Self-Powered and Self-Functional Cotton Sock Using Piezoelectric and Triboelectric Hybrid Mechanism for Healthcare and Sports Monitoring

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S1: Optimization of PEDOT:PSS concentration for coating

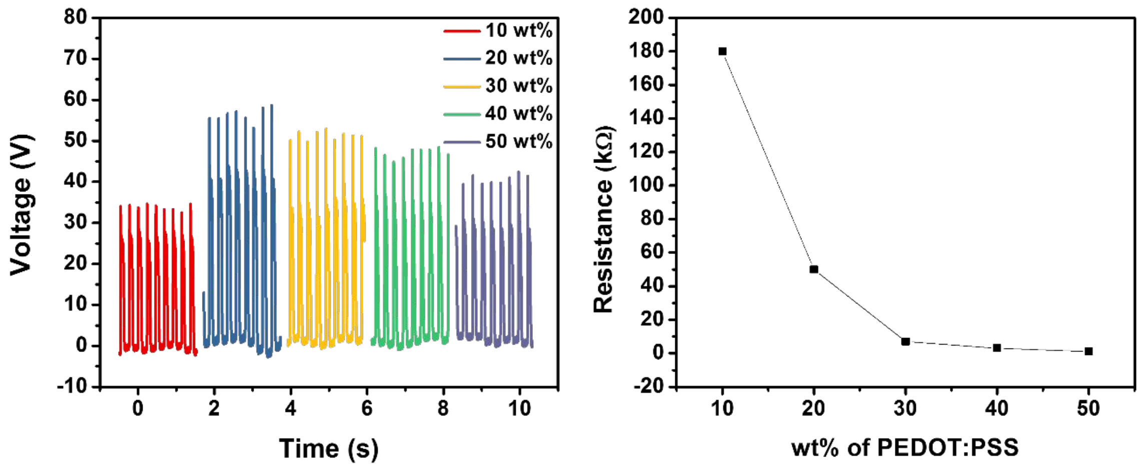

Figure S1. Optimization of PEDOT:PSS concentration for coating the cotton textiles through output voltage under a loading force of 3 N at 3 Hz frequency, both the measured data of output voltage and resistance are given. Five specimens include the concentrations of diluted PEDOT:PSS solution of 10 wt%, 20 wt%, 30 wt%, 40 wt%, and 50 wt%, and the size of each tested textile is 5 cm × 5 cm.

S2: Comparison of open circuit voltage of two triboelectric mode

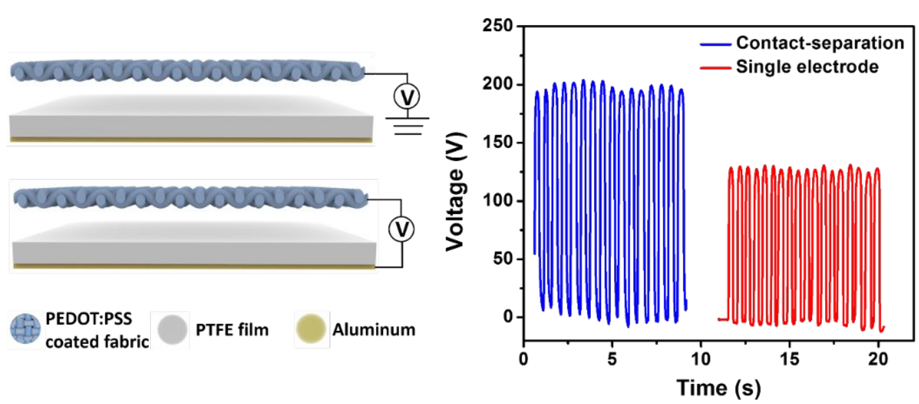

Figure S2. Comparison of open circuit voltage of two triboelectric mode: contact-separation and single electrode for wearing shoes conditions.

S3: Calibration curve of "FlexiForce®" resistive force sensor under changing loadings

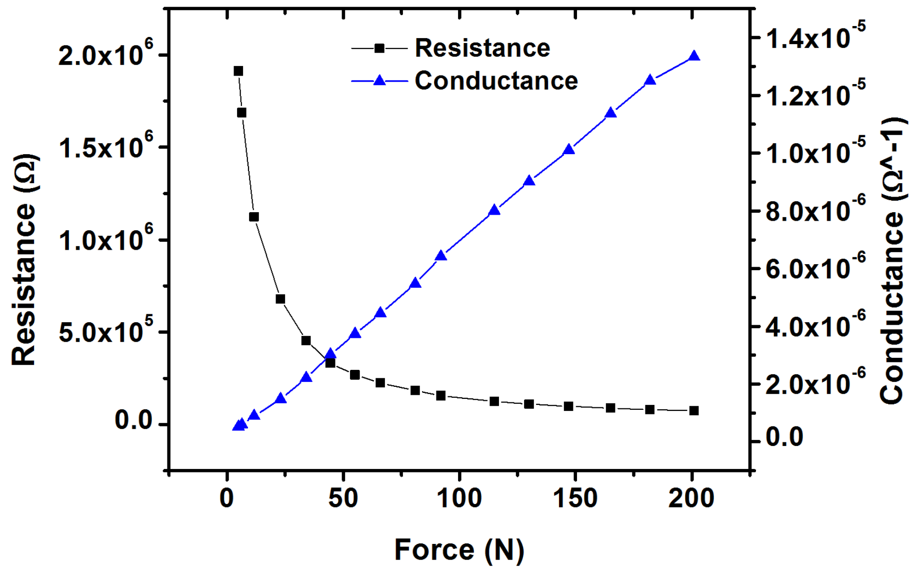

Figure S3. Calibration curve of "FlexiForce®" resistive force sensor under changing loadings from 2 N to 200 N, with 6 V of external power supply, both resistance and conductance are plotted. For the calibration of triboelectric sensor "TT", the resistive force sensor was stacked together to experience different impact force, and the current variations caused by changing resistance of "FlexiForce®" sensor were measured through oscilloscope. The current is then converted to conductance by Ohm's law for the determination of corresponding force.

S4: Characterization tests for changing temperature, humidity and contact area

Figure S4 provides several characterization tests regarding the TENG output voltage under changing humidity, temperature or contact area.

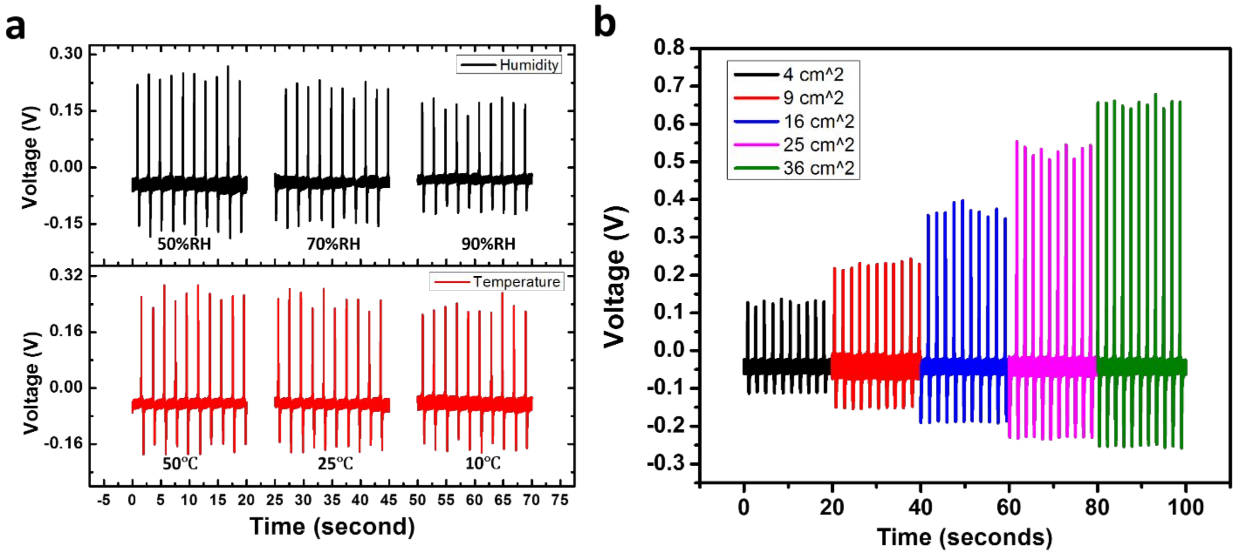

Figure S4. Characterization tests by force gauge (10N, 900mm/min): (a) TENG fabric (size: 9 cm^2) characterization tests for changing temperature or humidity. (b) Relationship between output voltage and contact area of TENG fabric at 70% RH.

S5: Comparisons of output with changing weight and humidity for pattern recognition

In Figure S5, to avoid the gait different among participants during analysis of weight influences, we conducted the tests by adding extra weight to same participant A. Theoretically, although different weights (forces) can change the contact area of soft materials, and further cause the output altering within a certain range. As human, the sock can easily achieve full contact even for female with light weight, hence, the output voltage would not change (no contact area variation) based on weight anymore. As a result, the signals from both voltages and charges are relative stable. On the other hand, the output signal from participant B (Figure S5a) shows more dependence on contact area (foot size). To conclude, variations of human weight will not affect the stability of sensor a lot. In Figure S5c, large humidity increment (20% higher) may lead to a minor decline of about

10% of output amplitude. Foot size also affect the signal intensity, but it is considered as a key feature of identification for gait analysis.

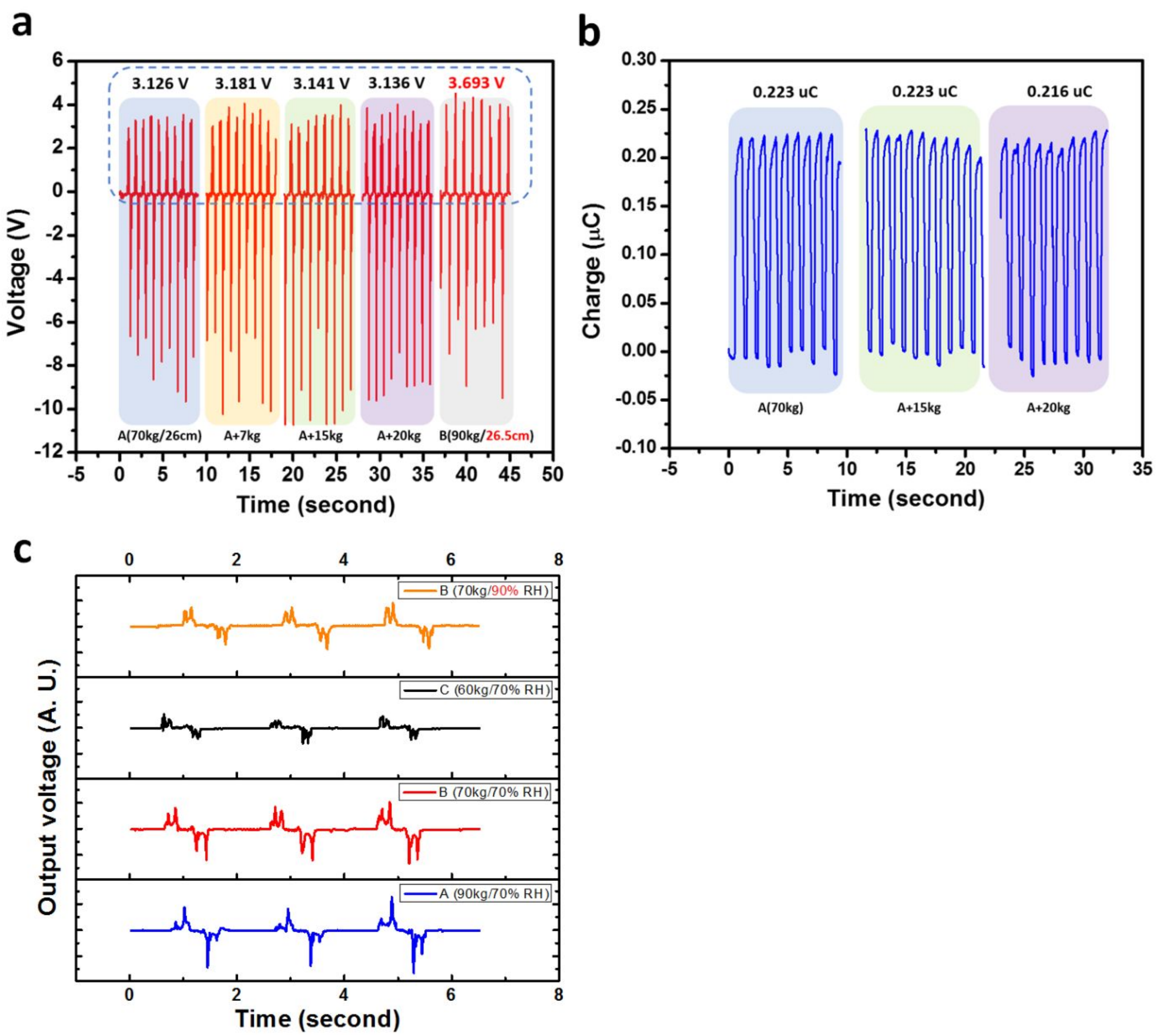

Figure S5. Indoor experiments (without shoes): (a) Comparisons of output intensity with increasing weight (participant A with changing additional loading:7 kg, 15 kg, 20 kg) or foot size (participant B), dash circled parts are positive peaks generated during contact. (b) Comparisons of charge generation with increasing weight. All the labelled magnitudes (voltages and charges) above are the mean values from 60 data points of each test, and the parts of output waveforms are selected for comparing. (c) Comparison of TENG walking pattern recognition with different weight (60kg, 70kg, and 90kg) and humidity (70%RH and 90%RH), test setup is the same as Figure 3c.

S6: Comparison of TENG motion tracking and Parkinson detection with varied weight, temperature and humidity

In Figure S6-S7, the TENG sensors for different applications (*i.e.,* Parkinson's Disease monitoring, gait sensing, motion tracking and pattern recognition) were tested under varied conditions. Data from four participants (male: A (90kg), B (70kg), C (60kg), female: D (45kg)) were collected. For motion tracking in Figure S6a, only less than 10% decay of signal were observed after increase the humidity to 90% RH, and the weight of different participants shows no effect on output. In terms of PD monitoring, temperature and humidity variations would not have significant influence (within 10% variations) on the output signal (Figure S6). For outdoor application (in shoes) of gait sensing (Figure S7), human weight and humidity variations would not affect the output. It is worth to mention that in Figure S7(ii), the shoes were changed to fit the female foot and led to new features of gait waveforms, two repeated cycles are provided to identify those features. Generally, all these sensing functions will able to remain fully operational under the influences of multiple factors. Further data processing is the key to normalize the signals for better quality of information.

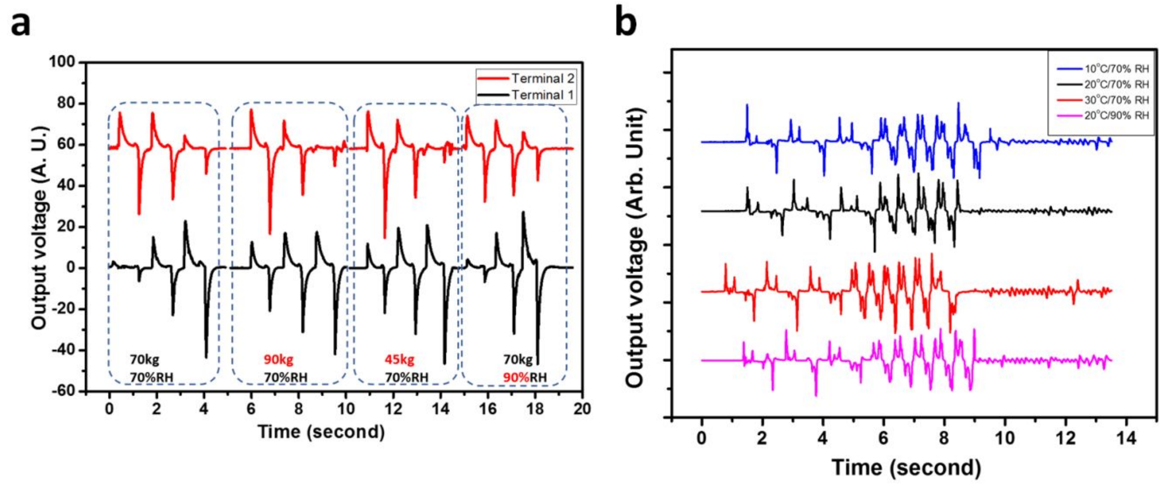

Figure S6. Indoor experiments (without shoes): (a) Comparison of TENG motion tracking with different weight (45kg, 70kg, and 90kg) and humidity (70%RH and 90%RH), test setup is the same as Figure 3d. (b) Stability tests of Parkinson's Disease under changing temperature (10 ℃, 20 ℃ and 30 ℃) and humidity (70% RH and 90% RH), test setup same as Figure 3e.

S7: Comparison of TENG gait sensing with different weight and humidity

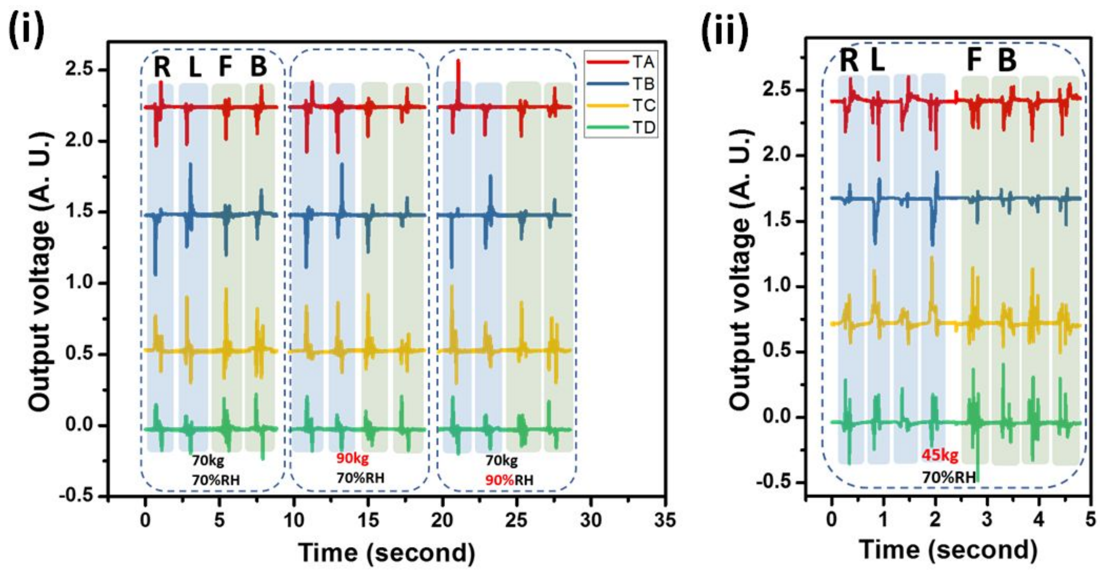

Figure S7. Outdoor experiment (in shoes): Comparison of TENG gait sensing (same test setup as Figure 5a, c) with different weight ((i) 90 kg and 70 kg male, (ii) 45kg female) and humidity (70% RH and 90% RH), R: right, L: left, F: forward, B: backward.

S8: Stability test of TENG sensors and enlarged output signals

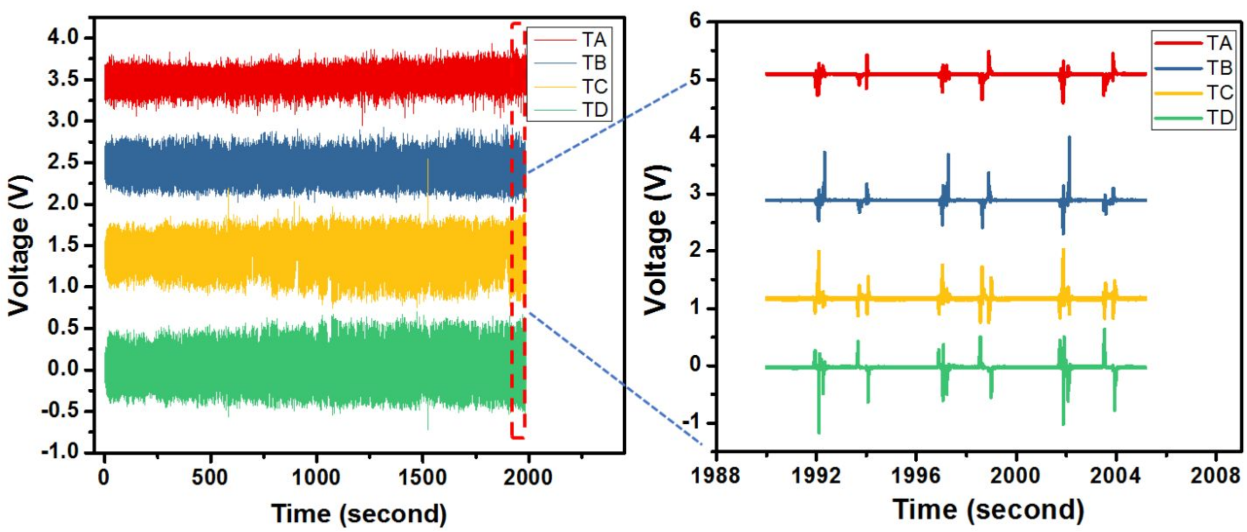

Figure S8. Outdoor experiment (in shoes): stability test of TENG sensors for 33 minutes and enlarged output signals at the end of test.

S9: Stability test of PZT sensors and enlarged output signals

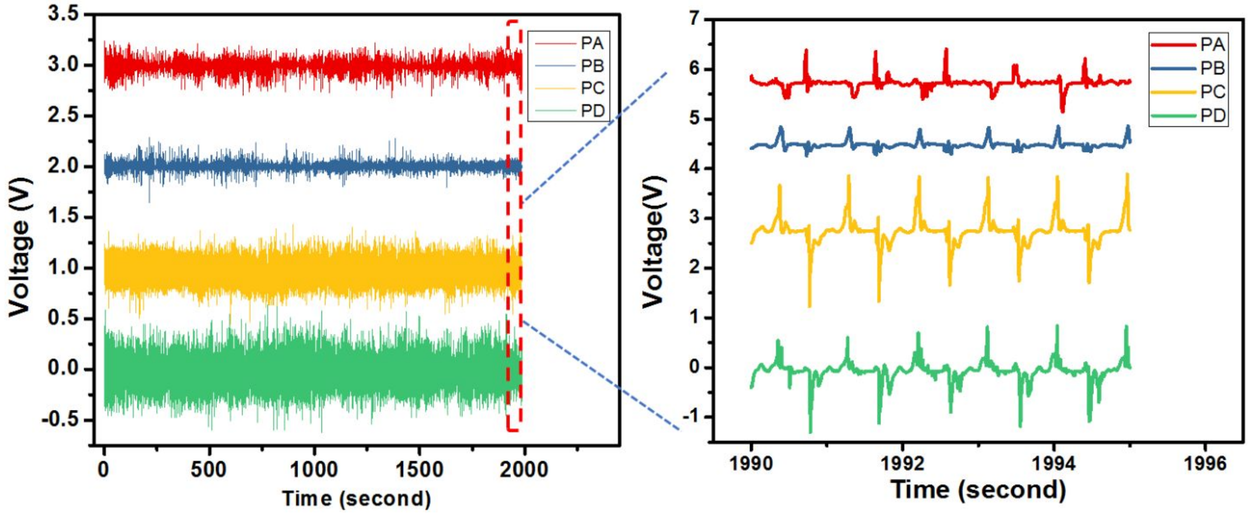

Figure S9. Outdoor experiment (in shoes): stability test of PZT sensors for 33 minutes and enlarged output signals at the end of test.

S10: Washability tests for PEDOT:PSS coated cotton fabric

The results of washability tests are illustrated in Figure S10, to investigate the degradation of output after each wash and the ultimate performance after cyclic washes. The largest decay happens after the first wash (Figure S10b), which is about 10~15%. After that, the degradation rate decreased to 5~10% for each wash and no more degradation observed after 5~6 washes. It is consistent with the resistance measurements: 30kΩ before wash and maintain at 500kΩ after 5~6 washes. We ran until 15 washes to further verifying the stability of output. As a result, it keeps 50-60% of its original output after multiple washes and still able to provide sensing function (shown in figure for gait sensor TC and TD). In future, we may improve the performance by adding dye fixative technique used in textile industry, since the current coating process does not include any treatment for protection.

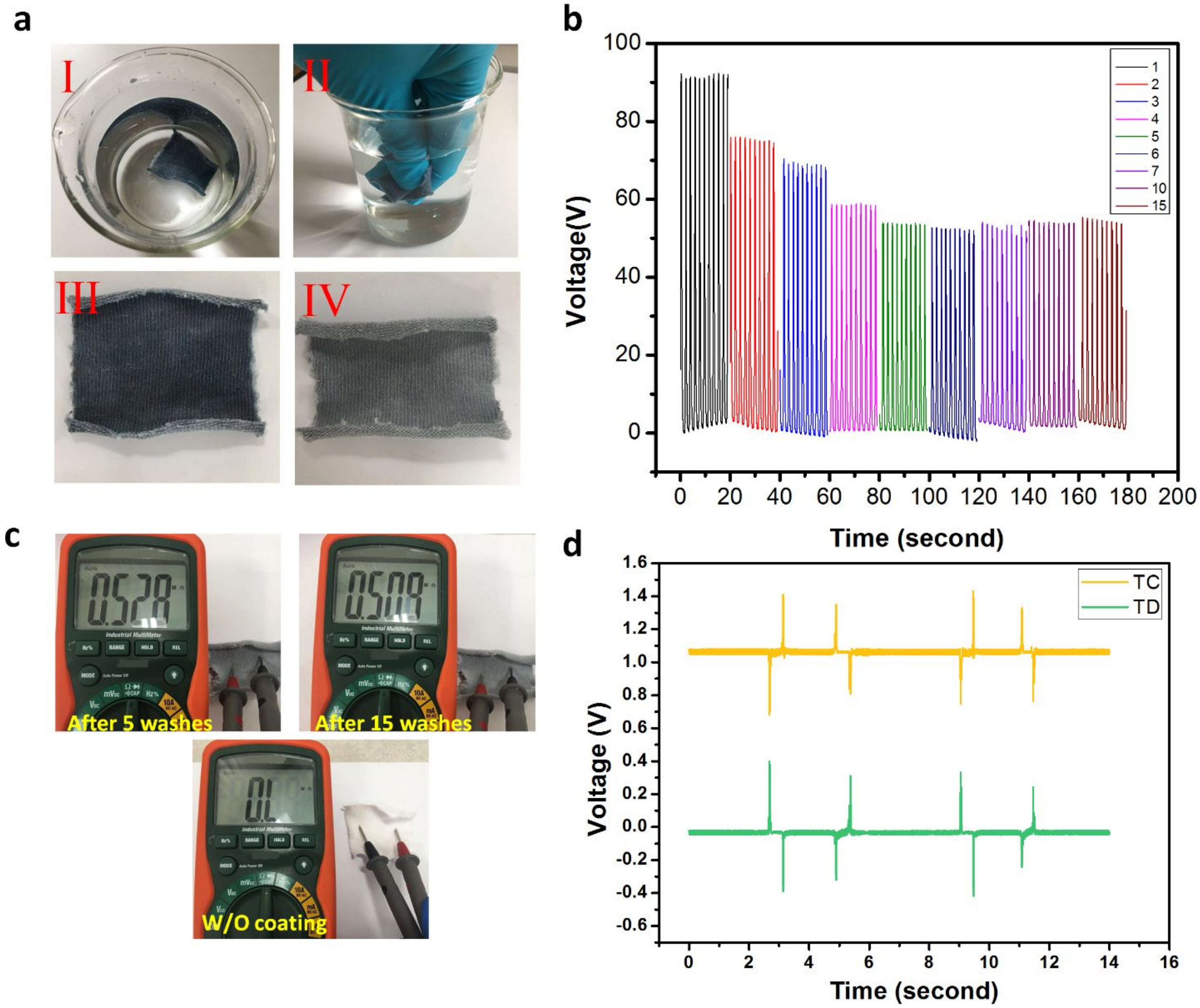

Figure S10. The preliminary reliability/washability tests for PEDOT:PSS coated cotton fabric without any pre-treatment. (a) Photos of coated fabric (III) before and (IV) after washing for 15 times, washing steps: (I) immersed into water for 5 minutes and (II) rubbed by hand for 2 minutes. (b) Comparison of the open circuit voltages after each wash. (c) Comparison of resistance measurements after 5 and 15 washes, as well as sock fabric without coating. (d) Sensing signal collected from the fabrics after 15 washes (same test setup as Figure 4c). The dye fixative techniques from textile industry may be a possible way to improve the performance after washing.

Supporting Videos

Movie S1. Motion tracking.

Movie S2. Mimetic detection of Parkinson Disease.

Movie S3. Gait sensing of pure contact.

Movie S4. Gait sensing of sliding motions.

Movie S5. Gait sensing of walking.