Electronic Supplementary Material (ESI) for Soft Matter.

Modeling the resistive viscoelasticity of conductive polymer composite for sensor usage

Quanyi Mu [1,2,*], Jikun Wang[3,*], Xiao Kuang[4]

[1] Ningxia Key Laboratory of Intelligent Sensing for Desert Information, School of Physics and Electronic-Electrical Engineering, Ningxia University, Yinchuan 750021, People's Republic of China
[2] State Key Lab for Strength and Vibration of Mechanical Structures, School of Aerospace Science, Xi'an Jiaotong University, Xi'an 710049, People's Republic of China
[3] Department of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY 14853, USA
[4]Division of Engineering in Medicine, Brigham and Women's Hospital, Harvard Medical School, Cambridge, MA 02139, USA

*Corresponding authors. Email: qmu@nxu.edu.cn; jw2586@cornell.edu

S1. The experimental setup for measuring the resistive viscoelasticity of silver wires

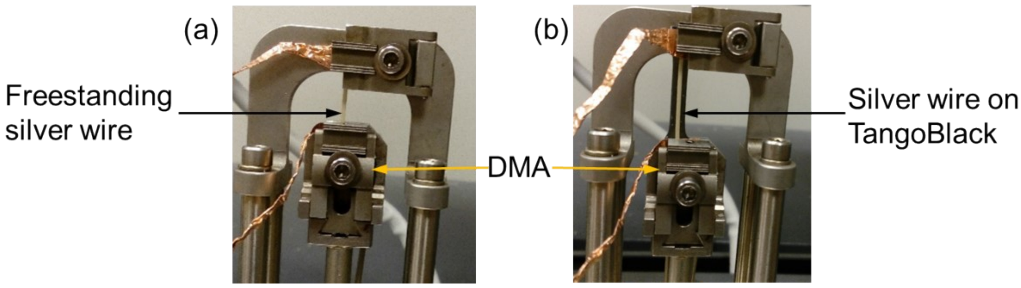

Fig. S1 A dynamic mechanical analysis (DMA) tester was used for measuring the resistive viscoelasticity of (a) freestanding silver wire, (b) silver wire on TangoBlack.

S2. Stress relaxation curves of cured silver wires

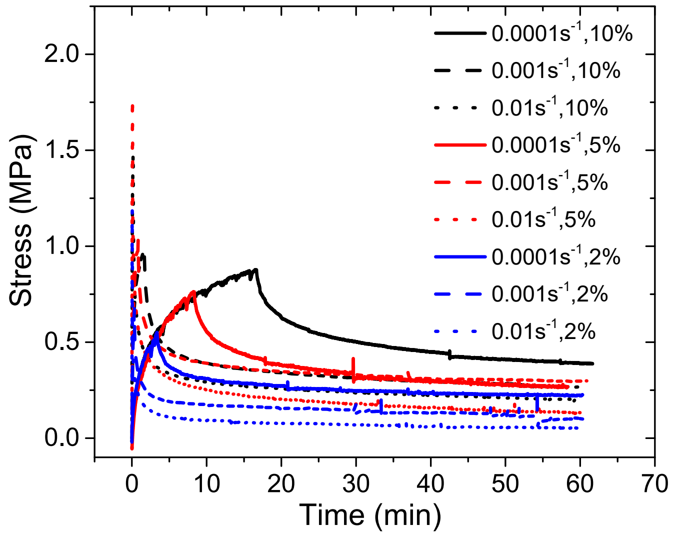

Fig. S2 Stress relaxation curves of cured silver wires at different strains (2, 5, and 10%) and strain rates (0.0001 s^{-1}, 0.001 s^{-1}, and 0.01 s^{-1}).

S3 Thermogravimetric analysis of cured silver wire

To find the mass of the polymer matrix in cured silver wire, thermogravimetric analysis (TGA, model STA 6000, PerkinElmer, Waltham, Massachusetts, USA) was conducted between 30 °C and 600 °C at a heating rate of 10 °C/min. As shown in Fig. S3, the derivative thermogravimetry (DTG) curve of cured silver wire has a prominent peak around 450 °C. Compared with the DTG curve of the uncured silver ink[1], the two peaks at a low temperature nearly disappeared, implying that the solvent had already been removed. However, some additives remained as the polymer matrix in cured silver wire. As seen from the TGA curve, the mass of the sample decreases with increasing temperature, and the residual mass of silver wire is 83 wt% of the initial mass at 600 °C. It suggests at least 17 wt% additives remain in the cured silver wire.

To get a general idea about the volume fraction of the organic remains, or termed polymer matrix, in our cured silver wire, we simply assume that the cured silver wire contains only two phases: silver particles (density number is 10.5 g cm^{-3} as pure silver metal) and polymer matrix (density number is 0.975 g cm^{-3} as natural rubber[2]). Thus, when the weight percent is 17 wt%, the volume percent of organic remains in the cured silver wire is about 69 vol%.

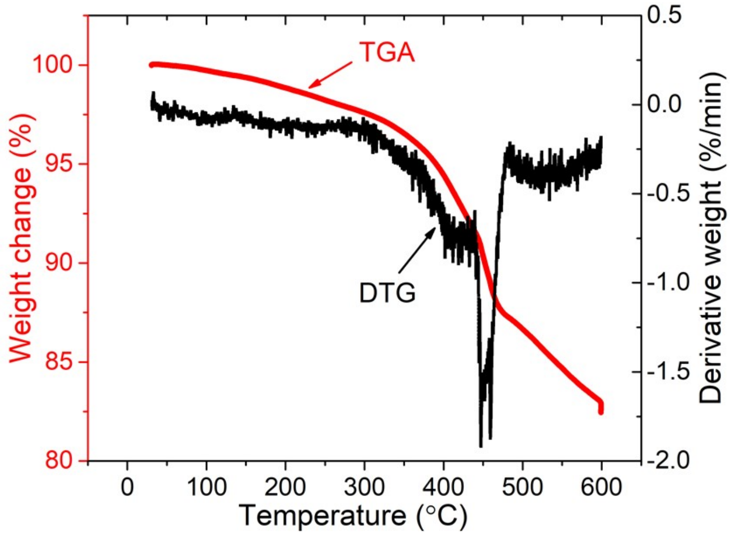

Fig. S3 TGA (red line) measurement of the cured (cure condition: 120 ℃, 20 min) silver wire by heating from 30 to 600 °C at 10.00 °C min^{-1} under a nitrogen (N_2) flow (20 mL min^{-1}).

S3. Dynamic mechanical analysis (DMA) test of the cured silver wires

The cured silver wire has a glass transition temperature of around 41°C (Fig. S4), suggesting elastomer composites properties.

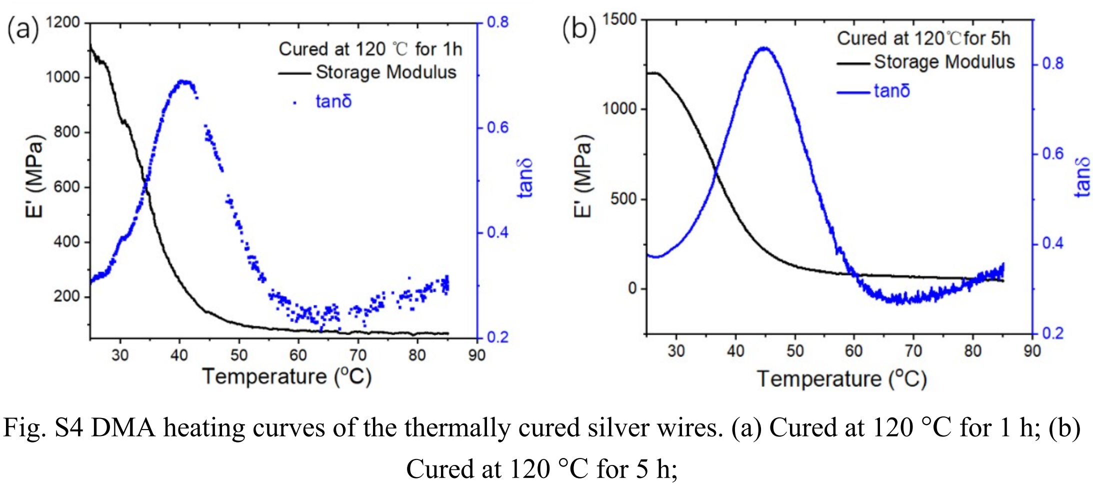

Fig. S4 DMA heating curves of the thermally cured silver wires. (a) Cured at 120 °C for 1 h; (b) Cured at 120 °C for 5 h;

Reference

[1] Q. Mu, C. K. Dunn, L. Wang, M. L. Dunn, H. J. Qi and T. Wang, *Smart Mater. Struct.*, 2017, **26**, 045008.
[2] Arroyo, M., M. Lopez-Manchado, and B. Herrero, Polymer, 2003. 44, 2447-2453