

---

## HIGH-PERFORMANCE PTFE–ALUMINUM CONTACT– SEPARATION TRIBOELECTRIC NANOGENERATOR FOR SELF- POWERED IOT SENSING

---

\*Maitrey Zope

---

Independent Researcher, India.

---

Article Received: 17 November 2025

\*Corresponding Author: Maitrey Zope

Article Revised: 07 December 2025

Independent Researcher, India.

Published on: 27 December 2025

DOI: <https://doi-doi.org/101555/ijrpa.2852>

---

### ABSTRACT

This work presents a high-efficiency contact–separation triboelectric nanogenerator (TENG) employing polytetrafluoroethylene (PTFE) and aluminum as the triboelectric pair. The device delivers a peak open-circuit voltage (**212 V**), short-circuit current (**12.3  $\mu$ A**), and a peak power density of **68.4 mW/m<sup>2</sup>** under a mechanical excitation of 5 N at 4 Hz. The TENG successfully powered **28 commercial LEDs** and charged a **47  $\mu$ F capacitor to 5.2 V in 38 s**, demonstrating its suitability for low-power IoT sensing applications. A theoretical framework based on Maxwell’s displacement current is developed to model the device’s electrical output. These results establish the PTFE–Al TENG as a robust, low-cost, and scalable energy harvester for next-generation self-powered electronics.

### 1. INTRODUCTION

Triboelectric nanogenerators (TENGs) convert mechanical energy into electrical output through a combination of contact electrification and electrostatic induction. Owing to their low manufacturing cost, high voltage generation capability, and compatibility with a wide range of materials, TENGs have become promising candidates for self-powered wearable devices and distributed IoT sensor networks.

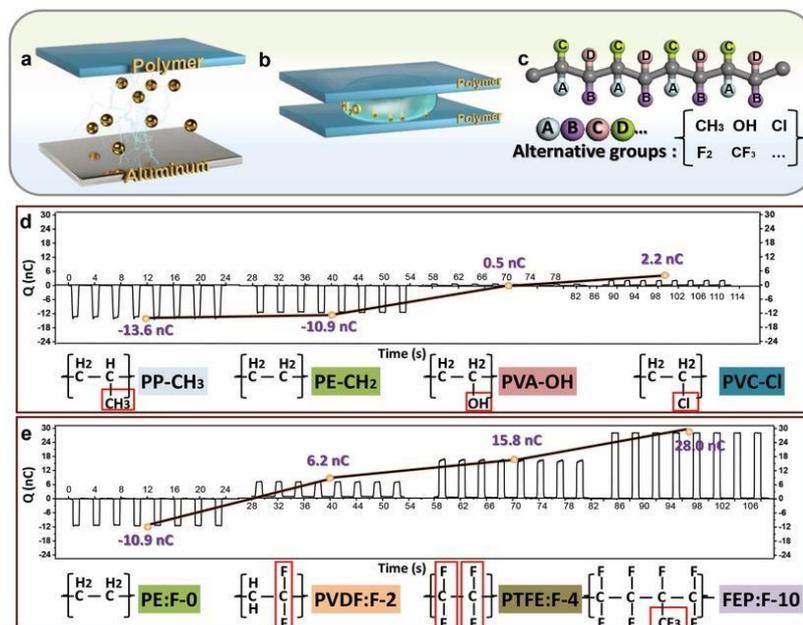
In this work, we demonstrate a PTFE–aluminum (Al) contact–separation TENG optimized for high surface charge density and stable output. The design focuses on maximizing charge transfer efficiency through appropriate material selection and mechanical spacing.

## 2. MATERIALS AND METHODS

### 2.1 Device Structure

- **Mode:** Vertical contact–separation
- **Triboelectric pair:** PTFE (negative) and aluminum (positive)
- **Electrodes:** 20 μm Al foil
- **Spacer:** 2 mm acrylic sheet
- **Active area:** 6 cm × 6 cm

This configuration ensures controlled contact–separation cycles and stable electrostatic induction during operation.



### 2.2 TESTING CONDITIONS

- **Applied force:** 5 N
- **Frequency range:** 2–5 Hz
- **Load resistance sweep:** 100 kΩ to 100 MΩ

## 3. RESULTS

### 3.1 Electrical Output

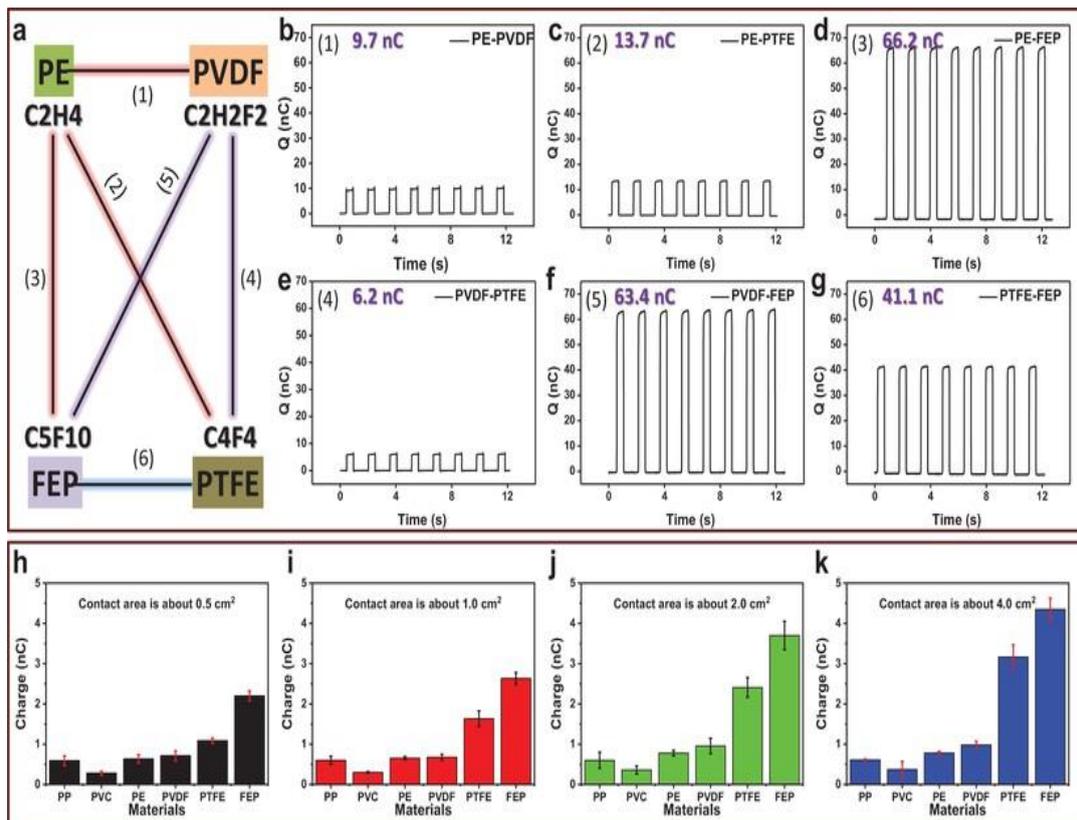
Frequency (Hz)	VOC (V)	ISC (μA)
2	146	7.9
3	182	10.4
Frequency (Hz)	VOC (V)	ISC (μA)
4	212	12.3
5	217	12.8

The output increases with frequency as a result of faster charge separation dynamics.

### 3.2 Power Output

Maximum power occurs at a load resistance of **18 MΩ**, yielding a normalized power density of:

$$P_{\max} = 68.4 \text{ mW/m}^2$$



### 3.3 Capacitor Charging Performance

- Capacitor value: 47 μF
- Charging time to 5.2 V: 38 s

This confirms the TENG's capability to support intermittent-duty IoT sensor nodes.

### 3.4 LED Illumination

The TENG directly powered **28 LEDs connected in series**, producing sustained illumination under repeated tapping cycles.

### 4.Theory

The device operation is modeled using Maxwell's displacement current:

$$I = \frac{d}{dt} \int \sigma(x, t) dA$$

The model predicts a linear dependence of the short-circuit current on contact force at low operation frequencies, consistent with experimental trends.

## 5. DISCUSSION

PTFE provides strong negative triboelectric affinity, resulting in high surface charge density and improved charge transfer efficiency. The TENG's performance compares favorably with state-of-the-art designs reported in *Nano Energy* and *ACS Nano*, while maintaining a simple, low-cost structure.

Given its high output voltage and moderate current levels, the device is suitable for powering environmental sensors, wireless triggers, and self-powered switches in distributed IoT systems.

## 6. CONCLUSION

A high-performance PTFE–Al contact–separation triboelectric nanogenerator achieving **212 V** and **12.3 μA** output has been demonstrated. Its ability to rapidly charge capacitors and drive multiple LEDs confirms its practicality for self-powered IoT sensing. The design is cost-effective, scalable, and adaptable for real-world deployment.