Supplementary Information

Sinusoidal alternating output of a triboelectric nanogenerator array with asymmetric-layer-based units

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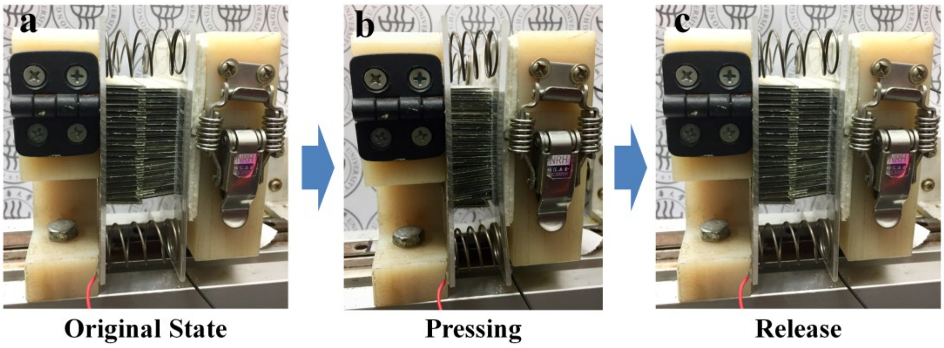

Figure S1 Digital photographs of the TENG array in the (a) original, (b) pressing, and (c) release states when it is tested.

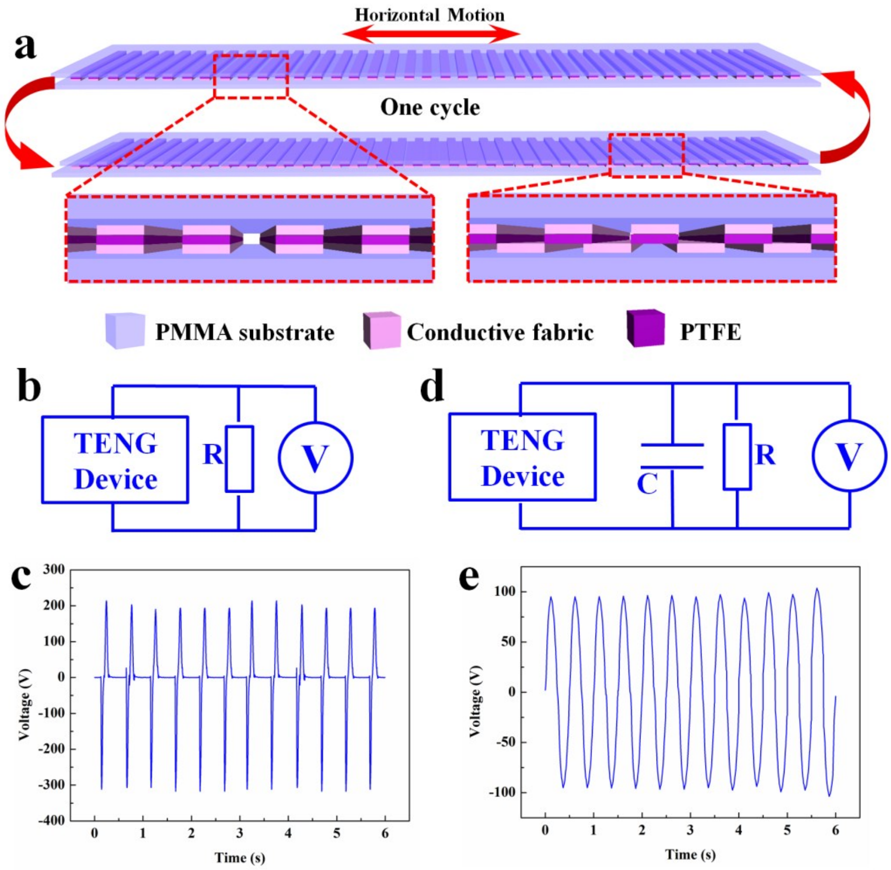

Figure S2 (a) Schematic diagram of a sliding-model TENG device consisting of 20 TENG units. (b) The circuit diagram and (c) corresponding output voltage of this TENG device. (d) The circuit diagram and (e) corresponding output voltage of this TENG device connecting with an external capacitance of 4.7 nF. The load resistance is 1 MΩ, and the testing frequency is 2 Hz.

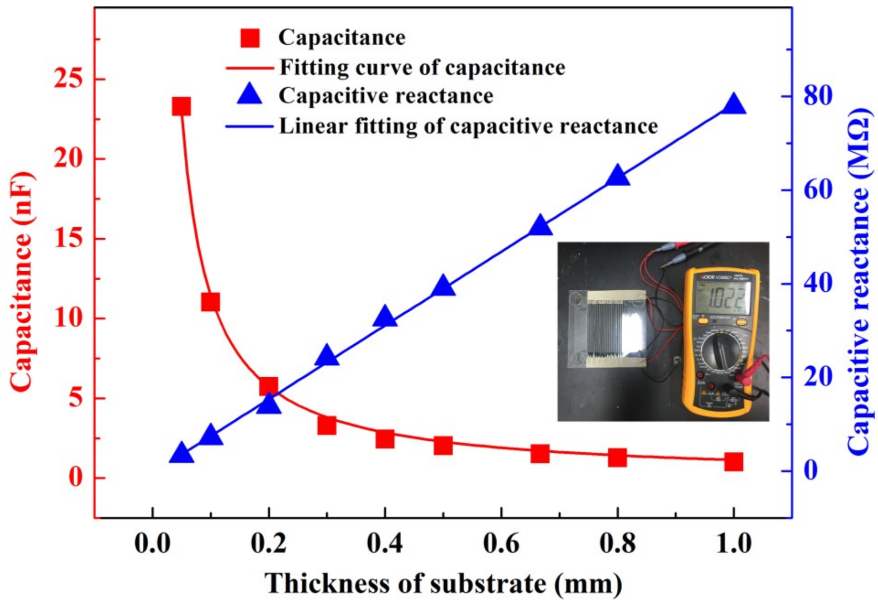

Figure S3 The internal capacitances and calculated capacitive reactance of TENG arrays with different thickness of substrates in units. Fitting curve for capacitance is shown by red, and linear fitting for calculated capacitive reactance is the blue one. The digital photograph shows the capacitance of the TENG array, in which the thickness of substrate is 1 mm.

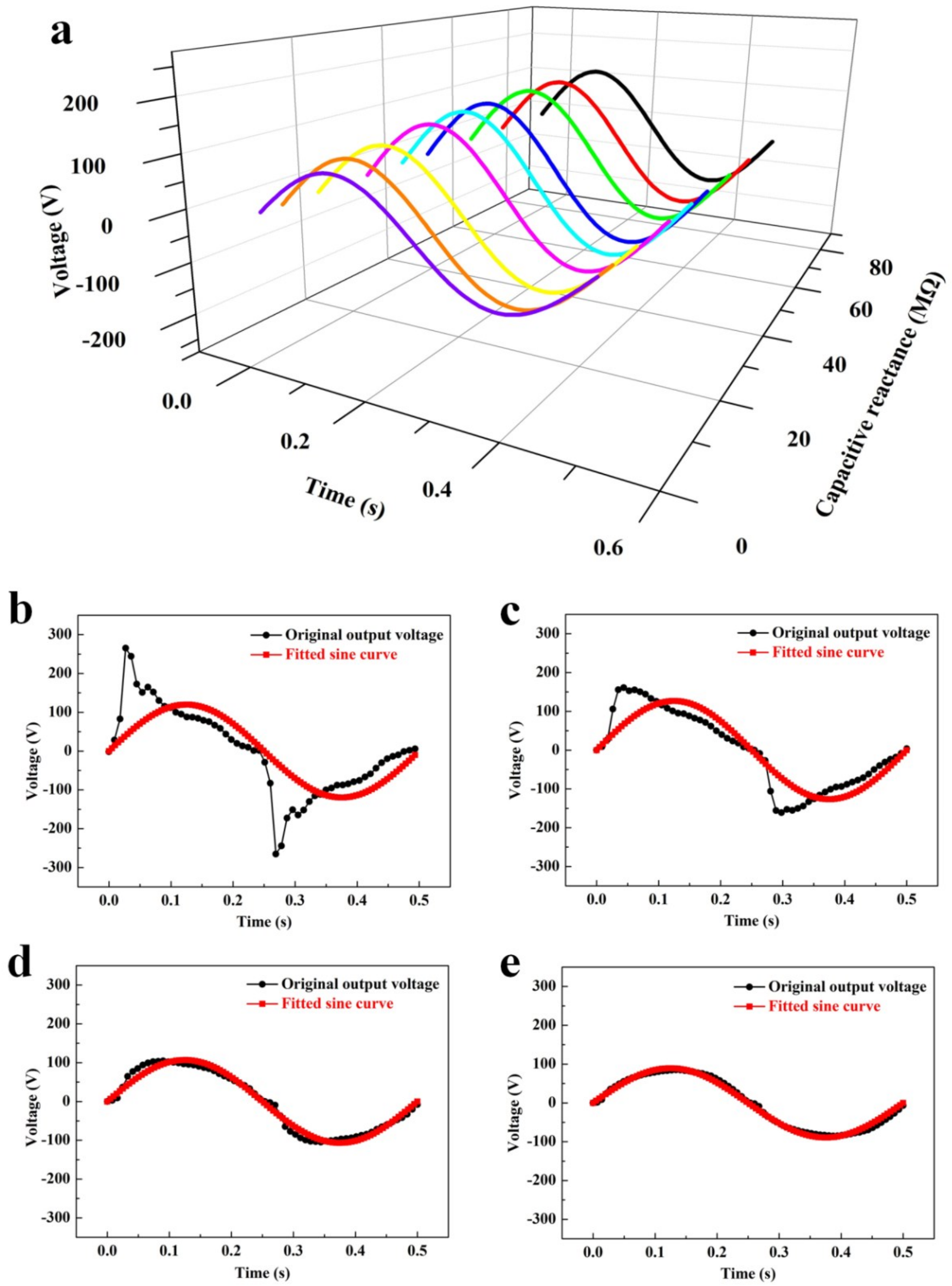

Figure S4 (a) The sinusoidal fitting curves for output voltages of the TENG arrays with different internal capacitances in one cycle. (b) - (e) Output voltages waveforms (black) and their sinusoidal fitting curves (red) of the TENG arrays with internal capacitive reactance of 78, 39, 14 and 3.4 MΩ in one cycle. The external load is 1 MΩ, and the testing frequency is 2 Hz.

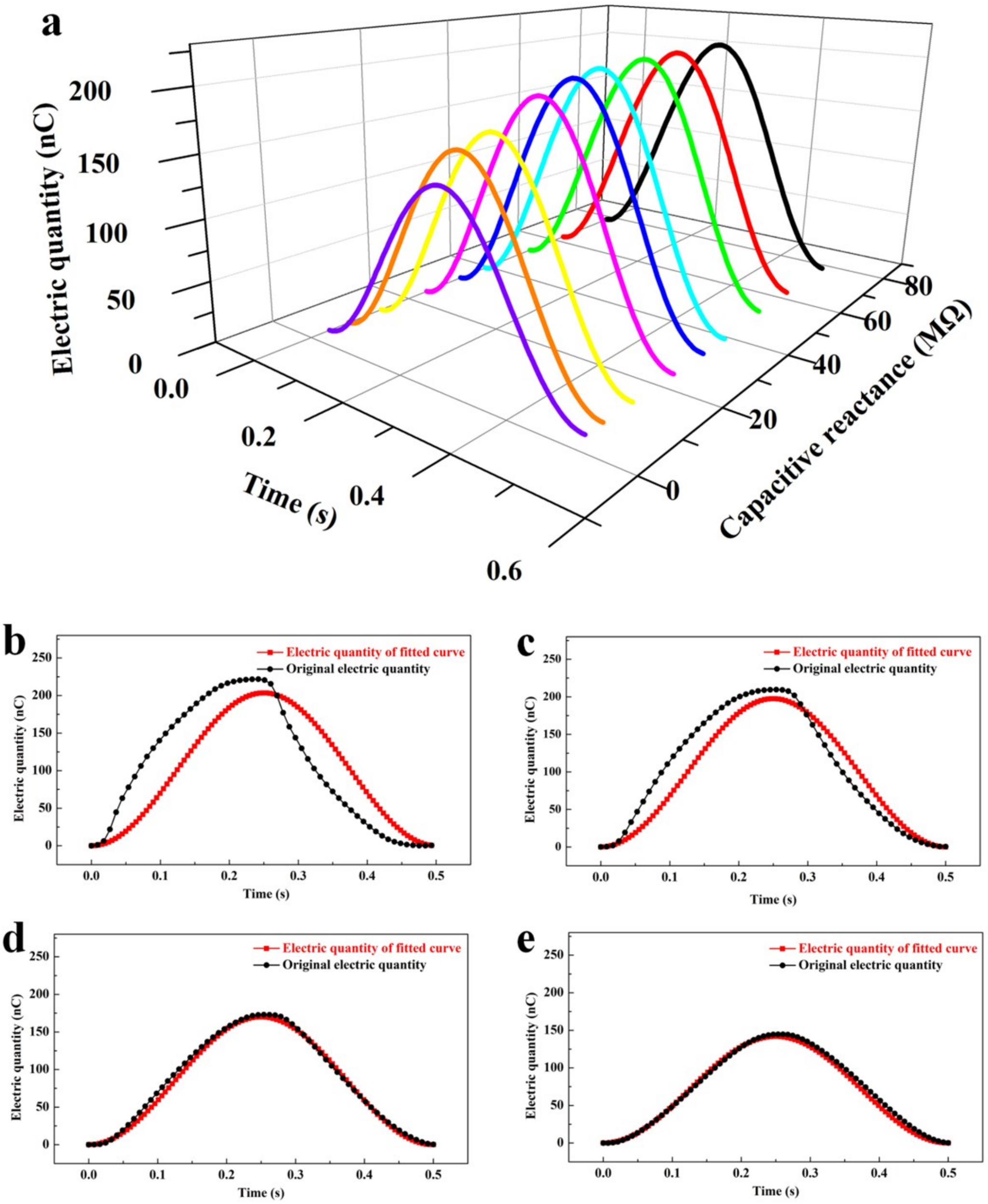

Figure S5 (a) The cosinoidal fitting curves for transfer charge of TENG arrays with different internal capacitances in one cycle. (b) - (e) Transfer charge waveforms (black) and their cosinoidal fitting curves (red) of the TENG arrays with internal capacitive reactance of 78, 39, 14 and 3.4 MΩ in one cycle. The external load is 1 MΩ, and the testing frequency is 2 Hz.

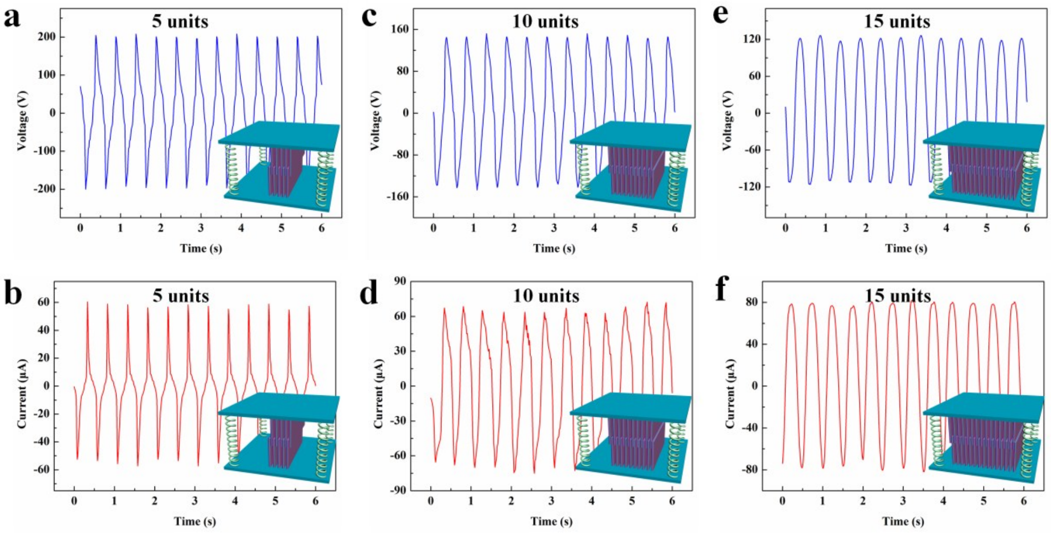

Figure S6 The output performances of TENG arrays containing different numbers of units. (a) The output voltage and (b) current waveforms of TENG array assembled with 5 units. (c) The output voltage and (d) current waveforms of TENG array assembled with 10 units. (e) The output voltage and (f) current waveforms of TENG array assembled with 15 units. The load resistance is 1 MΩ, and testing frequency is 2 Hz.

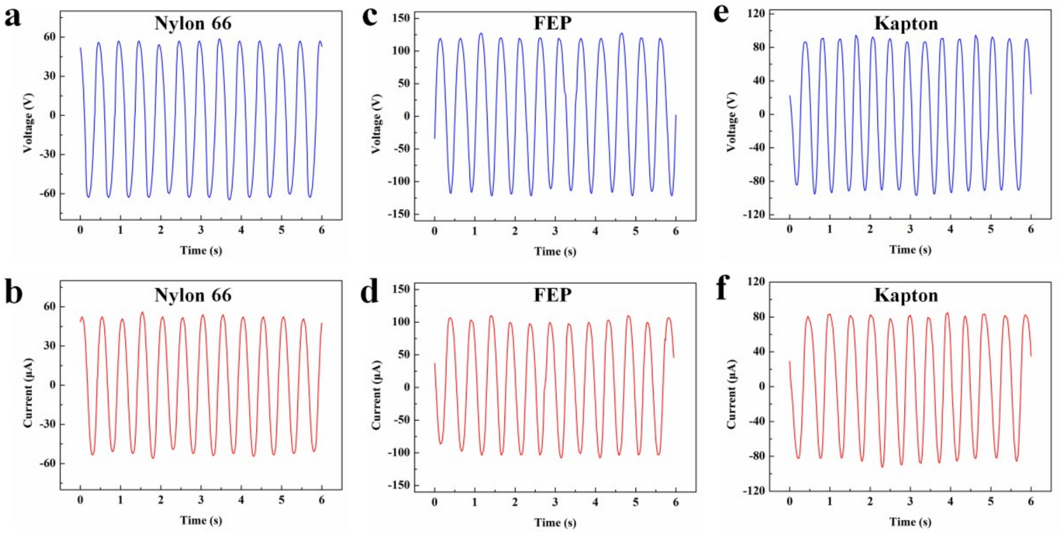

Figure S7 The output performances of TENG arrays containing asymmetric-layer-based units with different tribo-materials. (a) The output voltage and (b) current waveforms of TENG array assembled with polyamide 66 (Nylon 66) based units. (c) The output voltage and (d) current waveforms of TENG array assembled with fluorinated ethylene propylene (FEP) based units. (e) The output voltage and (f) current waveforms of TENG array assembled with polyimide (Kapton) based units. The load resistance is 1 MΩ, and testing frequency is 2 Hz.

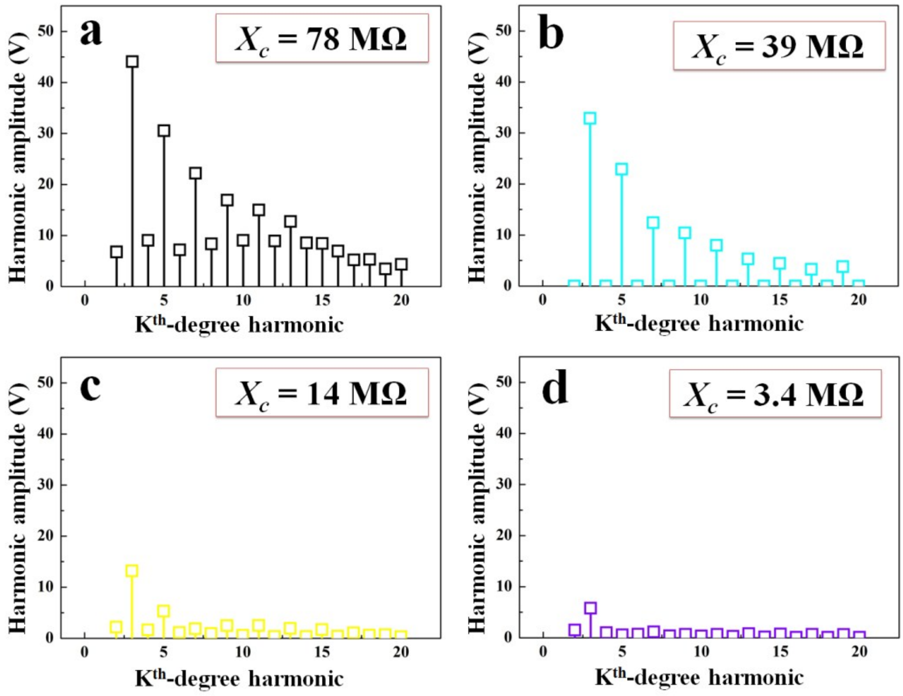

Figure S8 Amplitude spectrograms of harmonic with degree from 2nd to 20th (K = 2 to 20), calculated from sinusoidal Fourier transform of the output voltages of the TENG arrays with internal capacitive reactance values of (a) 78, (b) 39, (c) 14, and (d) 3.4 MΩ.

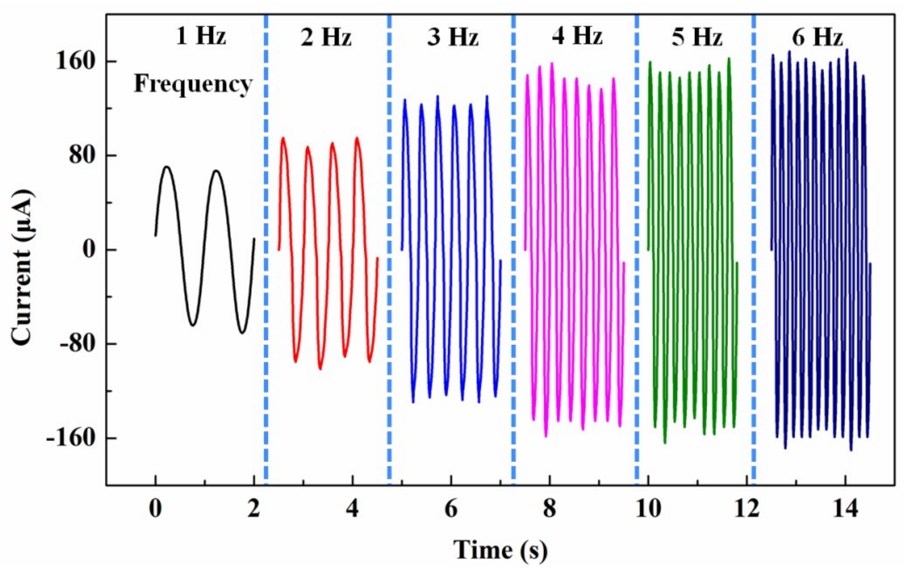

Figure S9 Current outputs of the optimized TENG array under different frequencies.

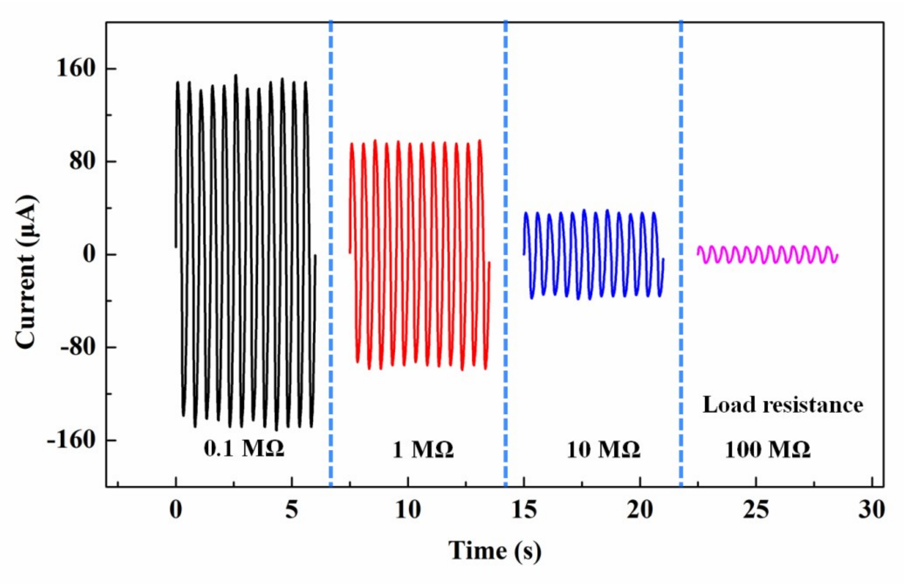

Figure S10 Current outputs of the optimized TENG array under different external load resistances.

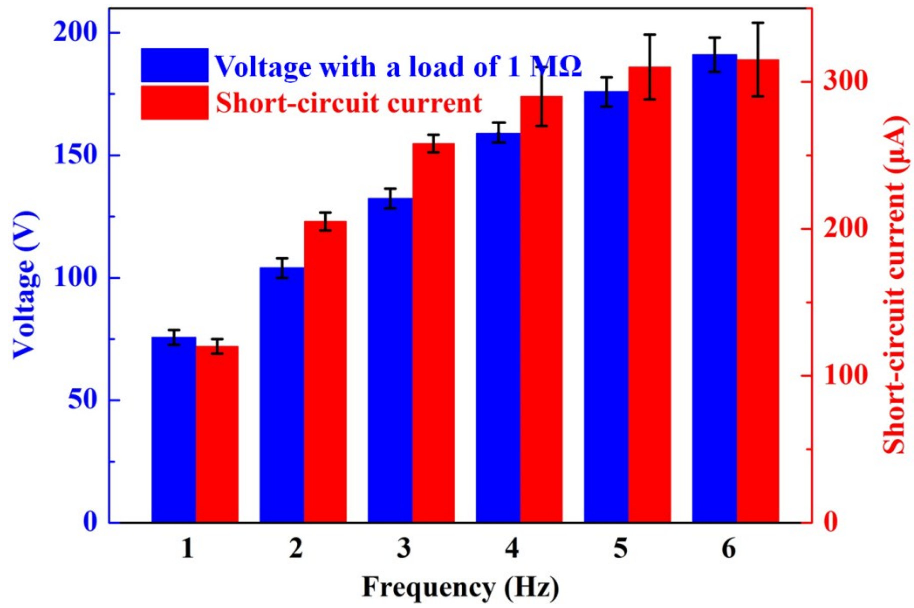

Figure S11 The statistical results for voltages with a load of 1 MΩ and short-circuit currents of the optimized TENG array at different frequencies.

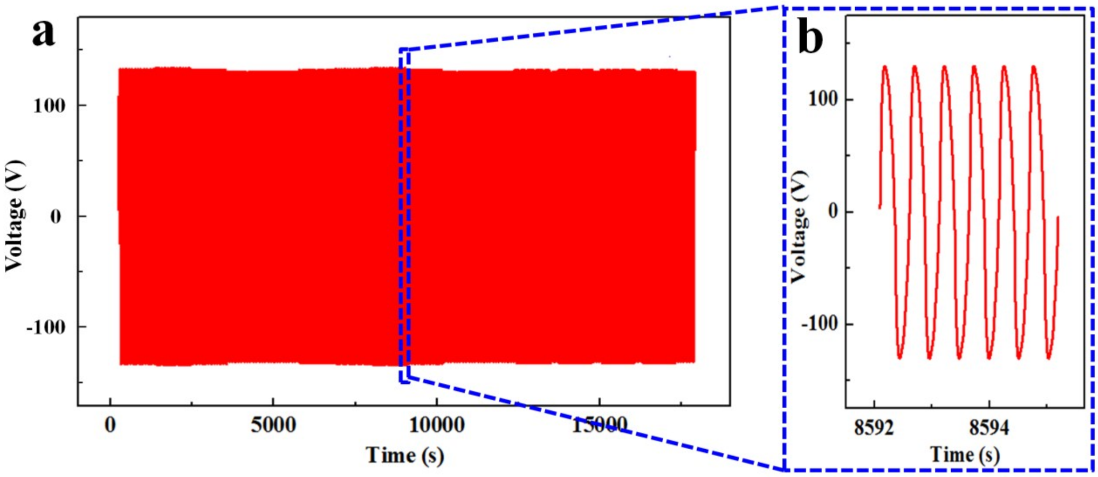

Figure S12 The stability testing for output voltage of the optimized TENG array with a load resistance of 1 MΩ at the frequency of 2 Hz. The test duration lasted 5 hours. The array presented good stability at the end of measurement.

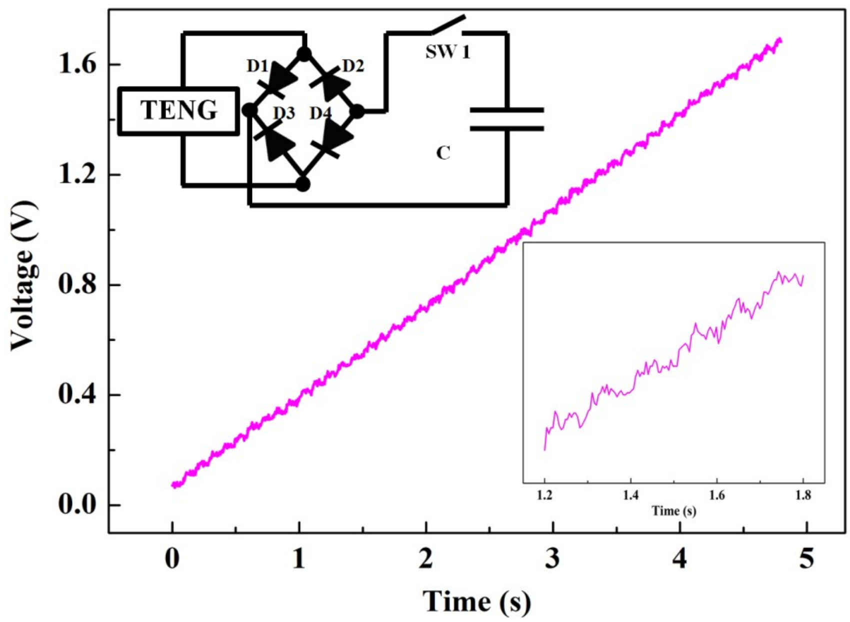

Figure S13 Charging curve of the optimal TENG array for an external capacitor of 100 μF. The potential of capacitor reaches 1.7 V after 5 seconds. Illustration in the upper left corner is the circuit diagram. Illustration in the lower right corner shows the detailed charging curve from 1.2 s to 1.8 s.

Note S1 Calculation of the capacitive reactance for the TENG array.

The capacitance C of the TENG array is described:

$$C = n\frac{\varepsilon S}{4\pi kd} \qquad \text{(S1)},$$

where n is the quantity of the asymmetric-layer-based triboelectric units in array, ε is dielectric constant of PMMA substrate, S is the friction area of one unit, k is electrostatic force constant, and d is the thickness of substrate.

The capacitive reactance X_C is described:

$$X_C = \frac{1}{2\pi Cf} \qquad \text{(S2)},$$

where f is frequency (here, the testing frequency is 2 Hz).

Table S1 The capacitances and calculated capacitive reactance of TENG array with various thicknesses of substrates in asymmetric-layer-based units.

Thickness of substrate d (mm)	Internal capacitance C_{int} (nF)	Internal capacitive reactance X_C (MΩ)
1.00	1.0	78
0.80	1.3	63
0.67	1.5	52
0.50	2.0	39
0.40	2.5	33
0.30	3.3	24
0.20	5.7	14
0.10	11.0	7.2
0.05	23.3	3.4

Video S1 A real-time live video of powering a lamp bulb with rated power of 3 W by the optimized TENG array, while subjecting it to continuous patting motion.