Supporting Information

Washable textile-structured single-electrode triboelectric nanogenerator for self-powered wearable electronics

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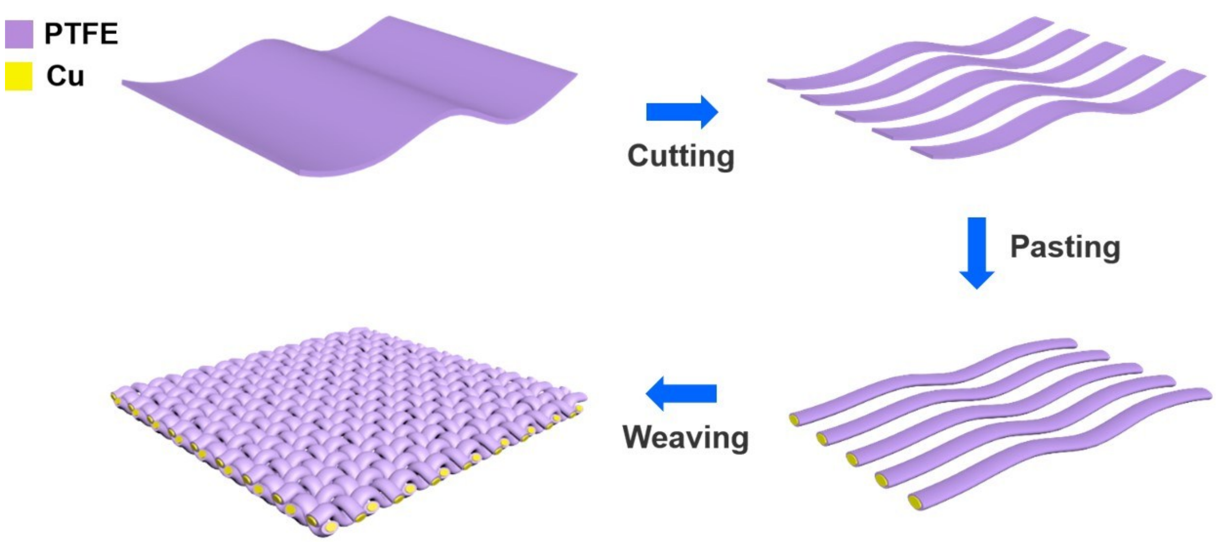

Fig. S1 The schematic flow chart for fabricating the TS-TENG.

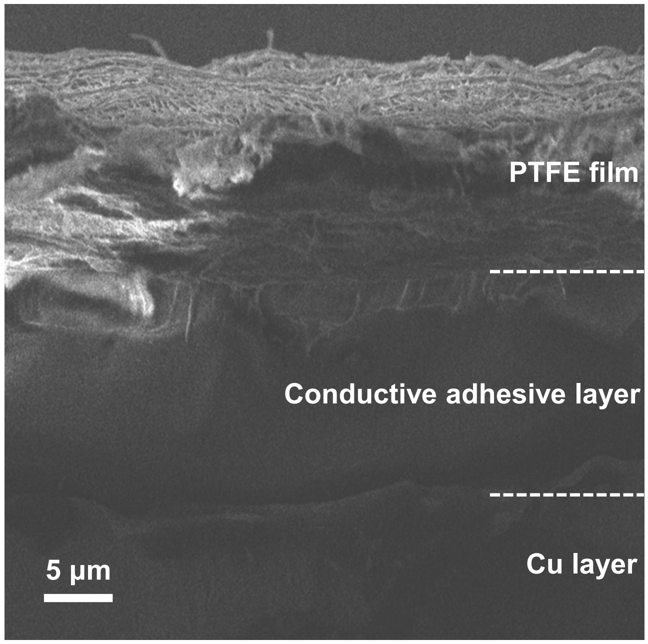

Fig. S2 The cross-section SEM image between the Cu foil tape and the PTFE film of the TS-TENG

Fig. S2 shows the cross-section SEM image between the Cu foil tape and the PTFE film of the TS-TENG. It can be seen that the PTFE film is closely attached with the conductive adhesive layer of the Cu foil tape. This good combination of the PTFE film and Cu electrode is beneficial to the charge inducing process of the TS-TENG and also favorable for the triboelectric output performance.

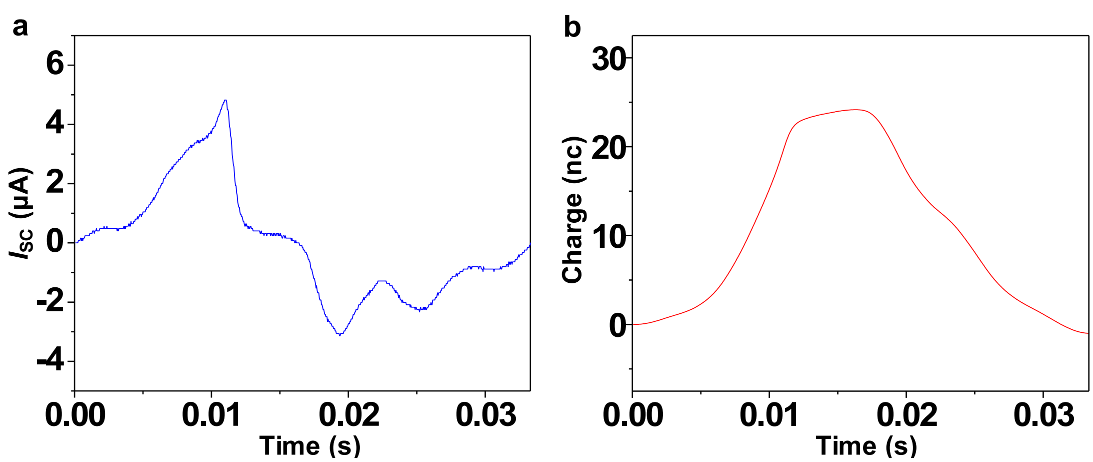

Fig. S3 (a) The current output signal generated from one contact-separation cycle of the TS-TENG. (b) The corresponding induced charge calculated from the integral area of the *I-t* curve in (a).

Fig. S3a exhibits the output current signal of a full contact-separation cycle. The output charge of the TS-TENG in one cycle was calculated from the integral area of the *I-t* curve in Fig. S3a by the following equation:[1,2]

$$q = \int_{a}^{b} I \, dt$$

where q is the induced charge, [a, b] is the time interval, I is the output current, and t is the time. When the cotton cloth initially approaching the PTFE to a fully contact state, the output charge increased from 0 to 24.1 nC as shown in Fig. S3b. After the electrical equilibrium state, the output charge gradually decreased to about zero in the separating process. The charge increasing and decreasing process are consistent with the positive and negative output current generated in a contact-separation cycle, respectively. Above results further evidenced the working mechanism (shown in Fig. 2) of the TS-TENG.

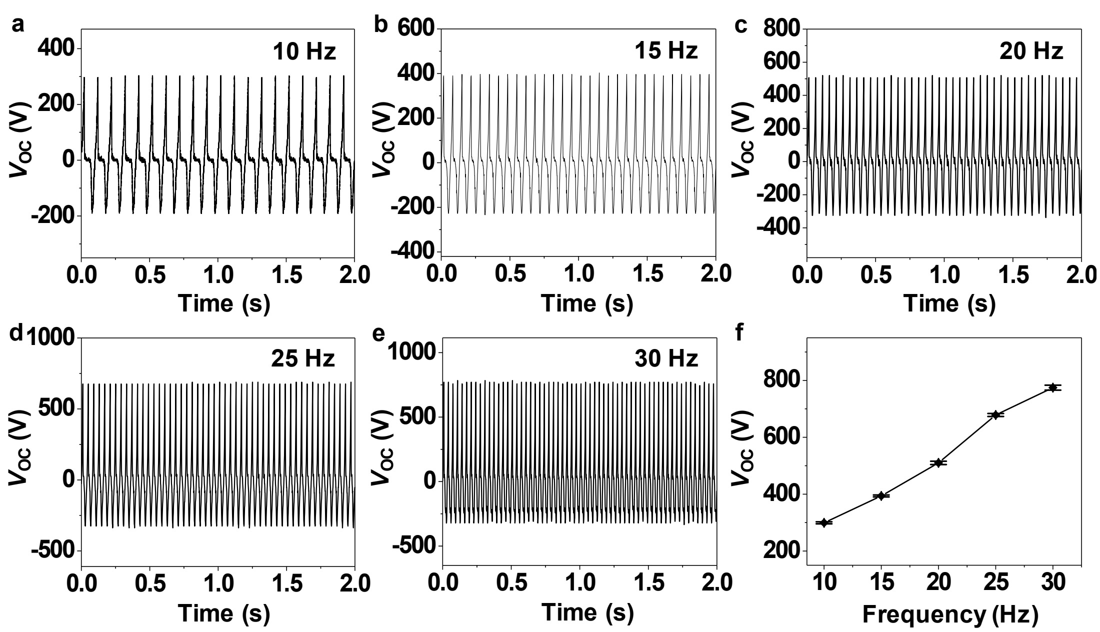

Fig. S4 (a-e) The output voltage signals of the TS-TENG under impact frequencies from 10 Hz to 30 Hz. (f)The corresponding peak V_{OC} of the TS-TENG under above various impact frequencies.

Fig. S4 illustrate the output voltages of the TS-TENG at various impact frequencies from 10 Hz to 30 Hz. It can be seen that higher impact frequency generated higher output voltage. The peak V_{OC} of the TS-TENG increased from 300 V to 780 V when the impact frequency increased from 10 Hz to 30 Hz. The increasing of the output voltage can be ascribed to the raised contact-separation rates of the friction surfaces that would induce more triboelectric charges within the same time frame.

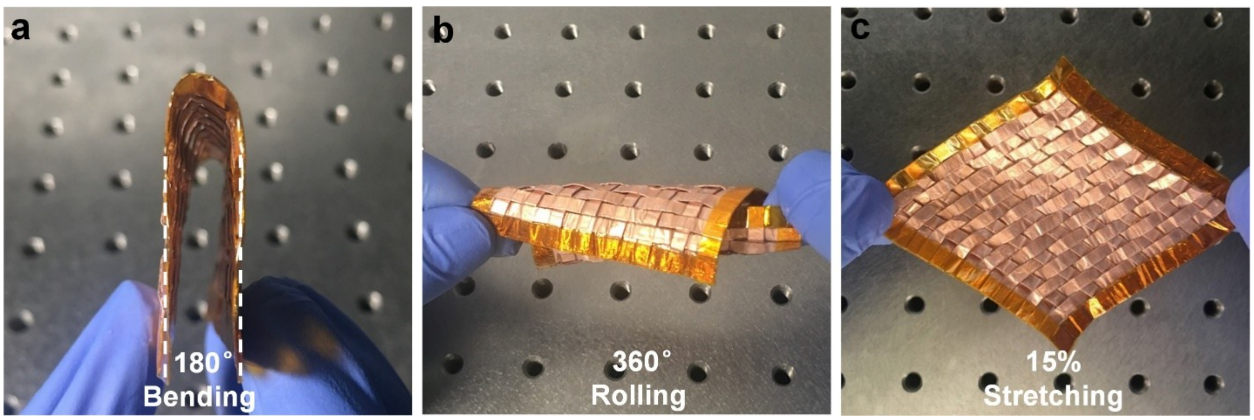

Fig. S5 The mechanical deformation capacity of the TS-TENG of (a) bending, (b) rolling and (c) stretching.

The mechanical deformation capacity of the TS-TENG was evaluated by bending, rolling and stretching, as shown in Fig. S5. The TS-TENG with a size of 5 cm × 5 cm can be easily bent to the angle of 180°, as presented in Fig. S5a. Fig. S5b shows a twisted TS-TENG, exhibiting the TS-TENG can be rolled up to 360°. As presented in Fig. S5c, the diagonal line of the TS-TENG can be stretched 15% beyond its original length. These results illustrate that the TS-TENG has an excellent mechanical deformation capacity.

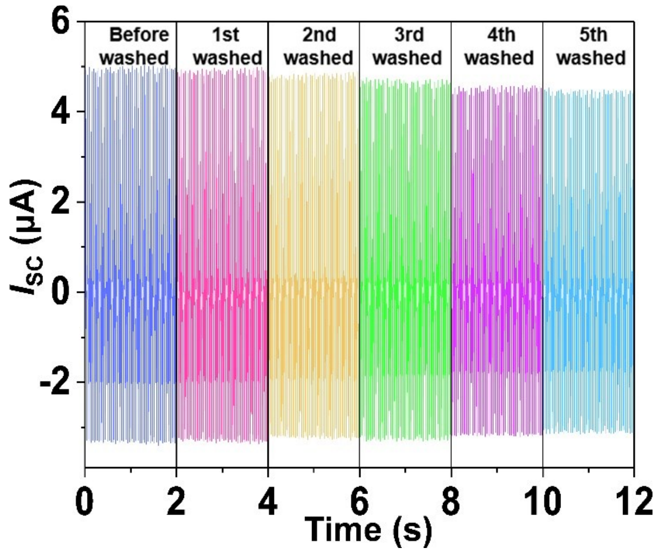

Fig. S6 The output current of the as-fabricated TS-TENG and after repeated washing cycles under impact frequency of 30 Hz.

Fig. S6 shows the output current of the unwashed and after repeated washing cycles under impact frequency of 30 Hz. It can be clearly seen that with the number of washing times increased, the peak I_{SC} slightly declined from 4.9 μA to 4.4 μA. The output current underwent a similar change with the output voltage of the TS-TENG as shown in Fig. 4b.

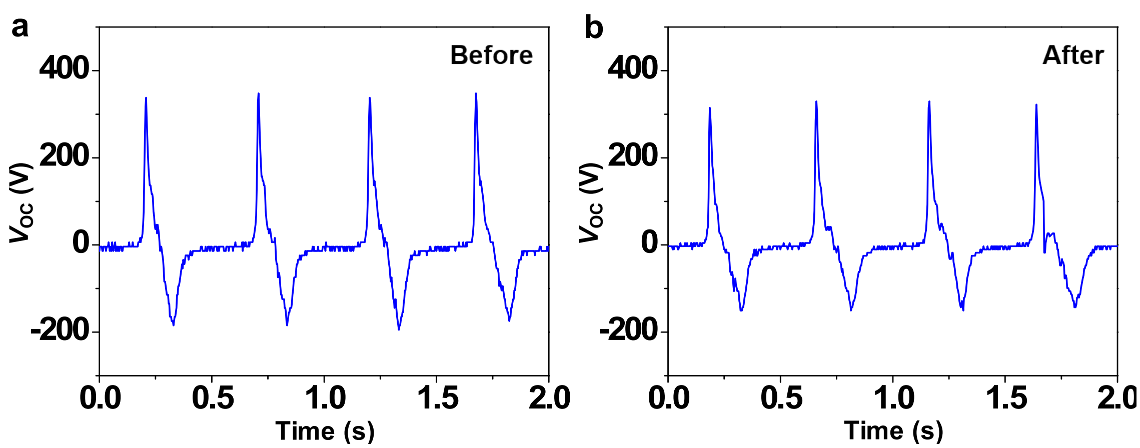

Fig. S7 The output voltages of the TS-TENG under sliding motions of 2 Hz (a) before and (b) after laundering in a washing machine for 30 minutes.

The washing machine stress test of the TS-TENG was conducted in a washing machine for laundering of 30 minutes. Fig. S7 shows the output voltages of the TS-TENG under sliding motions of 2 Hz before and after laundering. This frequency is similar with the frequency of swinging arms when people jogging. After laundering in the washing machine, the average peak V_{OC} was obtained to be 327 V, which was still maintained for 96% of the initial value (340 V). This output voltage value is lower than that of the impacting test because of its low sliding frequency. This washing machine stress test includes processes of bending, rolling, and washing for 30 minutes, which indicates the good durability the TS-TENG.

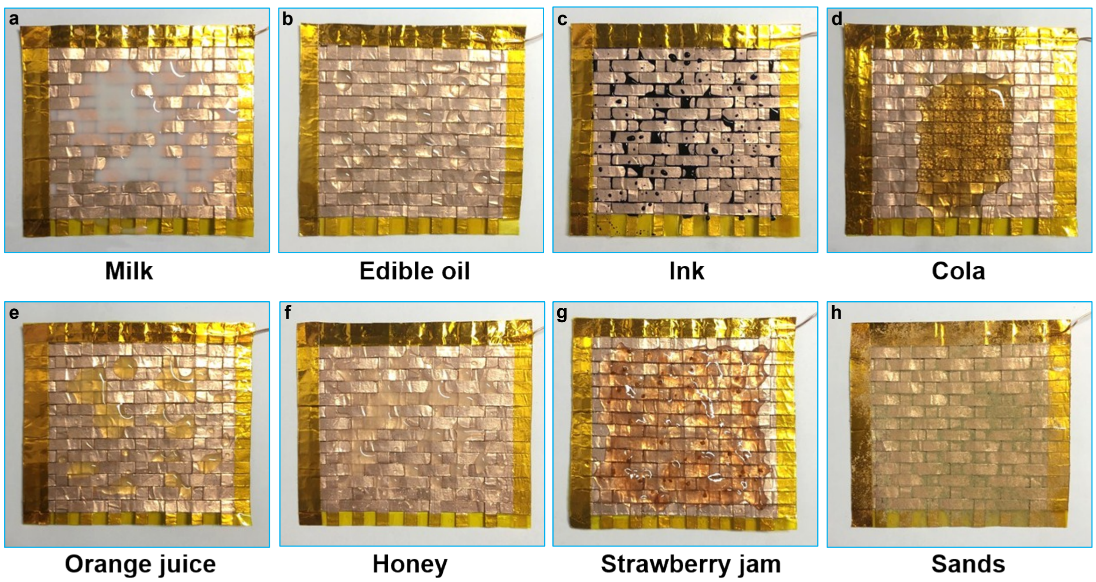

Fig. S8 (a) The TS-TENGs were stained by several common stains.

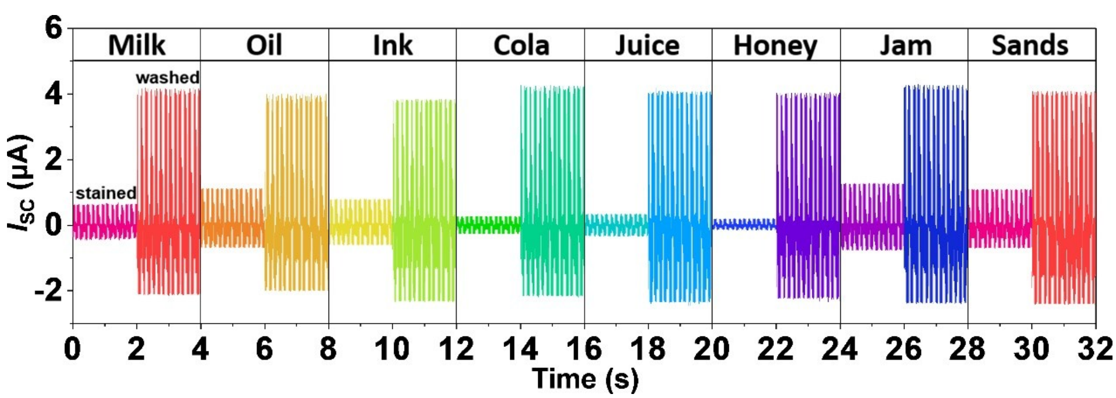

Fig. S9 The output current of the TS-TENG which was stained by several common stains and after washing.

8 TS-TENGs (5 cm × 5 cm) were fabricated and stained by different common stains like milk, oil, ink, cola, juice, honey, jam, and sands, respectively. The output current of these stained textile TS-TENGs and after washing were measured and shown in Fig. S9. The peak I_{SC} of the stained TS-TENG obviously dropped, and then noticeably recovered after cleaning by water. The change trend of the output current is consistent with the output voltage of the TS-TENG (Fig. 4d).

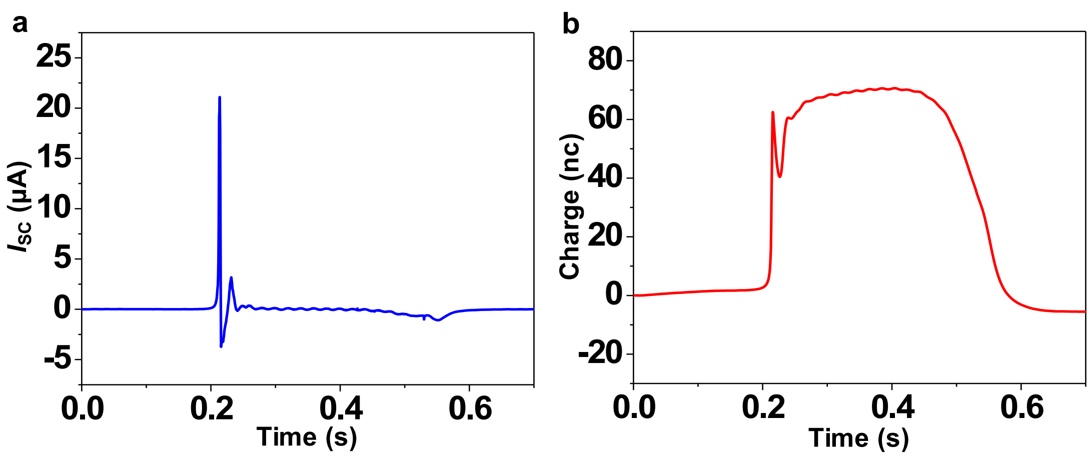

Fig. S10 (a) Output current generated from one contact-separation cycle of the TS-TENG on the lab coat. (b) The corresponding output charge calculated from the integral area of the *I-t* curve in (a).

Fig. S10a shows one cycle output current generated from the TS-TENG on the lab coat when operated by the action of swinging arms. The corresponding output charge was calculated by the integral area of the corresponding *I-t* curves, as depicted in Fig. S10b. The TS-TENG generated 70.6 nC output charge in one cycle, when operated by swinging arms.

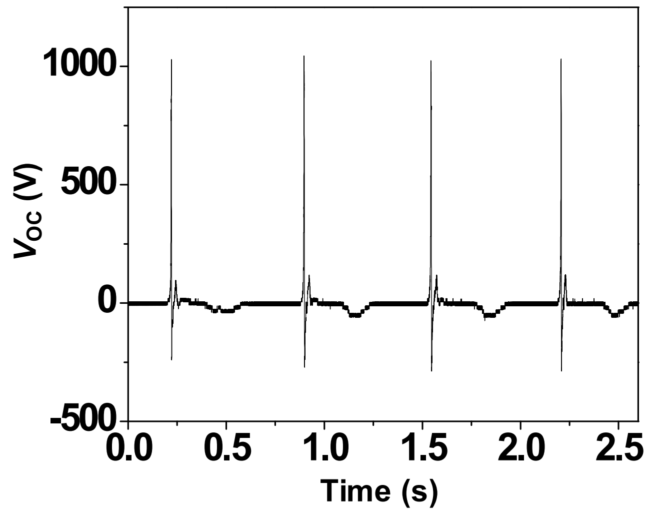

Fig. S11 The output voltage of the TS-TENG that attached on the clothes after 100 times of twisting.

The twisting test for the TS-TENG attached to the clothes was performed as shown in Fig. S11. The attached TS-TENG was twisted together with the clothes for 100 times. After 100 times of twisting, the average peak V_{OC} was obtained to be 1030 V, which was maintained for 98% of the initial value (1050 V). In our TS-TENG, the Cu foil was cut into narrow strips and the combined PTFE/Cu strips were woven by intercrossing the longitude and latitude lines to be a textile structure. This textile structure makes the TS-TENG possesses an excellent mechanical deformation capacity. Additionally, the large area (10 cm × 12 cm) of the TS-TENG that attached on the clothes offers a better flexibility.

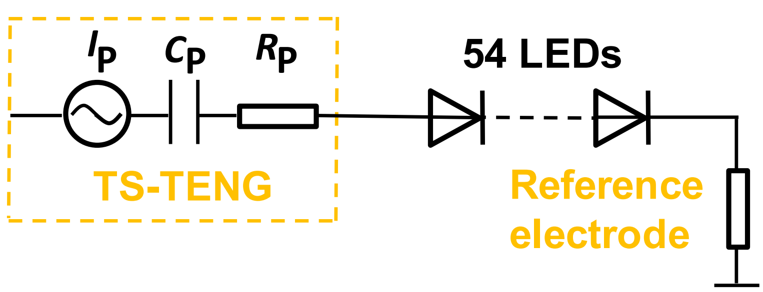

Fig. S12 The equivalent circuit for powering electronics.

Video S1 A TS-TENG was stained by milk, and then the stain was quickly removed by simply shaking in water.

Video S2 A wearable night running light composed of 54 commercial green LEDs was lit up by the TS-TENG on the lab coat.

Video S3 A digital watch without batteries was powered by the TS-TENG.

References

1. Z. H. Lin, G. Cheng, L. Lin, S. Lee and Z. L. Wang, *Angew. Chem. Int. Ed.*, 2013, **52**, 12545-12549.
2. M. Wang, N. Zhang, Y. J. Tang, H. Zhang, C. Ning, L. Tian, W. H. Li, J. H. Zhang, Y. C. Mao and E. J. Liang, *J. Mater. Chem. A*, 2017, **5**, 12252-12257.