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Supplementary information

A novel retractable spring-like-electrode triboelectric nanogenerator with highly-effective energy harvesting and conversion for sensing road condition

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1. The comparsion of output performance of single-layer TENGs with different surface roughness

Before fabricating the studied multi-layer spring-like-electrode TENG devices in our work, the output performance of single-layer TENG devices with the same material but different surface roughness were compared firstly, as shown in the Fig. S1. At the same amplitude of 5 mm and frequency of 5 Hz, it is evident that the open-circuit voltage of the device with sanding treatment could reach the maximum 24 V which is larger than the value 15 V of that without any surface processing. According to the equation given by [1]

$$V_{OC} = \frac{\sigma_0 \cdot x(t)}{\varepsilon_0},$$

where V_{OC}, ε_0, σ_0, and $x(t)$ are the open-circuit voltage, vacuum permittivity, triboelectric charge density on the PTFE surface and interlayer distance, respectively, under the same amplitude and frequency, the peak open-circuit voltage only depends on triboelectric charge density. Therefore, we conclude that the sanding treated surface of our TENG devices enhances the triboelectric charge density on the PTFE surface indeed.

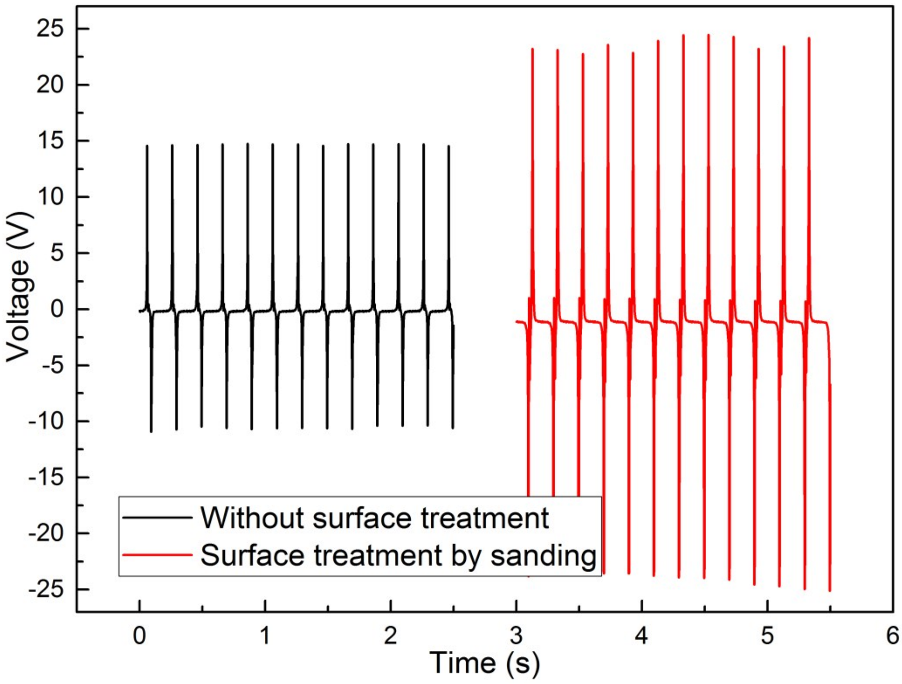

Fig. S1 The open-circuit voltage of single-layer TENGs with the same materials but different surface roughness (at frequency of 5 Hz and amplitude of 5 mm)

2. The details on the realization and explanation of simulation

In our paper, the finite-element simulation based on COMSOL multiphysics software was employed merely for further elucidating the working mechanism of a SL-TENG via the quantitative results of potential distribution under the open-circuit condition. Thereby, the relevant information of this simulation were not emphasized. The details on the realization of simulation include the following steps:

I) The structure charts of the SL-TENG under the contact state and separation state were designed by Solidworks graphics software and were imported into COMSOL multiphysics software respectively;

II) After completion of the geometric parameters and material choices according with the real device, the initial conditions (all electric potential were 0 and N steel electrode was grounded), boundary conditions (triboelectric charge density σ_0 on the N electrode and PTFE surface were 1e-6 C/cm2 and -1e-6 C/cm2, respectively) and interlayer distance x(t) (for contact state and separation state x(t) were 0 and 10 mm, respectively) of the device were set artificially in physical electrostatic field;

III) The computing grids of the device were built, then the calculation of potential distributions in space of the device were executed and thereafter the graphic results of the contact and separation state were acquired respectively;

IV) The graphic results were processed and finally exported from COMSOL.

Although the potential distributions in device's space under the contact and separation state depend on initial conditions and boundary conditions, it could facilitate us deeply understanding the working process of SL-TENG. As shown in Fig.2(e)(f), there is no obvious potential difference between the friction layers of steel and PTFE when device is in the fully contact state, while about 150 V potential difference between them is generated in the separation state. The results indicate that when the friction layers begin to separate from the contact state under the applied force, electric current would flow from the electrode N to electrode M so as to screen the produced electrostatic field until the device return back to its static equilibrium, and vice versa, which is consistent with the working mechanism illustrated in Fig. 2(a)-(d).

3. The stability and durability test

Under the frequency of 10 Hz and amplitude of 5 mm, a stability and durability test was carried out for about 10000 cycles (testing time were about 18 minutes). The results show that the output performance is relatively stable as no obvious change occurred after 10000 cycles, as shown in Fig. S2.

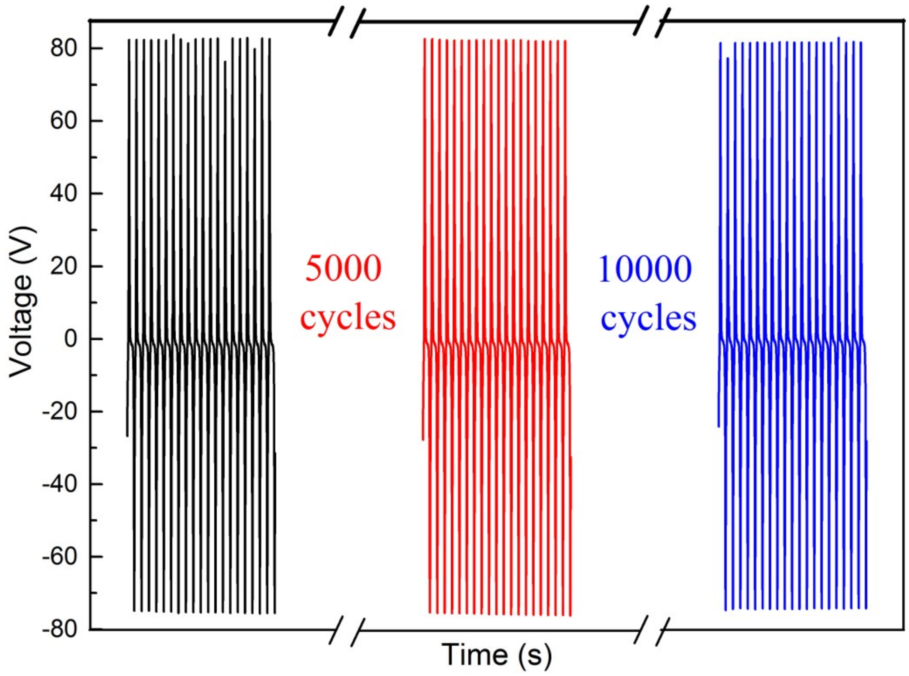

Fig. S2 The stability and durability test of the SL-TENG for about 10000 cycles.

Reference

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