Supporting Information

Highly stretchable strain-insensitive temperature sensor exploits the Seebeck effect in nanoparticle-based printed circuits

Yangyang Xin,† Jian Zhou,†,‡ and Gilles Lubineau*,†

†*King Abdullah University of Science and Technology (KAUST),*

Physical Sciences and Engineering Division (PSE), COHMAS Laboratory,

Thuwal 23955-6900, Saudi Arabia; Tel: +966 (12) 808 2983

‡*School of Materials Science and Engineering, Sun Yat-sen University,*

Guangzhou 510275. Guangdong, P.R.China

E-mail: gilles.lubineau@kaust.edu.sa

This PDF file includes:

1. Sample preparation and characterization: Figure S1 to S4;

2. Mechanical sensing: Figure S5 to S10.

Sample preparation and characterization

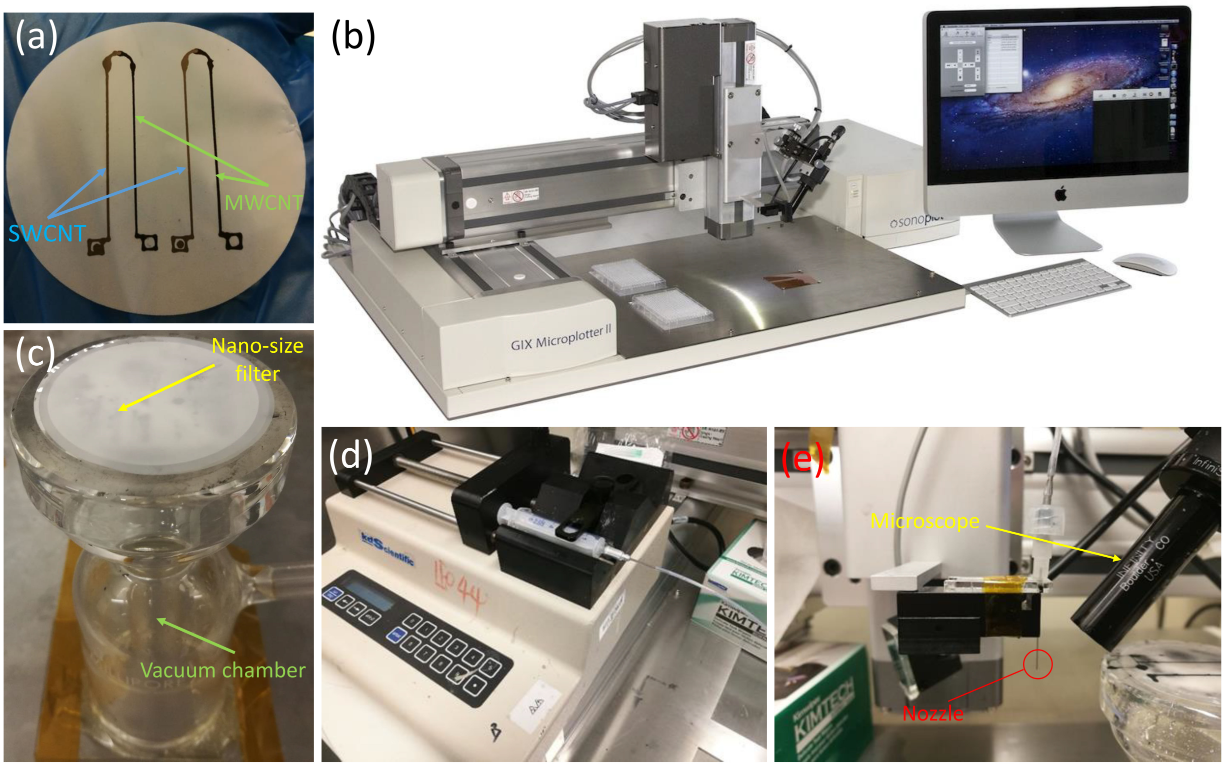

Figure. S1 Printing setup. (a) The “U”-shaped sample made of SWCNTs and MWCNTs printed on the nanofilter. (b) The GIX Microplotter II ink printer and control system. (c) Support base for the vacuum-assisted printing with the nanofilter. (d) The syringe pump used as the ink supply system. (e) The printing nozzle and a microscope to monitor the printing process.

Drawbacks of the two filter-removal methods. The first method of removing the polyethylene terephthalate (PET) nanofilter is to carefully peel it off from one side to the other (Figure S2(c)). The drawback of this method is that some of the printed ink may be removed with the filter from the cured substrate, especially when using SWCNTs. The other method is using dichloromethane (DCM) to dissolve the PET filter as shown in Figure S2(d). While this method does not affect the printed circuit, it may damage the substrate, especially if the substrate is thinner than 0.4 mm. Therefore, we used the first (peeling) method to remove the filter from thin (less than 0.4 mm) samples, and the second (dissolving) method for the thick (larger than 0.4 mm) samples.

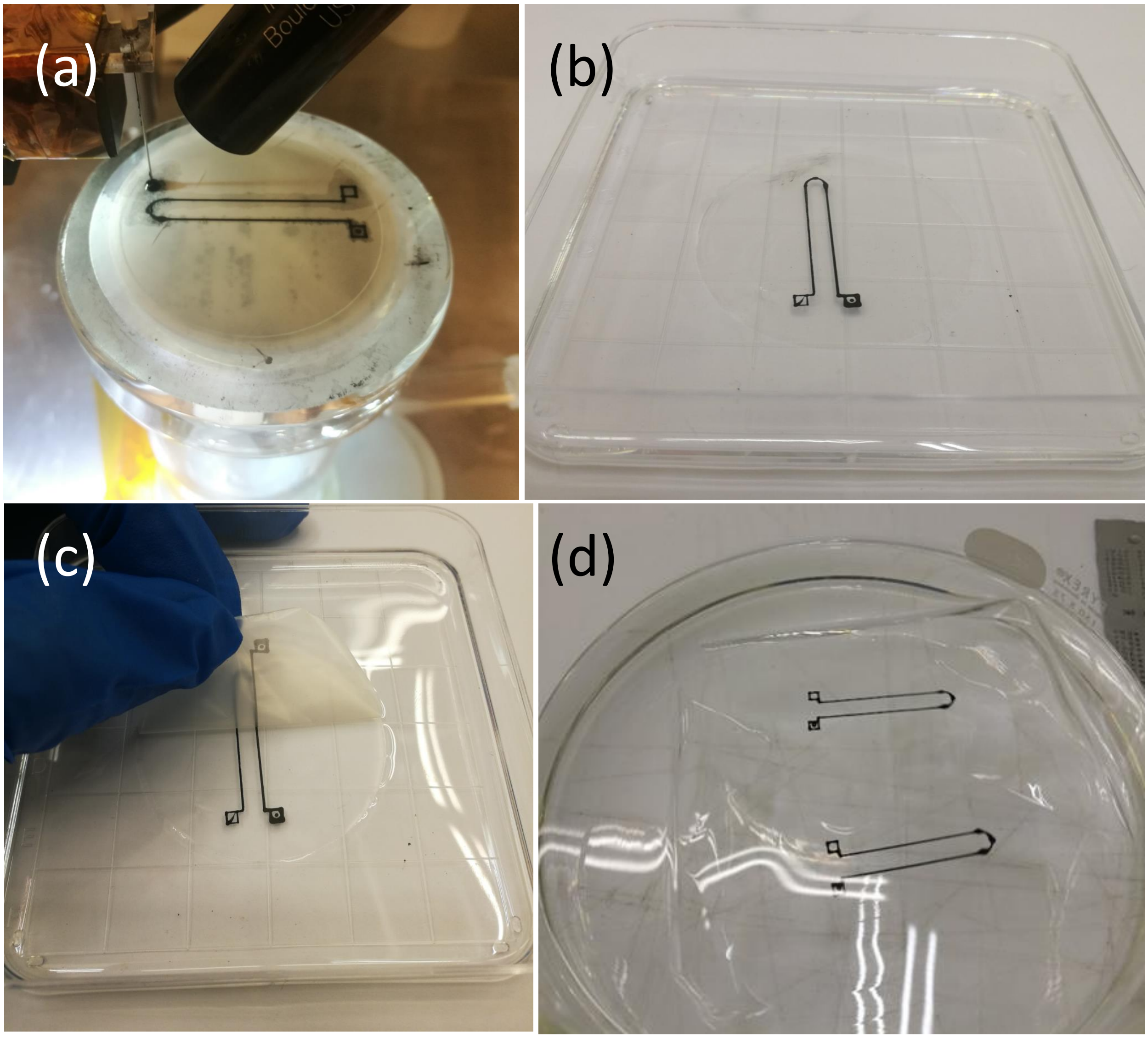

Figure. S2 (a) Preparation of the SWCNTs/MWCNTs sensor. (b) The nano filter with printed ink deposited on partially cured PDMS. (c) The filter was peeled off from the cured PDMS substrate. (d) The residue of the filter was dissolved by DCM solvent.

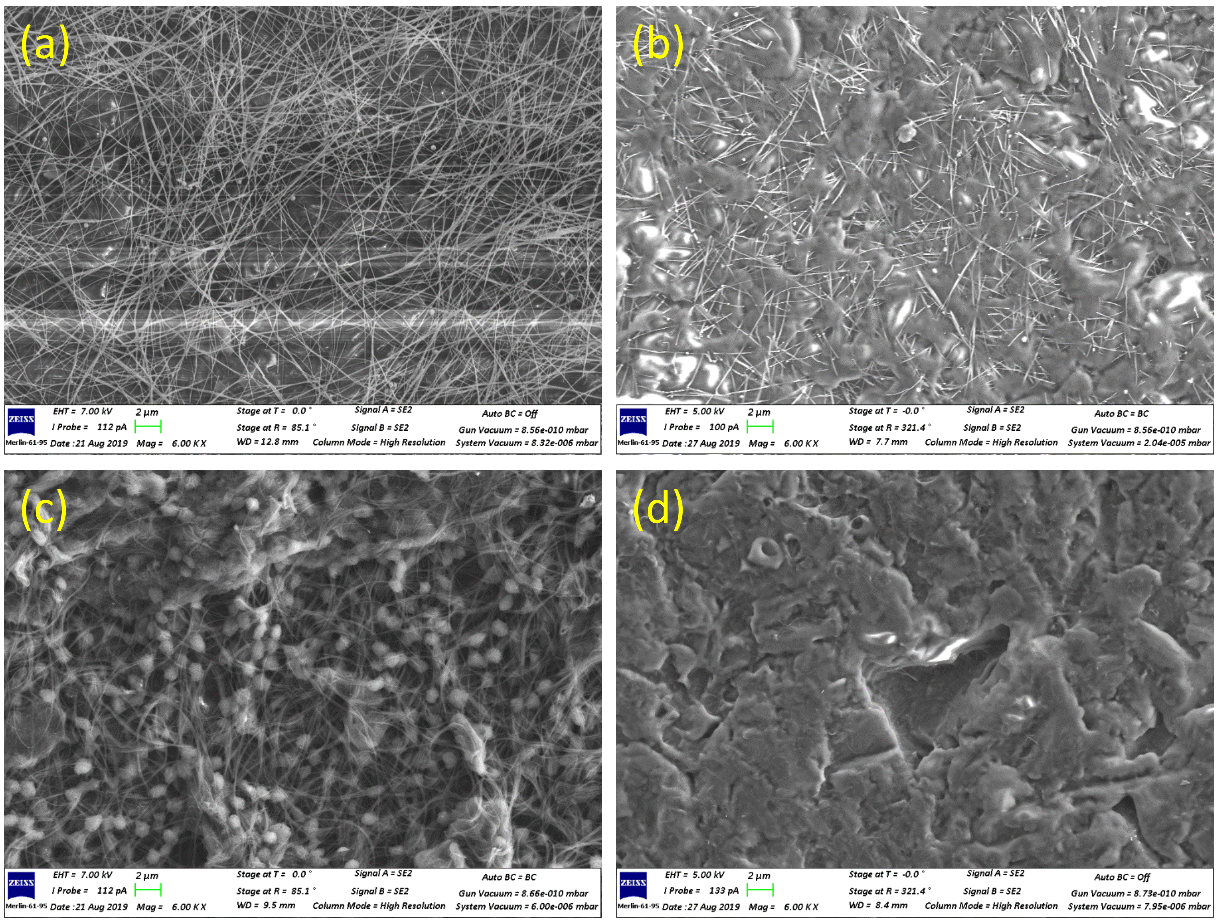

Figure. S3 (a) and (b) are the Silver nanowires on the filter and transferred to PDMS substrate, respectively; (c) and (d) are the SEM images of SWCNTs before and after the transfer process.

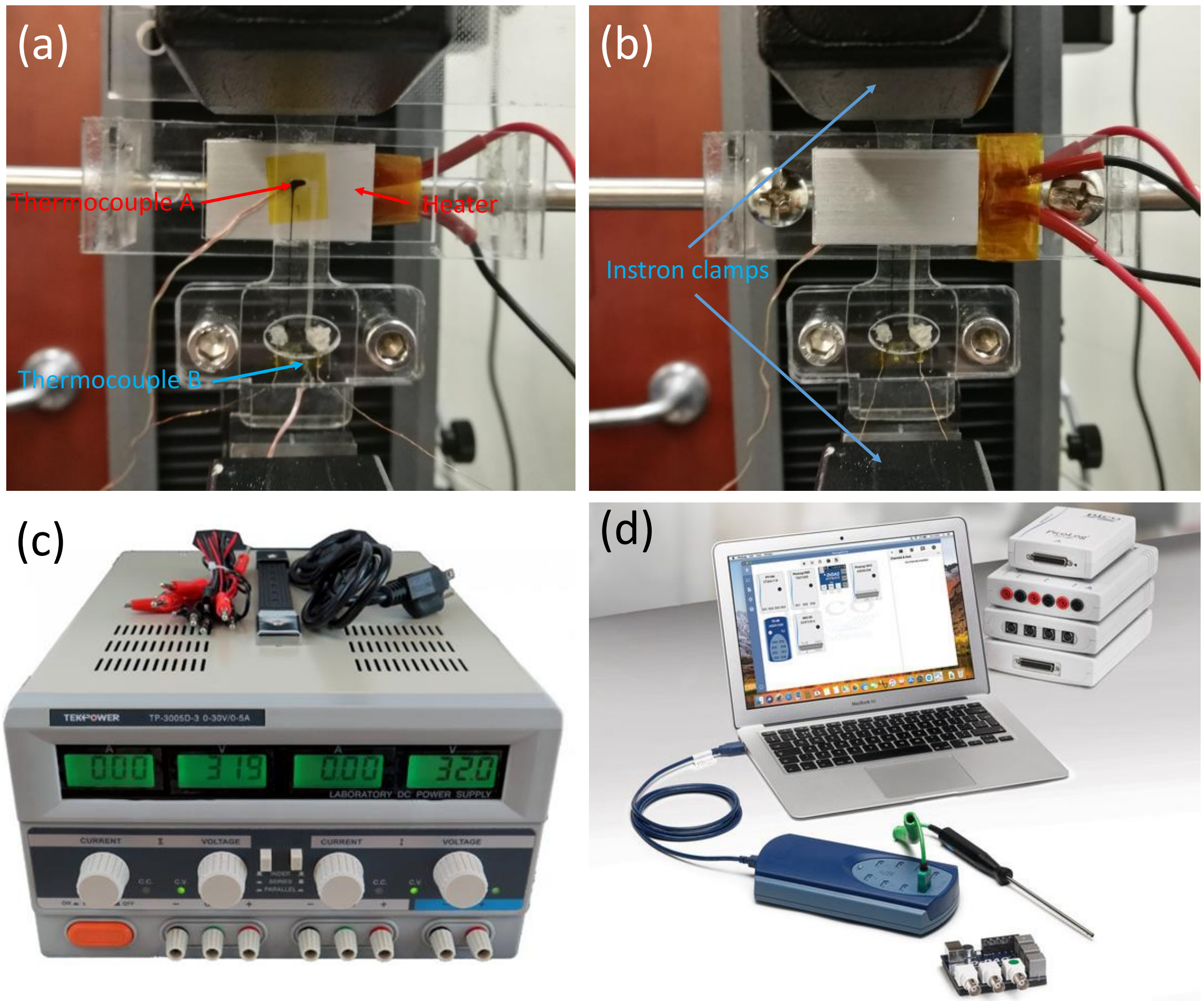

Figure. S4 Setup for temperature sensing. (a) The two thermocouples used to detect the temperature difference between the hot and cold points. (b) Two heaters were used to create a homogenous temperature field in the thickness direction. (c) The power source that supplied the heaters. (d) The picometer used to monitor the temperature difference measured by the two thermocouples.

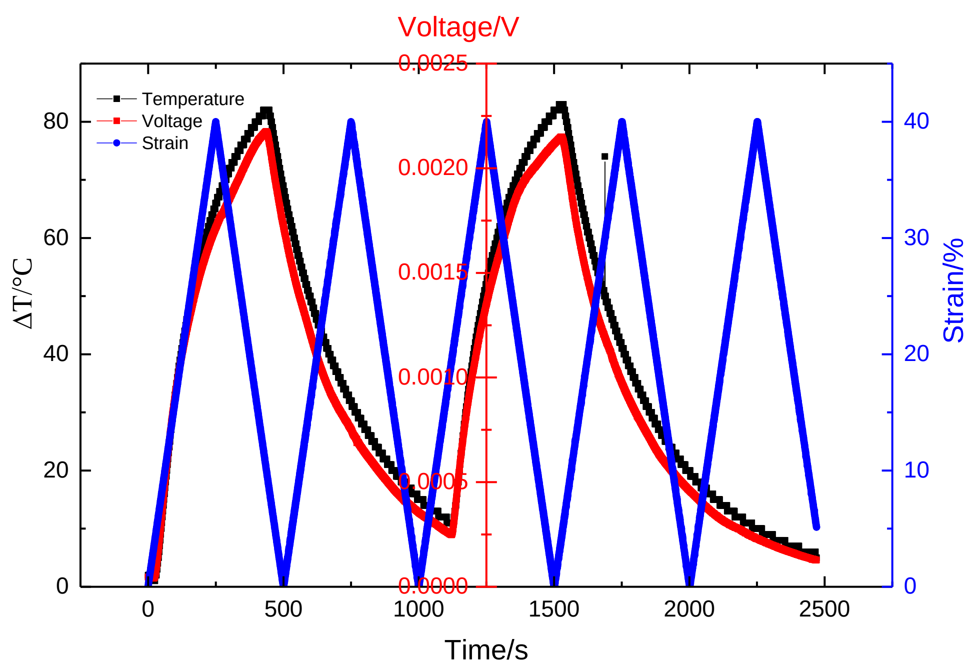

Figure. S5 The response of the temperature sensor under simultaneous strain and temperature stimulation.

Temperature sensing after mechanical cycles

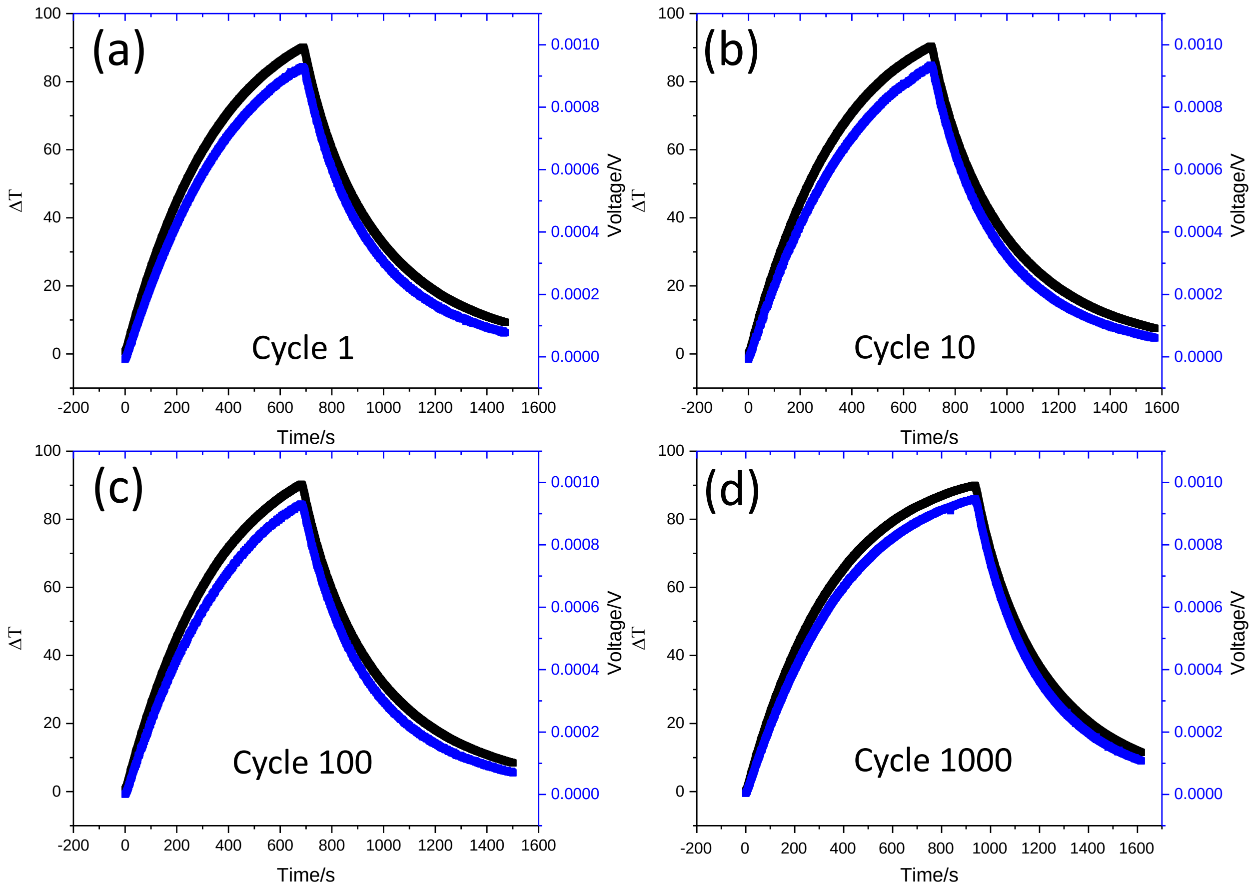

Figure. S6 Responses of the MWCNTs/AgNWs temperature sensor after 1, 10, 100, and 1000 mechanical cycles.

High-temperature and water stability of the temperature sensor.

First, we tested the high-temperature stability of this temperature sensor. The sensor was heated at 80 °C, 110 °C, 130 °C, 150 °C, and 170 °C, respectively, for half hour. Then, the temperature sensor was tested after each heating treatment, and no noticeable difference was observed. This proves the excellent high-temperature stability of our sensor. At last, the water durability of the temperature sensor was investigated. The sensor was immersed into water for 3, 6, 9, and 12 hours, respectively, followed by temperature sensing tests. The water immersions almost do not influence

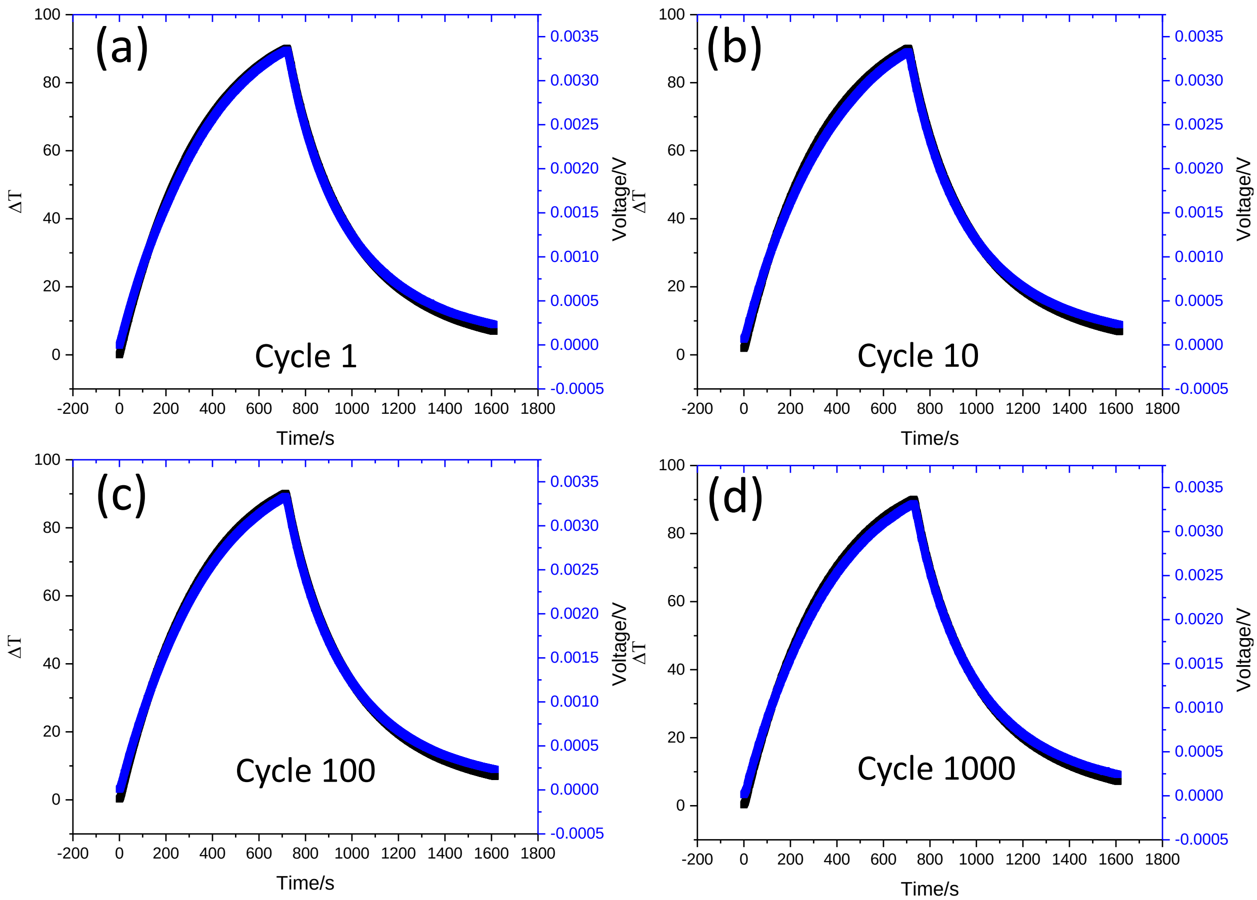

Figure. S7 Responses of the MWCNTs/AgNWs temperature sensor after 1, 10, 100, and 1000 mechanical cycles.

the performance of the temperature sensing.

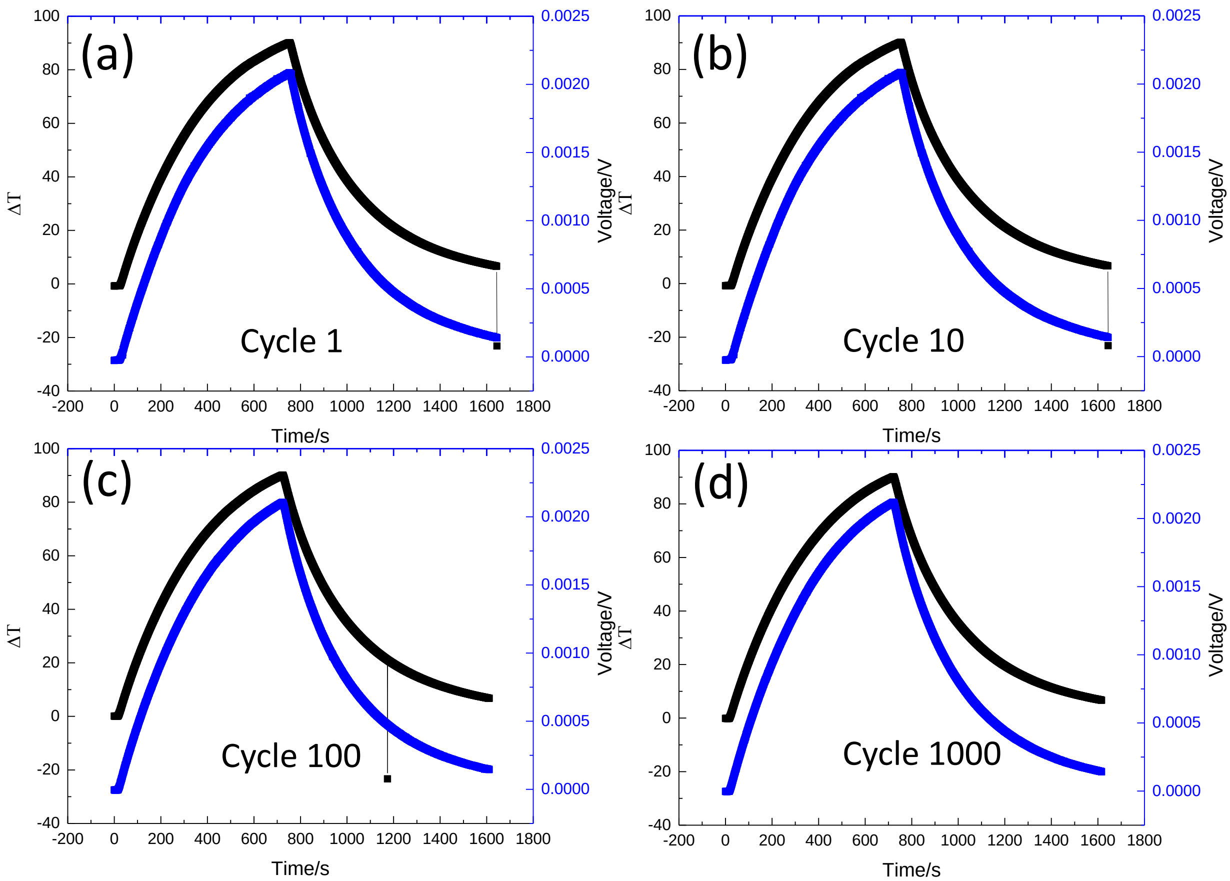

Figure. S8 Responses of the MWCNTs/SWCNTs temperature sensor after 1, 10 , 100 and 1000 mechanical cycles.

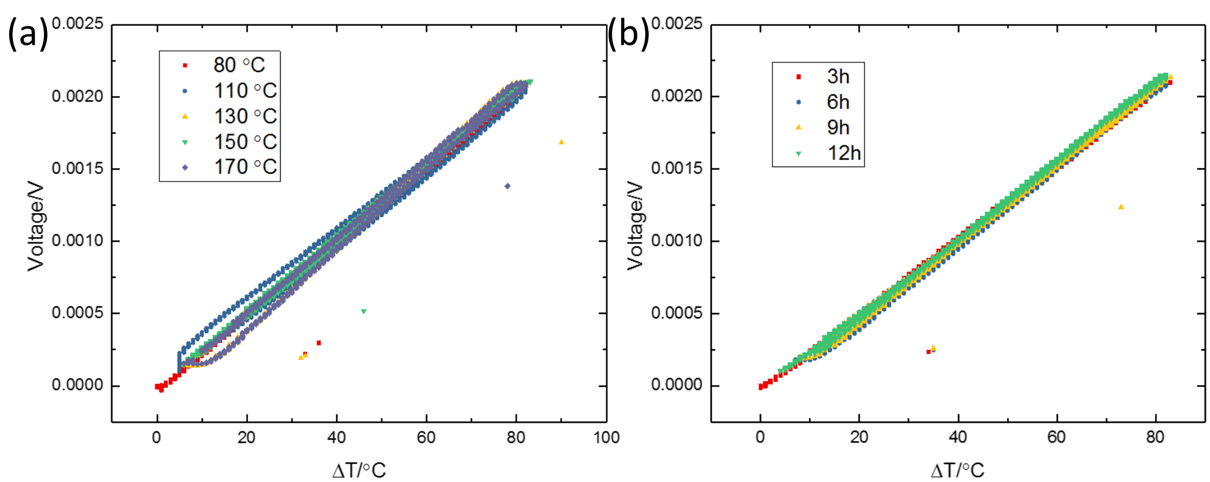

Figure. S9 (a) The high-temperature stability test of the temperature sensor; (b) The water durability investigation of the temperature sensor.

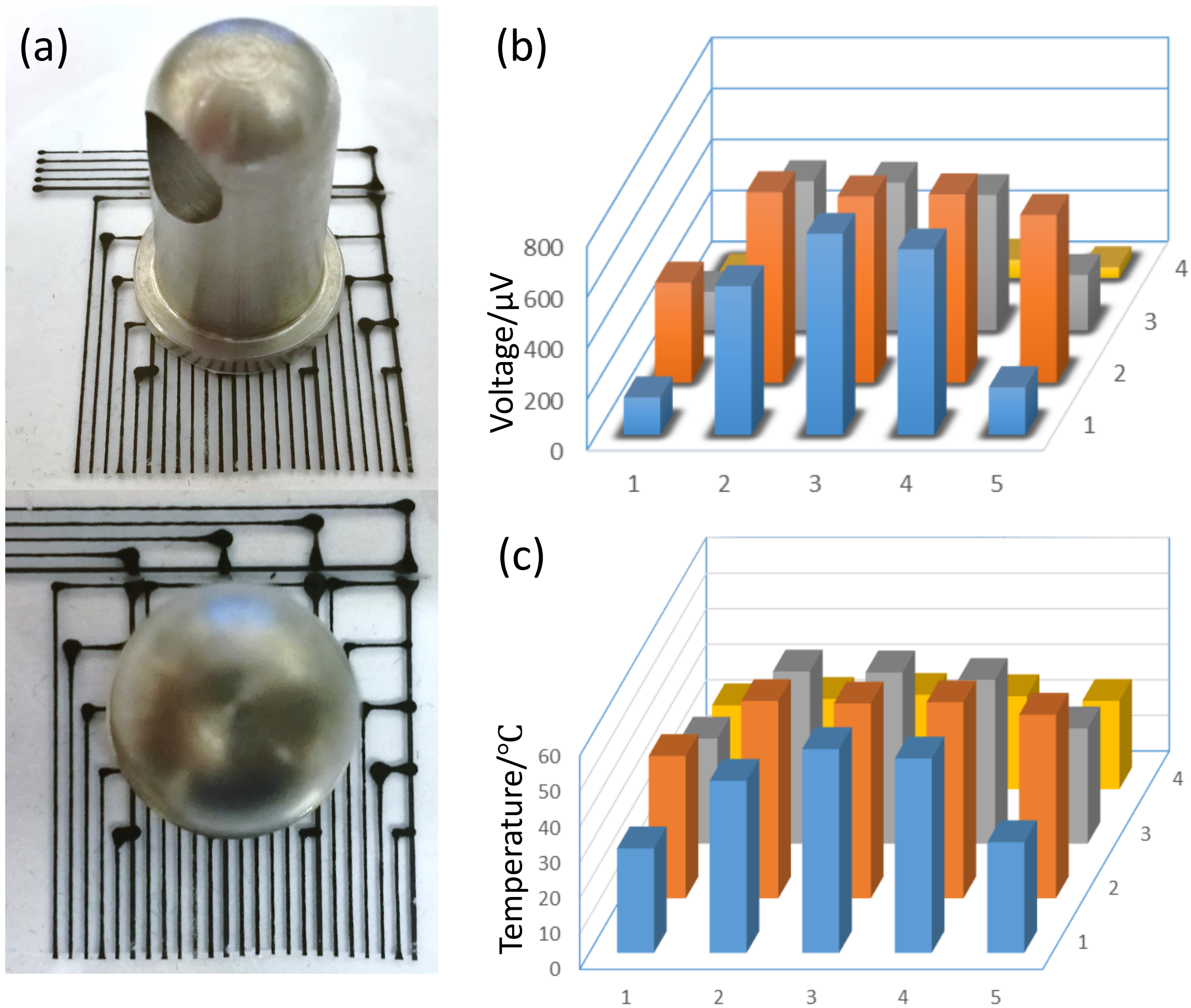

Figure. S10 (a) A hot steel block was put on the surface of the MWCNTs/SWCNTs temperature-sensor array. (b) The voltage distribution of the temperature-sensor array caused by the hot steel block. (c) The temperature distribution over the surface.