SUPPORTING INFORMATION

Wearable Triboelectric Sensors with Self-Powered Energy: Multifunctional Laser-Engraved Electrets to Activate Satellite Communication for Life Emergency Alert in Pandemics

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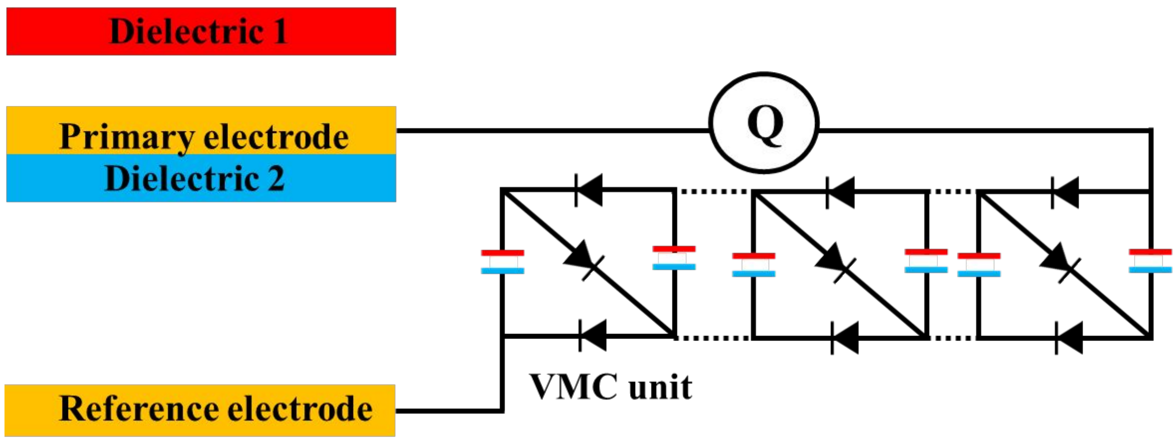

Figure S1. Schematic diagram of single-electrode TENG (SETENG) integrated with voltage multiplier units (VMC) for accelerated charge accumulation.

The calculation of fast charge accumulation in SETENG was adapted from the previous publication of two-electrode mode TENG.[1] As demonstrated in Figure S1, the capacitance and charge quantity of single-electrode TENG (SETENG) and capacitors are denoted by C, Q and C_o , Q_o, respectively during its initial position. After a dielectric 1 contacted with the primary electrode that attached to the dielectric 2, the charge of SETENG is obtained as

$$\frac{Q_o}{C_o} = \frac{Q_1}{C} \quad (1)$$

$$Q_1 = \frac{CQ_o}{C_o} \quad (2)$$

During the first contact of SETENG after its original state, charge transferred from SETENG to the capacitors is $\frac{Q_1}{2}$. When TENG is separated, the charge transferring from the capacitors back to SETENG is Q_2, then the expression can be written as

$$\frac{Q_o + \frac{Q_1}{2} - Q_2}{C_o} = \frac{Q_2}{C} \quad (3)$$

$$Q_2 = \left(Q_o + \frac{Q_1}{2}\right) \cdot \left(1 + \frac{C_o}{C}\right)^{-1} \quad (4)$$

Equivalently, the charge transferred to SETENG for the second contact is Q_3. Later when they are separated, the charges from capacitors moved back to SETENG is $\frac{Q_3}{2}$, one can rewrite as

$$\frac{Q_o + \frac{Q_1}{2} + \frac{Q_2}{2} - Q3}{C_o} = \frac{Q_3}{C} \tag{5}$$

$$Q_3 = \left(Q_o + \frac{Q_1}{2} + \frac{Q_2}{2}\right) \cdot \left(1 + \frac{C_o}{C}\right)^{-1} \tag{6}$$

Similarly for n contacts by SETENG, one can find the relationship as

$$Q_n = \left(Q_o + \frac{Q_1}{2} + \frac{Q_2}{2} + \frac{Q_3}{2} \cdots + \frac{Q_{n-1}}{2}\right) \cdot \left(1 + \frac{C_o}{C}\right)^{-1}, for\ n \geq 2 \tag{7}$$

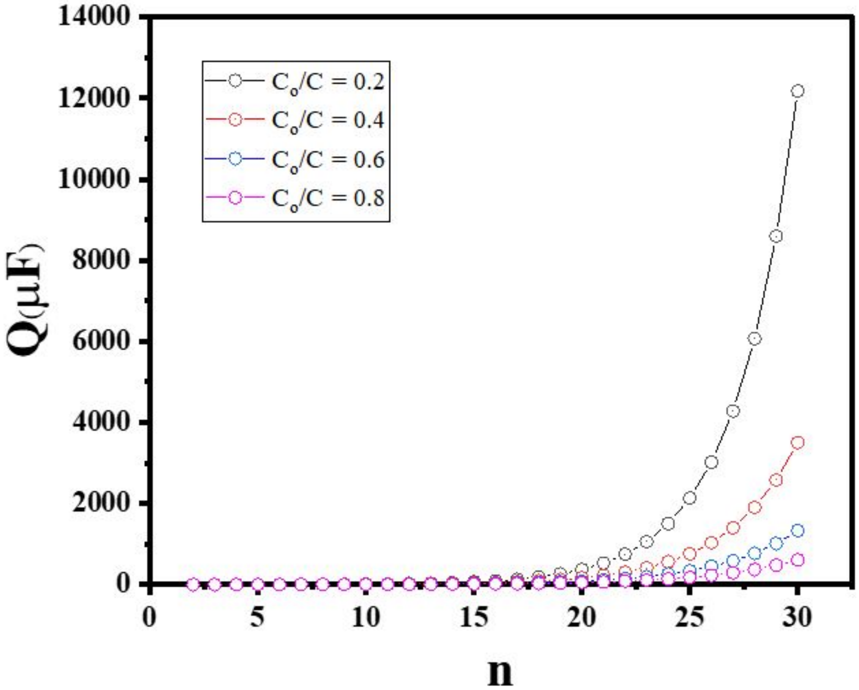

Figure S2. Theoretical calculation for accumulated charges by single-electrode TENG *vs.* the number of times of contact-separation at different ratios of C_o/C and Q_o = 1 μF.

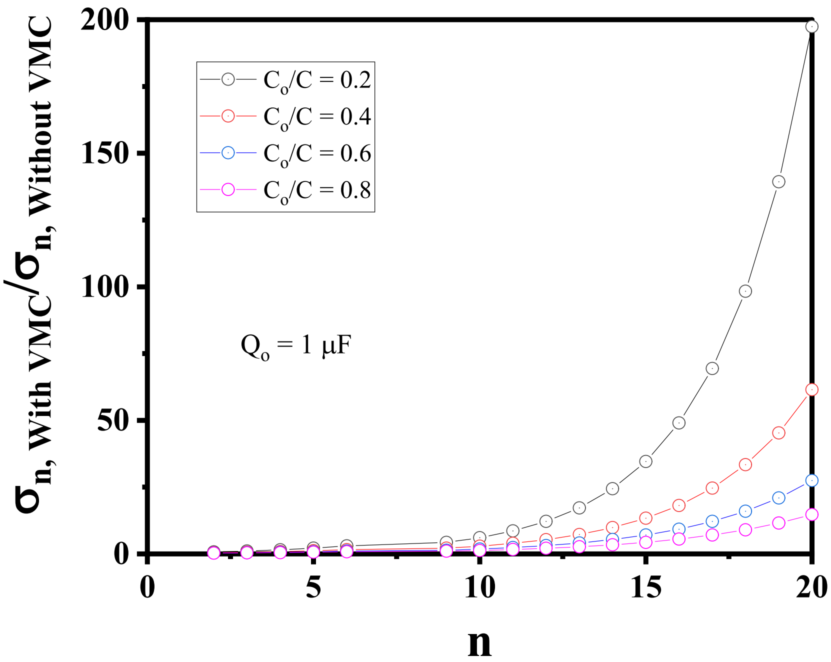

Figure S3. Theoretical calculation for a ratio between SETENG surface charge with and without-VMC circuit *vs.* the number of times of contact-separation at different ratios of C_o/C and Q_o = 1 μF.

The charge density of SETENG can be derived as

$$\sigma = \frac{\varepsilon_0 \varepsilon_r V}{d} \tag{8}$$

Where ε_o is the vacuum dielectric permittivity, ε_r denotes as relative permittivity, d is a separation distance, and V is the excitation voltage applied to TENG. Without the integration of VMC circuit, the SETENG surface charge with the number of times of contact-separation is define as

$$\sigma_{n,\,without\,VMC} = \frac{\varepsilon_0 \varepsilon_r Q_1}{dC} \tag{9}$$

Where in all cases, C is SETENG capacitance, while Q_1 is the charge quantity at the first contact-separation. It assumes that all charges from SETENG go through an energy harvesting system. For the case of VMC circuit integrated into SETENG, the surface charge with the number of times of contact-separation is described as

$$\sigma_{n,\,with\,VMC} = \frac{\varepsilon_0 \varepsilon_r Q_n}{dC} \tag{10}$$

Where Q_n is obtained from Equation (7) above.

The ratio of with and without-VMC SETENG surface charge can be written as

$$\frac{\sigma_{n,\,with\,VMC}}{\sigma_{n,\,without\,VMC}} = \frac{Q_n}{Q_1} \tag{11}$$

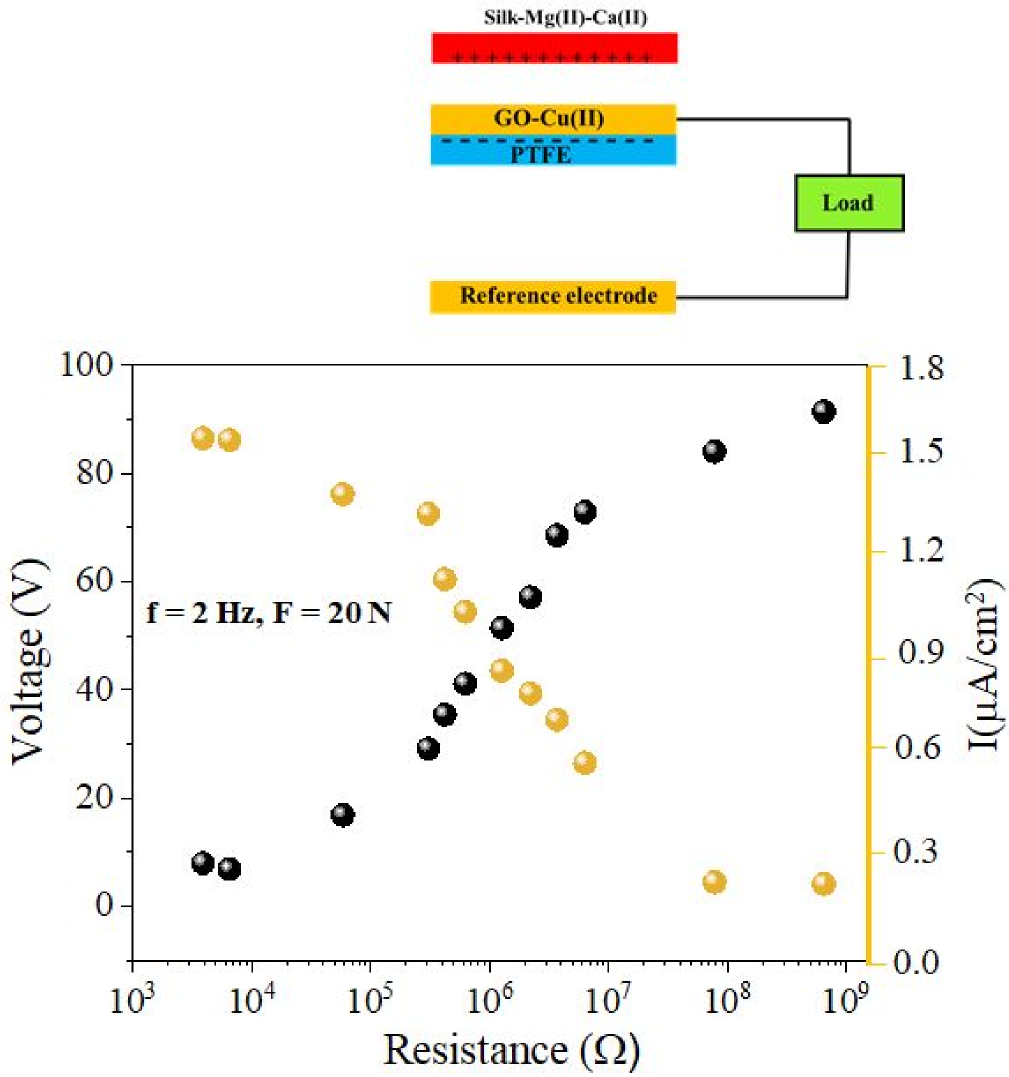

Figure S4. Output voltage and current density obtained for SETENG at different loading resistances.

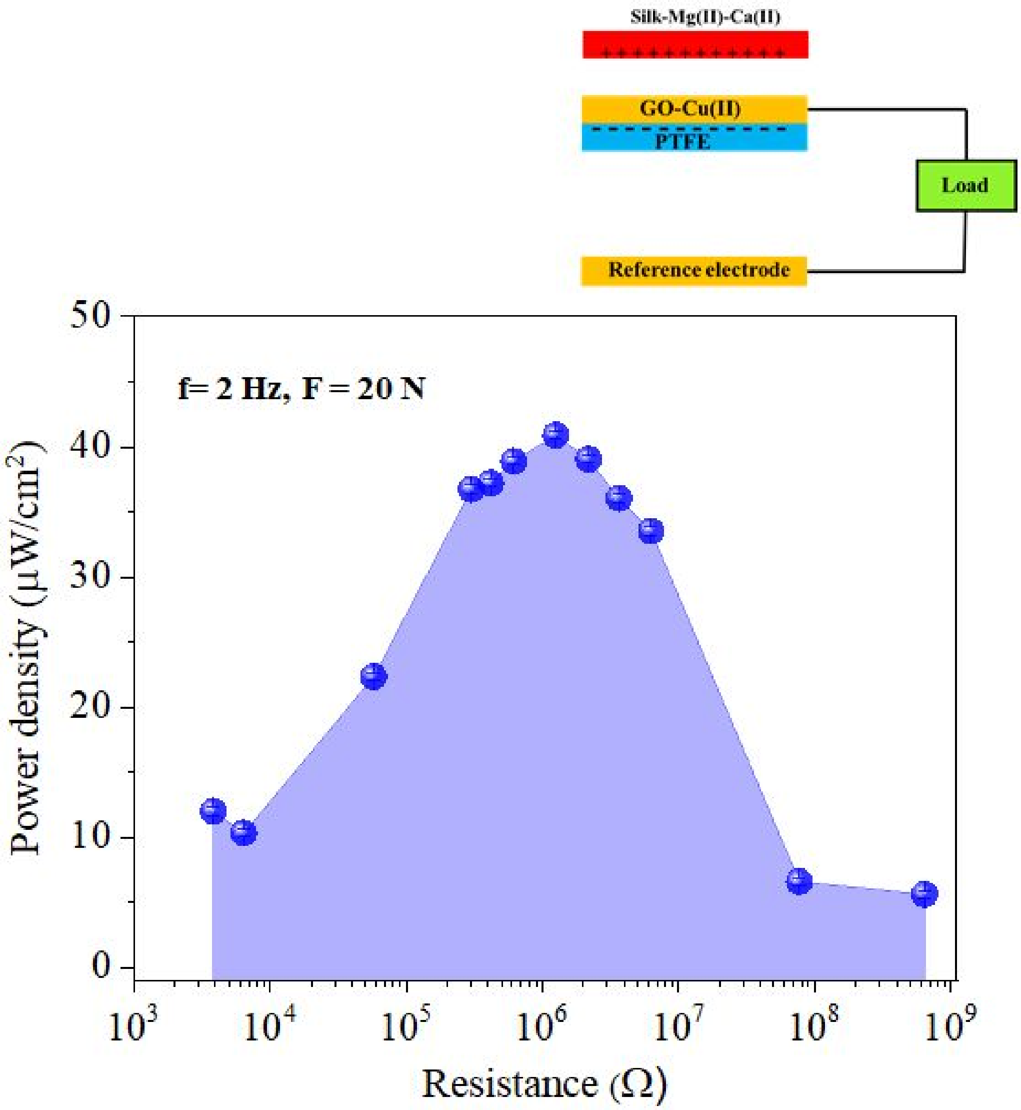

Figure S5. Output power density obtained for SETENG at different loading resistances.

The power density of the SETENG structure was obtained according to the expression as

$$P_{density} = \frac{P}{A} = \frac{I^2R}{A} \tag{12}$$

where $P_{density}$ is defined as the power density, P is the obtained power, R is the load resistance, I is the output current, and A is the effective contact area of SETENG.

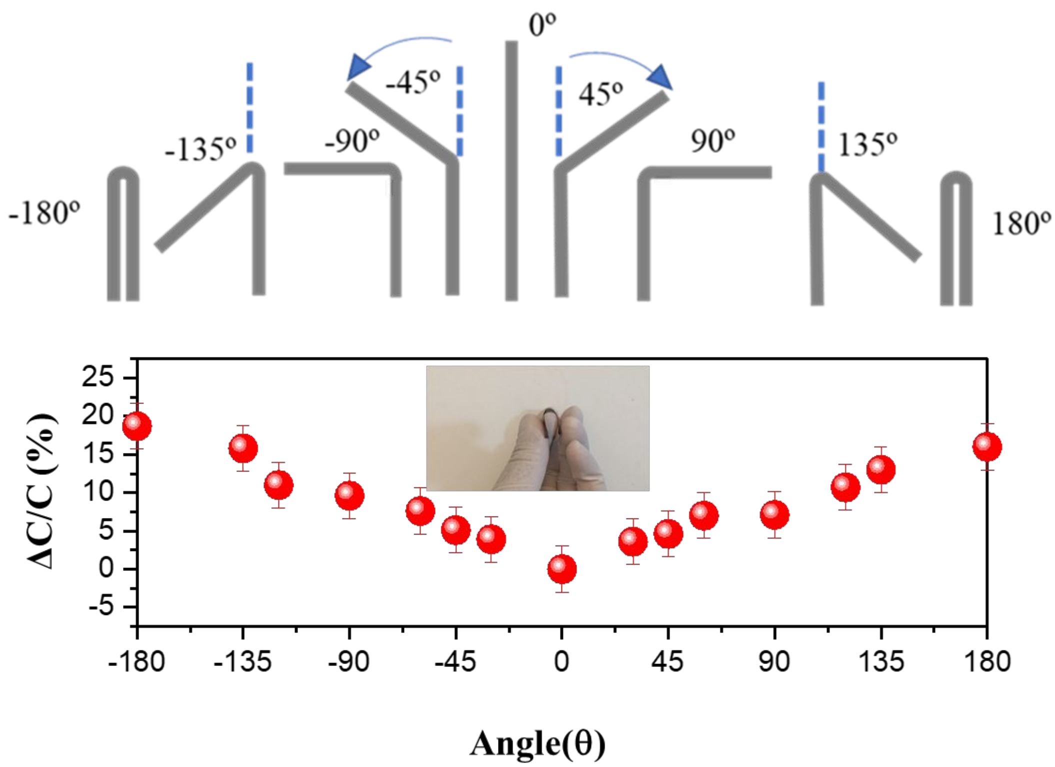

Figure S6. Normalized capacitance response for the laser-engraved electret with continuous angle change.

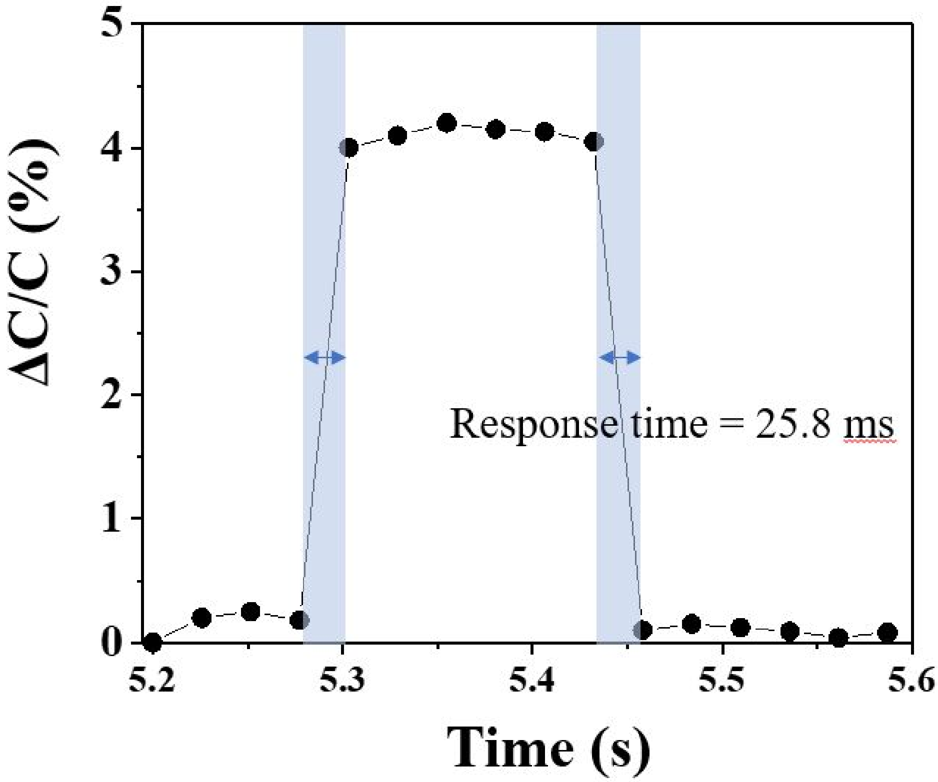

Figure S7. The response time of laser-engraved electret at the pressure detection limit of 1.9 Pa.

Table S1

Comparison of this output performance of the capacitive electret with other capacitive sensors.

Materials	Sensitivity (Range)	Detection Limit	Response Time	Ref
Microporous CNT/Ecoflex	0.6 kPa^{-1} (5 kPa)	0.2 Pa	n/a	[2]
GO/PDMS/Nylon	0.3 kPa^{-1} (1 kPa)	3.3 Pa	20 ms	[3]
PDMS/rGO	0.002 kPa^{-1} (10 kPa)	0.5 kPa	200 ms	[4]
AgNWs/Polyurethane	8.3 kPa^{-1} (1 kPa)	0.5 Pa	27.3 ms	[5]
Laser-engraved GO-Cu(II)/PTFE	1.5 kPa^{-1} (2.2 kPa)	1.9 Pa	25.8 ms	This work

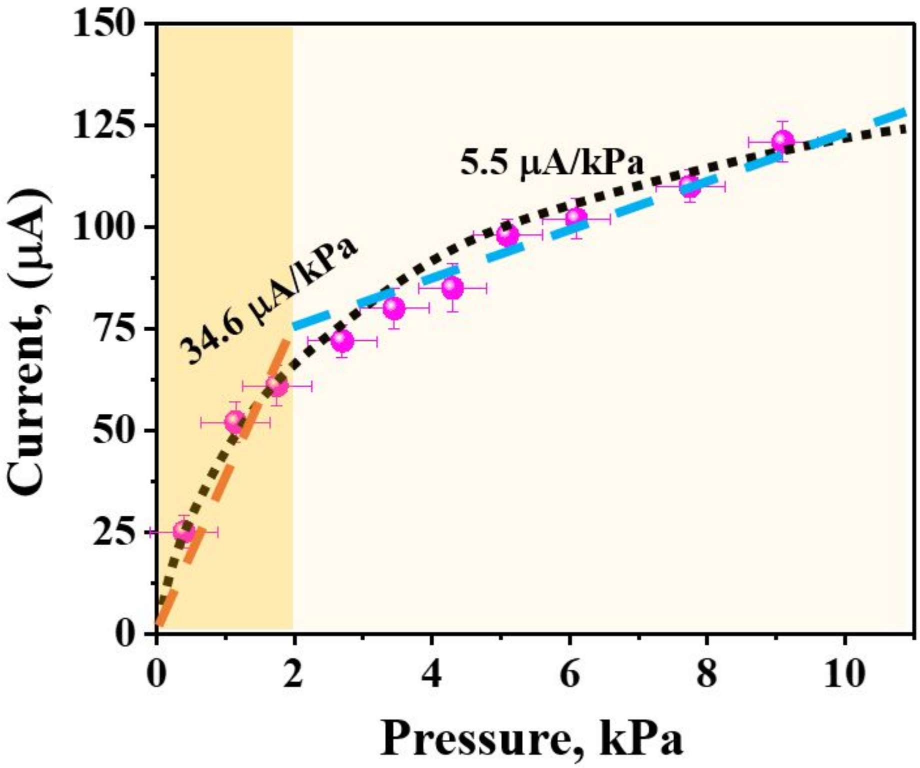

Figure S8. Output triboelectric current of single-electrode TENG under a human finger pressure.

Video S1. The self-powered SETENG wearable sensor for sending life-emergency requests.

Video S2. Demonstration to activate the SETENG wearable sensor by pressing the password “ACE”.

Video S3. Demonstration of SETENG wearable sensor to light on several LEDs.

References

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