Supporting Information

A tactile sensing textile with bending-independent pressure perception and spatial acuity

Jue Deng[†1], Wen Zhuang[†1], Luke Bao[1], Xiaoying Wu[1], Jingbo Gao[2], Bingjie Wang[1], Xuemei Sun[1], Huisheng Peng*[1]*

[1]*State Key Laboratory of Molecular Engineering of Polymers, Department of Macromolecular Science, and Laboratory of Advanced Materials, Fudan University, Shanghai 200438, China;*

[2]*State Key Laboratory of ASIC and System, School of Microelectronics, Fudan University, Shanghai 201203, China;*

[†]*These authors contributed equally to this work.*

**Corresponding authors.*

E-mail: *sunxm@fudan.edu.cn* (Xuemei Sun*), penghs@fudan.edu.cn* (Huisheng Peng).

1. Experimental Section

1.1 Calculation of touching position and applied force of sensing fiber

As the schematic illustration and the corresponding equivalent electrical circuit were shown in Fig. 3a and 3b, the touching position and applied force can be calculated from the measured data. The touching position to the right end of sensing fiber and the applied force were represented as L_1 and F, respectively. The contact resistance (R_x) at the touching position is determined by the applied force. According to the voltage-division principle in series circuit, the following equations are established:

$$R_1 = \frac{L_1 \times R_{CNT}}{L} \quad (1)$$

$$R_1 = \frac{V_1}{I} \quad (2)$$

$$R_x = \frac{V_0 - V_1}{I} \quad (3)$$

$$I = \frac{V_0}{R_x + R_1} \quad (4)$$

Thus, based on Equation (1) and (2), the touching position (L_1) can be written as:

$$L_1 = \frac{V_1 \times L_0}{R_{CNT} \times I} \quad (5)$$

Where L_0 and R_{CNT} are the measured length of sensing fiber and the whole resistance of CNT/PU electrode, respectively. Through accurately controlling the helical angle and thickness of CNT layer on the inner surface of PU tube, the measured resistance of CNT/PU electrode is 8.9 kΩ/cm. Thus, R_{CNT} is 40.05 kΩ as L_0 is 4.5 cm.

As shown in Fig. 2b, when L_1 is 2.5 cm, the sensitivity of the sensing fiber conincides with the following linear fitting formula:

$$I = aF + b \quad (6)$$

Here, based on linear regression analysis, a is 3.17×10^{-6}, b is 5.85×10^{-6} and R square is 0.991. Based on Equations (1), (4) and (6), it is easy to find:

$$R_x = \frac{V_0}{aF + b} - \frac{L_1 \times R_{CNT}}{L_0} \quad (7)$$

Compare Equation (3) with (7), the applied force (F) can be re-written as:

$$F = \left. \frac{\frac{V_0}{\frac{V_0 - V_1}{I} + \frac{L_1 \times R_{CNT}}{L_0}} - b}{a} \right. \quad (8)$$

Here, the values of V_0, L_1, L_0, R_{CNT}, a and b are 1 V, 2.5 cm, 4.5 cm, 3.17×10^{-6} and 5.85×10^{-6}, respectively. Therefore, according to Eqution (8), the applied force (F) is only related to V_1 and I and can be easily calculated from the two variables.

1.2 Materials

Copper wire (diameter, 50 μm) was purchased from Alfa Aesar Co. Ltd. and washed before use. The shape memory polymer (MP-4510) was purchased from SMP Technologies Inc. Polyurethane powders were purchased from Huntsman Co. Ltd. All the other reagents were commercially available without further purification.

1.3 Characterizations

The morphology and structure were characterized by three-dimensional X-ray micro-CT (Xradia 510 Versa 3D) and scanning electron microscope (SEM, Hitachi FE-SEM S-4800 operated at 1 kV). The applied force was controled by a table-top universal testing instrument (HY-0350, Hengyi). The resistance and current measurements were conducted at 1 V using a Keithley 2410 Source Meter. Divided voltage was recorded from a digital multimeter (15B, Fluke) with DC voltage mode.

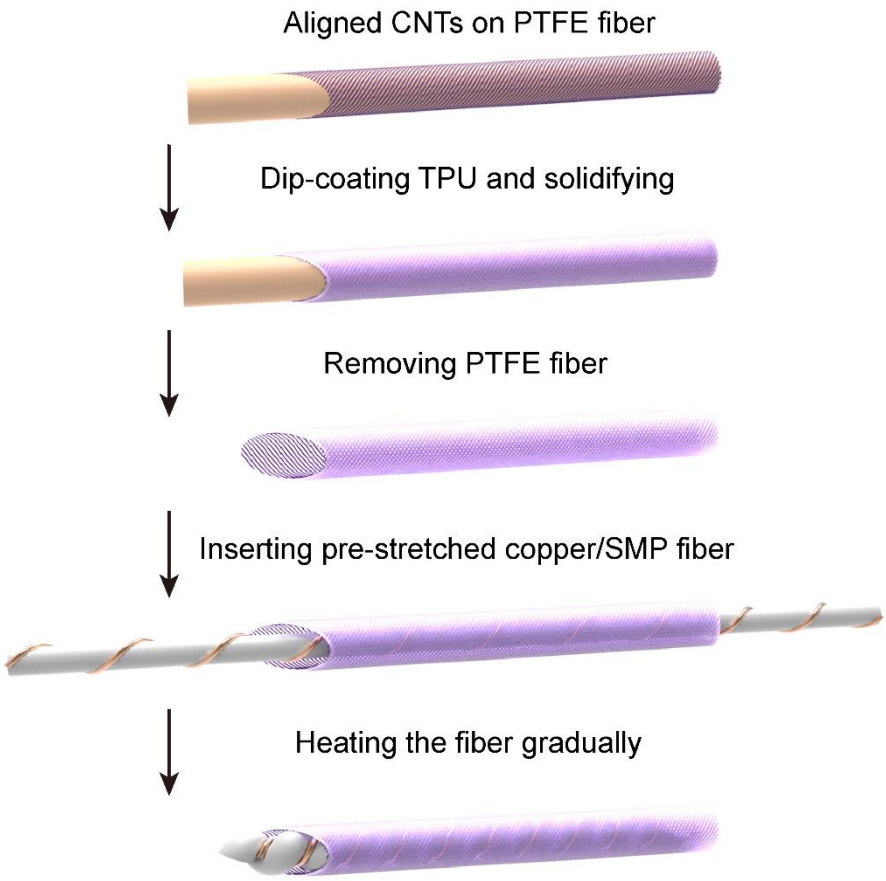

Figure S1. Schematic illustration of preparing CNT/PU sheath electrode and assembling the sensing fiber with pre-stretched copper/SMP core electrode.

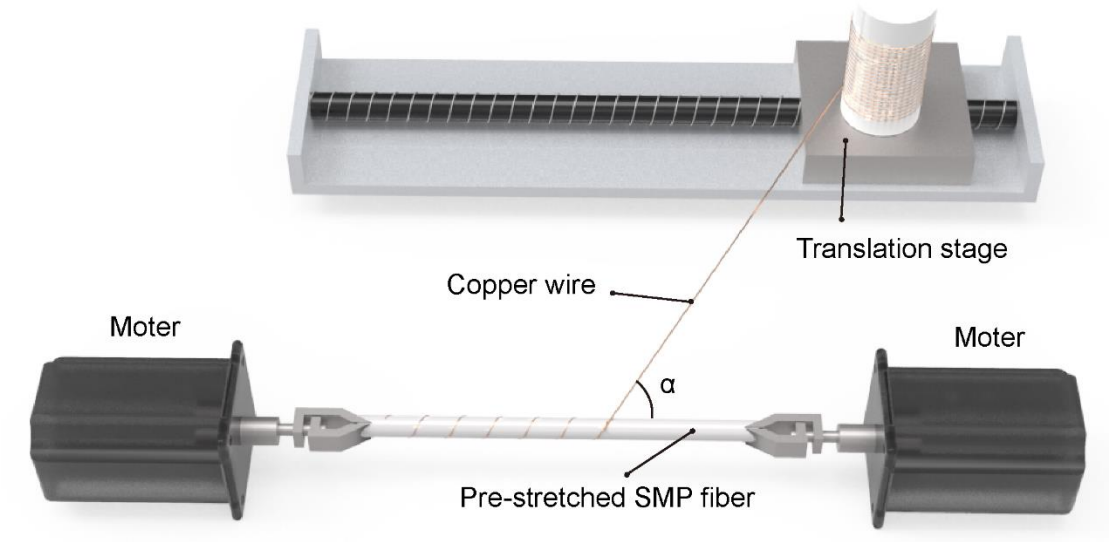

Figure S2. Schematic illustration of helically wrapping a copper wire on a pre-stretched shape memory polymer fiber. The helical angle and screw pitch can be controlled by the rotation of motor and speed of translation stage.

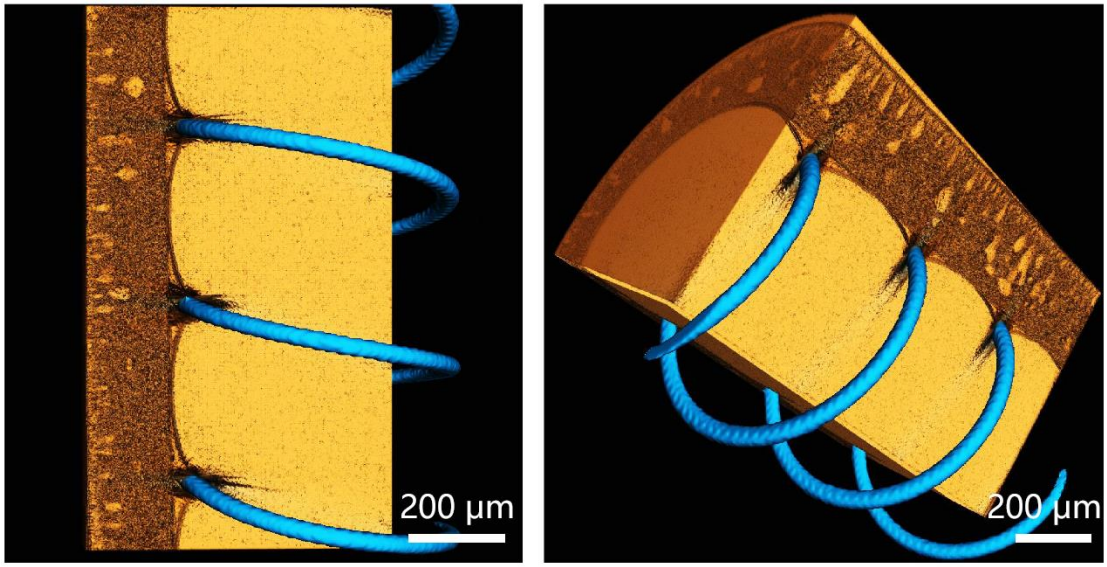

Figure S3. Three-dimensional X-ray micro-CT image of sensing fibers with a quarter of CNT/PU electrode and SMP fiber.

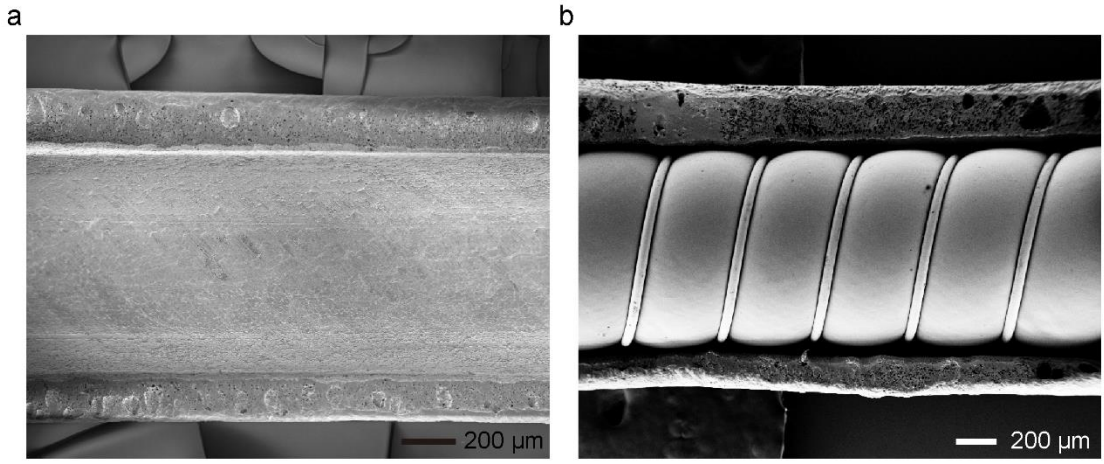

Figure S4. SEM images of straight-cut CNT/PU shearh electrode (a) and sensing fiber with core electrode and a straight-cut sheath electrode (b).

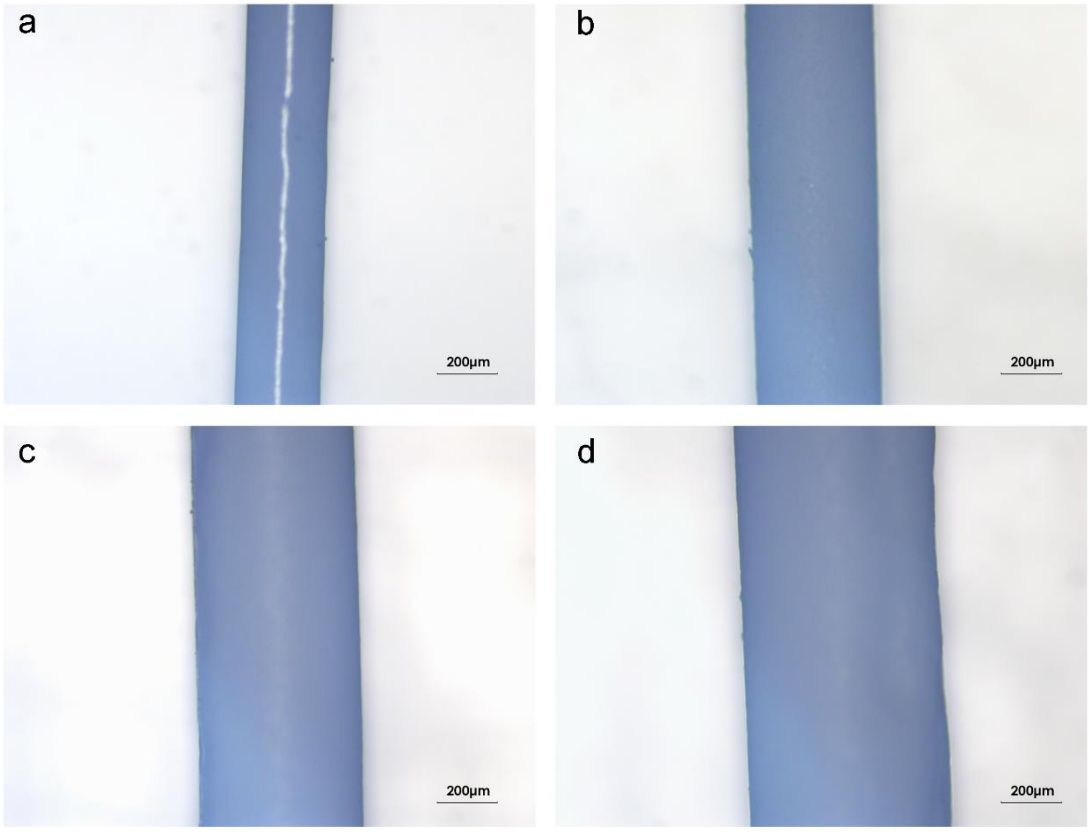

Figure S5. Microscopic images of sensing fibers with different diameters.

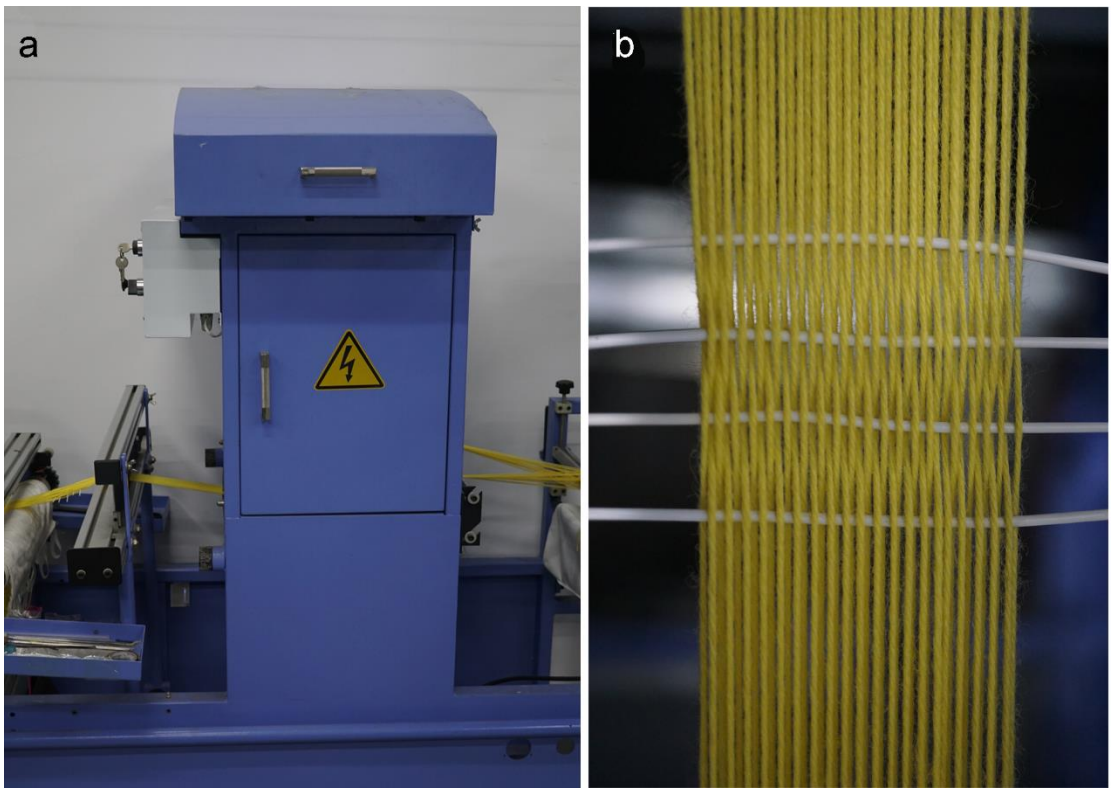

Figure S6. a, The preparation process of a sensing textile by commerical sewing machine. **b**, Optical image of sensing textile during sewing.

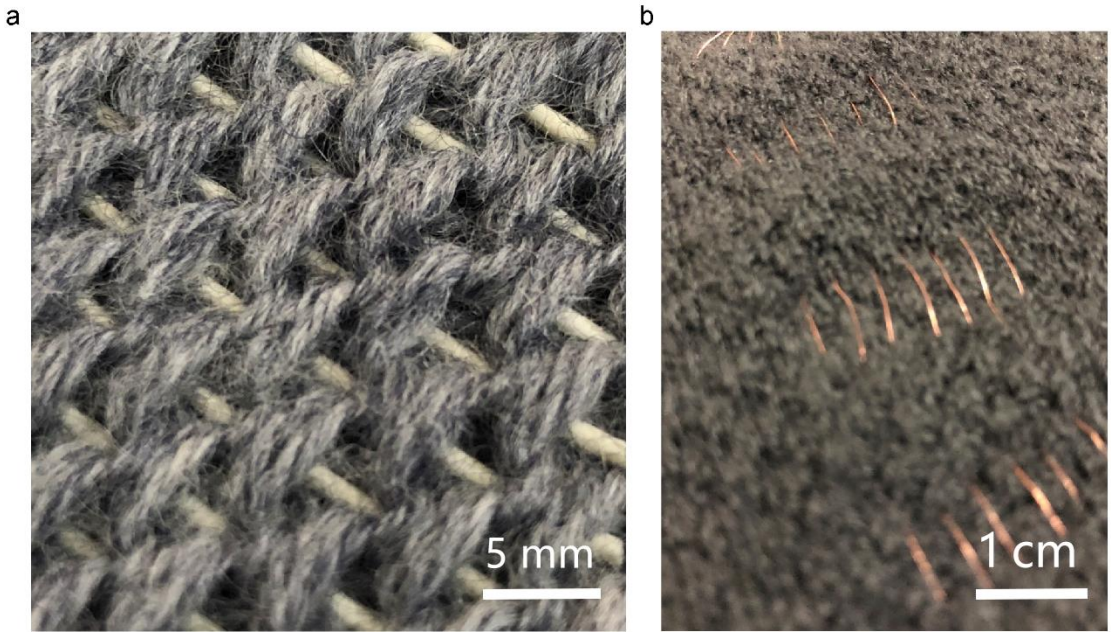

Figure S7. Enlarged optical images of woven sensing fibers (a) and connecting copper wires with insulated polymer layer (b) in the tactile sensing textile.

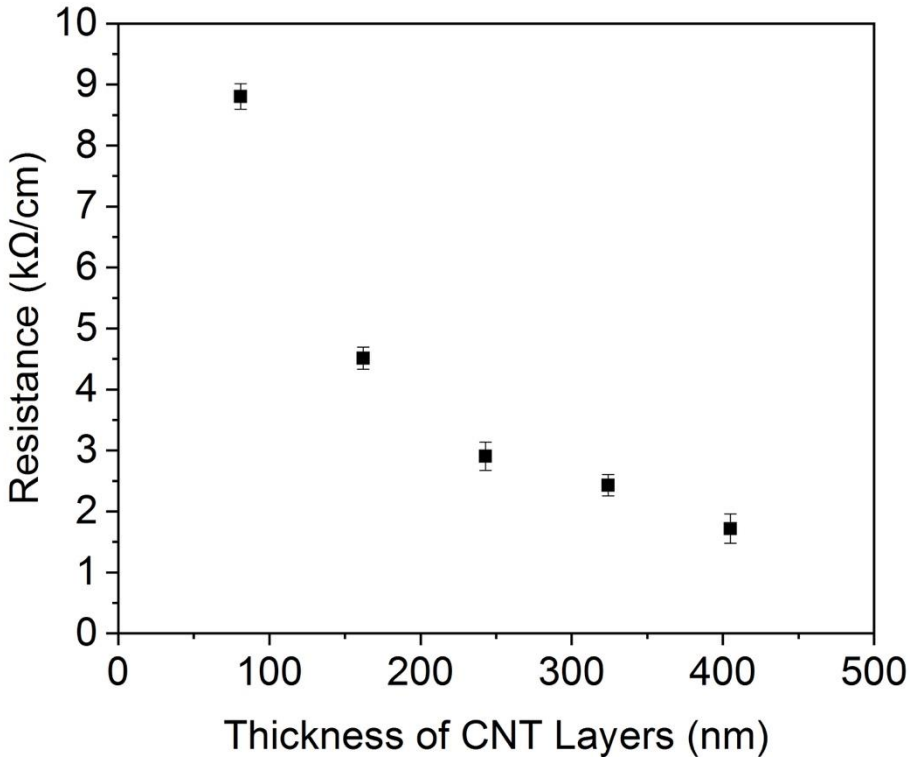

Figure S8. Dependence of electrical resistance on the thickness of CNT layer on the inner surface of sheath electrode.

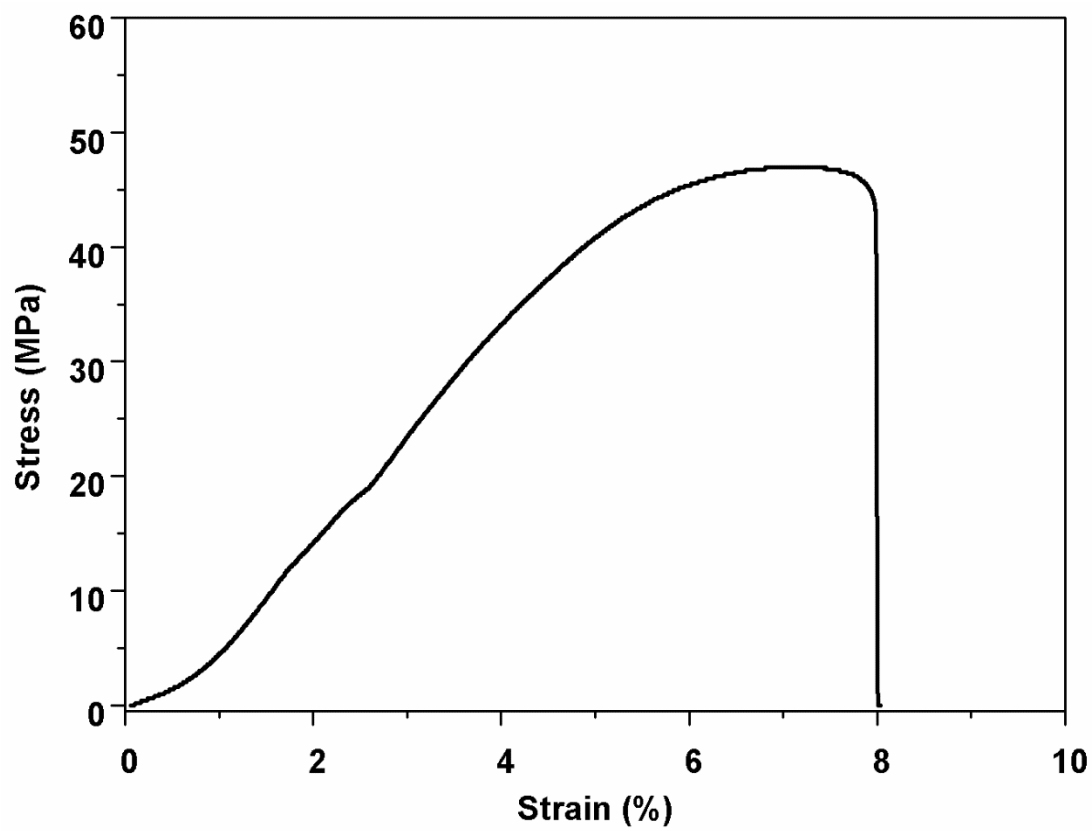

Figure S9. Stress-strain curve of the sensing fiber.

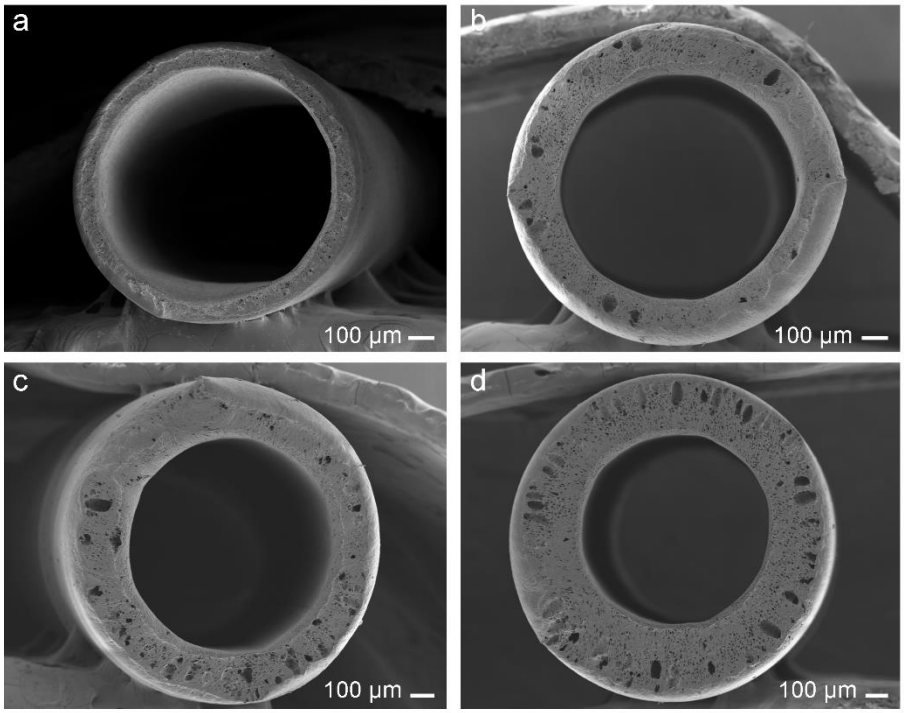

Figure S10. SEM images of PU tubes with different wall thicknesses.

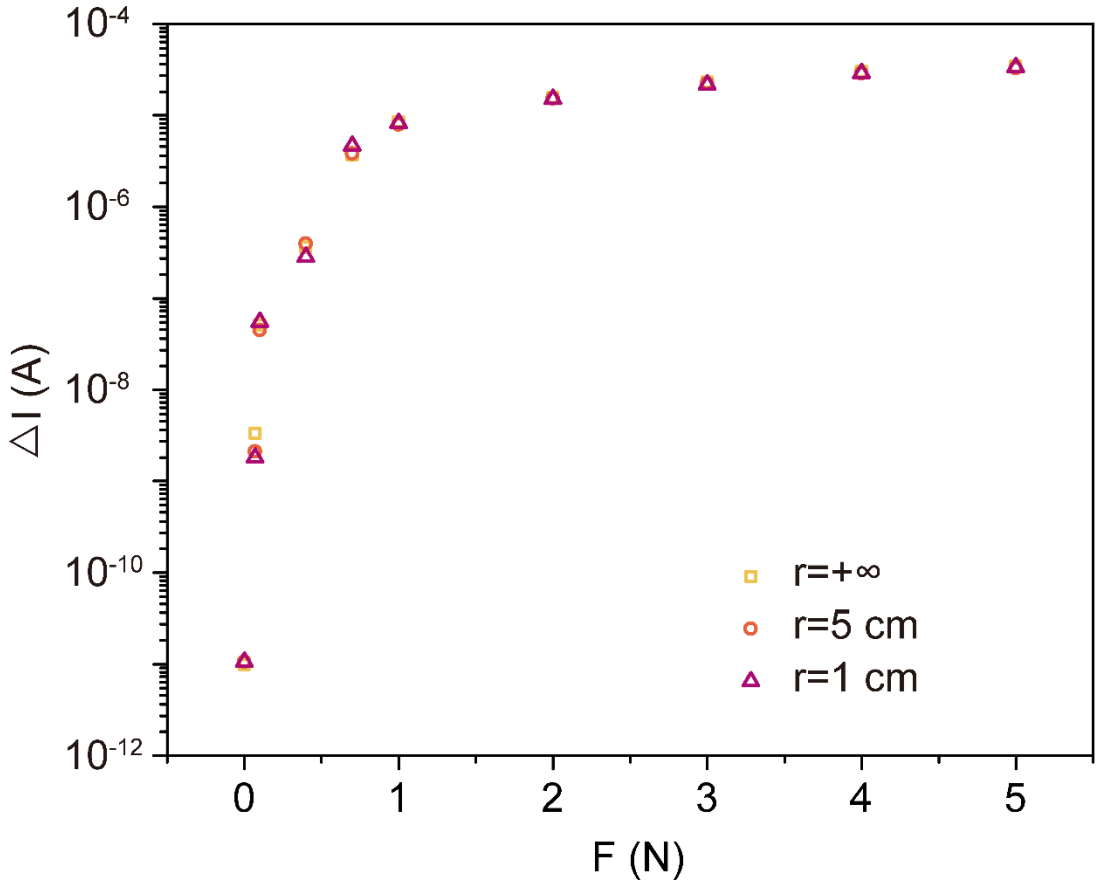

Figure S11. Dependence of current change on applied force for the pressure-sensing fiber under different curvatures.

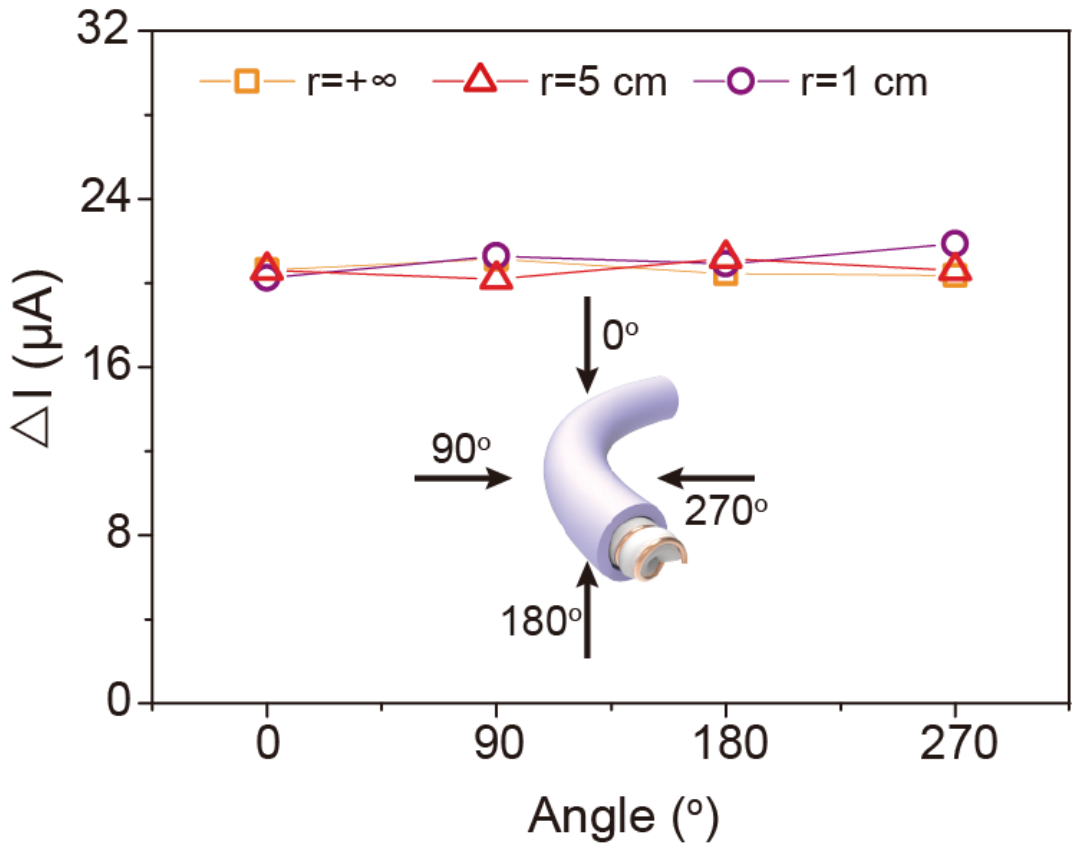

Figure S12. Dependence of current change on contact directions of sensing fiber with different bending curvatures.

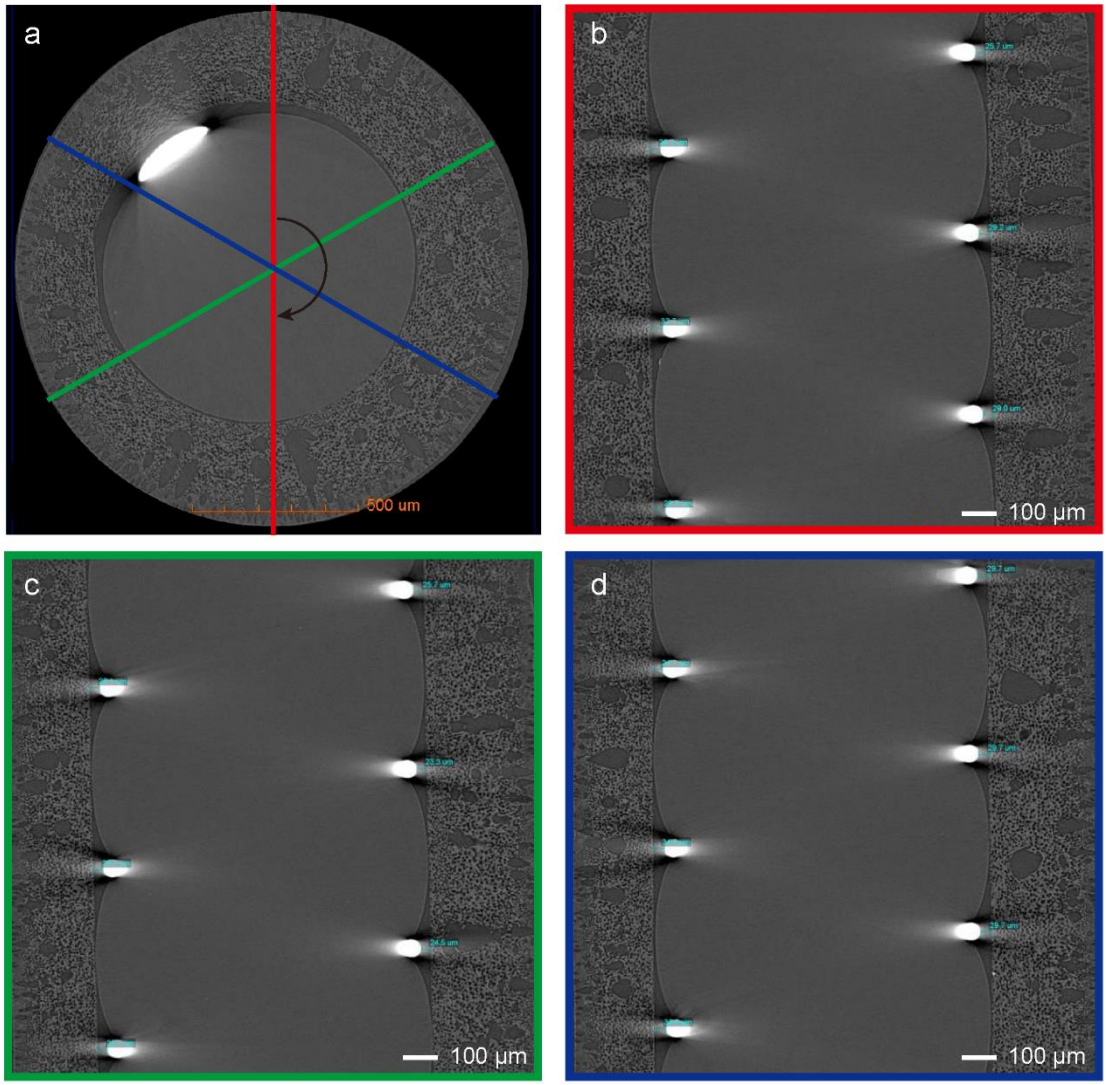

Figure S13. X-ray micro-CT images of a sensing fiber. **a**, Cross section. **b**, Vertically sectioned in the red plane in (**a**). **c**, Vertically sectioned in the green plane in (**a**)**. d**, Vertically sectioned in the blue plane in (**a**).

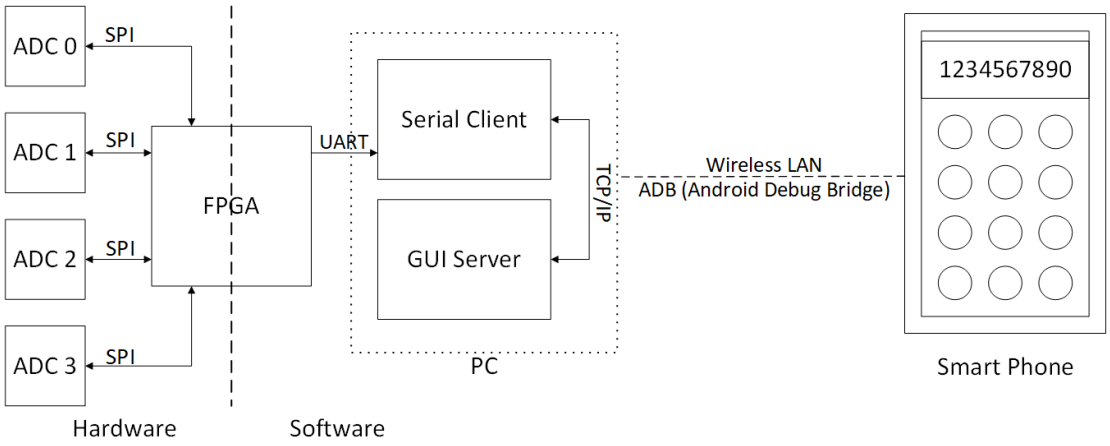

Figure S14. Data acquisition and analysis system for the wearable digital control panel. The terms of ADC, SPI, FPGA and UART refer to Analog-to-Digital Converter, Serial Peripheral Interface, Field-Programmable Gate Array and Universal Asynchronous Receiver Transmiller, respectively.