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## Supporting Information

### **A mechanically and electrically self-healing graphite composite dough for stencil-printable stretchable conductors**

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#### **Experimental Section**

**Materials Synthesis:** Graphite flakes (size < 45  $\mu\text{m}$ ) and branched polyethylenimine (bPEI, Mw  $\approx$  25,000, density = 1.030 g cm<sup>-3</sup> at 25 °C) were purchased from Sigma-Aldrich (UK). 3.5 g of bPEI was dissolved in 20 mL ethanol with gentle mechanical stirring and then 6.5 g of graphite was added. The stirring was kept until the complete evaporation of the solvent. The graphite/bPEI mixture was transferred into a grinding bowl. The graphite/bPEI composite dough was obtained after manually grinding for 30 min until a uniform and compact mixture was formed.

**Materials Characterization:** The microstructure of the graphite/bPEI composite dough was investigated by scanning electron microscopy (SEM) (Inspect F, FEI), imaged using a 10 keV acceleration voltage. Rheological measurements of bPEI and graphite/bPEI composite dough were carried out on an ARES-G2 rheometer (TA Instruments, Delaware) with a parallel-plate fixture (25 mm diameter) and a dynamic frequency sweep mode. The storage and loss moduli as a function of shear rate (ranging from 0.1 to 100 rad s<sup>-1</sup>) were measured at room temperature with 1-mm thick samples and a constant shear amplitude of 1% to keep the strain in the linear viscoelastic region. The electrical properties of the sample were monitored in two-point via a benchtop multimeter (Agilent 34401A, Keysight Technologies Inc.). For the conductivity test, a cubic sample (1 cm  $\times$  1 cm  $\times$  1 cm) was used and contacted to the circuit via aluminum electrodes. Tensile and compression tests were carried out using a Lloyd universal testing machine (Ametek Inc.). Samples for the tensile tests were cut into a rectangular shape (50 mm  $\times$  2 mm  $\times$  2 mm). A 10 N load cell was used with a speed of 50 mm min<sup>-1</sup> and the distance between the sample grips was 30 mm. Five specimens were tested for each measurement. The graphite/bPEI/thermoplastic polyurethane (TPU) conductor was constructed through stencil print by using a 100  $\mu\text{m}$ -thick Teflon sheet with a designed open (e.g. rectangle) as a mask. Briefly, the mask was placed on a TPU sheet, and graphite/bPEI was filled into the designed

open. The leftover was scratched with a scalpel to make the surface of graphite/bPEI parallel to the mask. The graphite/bPEI/TPU conductor with the designed element was obtained after removing the mask. The volume percentage of graphite was calculated using the following equation (1).

$$\text{vol}\% = (w_{\text{graphite}}/\rho_{\text{graphite}})/(w_{\text{graphite}}/\rho_{\text{graphite}} + w_{\text{bPEI}}/\rho_{\text{bPEI}}) \times 100\% \quad (1)$$

where  $w$  is the weight of the component and  $\rho$  is the density.  $\rho_{\text{graphite}} = 2.26 \text{ g cm}^{-3}$ .<sup>1</sup>

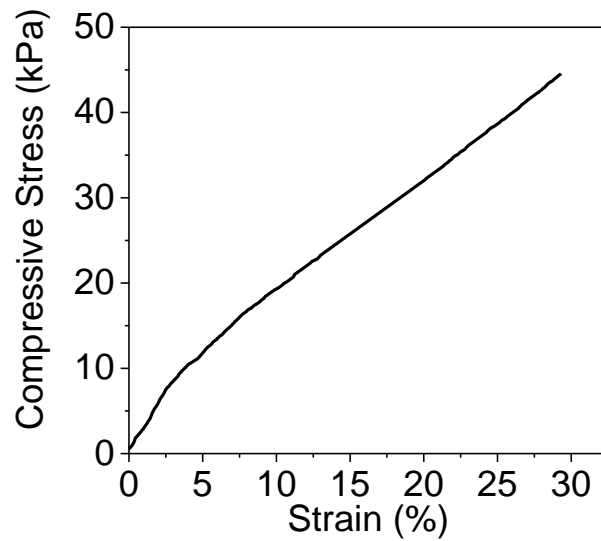


Fig. S1. Typical compressive stress-strain curve of the graphite/bPEI composite dough at room temperature.

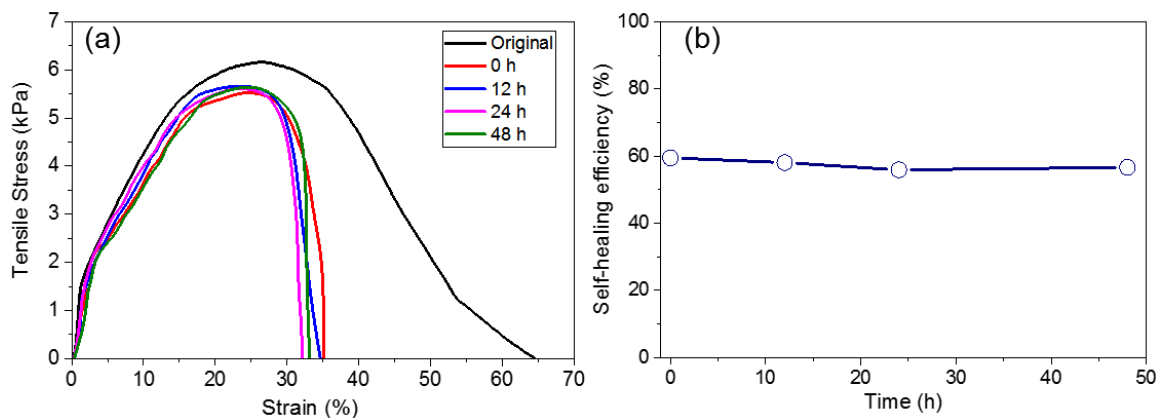


Fig. S2. a) Typical tensile stress-strain curves of original and healed samples. b) The healing efficiency of the graphite/bPEI composite dough as a function of the time period to keep the two freshly fractured surfaces apart before the self-healing process takes place. To heal the samples, the two fractured halves were pressed together by applying a gentle pressure of  $\sim 1 \text{ kPa}$  for 2 s, and then allowed to stand still for over 8 s for further healing.

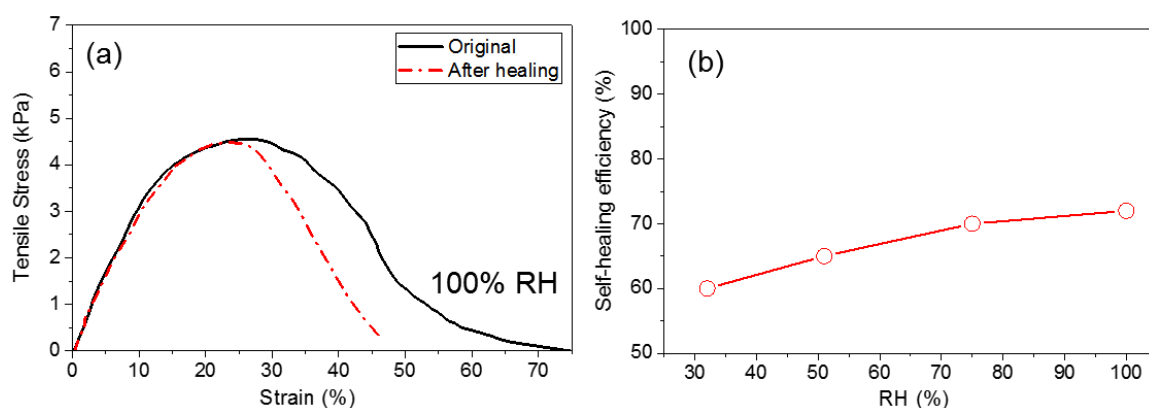


Fig. S3. The humidity dependence of self-healing. (a) Typical tensile stress-strain curves of original and healed samples at room temperature (20 °C) under 100% relative humidity (RH) and (b) the healing efficiency of the graphite/bPEI composite dough as a function of relative humidity. To heal the samples, the two fractured halves were pressed together by applying a gentle pressure of ~1 kPa for 2 s, and then allowed to stand still for over 8 s for further healing. To investigate the influence of humidity, the sample was left in constant RH at 20 °C for 16 h prior to each test: MgCl<sub>2</sub> saturated solution (SS) for 32% RH, Mg (NO<sub>3</sub>)<sub>2</sub> SS for 51% RH, NaCl SS for 75% RH, and deionized water for 100% RH (saturated water vapor).<sup>2</sup>

## References

1. J. Li and J. K. Kim, *Compos. Sci. Technol.*, 2007, **67**, 2114-2120.
2. J. F. Young, *J. Appl. Chem.*, 1967, **17**, 241-245.