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

Supporting Information

Powerfully dual-responsive soft actuator and photo-to-electric generator based on graphene micro-gasbags for bioinspired applications

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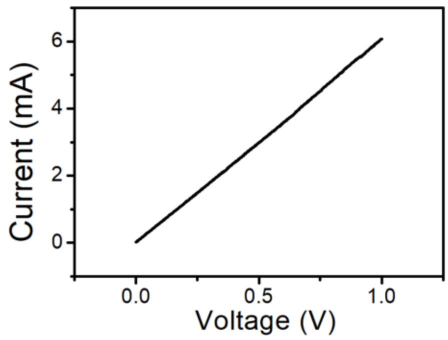

Figure S1. Current-voltage (I-V) curve of the SRGO/PI bilayer at room temperature.

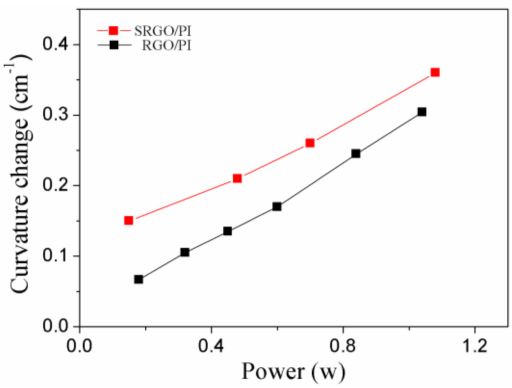

Figure S2. Deformation curvature change of the SRGO/PI bilayer actuator and the RGO/PI bilayer actuator under the applied different electric power.

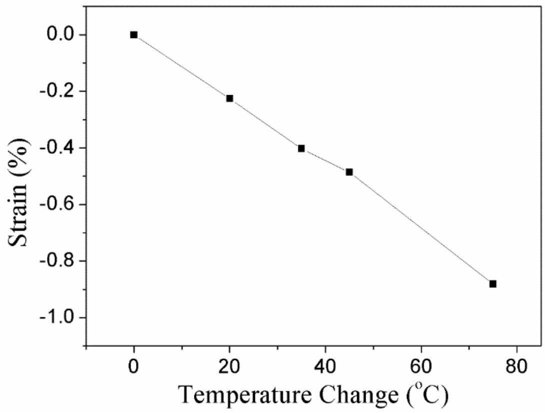

Figure S3. Deformation strain of the single SRGO film under different temperature change.

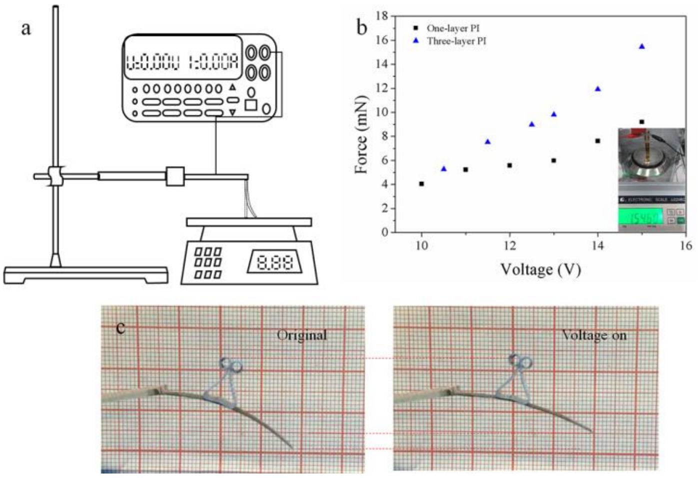

Figure S4. (a) Representation of the homemade setup used for measuring actuation force of the SRGO/PI bilayer actuator. (b) Blocking force of the actuator with different PI layer as a function of the input electrical voltage. The inset shows the measurement of the 15mN output force of the actuator upon electrical stimulation. (c) Optical photos of the metal clip (655mg) put onto the SRGO/PI bilayer actuator with three-lay PI, and elevated after applying electrical voltage.

Theoretical model

A simple theoretical model for bilayer structure was also employed to describe the bending movement of the SRGO/PI actuator. [1] The curvature of the actuator can be predicted by:

$$\frac{1}{\rho}=\frac{6(a_2-a_1)(T-T_0)(1+m^2)}{h(3(1+m)^2+(1+mn)(m^2+\frac{1}{mn}))}, \quad (1)$$

$$m=\frac{t_1}{t_2}, \quad (2)$$

$$n=\frac{E_1}{E_2} \quad (3)$$

where h is the total thickness of the actuator; T is the temperature; T_0 is the original temperature; a_1 and a_2 denote the thermal expansion coefficients of the polyimide tape (2.8×10^{-5}/°C)[2] and the SRGO (-1.16×10^{-4}/°C), respectively; t_1 and t_2 represent the thickness of PI tape and SRGO layer, respectively; and E_1 and E_2 is the Young's modulus of PI (2.5GPa)[3] and SRGO layer (5.0GPa), respectively. The values of curvature to different temperature predicted by the theory model, compared with the experimental results, are shown in Figure S2. It is shown that the curvature change with the temperature obtained by the experiments and predicted by the theory model have the consistent variation tendency, both increasing with the enhanced electrical power.

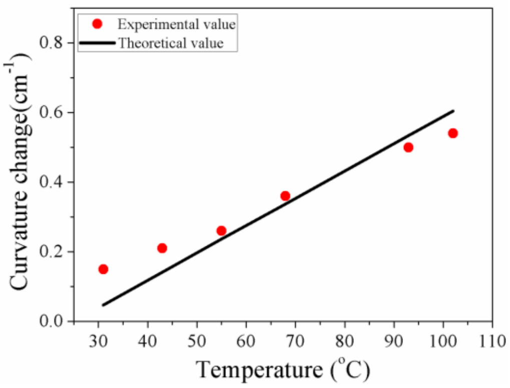

Figure S5. Comparison of the calculated curvature from theoretical bilayer model with the measured curvature from experimental results.

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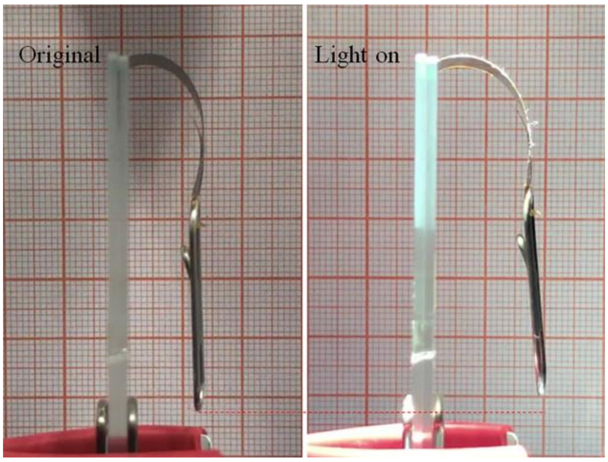

Figure S6. Lifting of the paper clip by the SRGO/PI bilayer actuator under the light irradiation.

Movie S1 Electrically induced actuation

Movie S2 Deformation of the graphene micro-gasbags

Movie S3 Lifting of paper clip upon electrical stimulation

Movie S4 Optically induced actuation

Movie S5 Electrically driven kicking motion

Movie S6 Electrically driven kicking motion without the blocking part

Movie S7 Mechanical gripper for grabbing the ball

Movie S8 Mechanical gripper for grabbing the vegetable leaf

Movie S9 Typical index finger motion upon electrical stimulation

Movie S10 Optically driven side-to-side movement

Movie S11 Optically induced creeping motion

References:

1. S. Timoshenko, Analysis of Bimetal Thermostats. J. Opt. Soc. Am., 1925, 11, 233.
2. J. Deng, J. Li, P. Chen, X. Fang, X. Sun, Y. Jiang, W. Weng, B. Wang and H. Peng, J. Am. Chem. Soc., 2016, 138, 225.
3. M. Amjadi and M. Sitti, ACS Nano., 2016, 10, 10202.