iScience, Volume *24*

Supplemental Information

Biodegradable metal-organic framework MIL-88A for triboelectric nanogenerator

Gaurav Khandelwal, Nirmal Prashanth Maria Joseph Raj, Venkateswaran Vivekananthan, and Sang-Jae Kim

Supplemental Information

Biodegradable Metal-Organic Framework MIL-88A for Triboelectric Nanogenerator

Gaurav Khandelwal,[1] Nirmal Prashanth Maria Joseph Raj,[1] Vivekananthan Venkateswaran,[1] Sang-Jae Kim,[1*]

[1] Nanomaterials and System Lab, Faculty of Applied Energy Systems, Major of Mechatronics Engineering, Jeju National University, Jeju 690-756, South Korea

[*] Corresponding Author and Lead Contact, Email: kimsangj@jejunu.ac.kr

Transparent Methods

Experimental

1. **Materials:** Iron chloride hexahydrate ($FeCl_3.6H_2O$) and fumaric acid were purchased from Daejung Chemicals Ltd. (South Korea). Ethylcellulose (48% ethoxy content) was purchased from Acros organics (USA).
2. **Synthesis of MIL-88A:** MIL-88A was synthesized using a procedure reported by Liao et al. (Liao et al., 2019). Briefly, 1.352 g of $FeCl_3.6H_2O$ and 0.580 g of fumaric acid was dissolved in 25 ml of deionized (DI) water. The solution was transferred to a Teflon-lined stainless-steel autoclave and placed at a temperature of 65 °C for 4 h. The product was collected and washed several times with DI water, followed by drying.
3. **Device Fabrication:** The MIL-TENG was fabricated in a vertical contact-separation mode with an active area of 2.5 cm X 2.5 cm. MIL-88A was attached uniformly on a conducting adhesive aluminum tape (3M). The excess material was removed with the help of air gun. The MIL-88A attached Al tape was fixed on a polyethylene terephthalate (PET) substrate. The commercial FEP (50 µm) and Kapton (50 µm) films were directly attached to the aluminum tape followed by the PET substrate's attachment. The 10 wt% (1:4 ethanol: toluene) ethyl cellulose solution was spin-coated on the Al tape followed by the PET substrate's attachment. The copper wires were attached to the electrode using a silver paste for collecting output. Finally, the MIL-TENG was assembled by attaching the MIL-88A and opposite layers using a spacer.
4. **Characterization:** The XRD measurements were performed using Malvern PANalytical Empyrean, with a generator voltage and tube current of 40 V and 30 mA, respectively. FT-IR measurements were taken on the Bruker Alpha II compact FT-IR spectrometer. The surface morphology image and EDS mapping were taken on Tescan MIRA-3 FE-SEM provided with Oxford EDS detector. The surface roughness analysis

was carried out using the NanoSystem NV2200 3D surface profiler. All the electrical measurements were performed under lab-made Faraday cage to reduce the noise. The force was applied using a LinMot Inc. linear motor. A Keithley 6514 electrometer was used to measure the voltage and charge of the MIL-TENG device. A Stanford Research SR570 low noise current preamplifier and Tektronix mixed domain oscilloscope MDO3000 series was used for the MIL-TENG device's current measurement. The trek 347 non-contact electrostatic voltmeter was used to measure the surface potential developed on MIL-88A.

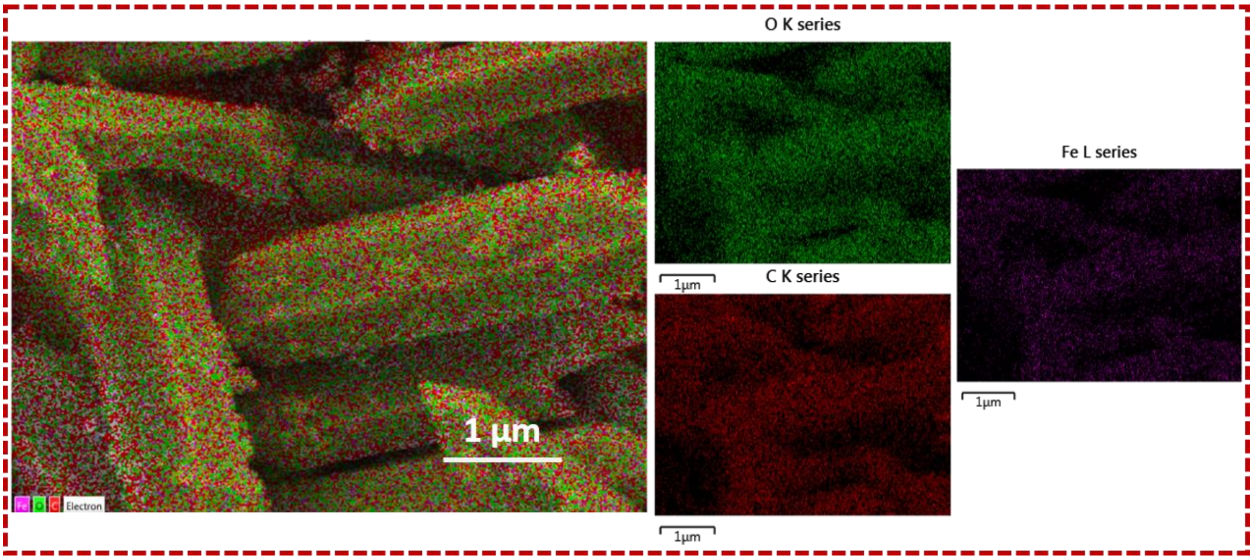

Figure S1. EDS elemental mapping for MIL-88A. (Related to Figure 1).

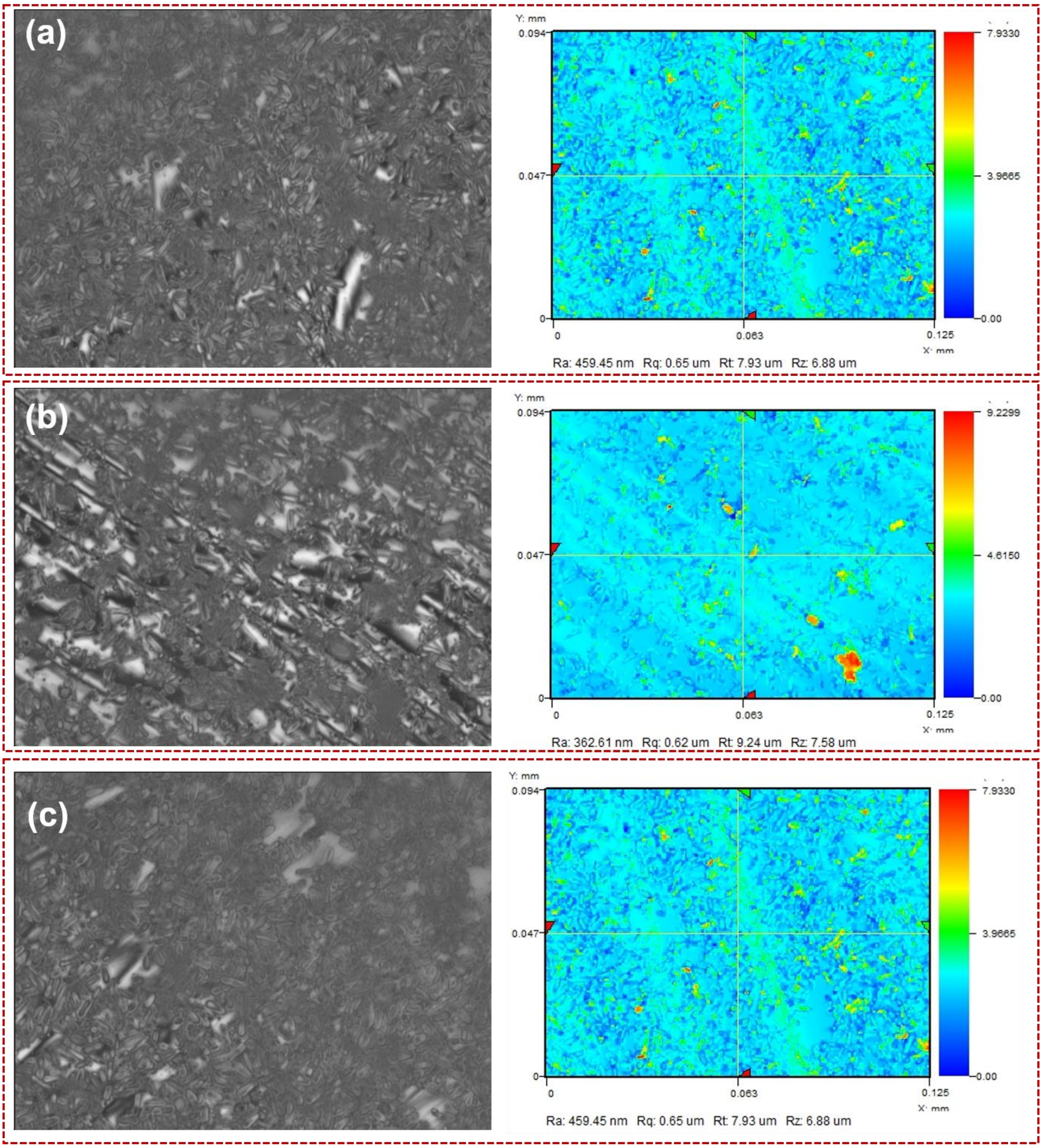

Figure S2. The optical and 2D profile images of the dispersed samples (Related to Figure 1).

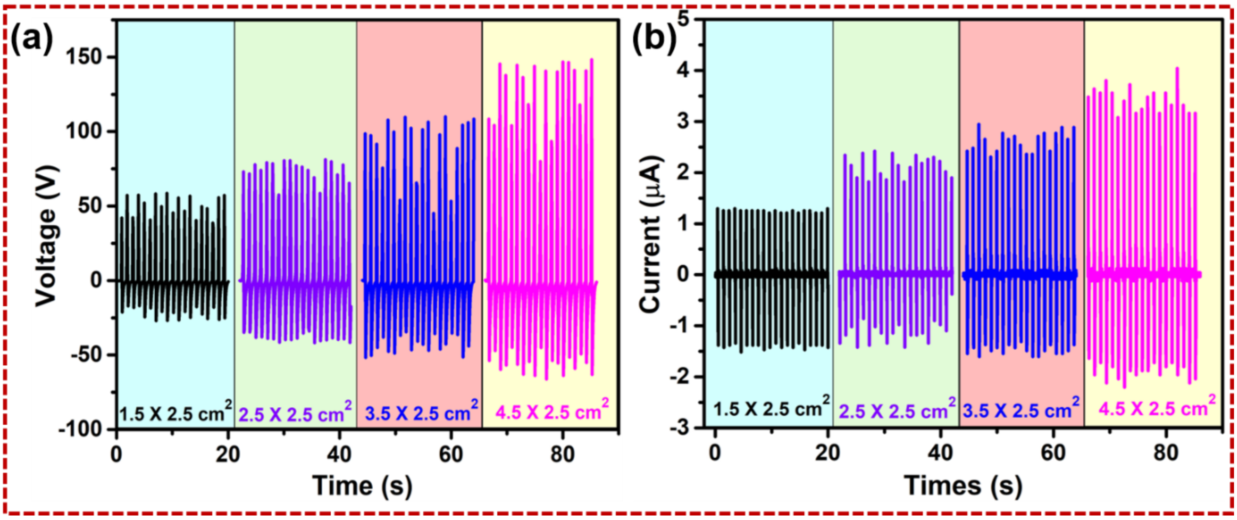

Figure S3. Voltage and current variation with the device size (Related to Figure 3).

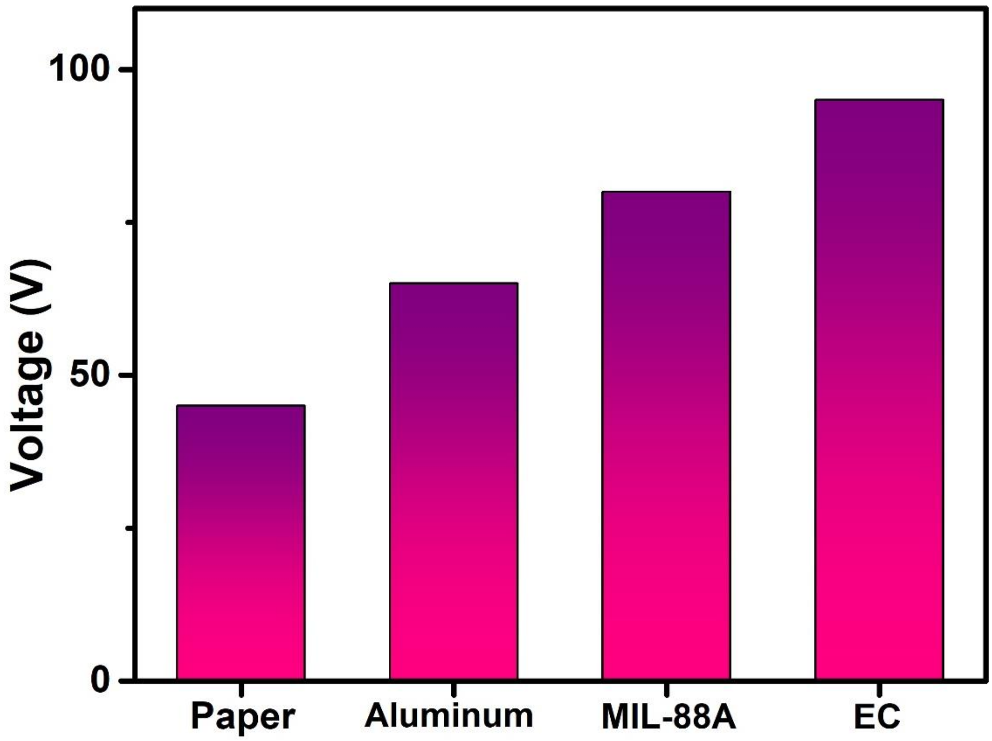

Figure S4. The comparison of voltage output generated by commonly used positive materials with MIL-88A (Related to Figure 3)

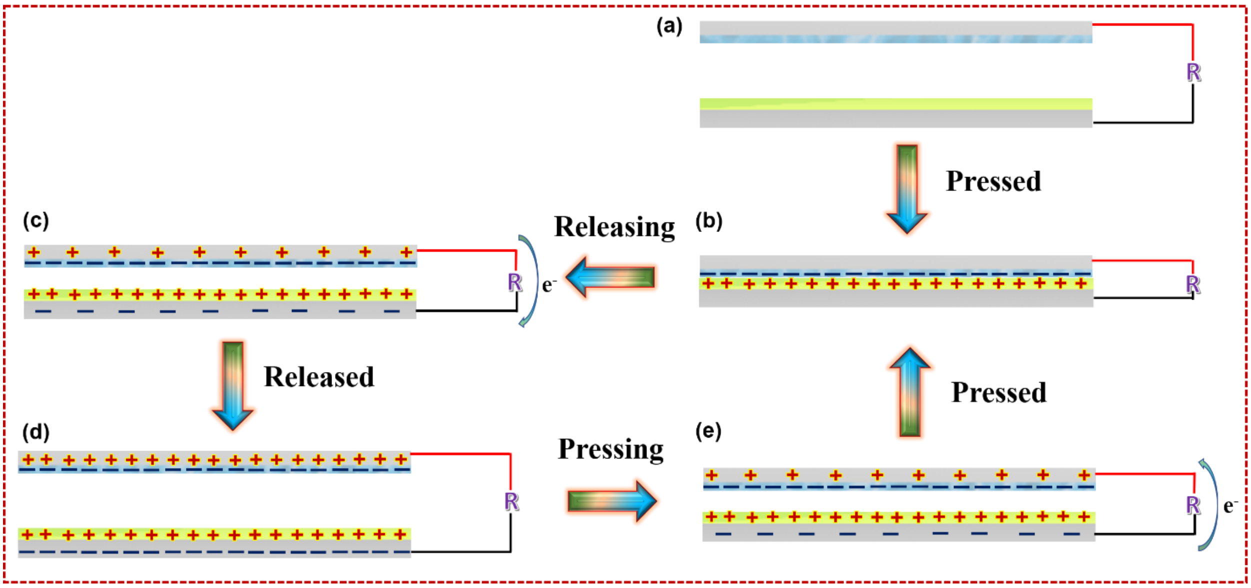

Figure S5. The schematic illustration of MIL-TENG working mechanism showing pressed, releasing, released and pressing conditions (Related to Figure 3).

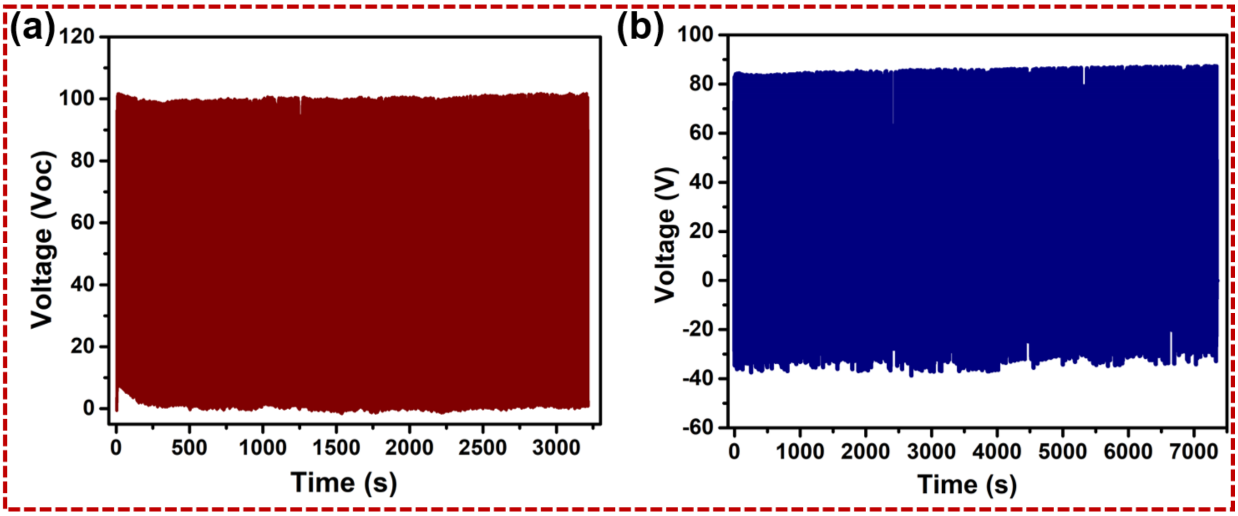

Figure S6. Stability of the device (Related to Figure 4).

(a) The stability of the open-circuit voltage and (b) long-term device stability.

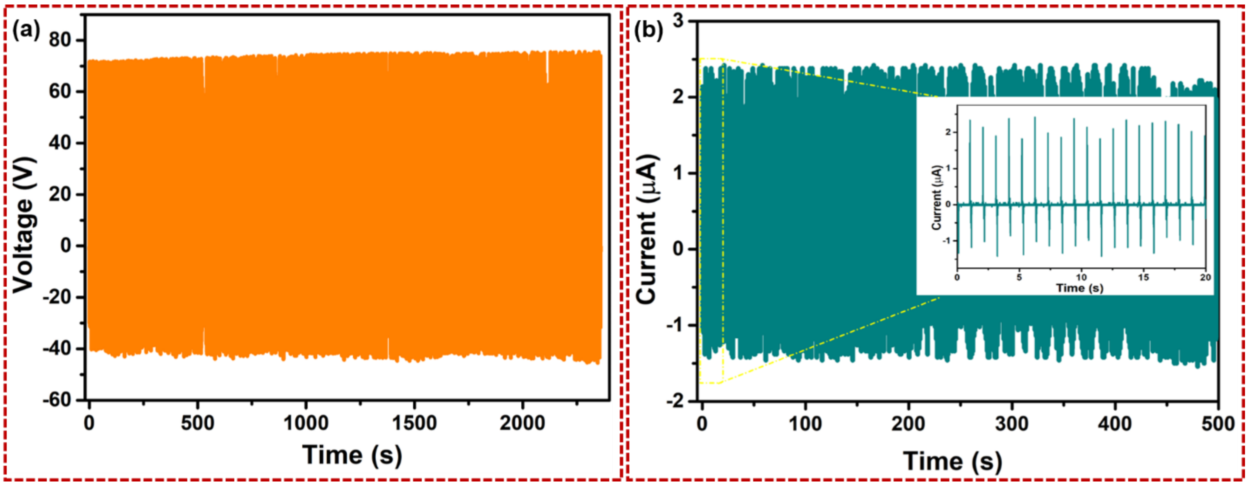

Figure S7. Voltage and current stability of MIL-TENG after 10 days (Related to Figure 4).

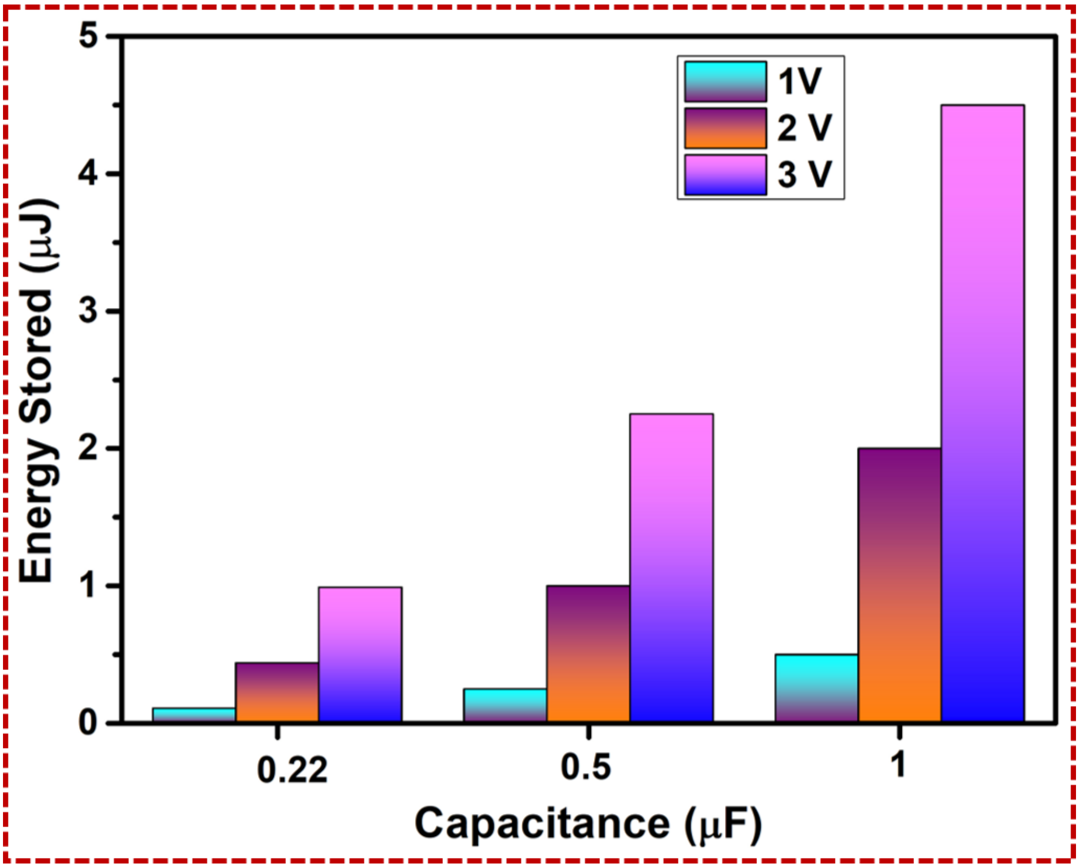

Figure S8. The energy stored in 0.22, 0.5 and 1 μF capacitor corresponding to 1, 2 and 3 V charging (Related to Figure 4).

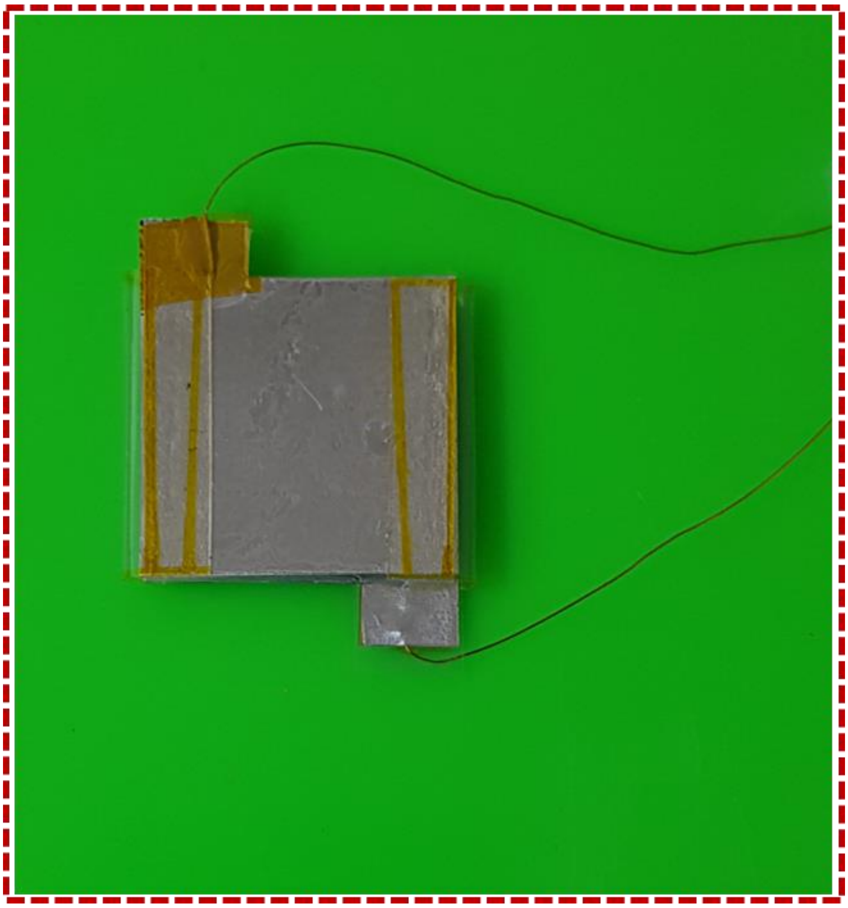

Figure S9. The image of the device used to power up the electronics via a capacitor (Related to Figure 5).

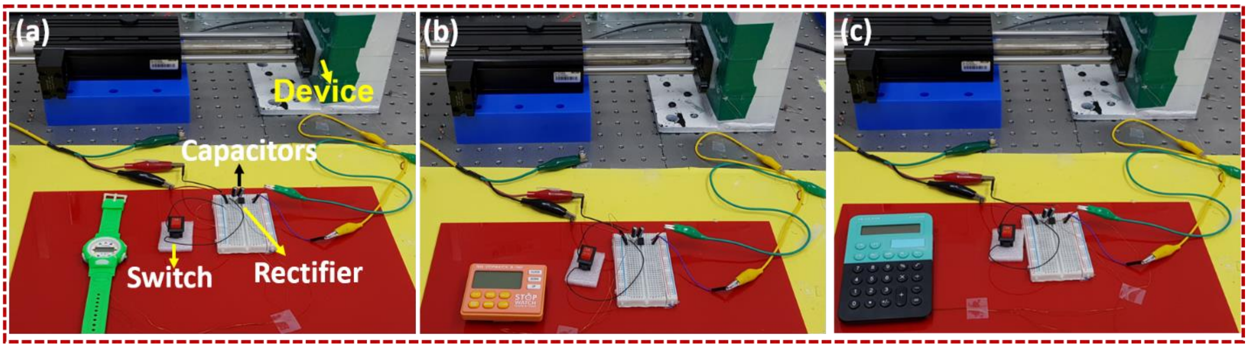

Figure S10. The detailed depiction of the electronics connected to the capacitor and rectifier (Related to Figure 5).

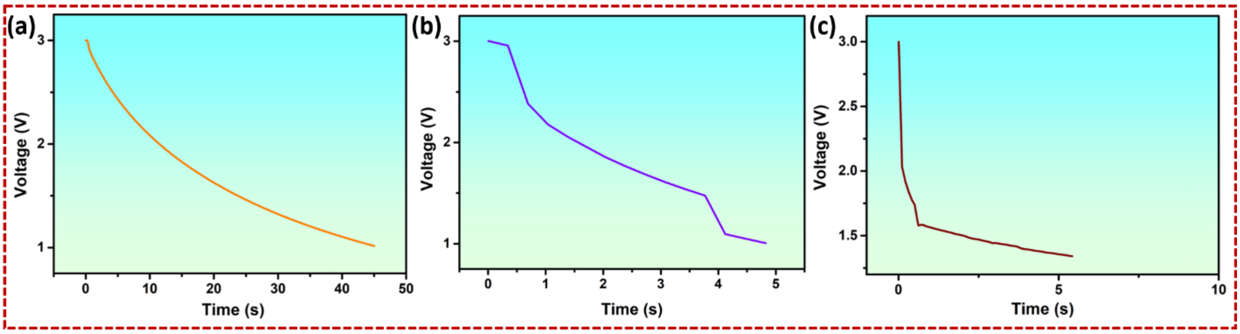

Figure S11. The capacitor discharge signal after turning on the switch to power up the electronics (Related to Figure 5).