Supporting Information

Microscopic bimetal actuator based on a bilayer of graphene and graphene

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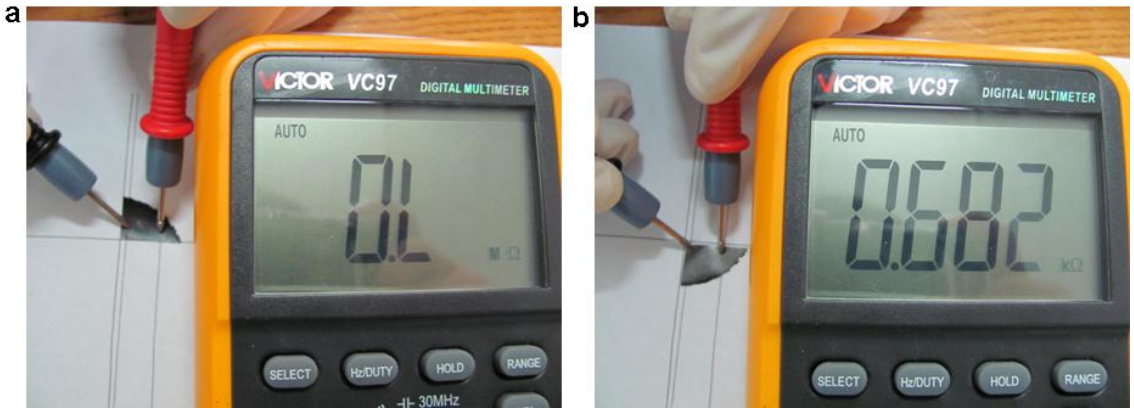

Figure S1 (a) The resistance of G-O paper is beyond the range. (b) The resistance of graphene paper is 782 Ω. Distance between two probes: ~1 cm.

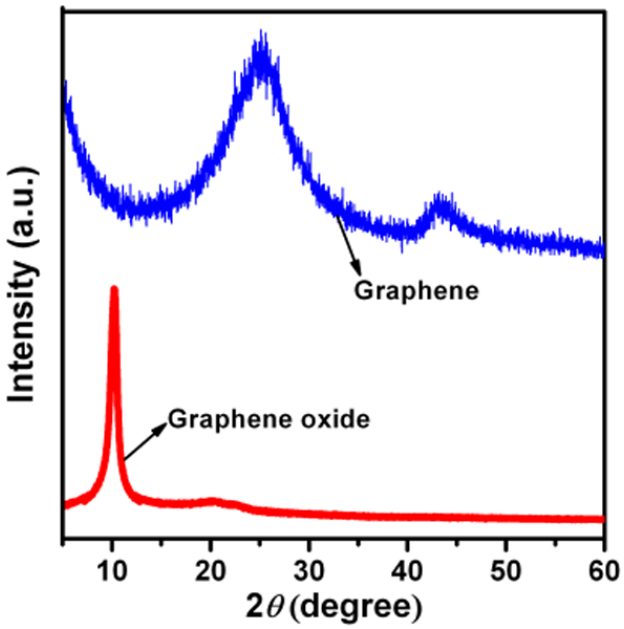

Figure S2. The XRD patterns of G-O and graphene. The interlayer spacing decreased from 8.8 Å (2θ=10.07°) for G-O to 3.55 Å (2θ=25.1°) for graphene according to Bragg's law. Both G-O and then reduced graphene has formed crystalline structures with fixed interlayer spacings, indicating the uniform oxidation and reduction process as well as the orderliness of graphene/G-O papery structures.

The XRD pattern of the prepared G-O was compared with that of graphene in Figure S2. Compared with the parent G-O, the graphene samples had a much smaller d002 value at 8.8 Å (2θ=10.07°) in G-O to 3.55 Å (2θ=25.1°) in the graphene samples. The interlayer d-spacing of the graphene sample was larger than that of graphite at 3.35Å (2θ=26.6°).[1,2] The larger basal spacing may be caused by the presence of residual oxygen and hydrogen, indicating the incomplete reduction of G-O sheets to graphene. Hence, the graphene sheets obtained here were not pure but chemically modified to different extents. The 002 reflection was broad for this and other samples, suggesting that the samples were poorly ordered along the stacking direction. This result was also an indication that the sample had an isotropic structure. The IR spectra and the XRD pattern of graphene and G-O confirmed the differences in respective structures, which may be responsible for the different thermal expansion coefficients.

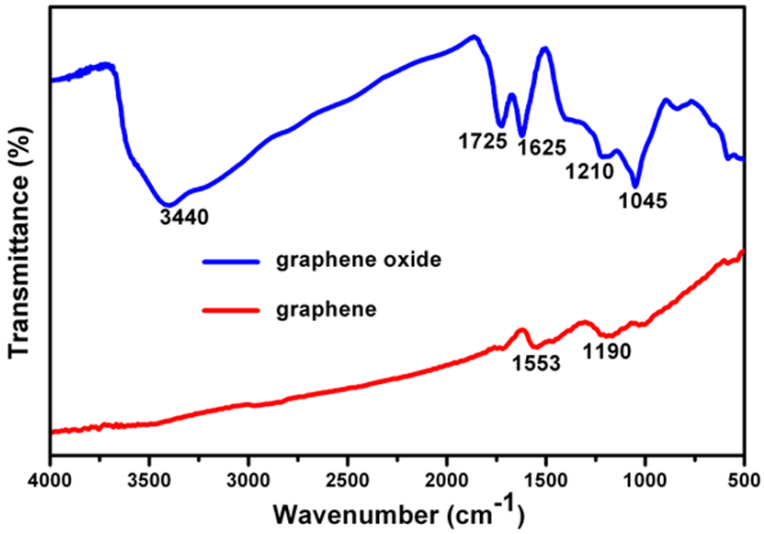

Figure S3. IR spectra of graphene and G-O papers. In the IR spectrum of G-O, the absorptions at 3440 and 1725 cm^{-1} corresponded to O-H and C=O stretching modes of COOH, respectively, which were absent in the spectrum of graphene. In addition, the absorption at 1553 cm^{-1} caused by the skeletal vibrations of graphene was observed.[2–4]

Figure S3 shows the IR spectra of G-O and graphene obtained by the hydrothermal reaction. In G-O, a strong and broad absorption at 3440 cm^{-1} caused by O-H stretching vibration was observed. The C=O stretching of the COOH groups situated at the edges of G-O platelets was observed at 1725 cm^{-1}.[2–4] The absorption due to O-H bending vibrations, epoxide groups, and skeletal ring vibrations were observed at around 1625 cm^{-1}.[3,4] The IR spectrum of graphene confirmed the reduction of G-O sheets. In the spectrum of graphene shown in Figure S3, the absorptions at 3440, 1725, and 1625 cm^{-1} were absent, which can be deduced as a thorough removal of oxygen-containing functional groups. However, a new absorption at around 1553 cm^{-1} due to the skeletal vibrations of the graphene platelets was observed.[3]

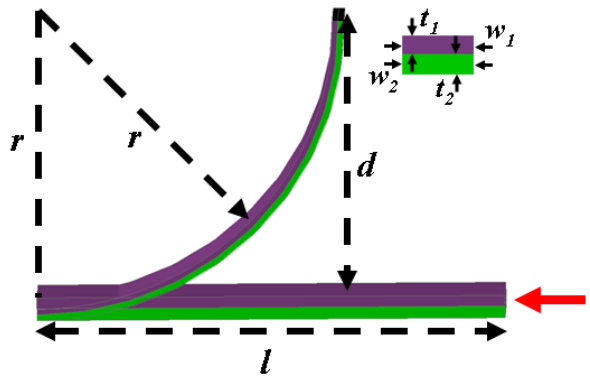

Figure S4. The parameters of the beam based on graphene/G-O papers (front view and right elevation, which is indicated by the red arrow).

The curvature is defined as the reciprocal radius (*1/r*). Figure S4 demonstrates the parameters of the beam based on bilayer paper. Each parameter is defined as follows:

l: Total length

r: The radius to the arc of the curved actuator based on bilayer paper

d: The horizontal displacement of the end of the actuator based on bilayer paper

t_1: The thickness of G-O paper

t_2: The thickness of graphene paper

w_1: The width of beam of G-O paper

w_2: The width of beam of graphene paper.

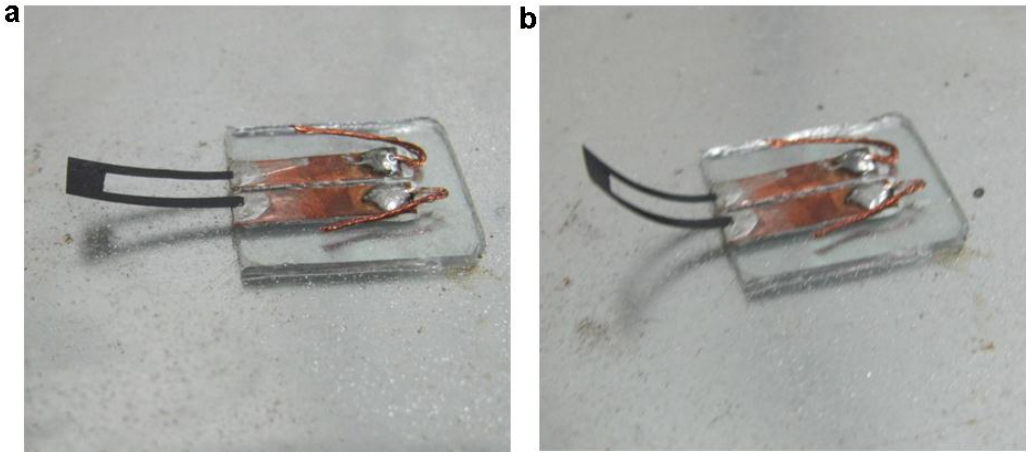

Figure S5 (a) The state of the beam under 14 °C. (b) Great bending of the beam was observed at ~31 °C. This experiment was conducted in a drying oven with precise temperature control.

References

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