Supporting Information

Ultralight Paper-Cutting Based Self-Charging Power Unit for Self-Powered Portable Electronic and Medical Systems

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Supporting Information Note:

Numerical analysis of output performance for the PC-TENG with different unit numbers

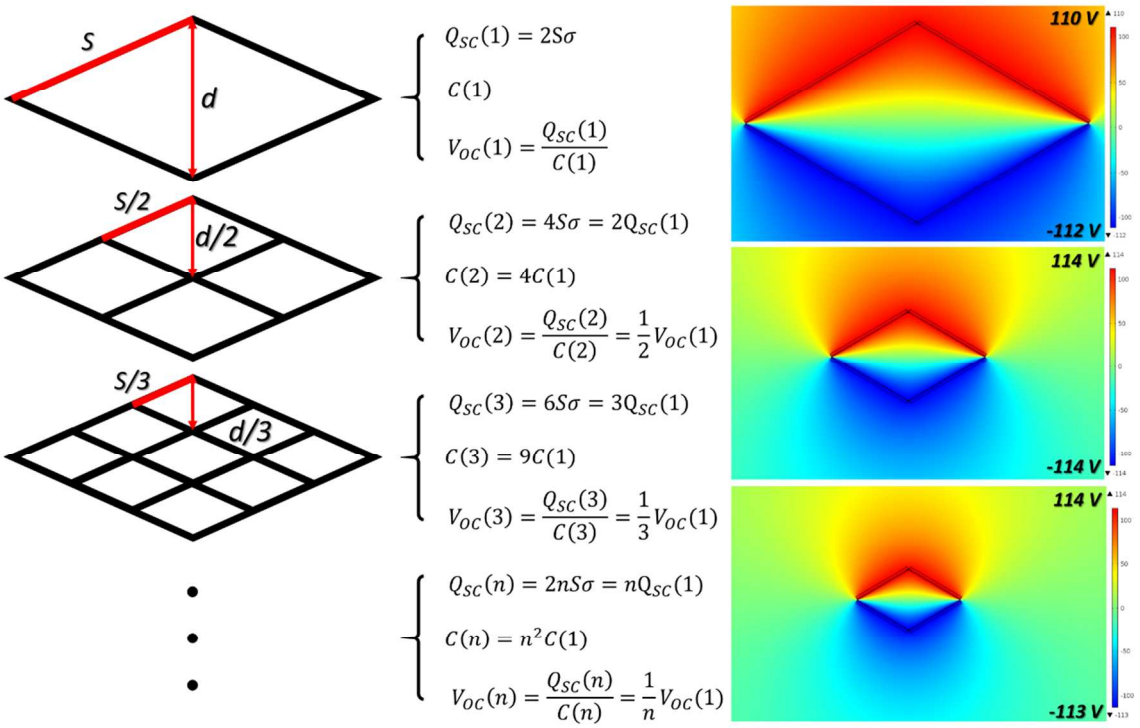
In this analysis, three kinds of PC-TENGs (1 × 1 unit, 2 × 2 units and 3 × 3 units) were employed for further deriving the general relationship among output charge, voltage and capacitance. Here, we define some assumptions for this numerical analysis at beginning. First, we set contact state as the equilibrium state once the PC-TENG have being fully compressed, thus the open circuit voltage can be regarded as the potential difference of the top and bottom electrode when PC-TENG getting fully released. Secondly, $Q_{SC}(n)$ represents the transferred charge quantity for PC-TENG (n is the integrated unit number), C(n) represents the capacitance of PC-TENG, and $V_{OC}(n)$ represents the open circuit voltage of PC-TENG. In addition, S and d stands for the surface area of each paper-cutting tribo-layer (σ is the surface charge density) and the effective gap between top and bottom layers of PC-TENG with 1 × 1 unit, respectively.

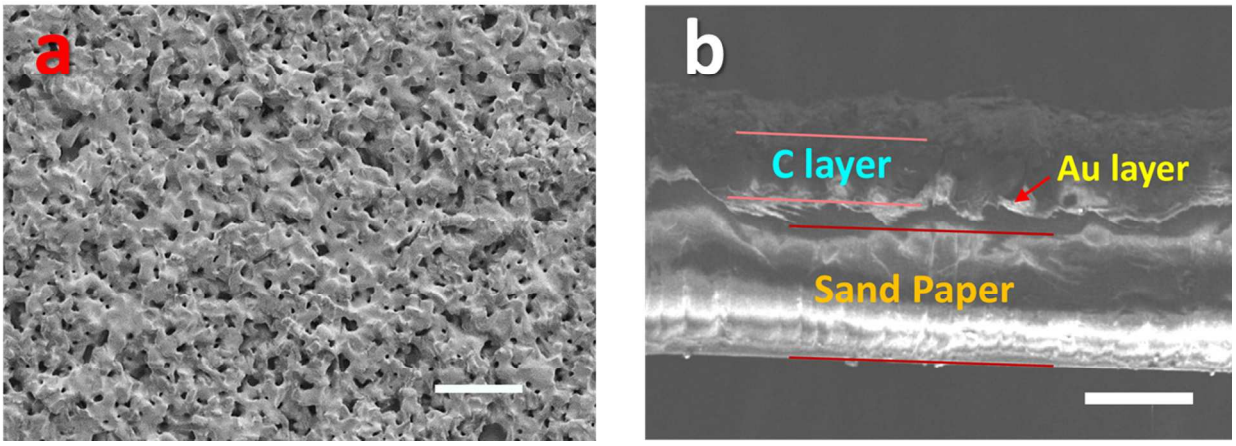
As defined above, V_{OC} for each PC-TENG can be expressed as $V_{OC}(n) = Q_{SC}(n)/C(n)$. For the case of PC-TNEG with 1 × 1 unit, the charge quantity $Q_{SC}(1) = 2S\sigma$ should be transferred between two electrodes once the tribo-layers get separated. The value of capacitance can be presented as C(1). It can be proven by COMSOL (set the same amount of charge on the electrodes) that the rhombic-shaped capacitance would stay constant when it being proportionally magnified or minified. Similarly, $Q_{SC}(2) = 2Q_{SC}(1)$, $Q_{SC}(3) = 3Q_{SC}(1)$ and $C(2) = 2^2C(1)$, $C(3) = 3^2C(1)$ can be easily obtained. Meanwhile, $V_{OC}(2) = V_{OC}(1)/2$ and $V_{OC}(3) = V_{OC}(1)/3$ can also be derived. In general, we can derive the universal equations for rhombic-shaped TENG:

$$Q_{SC}(n) = n\,Q_{SC}(1)$$

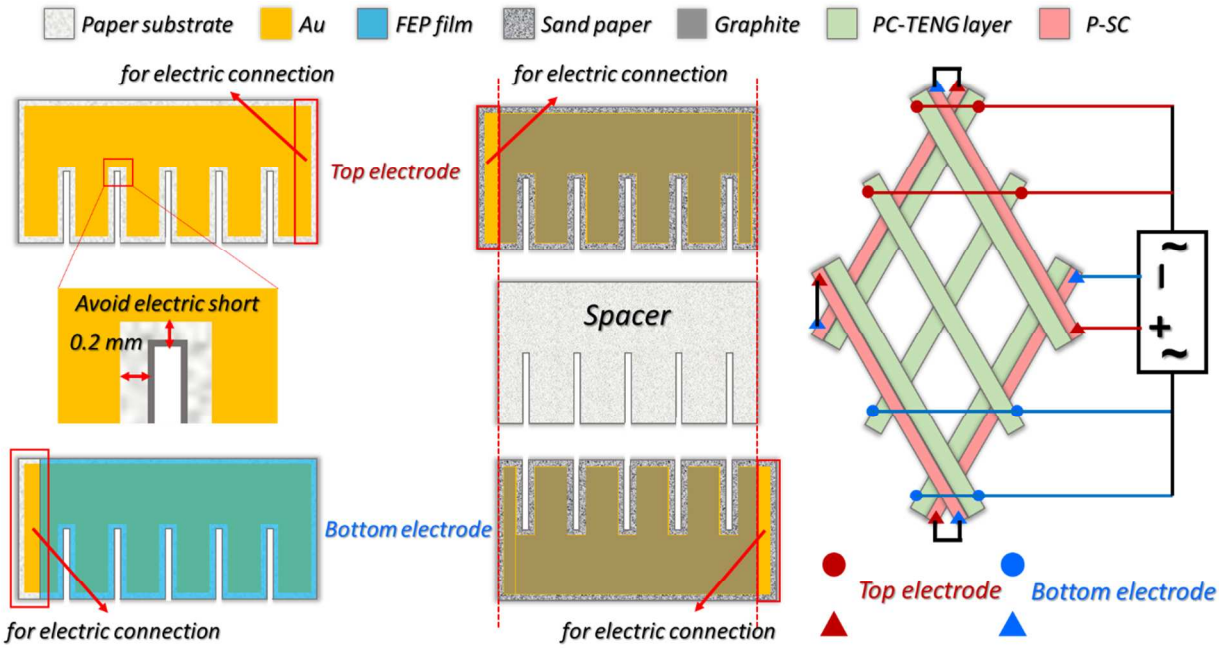
$V_{OC}(n) = V_{OC}(1)/n$.

Which indicate that total charge output can be proportionally enhanced with increasing of integrated units. Meanwhile, the voltage output can be reciprocally reduced. Since the energy output E(n) is related to $Q_{SC}(n) \times V_{OC}(n)$, the theoretical power output for PC-TENG would not be changed with different integrated unit numbers. The corresponding schemes and expressions are presented below.

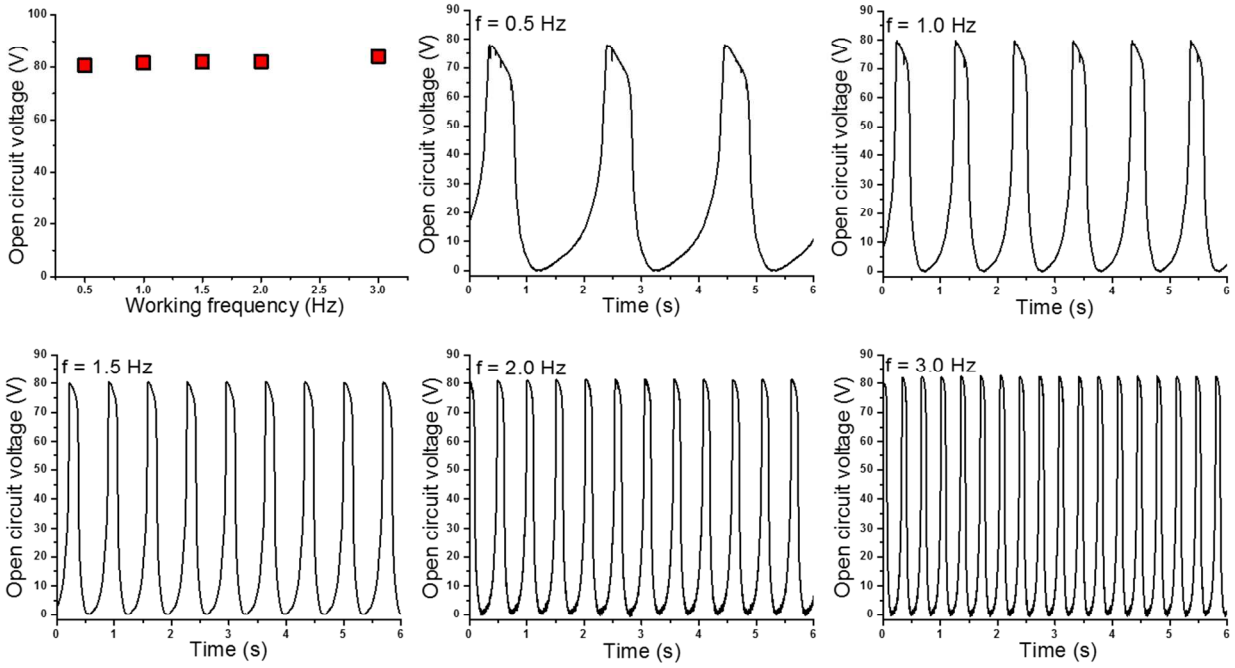




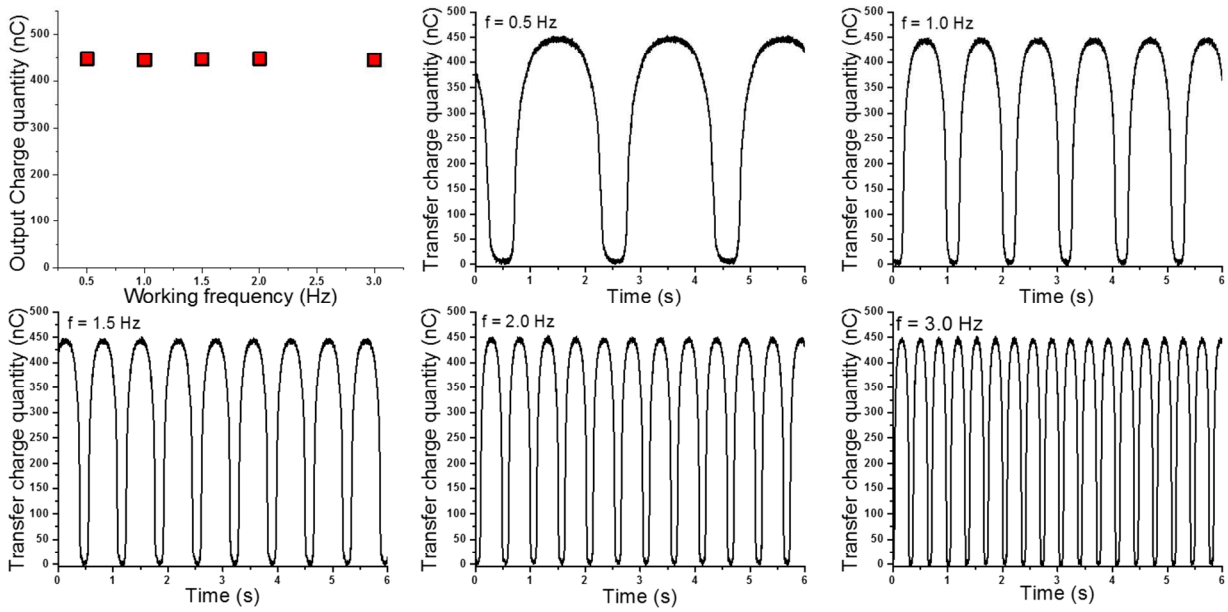
Supporting Information S1. a) SEM image of the surface of the sand paper. b) SEM image of the cross section of the graphite based electrode for P-SC.



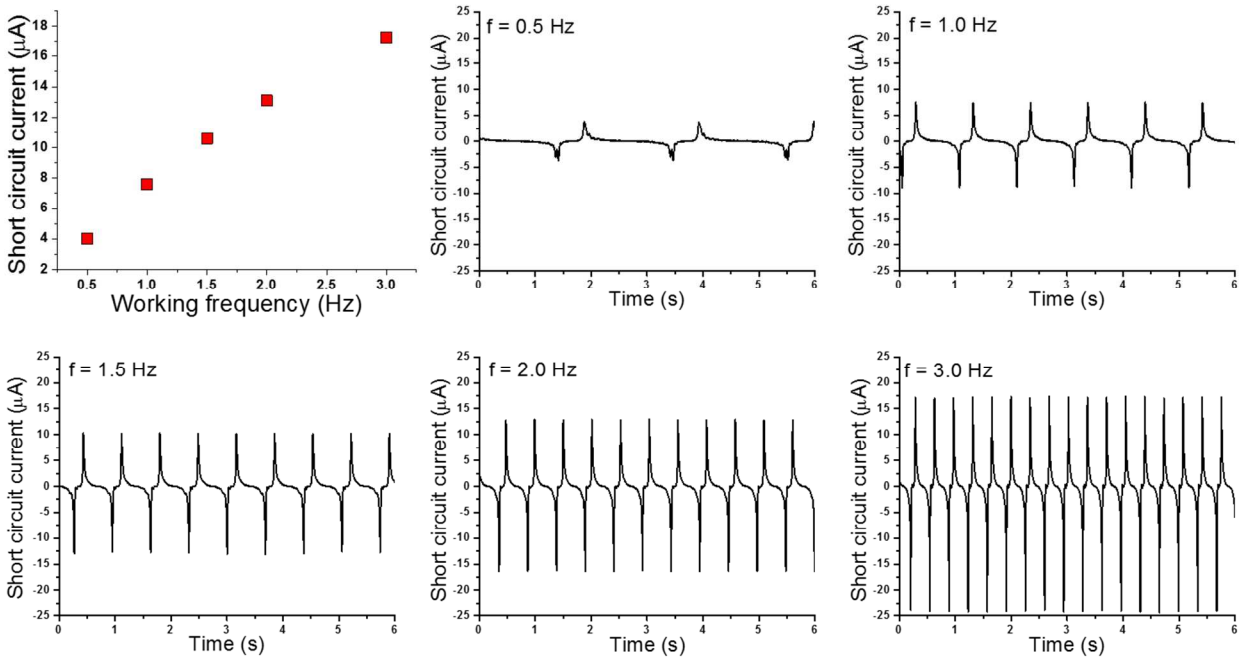
Supporting Information S2. The electric connection design and schematic illustration of PC-TENG.



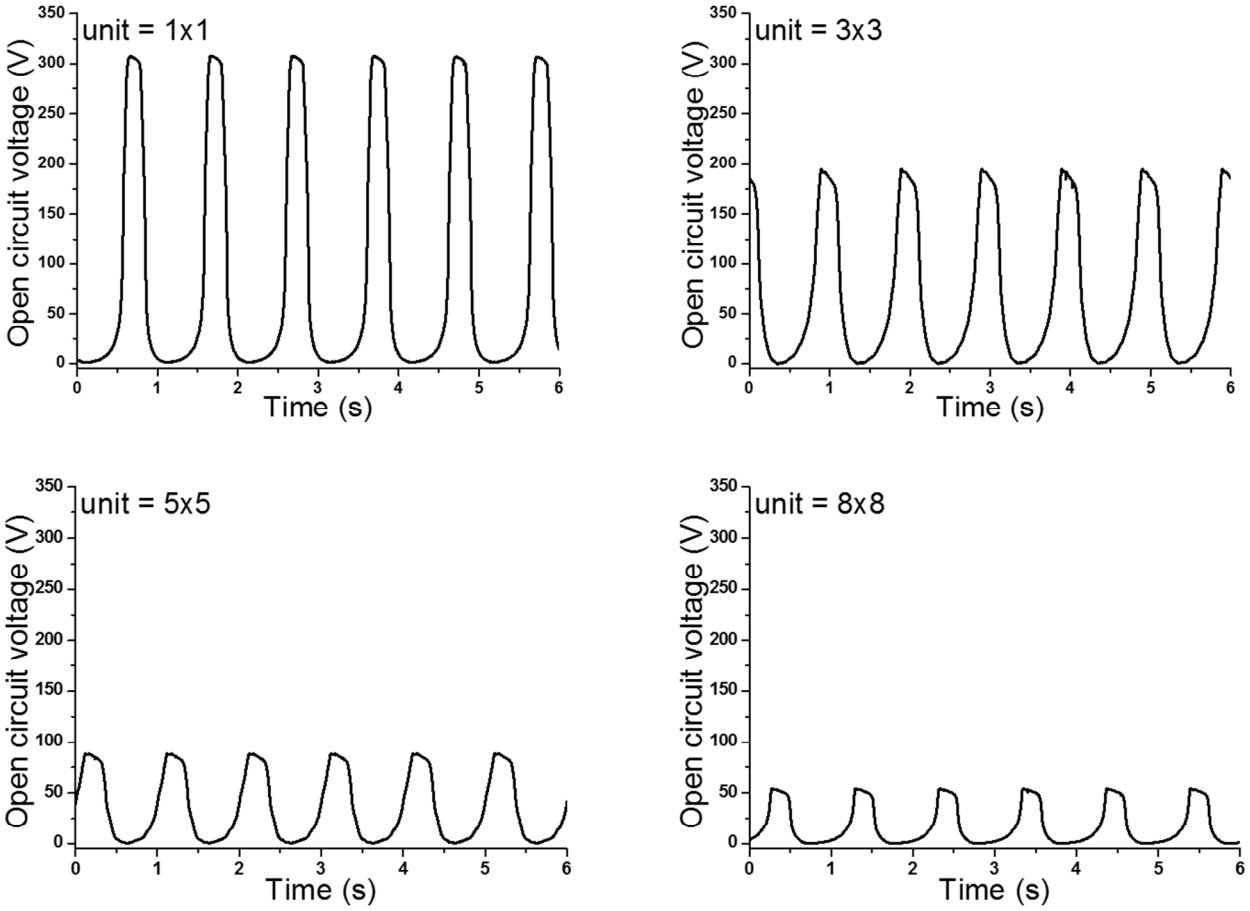
Supporting Information S3. The output open circuit voltage curves of PC-TENG (unit=5×5) under various working frequency.



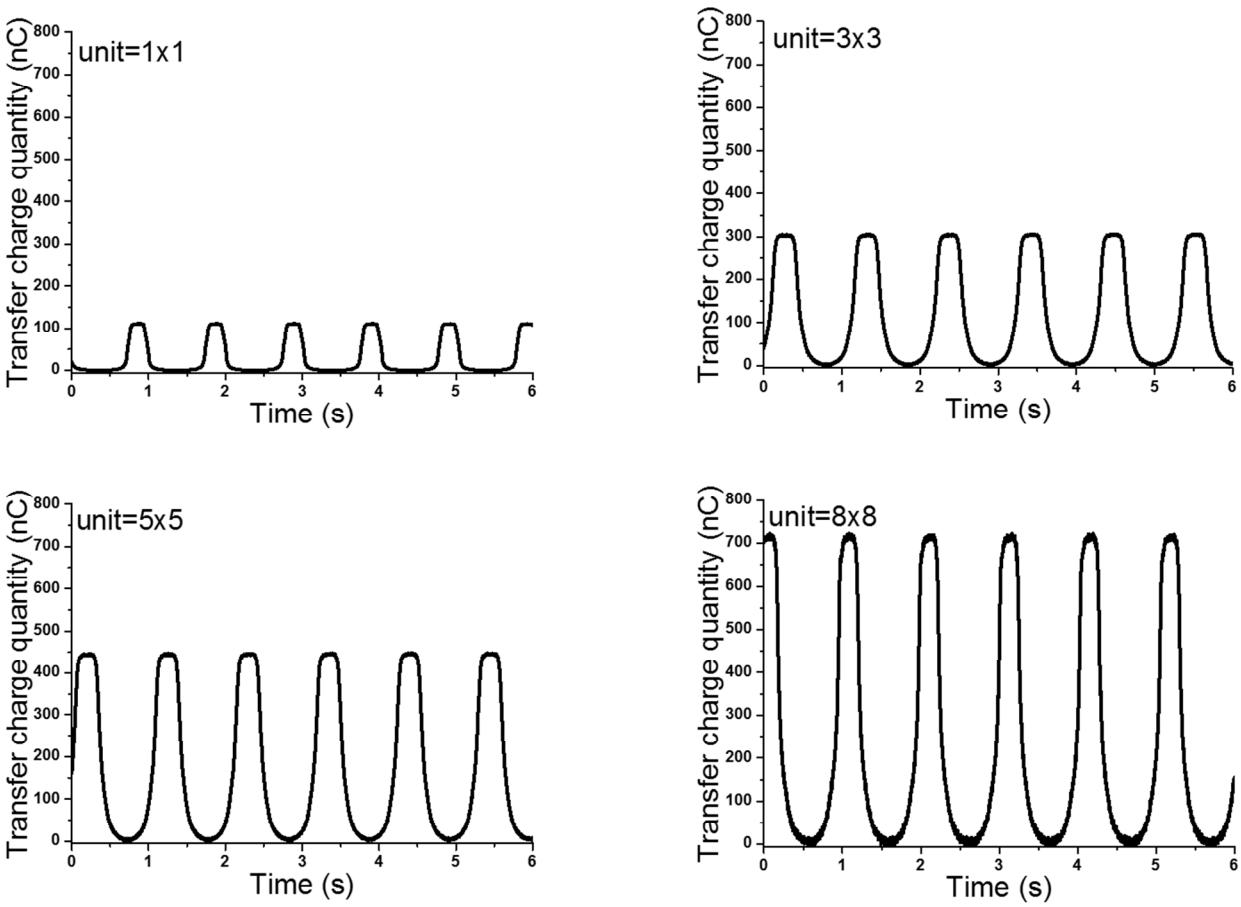
Supporting Information S4. The output charge curves of PC-TENG (unit=5×5) under various working frequency.



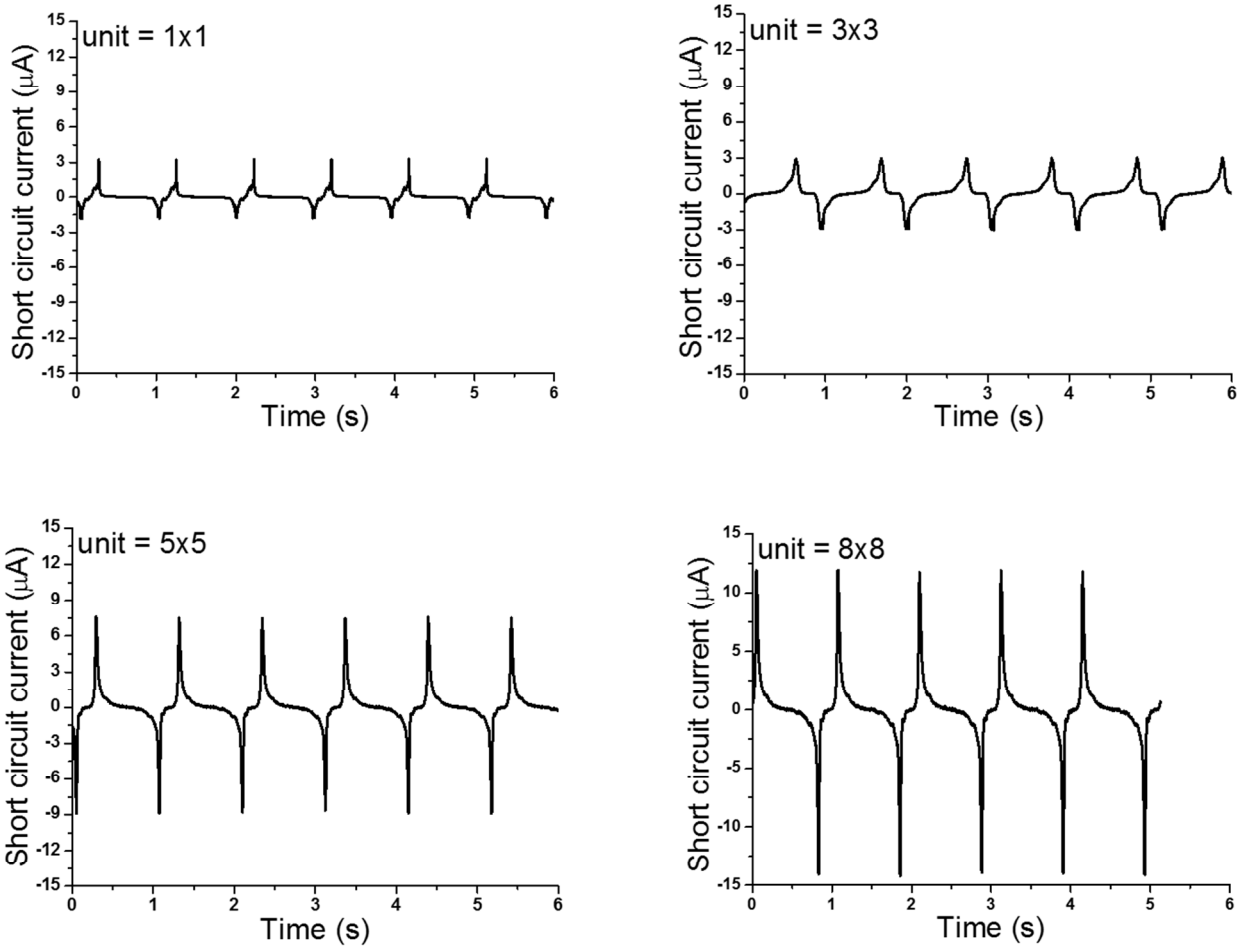
Supporting Information S5. The output short circuit current curves of PC-TENG (unit=5×5) under various working frequency.



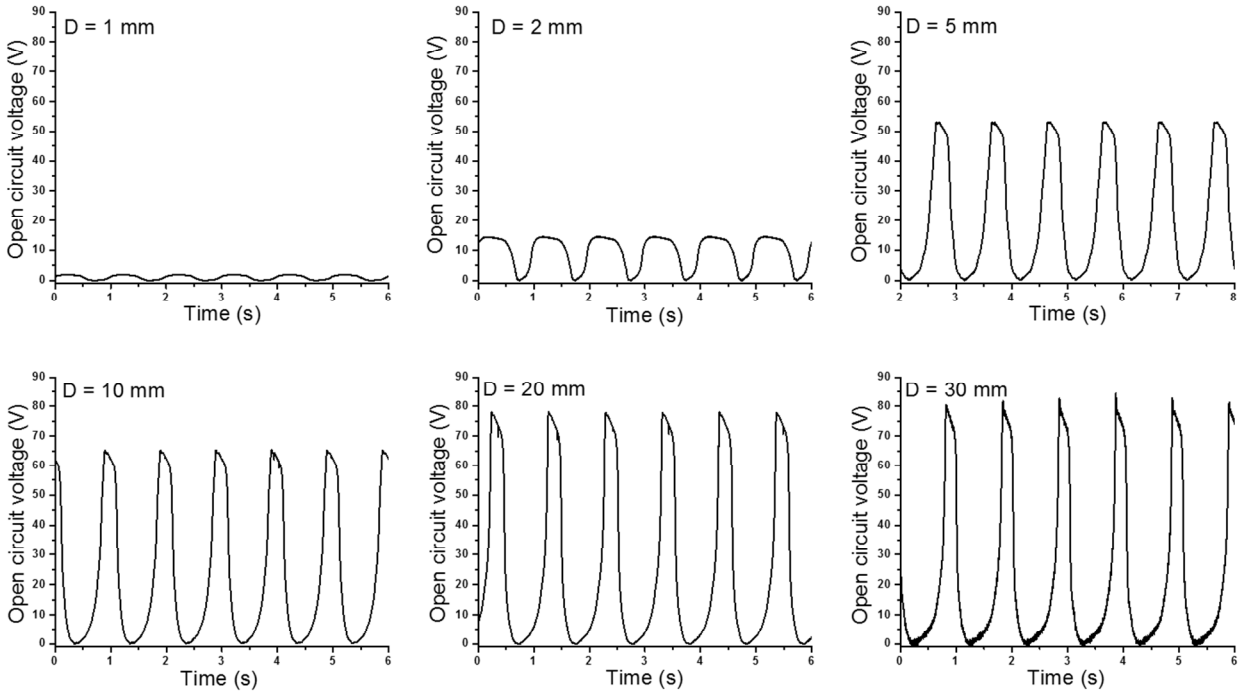
Supporting Information S6. The output open circuit voltage curves of PC-TENG with different unit numbers (working frequency=1.0 Hz).



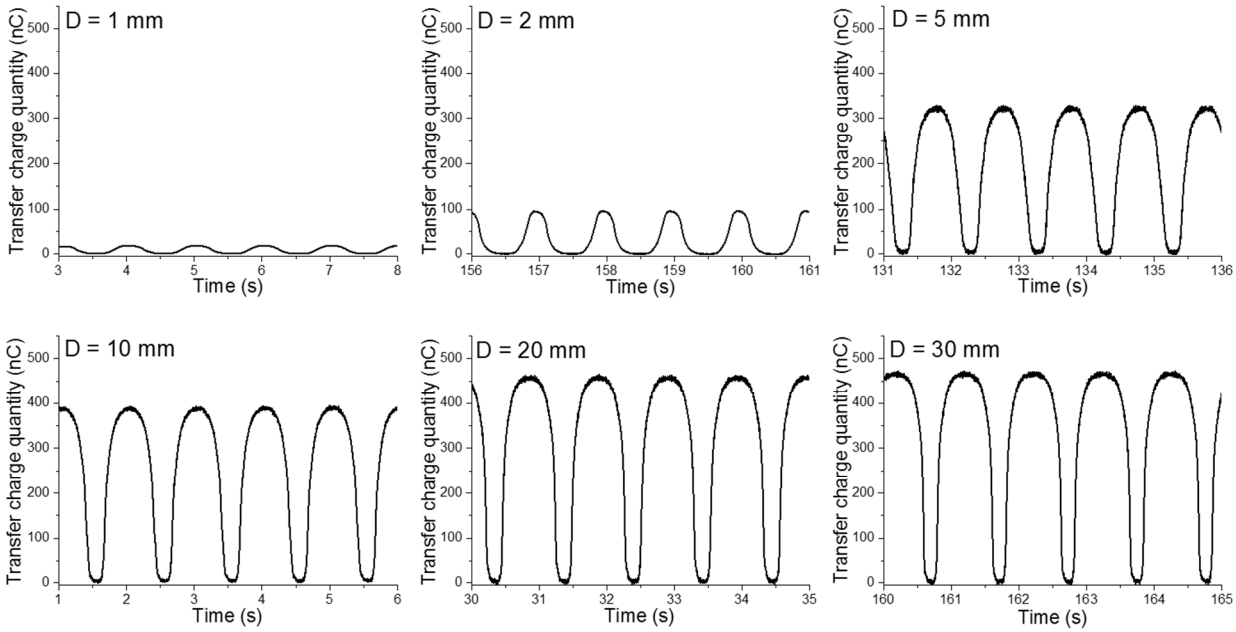
Supporting Information S7. The output charge curve of PC-TENG with different unit numbers (working frequency=1.0 Hz).



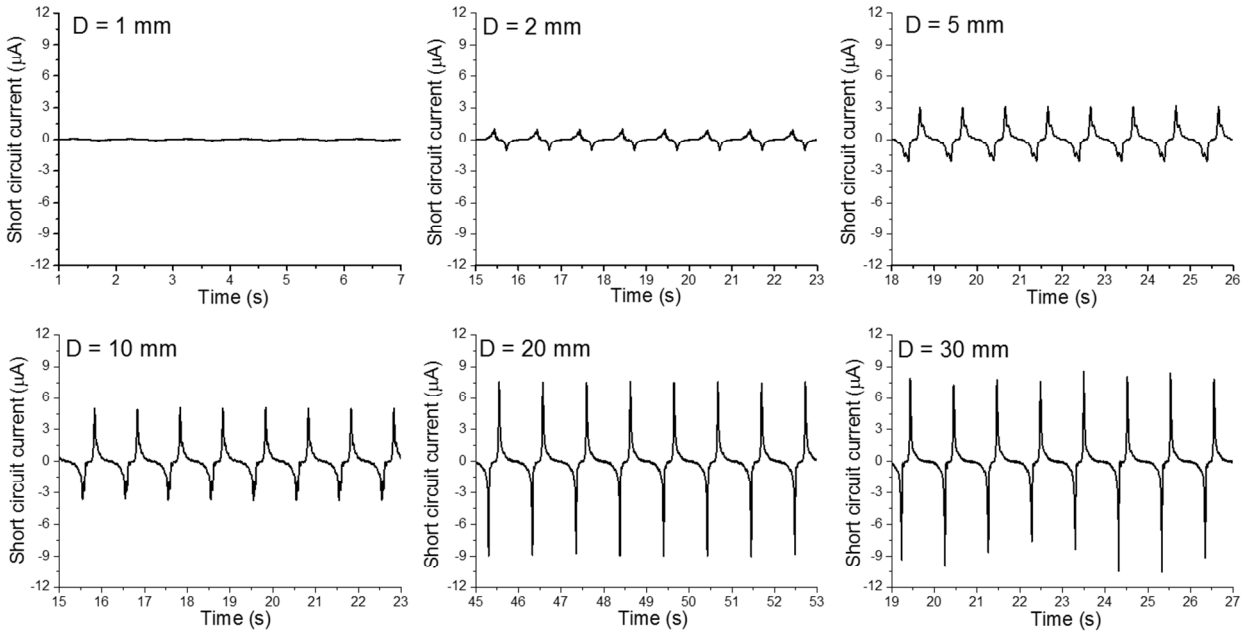
Supporting Information S8. The output short circuit current curves of PC-TENG with different unit numbers (working frequency=1.0 Hz).



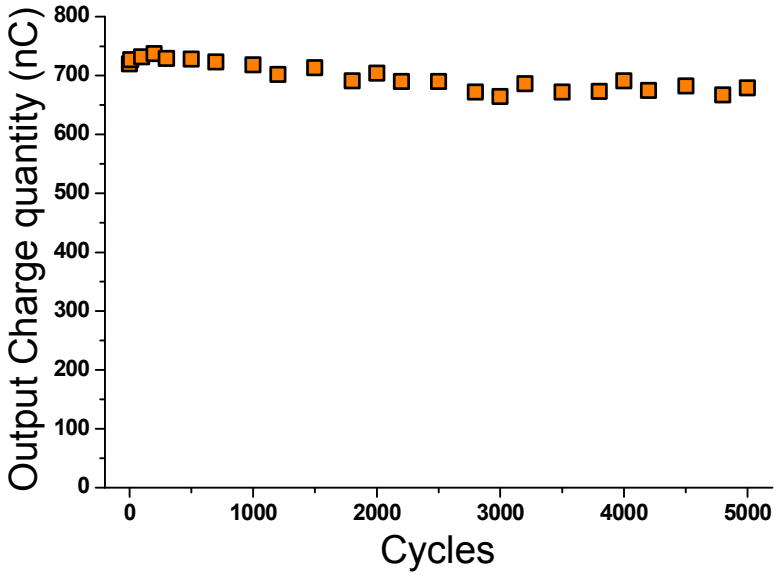
Supporting Information S9. The output open circuit voltage curves of PC-TENG with different separation distance (working frequency=1.0 Hz).



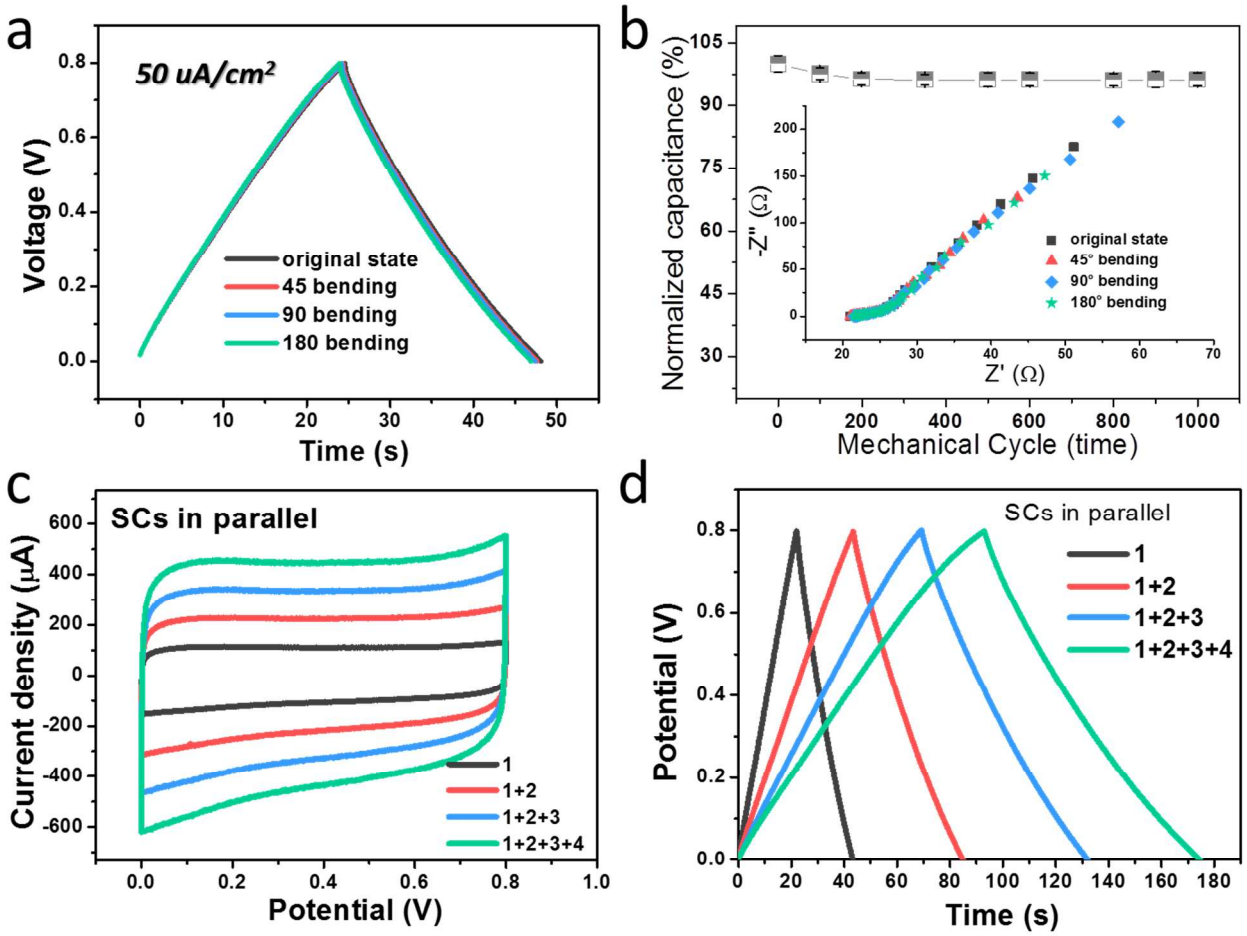
Supporting Information S10. The output charge curves of PC-TENG (unit=5×5) with different separation distance (working frequency 1.0 Hz).



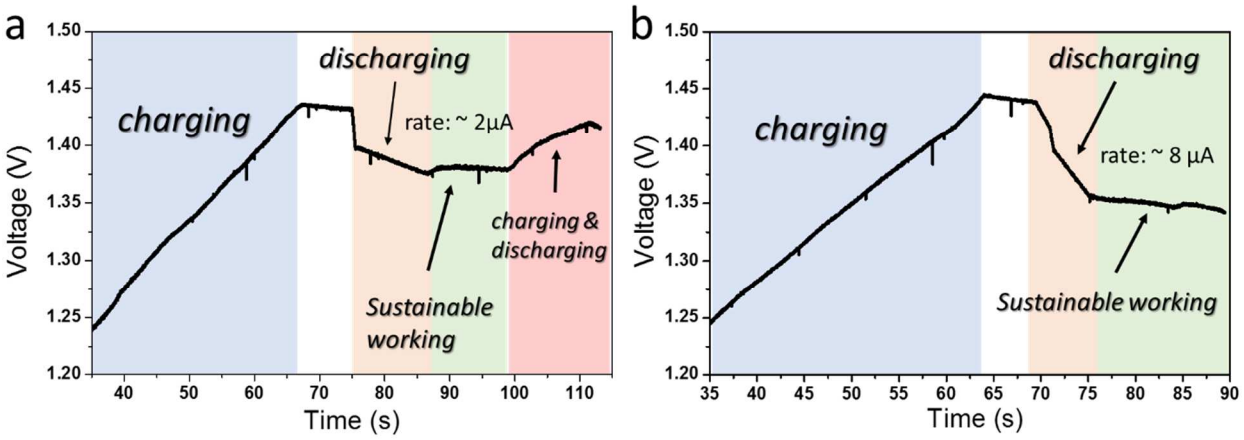
Supporting Information S11. The output short circuit current curves of PC-TENG (unit=5×5) with different separation distance (working frequency=1.0 Hz).



Supporting Information S12. The stability test of PC-TENG during continuously 5,000 working cycles.



Supporting Information S13. a) the CD curve of the P-SC under various bending angle. b) the mechanical durability of the P-SC during 1,000 continuously bending and releasing cycles. The inset shows the ESI spectrum of the P-SC under different bending state. c) the CV curve and d) CD curve of P-SCs connected with different units in parallel.



Supporting Information S14. The $V-t$ curve of the PC-SCPU under various operating modes for driving up the a) electric watch and b) temperature sensor.