Electronic Supplementary Material (ESI) for Sustainable Energy & Fuels.

Supplementary Information

A Facile Mechanical Energy Harvester based on Spring Assisted Triboelectric Nanogenerator

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FT-IR analysis of spin coated PVDF

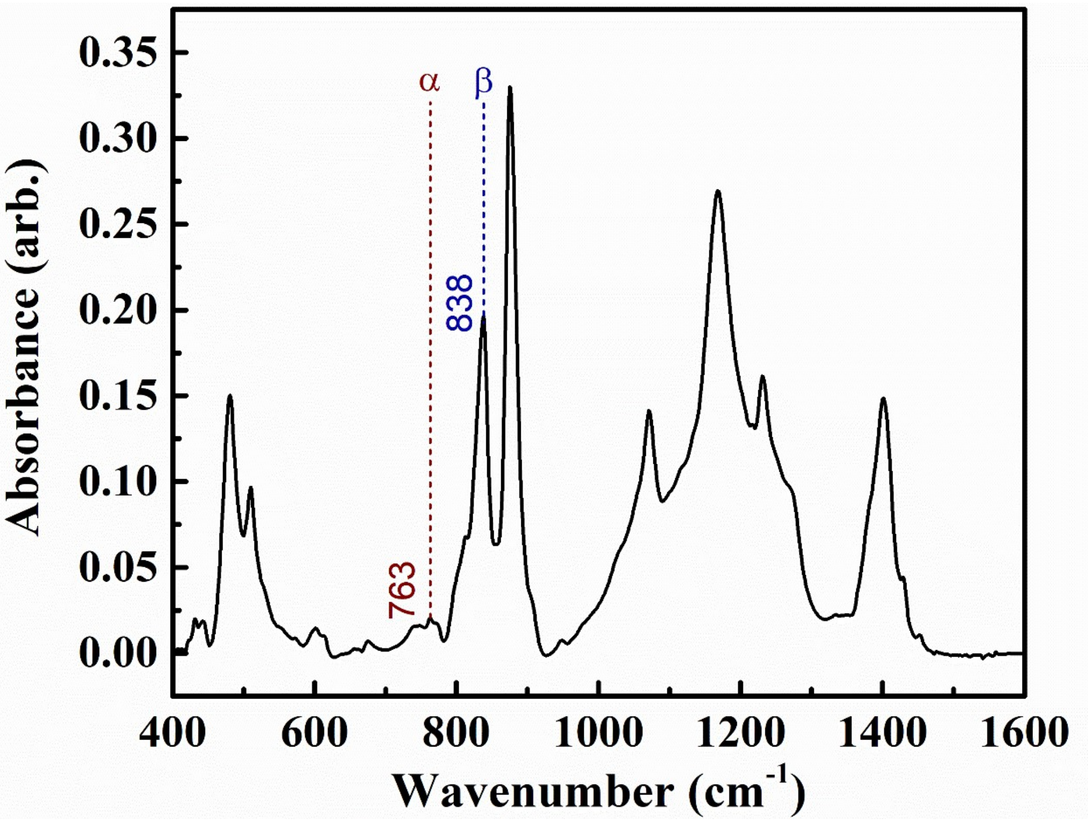

Figure S1: FTIR absorbance spectra of the spin coated PVDF.

In different phases of the PVDF polymer, the β-phase is the most polar one with the highest spontaneous polarization value. So, the fraction of β-phase (F(β)) in the spin coated PVDF was calculated using

$$F(\beta) = \frac{A_\beta}{\frac{K_\beta}{K_\alpha}A_\alpha + A_\beta}$$ …………….(1s)

Where A_α and A_β are the absorbances at 763 and 838 cm^{-1}; K_α and K_β are the absorption coefficients at respective wavenumber, which has values of $6.1 x 10^4$ and $7.7 x 10^4$ cm^2mol^{-1}. The two peaks denoted on the FT-IR diagram (Fig S1) were used for the phase calculations. The two peaks are the CF2 bending peak (763 cm^{-1}) in the alpha phase and CH2 rocking (838 cm^{-1}) peaks of the beta phase. The fraction of β-phase was obtained as 88.36%.

The output of Sa-TENG measured using a custom-made force impactor

A custom-made force impactor is built based on an electric sewing machine, which delivers a constant force of 15 N (measured using a force gauge AFT500, Apple Electroniks) at 4 Hz frequency. The output of Sa-TENG is then measured utilizing this force impactor, where the separation distance of Sa-TENG is kept at 6 mm. The separation distance is increased because then only the Sa-TENG could be characterised using the force impactor. The output profile obtained (Fig S2) is more uniform compared to the profile obtained using finger tapping owing to the uniform force delivery in both magnitude and area. However, since the separation distance increased the output potential increased even crossing the limit of the measuring system (denoted by red dotted line) and the short circuit current decreased, which is agreeing with the literature (Nano Energy, 68, 104272, 2020. 10.1016/j.nanoen.2019.104272).

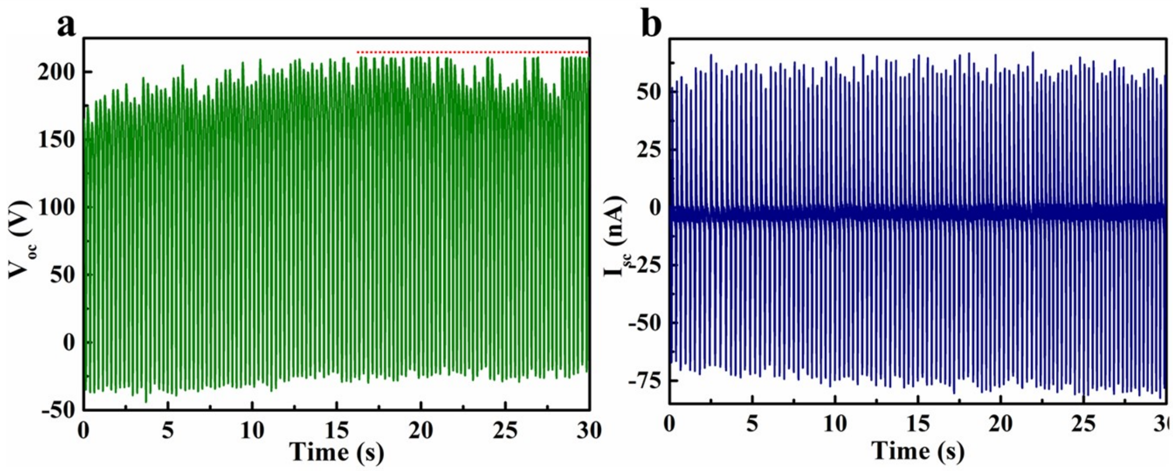

Fig S2: Output (a) voltage and (b) current of the Sa-TENG (with separation distance of 6 mm) measured using a custom-made force impactor.

Charge calculation from the current profile of Sa-TENG

The current profile of the Sa-TENG is enlarged and is shown in Fig. S3. Additionally, since the integral of the current signal would give the value of the total charge.

$$Q = \int I \, dt$$

Where Q is the total free charges on the electrodes, I is the current and t is the time. So, the area of three sample peaks from the current profile is evaluated and from that area calculation the total free charge on average was obtained to be around 10 nC. Since the separation distance is much larger than the thickness of the materials the total free charge is similar to the total triboelectric charge (Nature Communication; 10; 1427; 2019, 10.1038/s41467-019-09461-x). So, the triboelectric charge could be assumed to be also 10 nC.

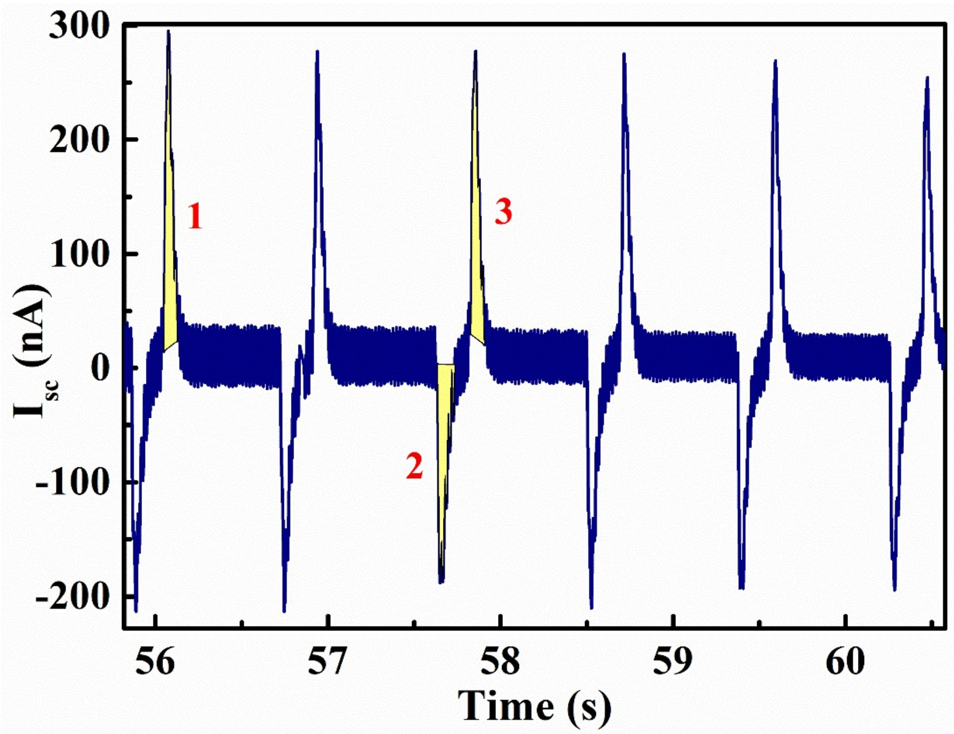

Fig S3: Enlarged profile of the short-circuit of the Sa-TENG.

The output of the TENG after 30 days

The output performance of the Sa-TENG was measured for 30 days, the open circuit voltage and current remain as same as of the fresh device. No considerable degradation of the device performance was observed. Additionally, another Sa-TENG having separation distance of 6 mm was measured for about 50 minutes (more than 10000 cycles) using a custom-made force impactor capable of delivering 15 N force at 4 Hz frequency.

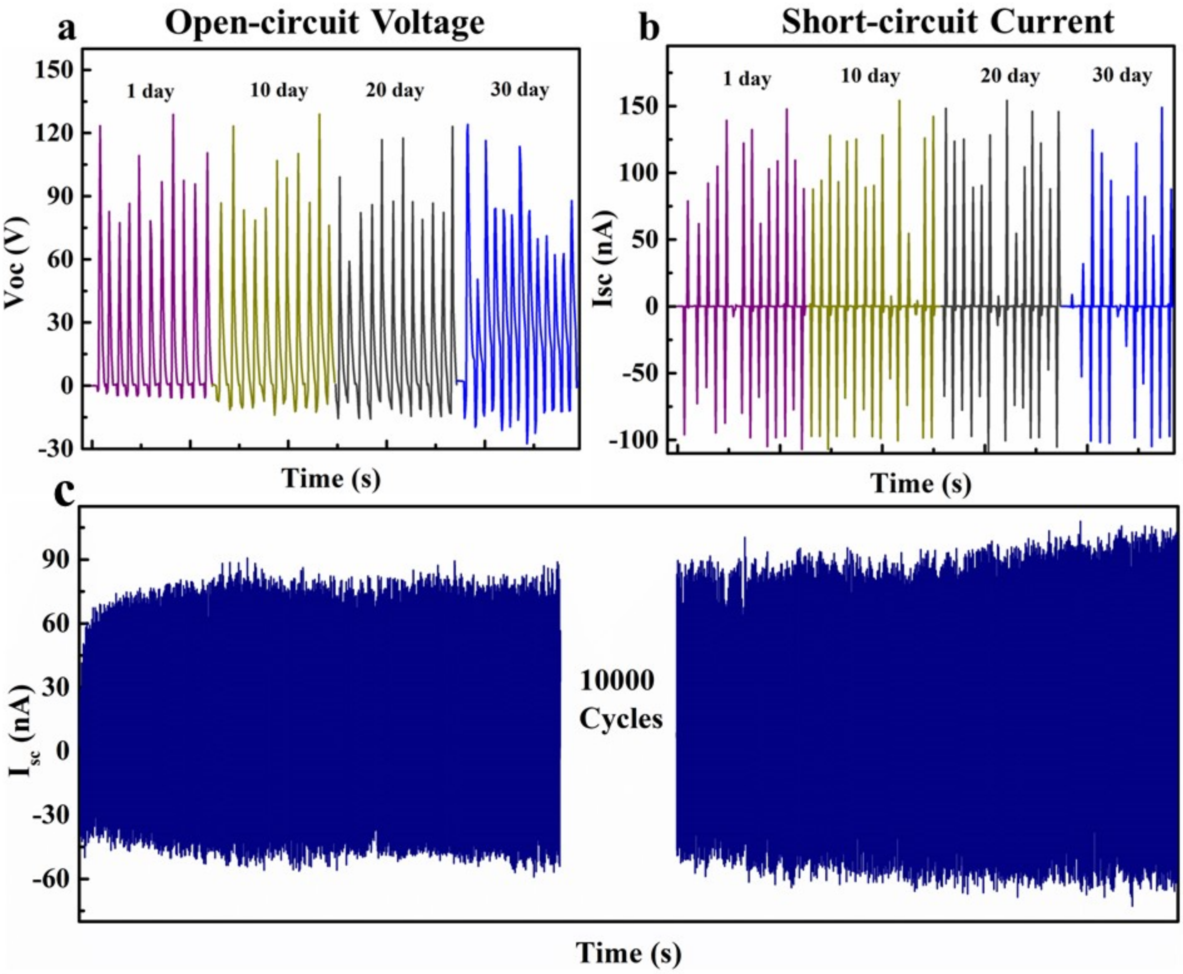

Fig S4: Output (a) voltage and (b) current of the Sa-TENG measured for 30 days using finger tapings. Additionally, the durability of Sa-TENG (having separation distance of 6 mm) tested continuously for over 10000 cycles of operation.

Dependence of contact area and separation distance on simulated potential.

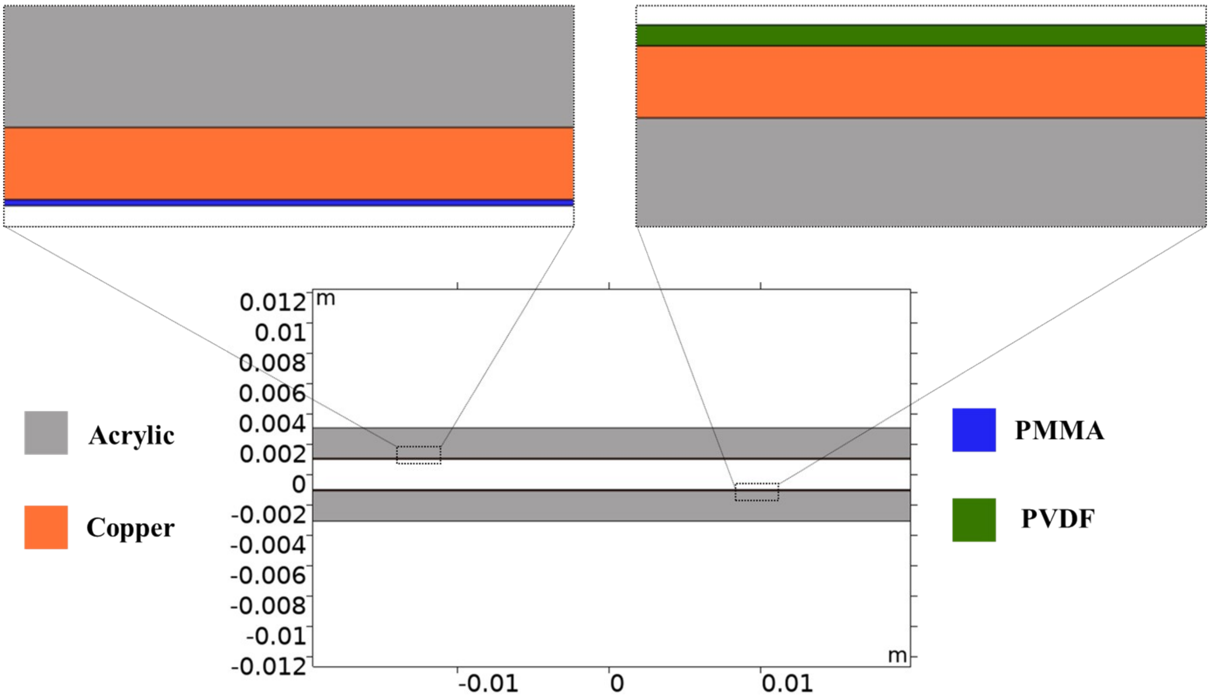

Fig S5: The geometry of Sa-TENG modelled in COMSOL.

The geometry containing the triboelectric pair and electrodes is shown in figure S5, additional to that air domain is also added to the geometry. Then using the electrostatic module and stationary solver the model was computed. Figure S6a and S6b represent the increase in the potential value as, for the TENG with 16 cm^2 area, as the gap distance increases from 1 mm to 3 mm. Figure S6c and S6d are the potential values of Sa-TENG with contact areas 1 cm^2 and 4 cm^2 respectively. The potential increases with an increase in both contact area and gap distance.

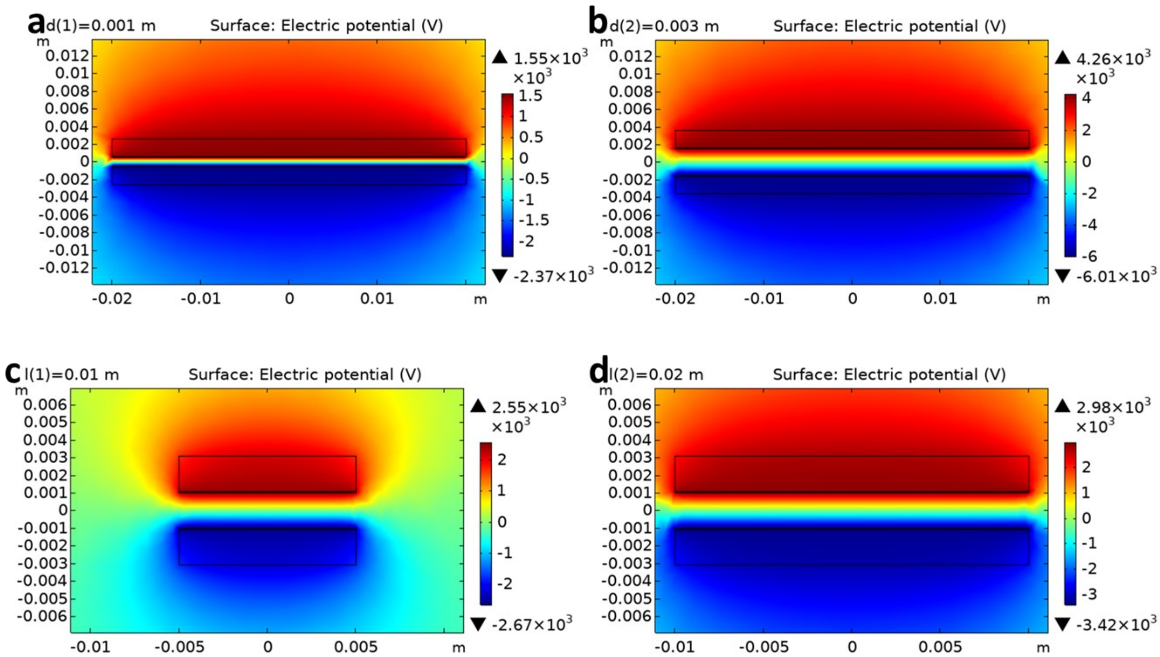

Fig S6: Dependence of contact area and separation distance on simulated potential.

Films spin coated in different areas.

Polymers spin coated on areas 1 cm^2, 4 cm^2 and 16 cm^2 are represented below. PVDF (on right side) films are whitish in colour while PMMA are transparent

Fig S7: PVDF and PMMA polymers spin coated in different areas.

Load dependence of Sa-TENGs with different areas.

Load dependence of Sa-TENG with area 1 cm^2 is represented in figure S8a and 4 cm^2 is represented by figure S8b.

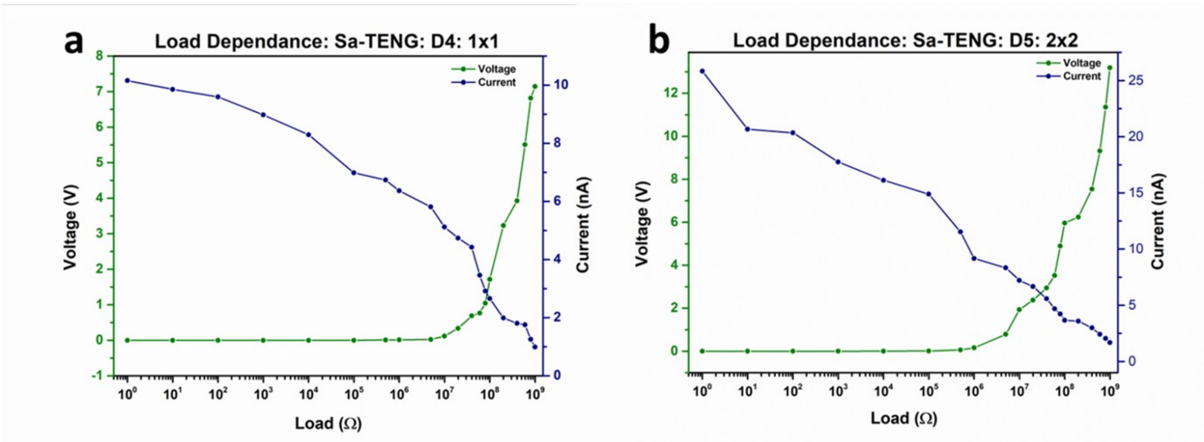

Fig S8: Load dependence of TENGs with different areas.

Short-circuit current of Sa-TENGs with different input forces.

The short-circuit current density of Sa-TENG is measured using different input like finger tapping, palm tapping and heel tapping. The output increases with the increase in the force (Fig. S9). The short-circuit current for finger tapping is about 150 nA and for palm tapping it increases up to 500 nA. Heel tapping generates more force and correspondingly the output was the highest around 1400 nA.

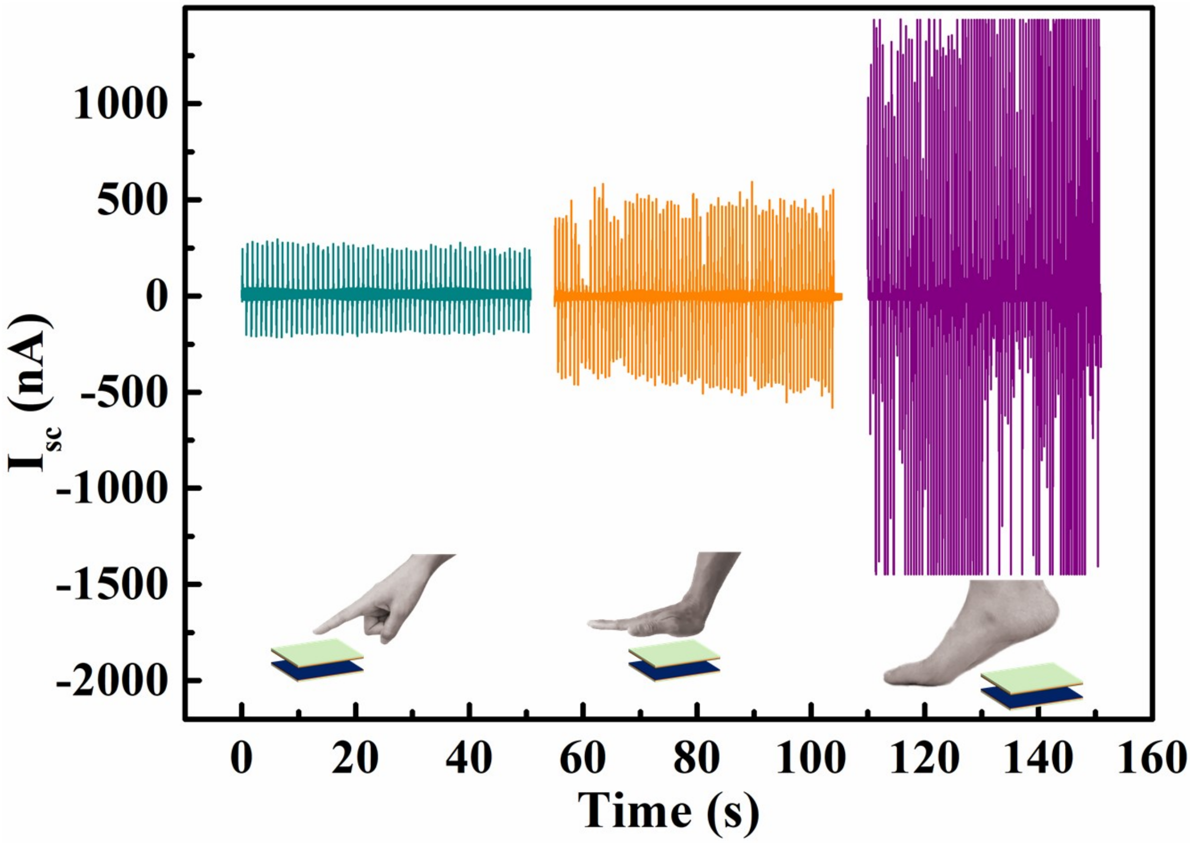

Fig S9: Short-circuit current of Sa-TENGs with different input forces.

Supplementary Video 1: Open circuit voltage of Sa-TENG

Supplementary Video 2: Powering LCD using the Sa-TENG