Supporting Information

Low-Cost, Environmentally Friendly, and High-Performance Triboelectric Nanogenerator Based on a Common Waste Material

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Author Contributions

Yanhong Li, Zhihao Zhao, Yikui Gao contributed equally to this work.

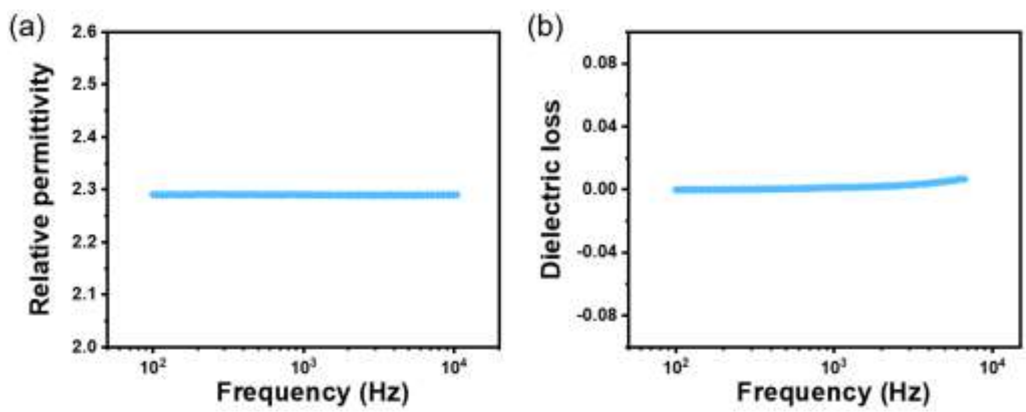


Figure S1. Dielectric properties of the used PE film. (a) The relative permittivity of PE film. (b) The dielectric loss of PE film.

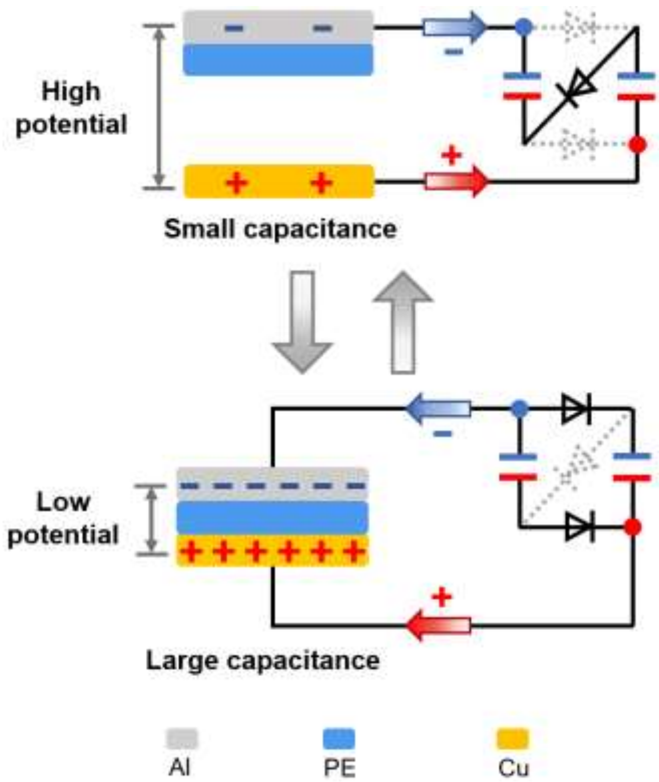


Figure S2. The detailed working mechanism of self-charge excitation TENG which is prepared with the waste PE film.

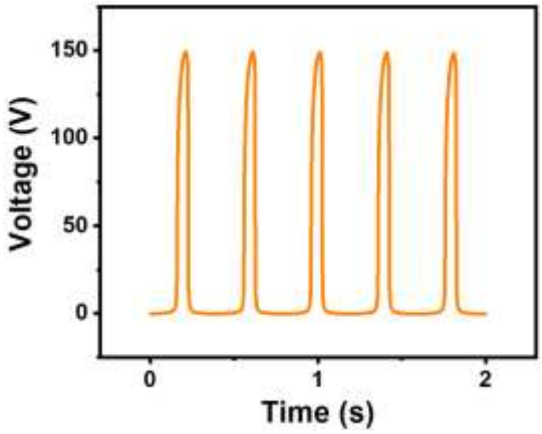


Figure S3. The voltage of self-charge excitation TENG which is prepared with the waste PE film.

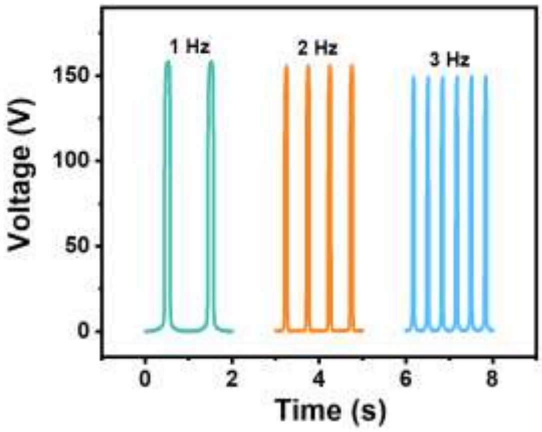


Figure S4. The voltage of self-charge excitation TENG under different working frequencies.

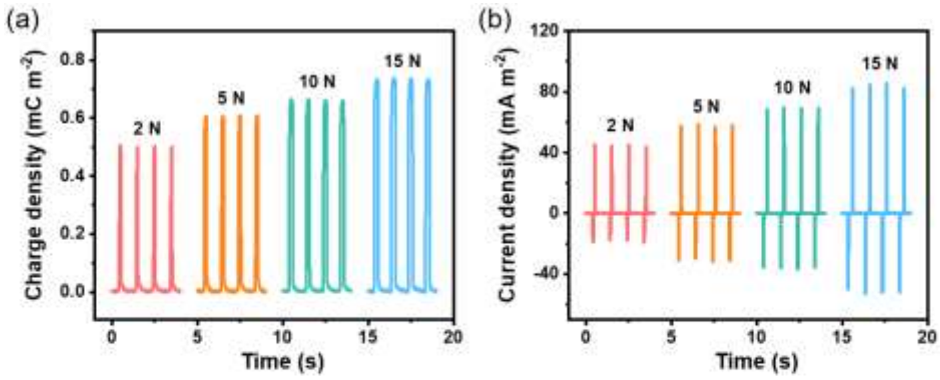


Figure S5. The output of self-charge excitation TENG under different working pressures at operation frequency of 1 Hz. (a) The charge density of self-charge excitation TENG. (b) The current density of self-charge excitation TENG.

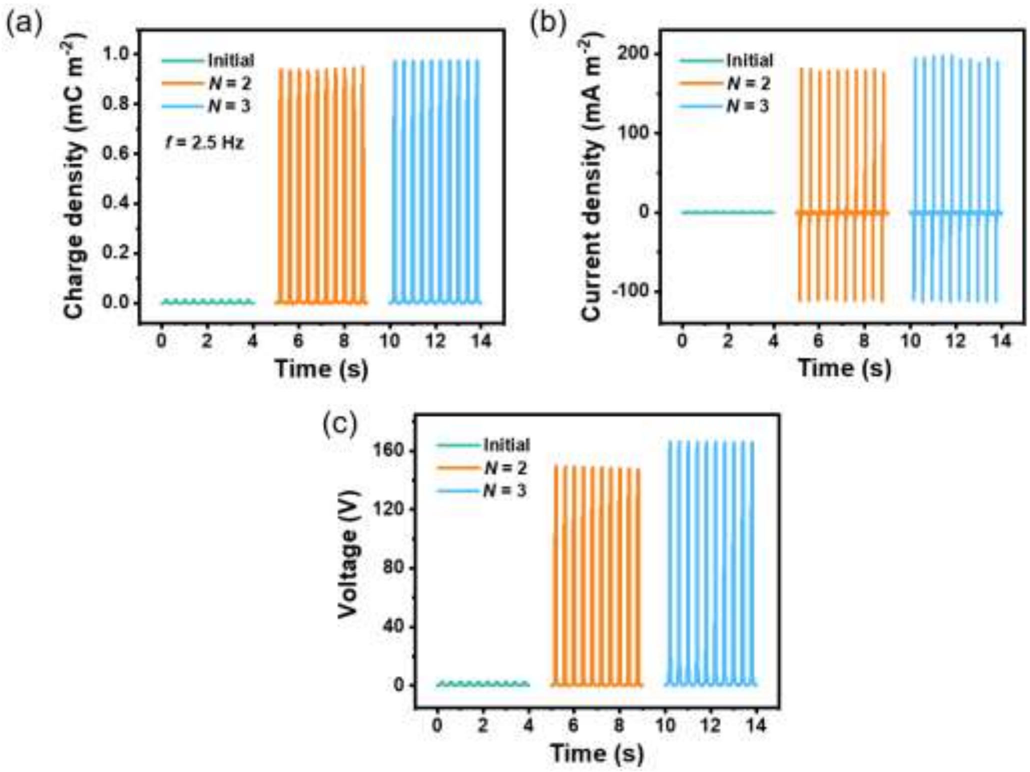


Figure S6. Summary of the output performance of TENG under initial state and combined with two-order and three-order voltage multiplier circuit. (a) The charge density of self-charge excitation TENG. (b) The current density of self-charge excitation TENG. (c) The voltage of self-charge excitation TENG.

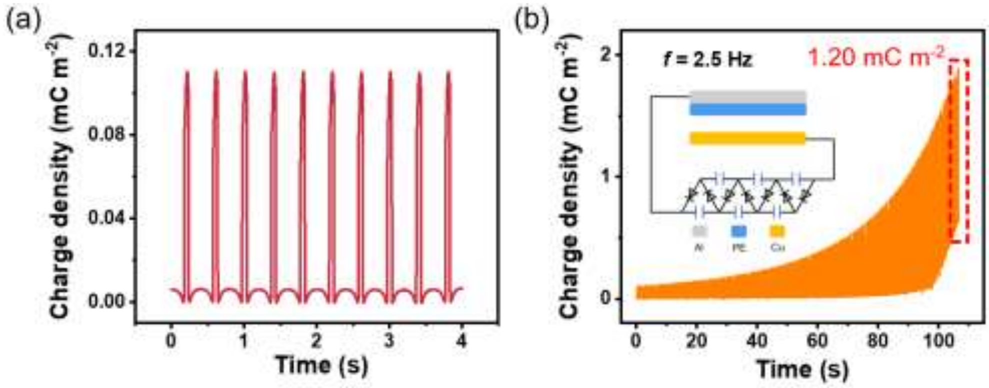


Figure S7. The charge density of TENG based on the waste coke can. (a) The initial charge density of TENG based on the waste coke can. (b) The improved charge density of TENG based on the waste coke can (insert is the simplified circuit diagram of self-charge excitation TENG with three-order voltage multiplier circuit).

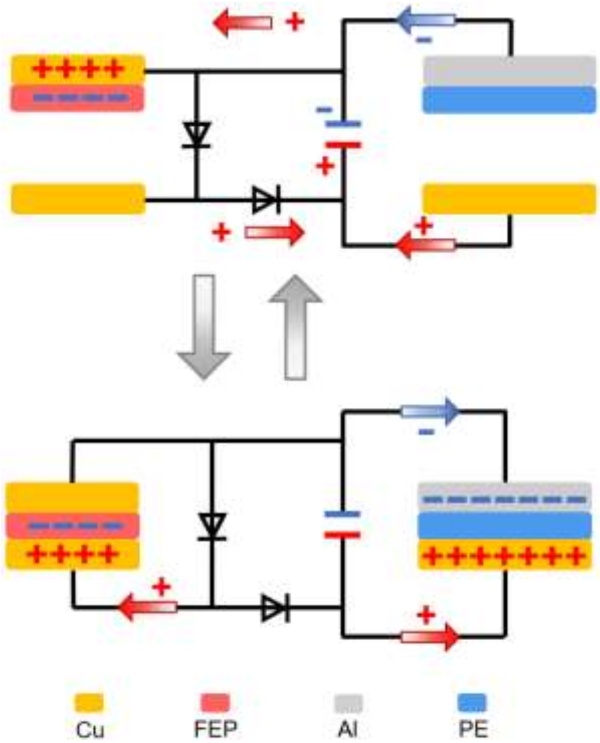


Figure S8. The detailed working mechanism of external charge excitation TENG prepared with the waste PE film.

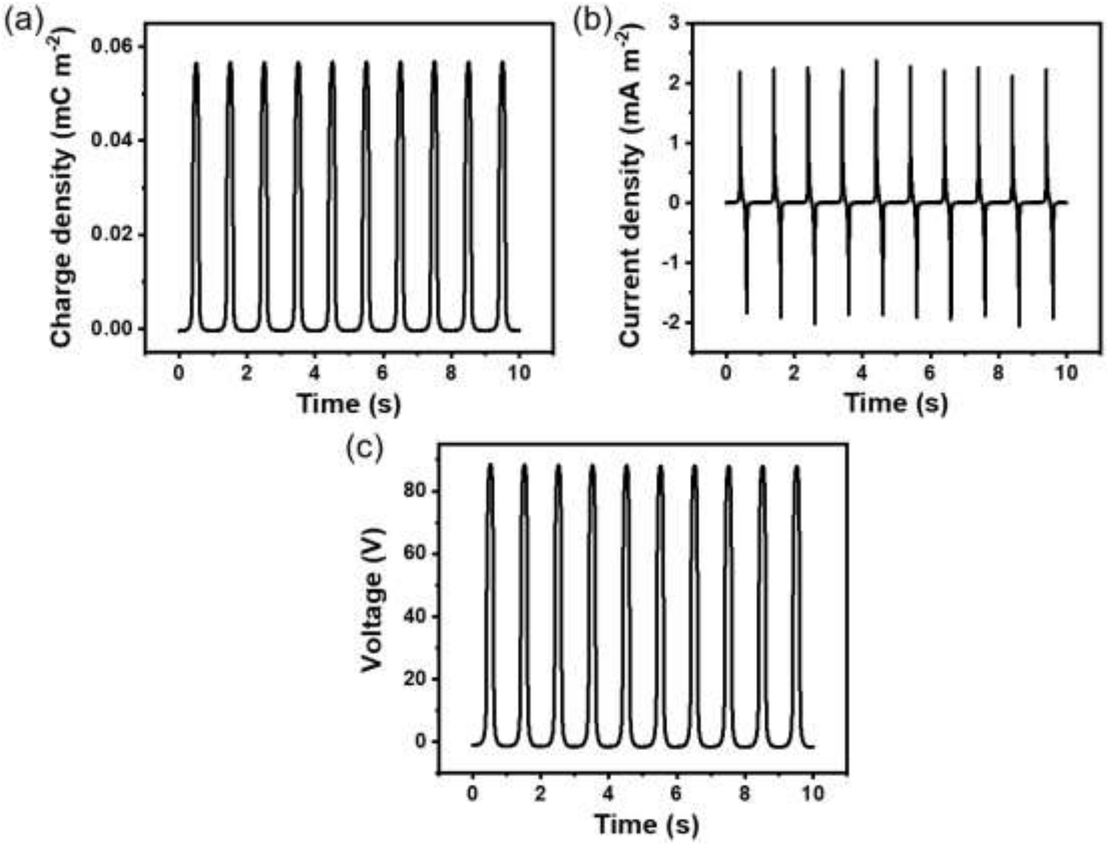


Figure S9. The output performance of excitation TENG at working frequency of 1 Hz. (a) The charge density of excitation TENG. (b) The current density of excitation TENG. (c) The voltage of excitation TENG.

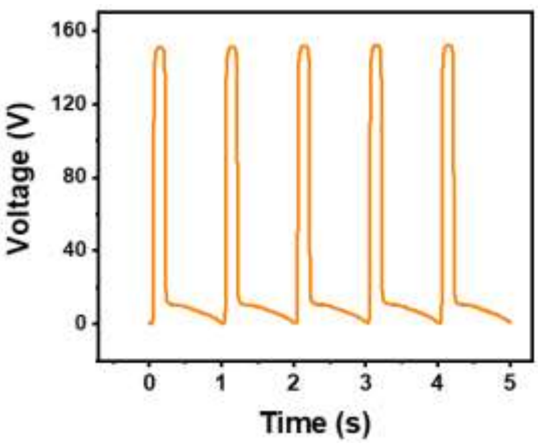


Figure S10. Voltage of external charge excitation TENG at working frequency of 1 Hz.

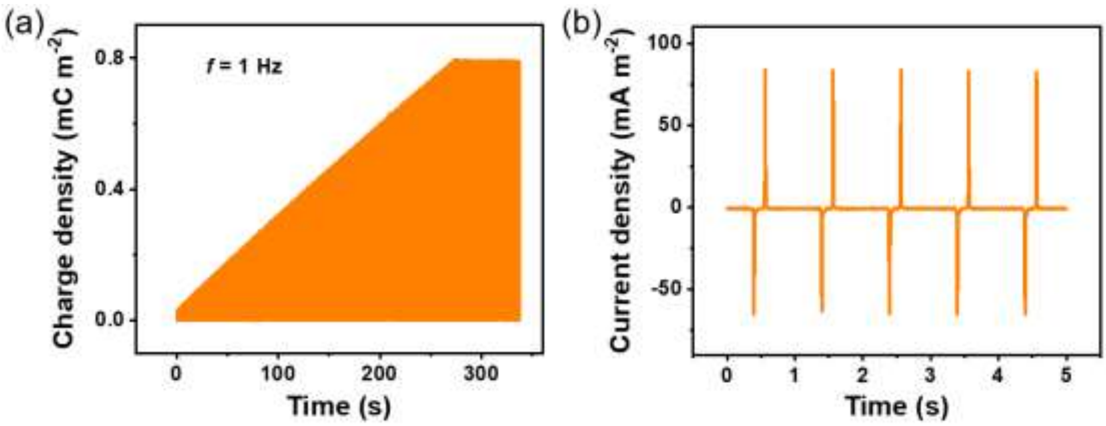
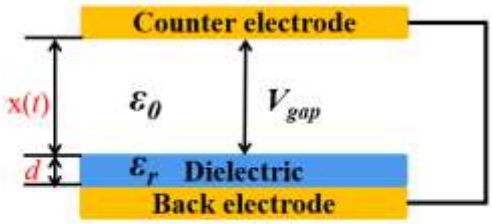


Figure S11. The output performance of external charge excitation TENG with voltage stabilization. (a) The complete charge accumulation curve of external charge excitation TENG. (b) The current density of external charge excitation TENG at working frequency of 1 Hz.

Note S1 The air breakdown model and theoretical maximum charge density of TENG.



With the contact-separation mode of TENG, the gap voltage (V_{gap}) between contact surfaces under short-circuit condition is given by:[S1]

$$V_{gap} = \frac{\sigma d x}{\varepsilon_0 (d + \varepsilon_r x)} \tag{S1}$$

where d and ε_r are the thickness and relative permittivity of the dielectric film, σ is the surface charge density, x is the gap distance, and ε_0 the vacuum permittivity ($\varepsilon_0 \sim 8.85 \times 10^{-12}$ F m^{-1}).

According to Paschen's law, the relationship between the gaseous breakdown voltage (V_b) and the product of the gas pressure (P) and gap distance (x), and is given by:

$$V_b = \frac{APx}{\ln(Px) + B} \tag{S2}$$

where A and B are the constants determined by the composition and the pressure of the gas. For air at standard atmospheric pressure (atm, i.e., the conventional operation condition of TENG), A is 2.87×10^5 $V\ atm^{-1}\ m^{-1}$, and B is 12.6.

In order to avoid air breakdown effect, the V_{gap} needs to remain smaller than V_b at any $x > 0$ states.[S2,S3] Thus, the following relationship is needed:

$$V_{gap} \le V_b \tag{S3}$$

According to Supplementary Equation S1-S3, the theoretical maximum charge density of TENG can be expressed as:

$$\sigma_{max} = \left(\frac{AP\varepsilon_0(d+\varepsilon_r x)}{(\ln(Px)+B)d}\right)_{min} \quad \text{(S4)}$$

From Equation S4, it can be found that a small thickness of dielectric material is advantageous for achieving a high charge density of TENG.

References:

[S1]Wang, S.; Xie, Y.; Niu, S.; Lin, L.; Liu, C.; Zhou, Y. S.; Wang, Z. L. Maximum Surface Charge Density for Triboelectric Nanogenerators Achieved by Ionized-Air Injection: Methodology and Theoretical Understanding. *Adv. Mater*. **2014**, *26* (39), 6720-6728.

[S2]Wang, J.; Wu, C.; Dai, Y.; Zhao, Z.; Wang, A.; Zhang, T.; Wang, Z. L. Achieving Ultrahigh Triboelectric Charge Density for Efficient Energy Harvesting. *Nat*. *Commun*. **2017**, *8* (1), No. 88.

[S3]Zhang, C.; Zhou, L.; Cheng, P.; Yin, X.; Liu, D.; Li, X.; Guo, H.; Wang, Z. L.; Wang, J. Surface Charge Density of Triboelectric Nanogenerators: Theoretical Boundary and Optimization Methodology. *Appl. Mater. Today* **2020**, *18*, No. 100496.