actuation process of GO film-based actuator (scale bar, 4 cm).

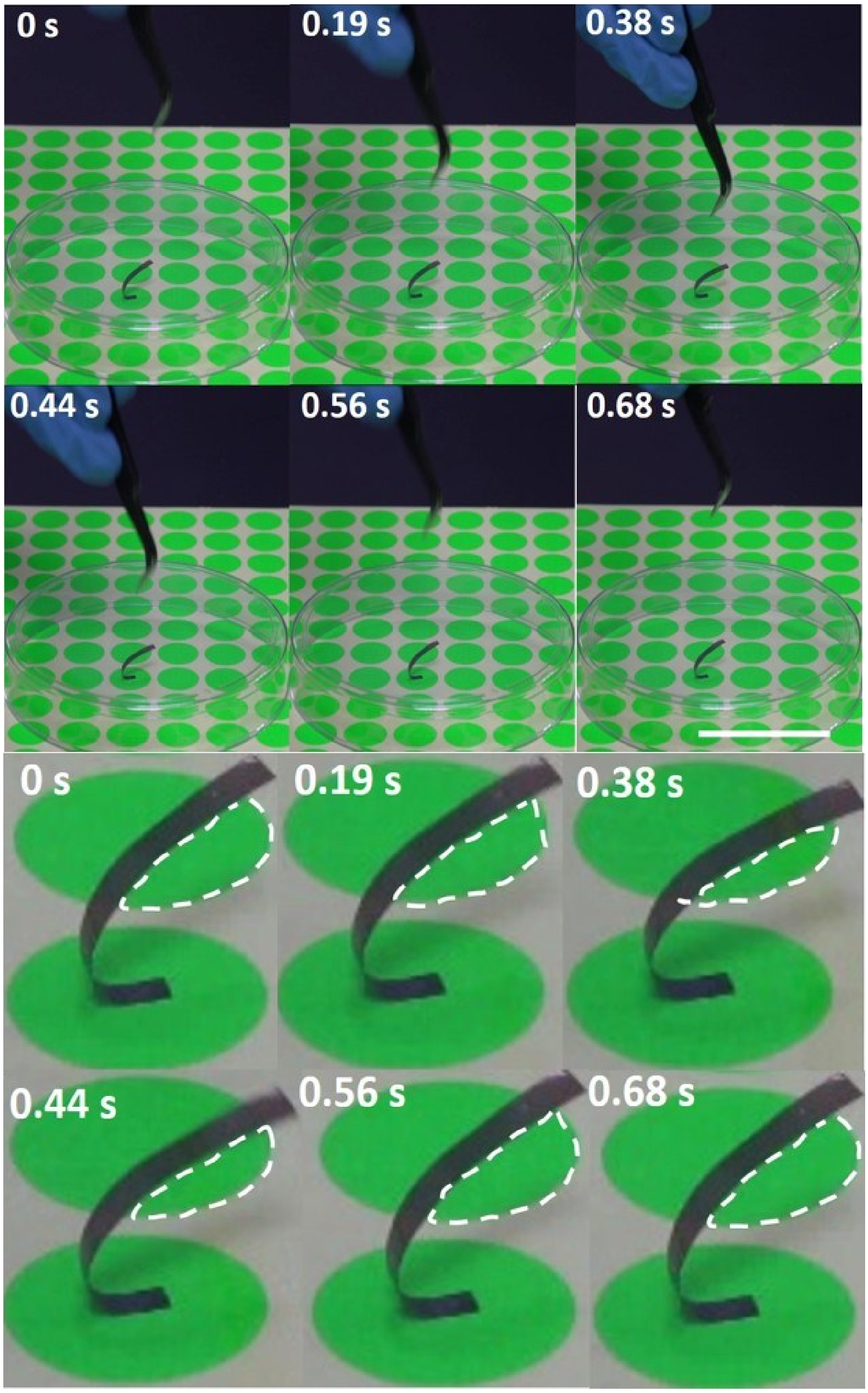

Fig. S8 Optical images and their local magnification of the metal tweezer induced actuation process of GO film-based actuator (scale bar, 4 cm).

Fig. S9 Triboelectric series of common materials with the highlighted positions of human skin, glass, paper, steel, polystyrene (PS), and polytetrafluoroethene (PTFE).

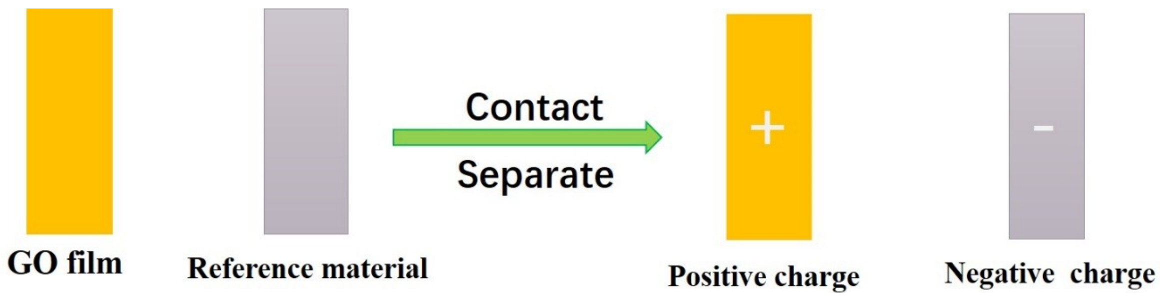

Fig. S10 Schematic representation of contact electrification of GO film.

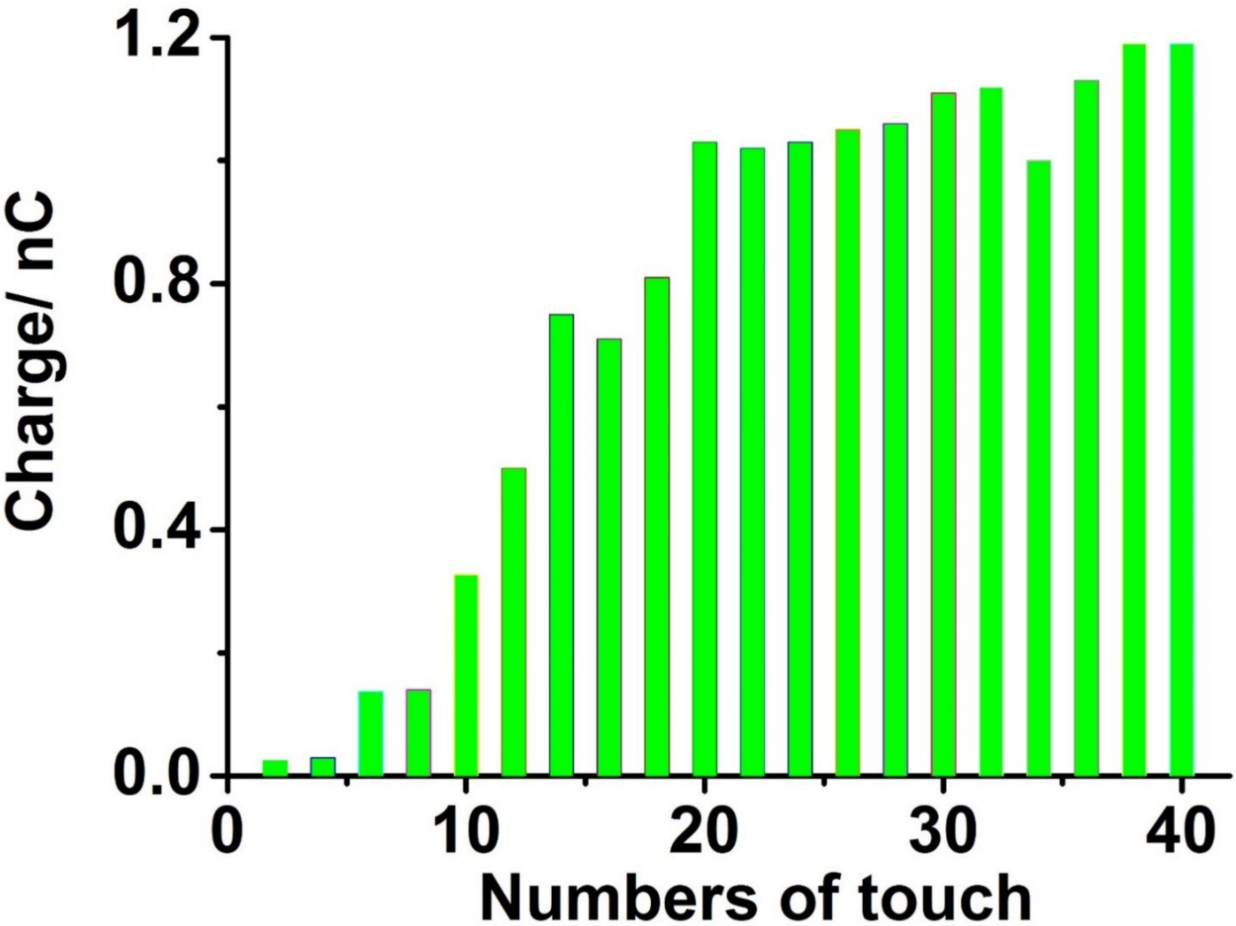

Fig. S11 The relationship of the charge of GO film and numbers of touch (contact with glass).

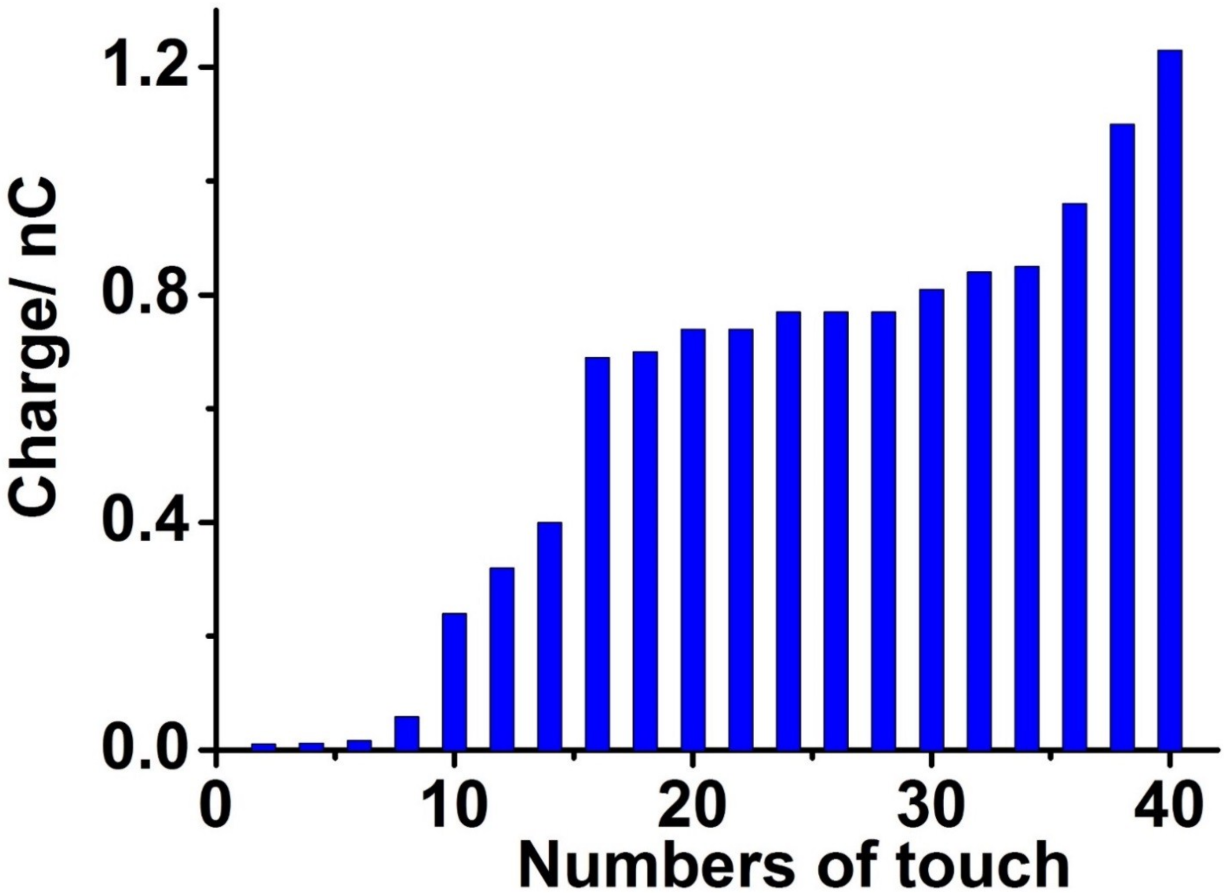

Fig. S12 The relationship of the charge of GO film and numbers of touch (contact with paper).

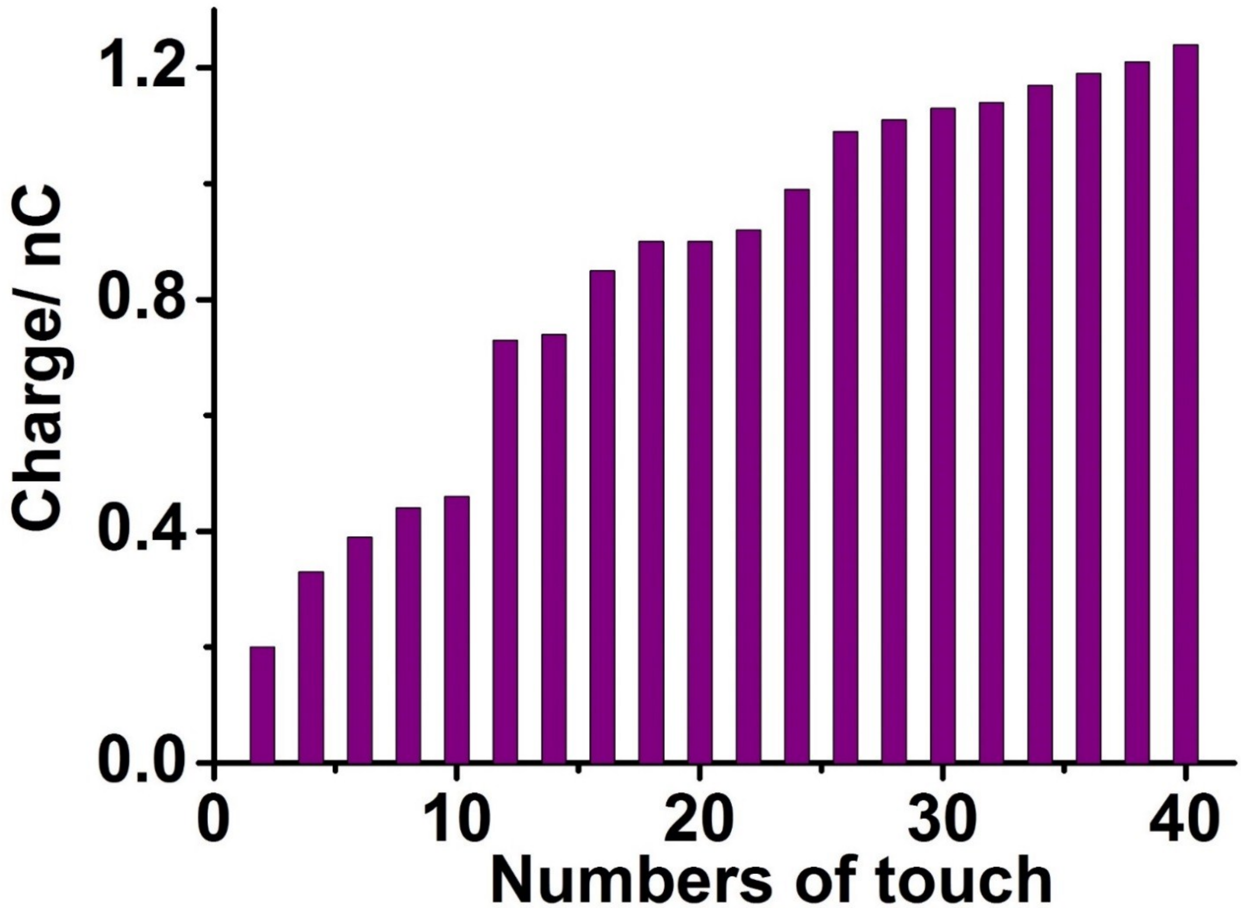

Fig. S13 The relationship of the charge of GO film and numbers of touch (contact with PTFE).

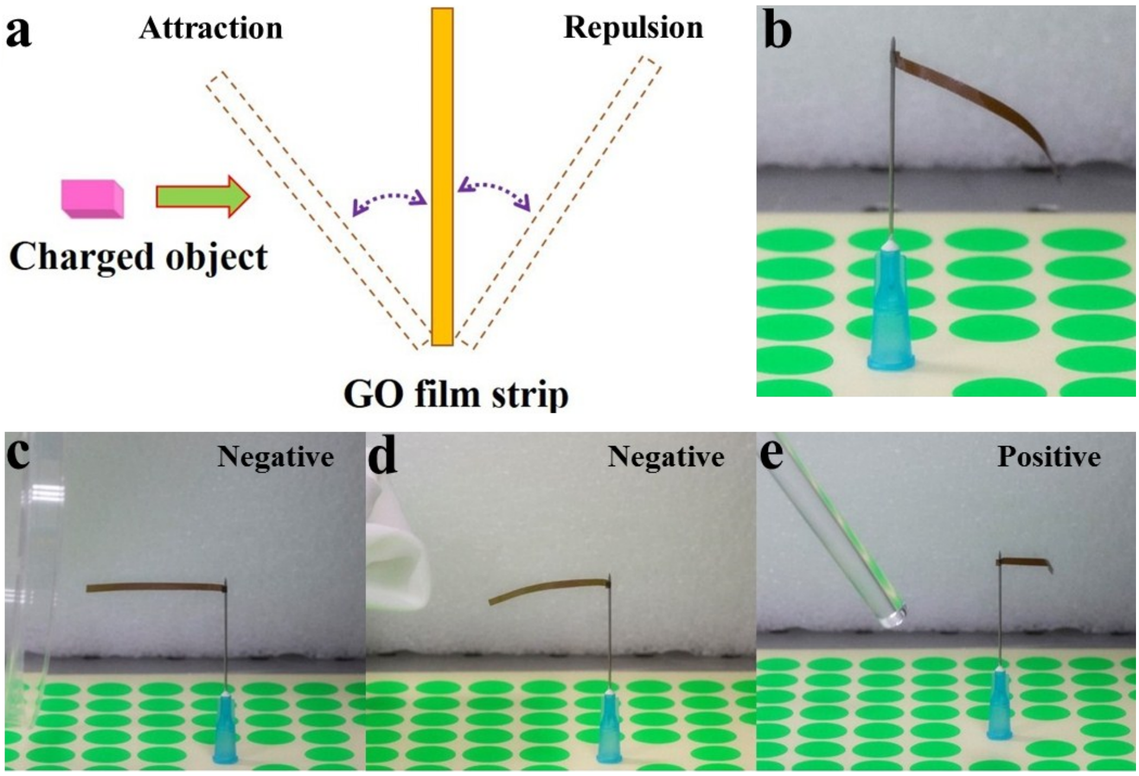

Fig. S14 (a) Representation of the bending of GO film strip caused by charged objects. (b-e) Optical images showing the GO film strip attached on a needle and the bending process of the GO film strip in response to different charged objects: PS dish (negatively charged), washcloth (negatively charged), and glass rod (positively charged).

Calculation of the electrostatic attractive forces produced by the GO film strip and the PS dish without and with the piece of PTFE film. All calculations were conducted using COMSOL Multiphysics (COMSOL Inc). Briefly, the geometries of the models, including the GO film strip, PS dish, and the piece of PTFE film were drawn as displayed in Fig. S16. One surface of the PS dish had a charge density of - 4 μC/m^2. The charge density of GO film strip and the PTFE film were 0.5 μC/m^2 and -7 μC/m^2. The relative permittivities of GO film, PS, and PTFE were approximately 4.3[S2-S3], 2.5, and 2.1, respectively. After solving the electric potential around the geometries of the models, the electrostatic attractive forces produced by the GO film strip and the PS dish without the piece of PTFE film, PTFE film at 5 cm and PTFE film at 1.5 cm were calculated.

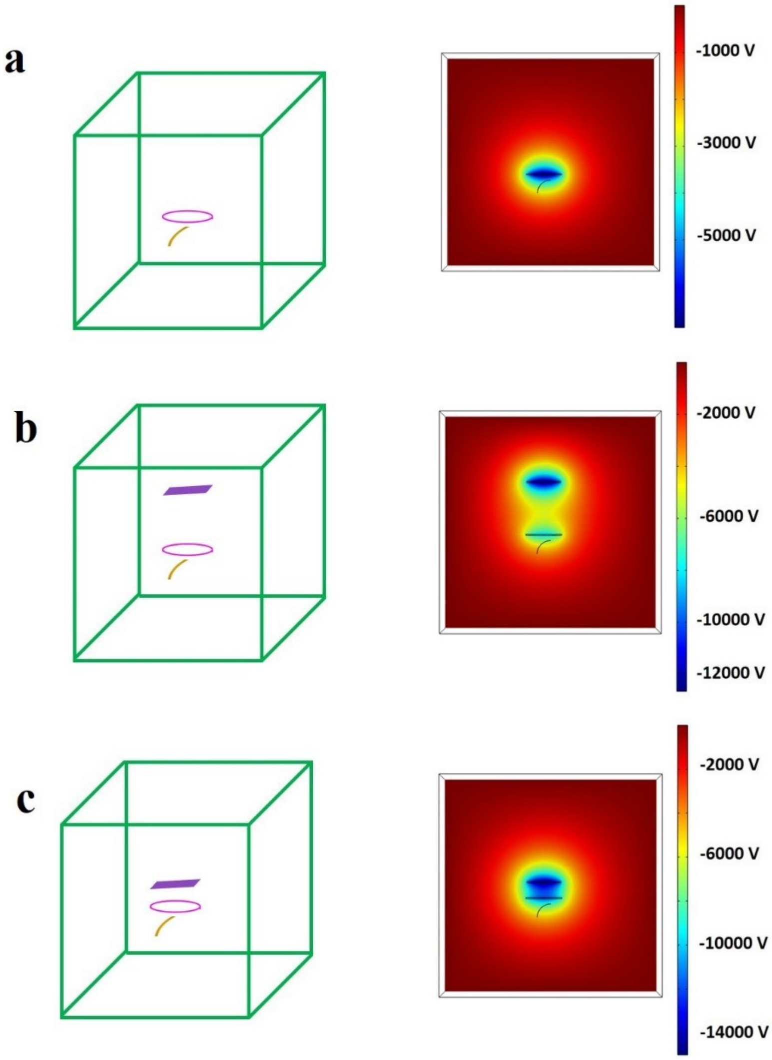

Fig. S15 Geometries of the models and the corresponding electric potentials involving the GO film strip and PS dish (a) without the piece of PTFE film, (b) PTFE film at 5 cm, and (c) PTFE film at 1.5 cm.

S1 J. Chen, Y. Li, L. Huang, C. Li and G. Shi, *Carbon*, 2015, **81**, 826.

S2 S. Brian, M. Anthony, S. Emma and B. Marc, *Nano Lett.*, 2012, **12**, 1165.

S2 A. Gonc, Z. Pavel, R. Konstantin, L. Sergey, K.Yakov and K. Andrei, *Nat. Commun.*, 2015, **7572**.