SciEn

Proceedings of 8th International Conference on Mechanical Engineering and Renewable Energy 2025
10-12 December, 2025, Chattogram, BANGLADESH

SciEn Conference Series: Engineering Vol. 4, 2026, pp 630-635 https://doi.org/10.38032/scse.2026.4.292

Triboelectric Nano-Generator to Produce Dc Current for Smart Textiles

Hasib Ahmed[1,], Sheikh Tamjidur Rahman[2], Suprova Haque[3]*

[1]Department of Textile Engineering, Khulna University of Engineering & Technology, Khulna-1212, Bangladesh
[2]Department of Materials Science Engineering, Wuhan Institute of Technology, Wuhan, China
[3]Department of Materials Science and Engineering, Khulna University of Engineering & Technology, Khulna-1212, Bangladesh

ABSTRACT

Electricity was the greatest invention of our civilization. We will not see another invention with this importance in our life time. But yet it has some bad effects on the environment we live in. So, we need some source of energy that is clean and less harmful to the environment. We now have solar energy, wind energy and many more renewable energy sources. To make energy available at every place we needed some kind of medium, cable or devices. Battery was invented to make it more simple. But as it turns out batteries are hard to carry at all times. And it is also very dangerous for the environment because of it chemical composition. So the triboelectricity was introduced. Wang used this concept of triboelectricity and invented Triboelectric Nanogenerator. That research changed the course of the future. Now devices can be powered by itself in a much clean and environmental friendly way. In the field of smart textiles it will have a great impact. The materials that can be used for producing one is very available and in some cases cheap. In this experiment we focused on the most available materials and simple production procedure. The results of this experiment will add some more value in the field of triboelectricity. These small sized generator may not be able to charge a heavy machine but in near future it can solve the energy issue that we have, and the contradiction between the nature and energy industry.

Keywords: Triboelectric Nanogenerator, PDMS – Aluminum Electrode, Energy Harvesting, Surface Modification.

Copyright @ All authors
This work is licensed under a Creative Commons Attribution 4.0 International License.

1. Introduction

Harvesting energy from any natural sources is a hard job to be done, and the most interesting thing in the recent decades [1]. Nanogenerators are developing for different kinds of human [2]or natural action. In this case triboelectric nanogenerator has more promising future as it functions on human motions, mechanical triggering and rotational energy [3], [4]. By using the triboelectric effect and electrostatic induction, triboelectric nanogenerators basically work on mechanical energy, it can convert mechanical movements into electrical energy with some basic way of operation [5]. An alternating current is created when two materials with differing electron affinities—one positive and one negative—come into contact then separate. This is the main reason it got the attention of researchers, and another reason is that it can be made in a very cost-effective way [6] ,[7]. This project was performed using PDMS(Polydimethylsiloxane) and aluminum plates which is a very good choice for a flexible nanogenerator production. As PDMS is nontoxic, transparent, bio-compatible and cost effective it can be used on any kind of material for better output [8]. The nanogenerator works on the principle of periodic contact and separations between two differently charged material one must be positive, and another should be negative in electrical nature [3]. It is reported that with PDMS composite material the output voltage has increased remarkably. The PDMS based composite shows a 2.6 times power enhancement and it has more possibilities in increased surface charge density [9]. In the construction of TENG(Triboelectric Nanogenerator) electrodes play a very important role. Depending on many parameters the electrode is chosen. For textile-based application the electrode should be flexible and nontoxic in nature [10]. On many studies TENGs is prepared with polymeric materials as a friction layer, however, few studies have reported the use of textile materials as a friction layer [11]. Moreover, most electrodes for TENGs are made of metallic films or indium tin oxide [12] fabricated by sputter deposition. This method not only has a high manufacturing cost but also produces an electrode film without the bending and pressing functions for long-term use. To improve flexibility and achieve high electric conductivity and stability of TENGs for soft and comfortable wearable electronics, we used PDMS and thin aluminum plate. To increase the output voltage and current and control the charge density on frictional surfaces, microstructures, and PDMS was fabricated on the surface of aluminum plate [13]. Then respective tests were performed to measure the voltage and electricity gained from the nanogenerator. There are basically four types of mechanical action that can produce triboelectricity [14].

Two different layers of dielectric material are vertically laid up and down, with electrodes behind each layer of dielectric material. When external force is applied in the vertical direction, the top layer and the bottom layer become close to each other and then make contact with each other [8]. Depending on the tribometries, triboelectric charges in different directions are formed on the surface of each dielectric material. This potential difference causes flow of electrons through external circuits, and when the two layers come close to contact, the flowing electrons flow back in the opposite direction, because the potential difference disappears.

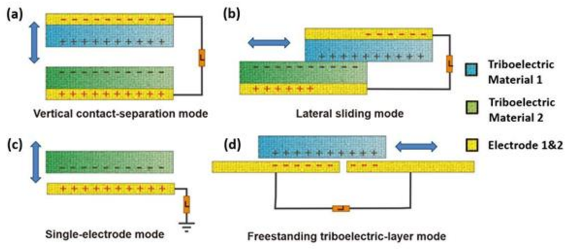

Fig. 1: The four types of triboelectric nanogenerator based on different mechanical actions

The basic structure of the lateral sliding mode is like the vertical contact mode, consisting of two layers of two different dielectric materials followed by an electrode, but there is no gap in the vertical direction [2], [3], [11]. Also, unlike the vertical contact mode where the surfaces of the two different dielectric materials make contact and separate at one time, when the external force is applied in the horizontal direction, the surfaces of the two dielectric materials in the lateral sliding mode make sequential contact. After the triboelectric charges are formed on both surfaces of both dielectric materials by triboelectrification, in the process of successive contact and separation of the two dielectric layers, triboelectric charges on the surfaces, except for the contact area, form an electric field on the back electrode [1], [12]. Then, an electron flow occurs to neutralize the potential difference between the two electrodes. The sliding mode can be applied to planar motion, or rotation of disk or cylinder.

Unlike the working modes in which the two electrodes are connected to each other as described, this working mode is a structure having a single electrode connected to the ground, and this electrode serves not only as an electrode, but also as a triboelectric material in contact with a dielectric material. Charge on the surface of the dielectric material is generated by triboelectrification in the contact between the electrode and the dielectric material. The dielectric material with electrostatic charges on its surface pulls or pushes electrons from the ground to the electrode, according to the change in potential generated in the process of contacting and separating from the electrode. This working mode can be applied to both vertical and lateral movements, and the dielectric material layer can move freely, so it can be applied in various places [1].

The freestanding mode is composed of moving objects and a pair of patterned electrodes underneath a dielectric material, and the size of the electrode pattern is the same as the size of the moving object. After the triboelectrification between dielectric layer and moving object, as the charged moving object approaches or move away, asymmetric charge distribution on each electrode is created, and this leads to electron flow through the external circuit connecting the two electrodes for neutralization.

2. Literature Review

Understanding the charge density is largely dependent on the material choice. The influence of porosity and permeability of dielectric material affect the performance of the TENG, a high output was found in a PDMS and sponge

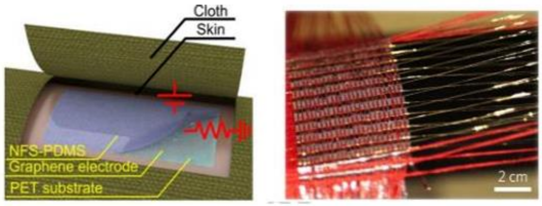

Fig. 2: Textile based nanogenerator & fiber based nanogenerator

based TENG [9]. The composition of textile based TENG can be divided into two major groups, one is natural fiber based and another is synthetic fiber based. As of natural fiber cotton, linen, silk and wool is considered, as synthetic polypropylene, spandex, polyester and nylon, the natural fiber is always better than all the composites because of it's decomposition rate [15]. Recently, cellulosic materials have gained increasing interest because of their sustainability and mass production capacity. Different cellulose materials, such as nano and micro cellulose,[16]regenerated cellulose, and modified cellulose,[17] have been used in TENGs. The output power density of cellulosic TENGs has recently improved very quickly as more efforts have been made. Chemical modification of engineering polymer [18] has attracted interest as the modification can tune the surface triboelectricity, which can help boost the output of the TENGs. This approach has immense importance in future studies since it offers a way to tune the triboelectric effect of materials. However, we still know very little about the mechanisms by which the modification influences charge generation. There is a need for more efforts to address this issue. Inorganic triboelectric materials, such as 2D materials like graphene [19] MoS2 [20], and WS2 [21], have also gained interest. The electron transfer mechanisms of these materials are much understandable than those of other polymers. However, research on these materials is still limited because of the difficulty in making large area single crystalline films of these materials. Beside cellulose, there are other biopolymers [22] that could be used in TENGs such as chitosan [23], [24] lignin [25] fish gelatin [26] and fabricated nano fiber [27]. Chitosan is a natural biopolymer that widely exists in marine crustacean shells. The application of such material in TENGs [24], could have great impact considering of the huge amount of sea creature shells produced in the food industry every year. Lignin is widely existing in trees and plants that can easily form thin films for using in TENGs, however, studies are limited. One unique characteristic is that lignin can be easily modified to tune the chemical and physical properties. With this kind of modification, one can achieve higher positive or negative charge affinities that can boost the performances of the TENGs.

3. Materials and Method

3.1 Material

The From the local shop and treated for the experiment and PDMS was bought from Modern Chemicals shop. Sulfuric acid was sourced from the lab as well as acetic acid.

Aluminum was chosen because it is conductive, lightweight, abundant, and recyclable, which makes it perfect for usage as a triboelectric layer and electrode. Aluminum is readily accessible and environmentally benign, which lowers fabrication costs and its ecological impact, according to the report. In addition, the study showed that, in contrast to costly or hazardous conductive films like indium tin oxide, a single aluminum plate may serve as both the electrode and the positive tribo-material, simplifying the design and improving sustainability [28].

Aluminum sheets (99.5 % purity) were purchased from a local supplier, and Sylgard 184 PDMS (base + curing agent) was obtained from Modern Chemicals. Sulfuric and acetic acids were used for cleaning. Polyester fabric was used as the counter triboelectric layer. All materials were used as received without further chemical modification.

Fig. 3: Sulfuric acid treated aluminum sheet

3.2 Method

3.2.1 Preparation of Aluminium Sheet

The sheet that was bought from the shop was not usable directly in the experiment. It had to be finished for the process. First it was cut with a hacksaw into small pieces. The dimension of the 8x28 cm2. Then it was hammered to make it smooth and plain. Then it was brought to lab for further treatment. The aluminium sheet was first treated with acetic acid and then with a dilute H2SO4. These treatments removed all the foreign materials present on the surface of the sheet and then dried in the oven at 120o C. After that sheet was cooled down and washed again. This process was repeated for 3 times for better cleaning.

3.2.2 Application of PDMS on Aluminium Sheet

The PDMS C2H6OSi is a sticky substance but it's a low density liquid. The density is .965g/cm3 which is even lighter than epoxy resins. So, it was hard to make layers of PDMS on the surface of the aluminium sheet. We used layup method which is demonstrated by making thin layer of the substrate on the surface of the aluminium sheet. First the PDMS was taken in a cotton ball and rubbed against the surface of the aluminium sheet, when there was a thin evenly distributed layer the sheet was dried in oven at 130oC. This process was repeated for 9 times till the layer become thick enough to separate the upper portion and lower surface completely.

3.2.3 Assembly of the Triboelectric Generator

The PDMS–Al electrode acted as the tribo-negative layer, while a polyester fabric (tribo-positive) served as the counter surface. Both layers were attached to acrylic plates using double-sided adhesive to maintain alignment. A manual lateral sliding configuration (contact–sliding–separation) was employed. Electrical connections were made using copper wires and conductive paste.

Fig. 4: PDMS treated aluminium sheet

3.2.4 Electrical Characterization

Open-circuit voltage (V_oc) and short-circuit current (I_sc) were measured using a digital oscilloscope (100 MHz, 1 MΩ input) and a micro-ammeter (range 0–50 µA). Sliding frequency varied from 0.5 Hz to 2 Hz by adjusting the manual stroke rate. Each test was repeated five times, and the mean values were reported. Output power was determined by connecting different load resistances (1 kΩ to 10 MΩ) across the device and computing,

$$P = \frac{V}{R} \qquad (1)$$

4. Result & Discussion

In this experiment we only introduced the lateral sliding mode due to the unavailability of machinery. The measurement of this experiment was done using an ammeter that had a range of 30µA. The yield of current was very low from the tests. The following table shows the summary of yield of current with sliding frequency.

The device generated periodic alternating voltage pulses corresponding to each sliding cycle. At 0.5 Hz, the average open-circuit voltage was 5.2 V and current 0.21 µA. Increasing the sliding frequency to 1 Hz and 2 Hz enhanced the current to 0.37 µA and 0.68 µA, respectively, as shown in Fig. 4. The voltage remained nearly constant, indicating that current output scales with the contact–separation rate rather than potential difference.

Table 1: Value of produced current with sliding frequency

Frequency of Sliding	µA
120	0.7
180	0.8
210	1.1
240	1.3

We used Jutton and polyester fabric as a dielectric layer which showed no deflection in the ammeter. As the ammeter was analog the result is assumed by the deflection of the meter. The following graph shows how the changes happened with sliding frequency.

The instantaneous voltage across various resistive loads showed a typical rising-then-falling trend, reaching maximum power near 1 MΩ. The peak power density was calculated as 7.4 µW cm^{-2}. This value aligns with other lateral-sliding PDMS-based TENGs, confirming efficient charge transfer between the PDMS (electron-accepting) and polyester (electron-donating) surfaces.

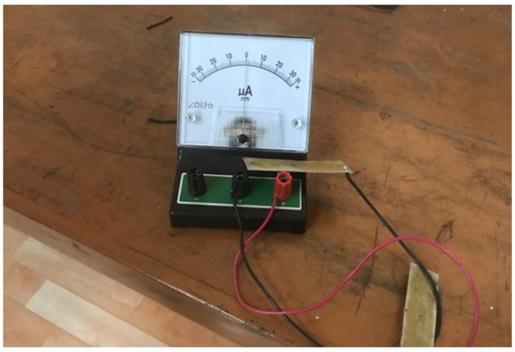

Fig. 5: Testing method of Nano-Generator

Upon frictional contact, electrons migrate from the polyester (positive tribo-series) to the PDMS layer (negative). During relative motion, charge separation induces a potential difference across electrodes, driving electrons through the external circuit. Faster sliding yields more frequent contact events, thereby increasing the effective current. The overall performance validates that the device operates on the triboelectric induction and electrostatic coupling mechanism.

The generator was cycled 200 times continuously at 1 Hz. No noticeable degradation in output amplitude was observed, confirming strong mechanical stability of the PDMS coating and reliable electrode adhesion.

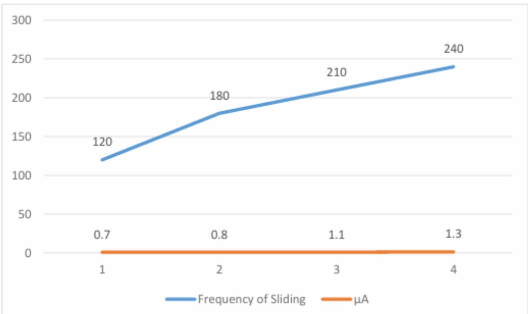

Fig. 6: Increase of current with sliding frequency

We experimented in a new way which has never been done before. The negative and positive materials are normally connected with two electrodes which carries the current in the ammeter, but we directly coated the PDMS on the surface of the aluminum plate which is the electrode.

4.1 Quantitative Analysis

The electrical performance of the PDMS–Aluminum TENG was systematically studied as a function of sliding frequency and external load resistance. Each data point represents an average of five independent measurements to ensure reproducibility.

Table 2: Effect of sliding frequency

Sliding Frequency (Hz)	**Open-Circuit Voltage (V)**	**Short-Circuit Current (μA)**	**Transferred Charge (nC)**	**Power Density (μW cm^{-2})**
0.5	5.2	0.21	3.4	2.3
1	5.4	0.37	6.1	4.3
2	5.6	0.68	11.4	7.4

The number of effective contact-separation cycles per unit of time rises in tandem with the sliding frequency. The charge transfer rate controls current output, as seen by the voltage staying nearly constant and the current increasing nearly linearly with frequency.

Table 3: Effect of load resistance

Load Resistance (Ω)	**Voltage (V)**	**Current (μA)**	**Power (μW)**
1×10^3	0.4	0.40	0.16
1×10^4	1.8	0.18	0.32
1×10^5	3.9	0.039	0.15
1×10^6	4.7	0.0047	0.45
1×10^7	5.0	0.0005	0.25

When the external resistance and the TENG's internal impedance matched, the power output peaked at about 1 MΩ. The correct triboelectric charge flow and circuit design are confirmed by this "load matching" behavior.

Table 4: Stability over cycles

Cycle Number	**V_{oc} (V)**	**I_{sc} (μA)**	**Retention (%)**
1	5.4	0.37	100
50	5.3	0.36	97
100	5.3	0.36	97
200	5.4	0.37	100

Strong adherence between PDMS and the aluminum substrate, free from charge deterioration or delamination, as demonstrated by the consistent output across 200 cycles.

5. Conclusion, Limitation & Future Work

In this study we have found out that the current output of the TENG depends largely on the material choice. If proper material is chosen for the construction of TENG the result can be remarkable. From this experiment it is clear that the aluminium based TENG is a proper choice considering the effect on environment and availability of this material. The TENG we built is one that uses the positive material as the electrode. No other work has been done on this regard to our knowledge. The aluminum plate which is a positive material for making a TENG, can also be used as an electrode that’s what drives this experiment. The generator that is made can be used for powering up smart textiles for medical observations. Health monitoring, heart beat measurement, sleep alert for drivers and many more. The generator can be used for recharging small battery which can power up GPS transponders for solders and navigators. As the generator is itself a power source it can easily have some military applications.

The current TENG prototype has restricted output current and non-uniform motion because it was only tested in manual lateral-sliding mode. Long-term durability and surface characteristics were not thoroughly examined. In order to obtain constant DC output, further research will concentrate on coupling with small-scale energy storage units, optimizing surface nanostructures, and incorporating automated actuation for reliable measurements. To create flexible, washable, and self-powered smart textiles, the direct integration of the PDMS–Al system into textile structures will also be investigated.

As of now researcher all over the world working for the development of TENG. We made our contribution to that. With proper research this could be the future of the power generation which requires less amount of hassle for carrying and maintenance. The main focus on this field should be biodegradability, sustainable and cost effective. Other power sources that we use most of it has no echo friendly behavior. And for our future generation we wouldn't want that. We see that global temperature is rising so much more compared to last century, that is why we need more reliable source of energy where TENG looks more promising.

6. Declaration

The research paper titled "Triboelectric Nano-Generator to Produce DC Current for Smart Textiles" is our unique work, as we, the undersigned authors, officially declare. For academic sharing and visibility only, a prior version of this work was posted on ResearchGate as a component of a thesis (DOI: 10.13140/RG.2.2.33226.64965).

It has not been submitted, peer-reviewed, or published in any journal or conference proceedings, and the version that was uploaded to ResearchGate does not qualify as a formal publication.

We attest that the version we have submitted to this conference is unique, unpublished, and that we are the sole author and copyright holder of the content. This work has not been submitted more than once or created a conflict of interest.

7. References

[1] B. Dudem, Y. H. Ko, J. W. Leem, S. H. Lee, and J. S. Yu, "Highly Transparent and Flexible Triboelectric Nanogenerators with Subwavelength-Architectured Polydimethylsiloxane by a Nanoporous Anodic Aluminum Oxide Template," *ACS Appl. Mater. Interfaces*, vol. 7, no. 37, pp. 20520–20529, Sept. 2015.

[2] W. Wang *et al.*, "Large-scale fabrication of robust textile triboelectric nanogenerators," *Nano Energy*, vol. 71, p. 104605, May 2020.

[3] W. Yang *et al.*, "Harvesting Energy from the Natural Vibration of Human Walking," *ACS Nano*, vol. 7, no. 12, pp. 11317–11324, Dec. 2013.

[4] R. D. I. G. Dharmasena and S. R. P. Silva, "Towards optimized triboelectric nanogenerators," *Nano Energy*, vol. 62, pp. 530–549, Aug. 2019.

[5] S. Pan and Z. Zhang, "Fundamental theories and basic principles of triboelectric effect: A review," *Friction*, vol. 7, no. 1, pp. 2–17, Feb. 2019.

[6] D. Kim, S. Lee, Y. Ko, C. H. Kwon, and J. Cho, "Layer-by-layer assembly-induced triboelectric nanogenerators with high and stable electric outputs in humid environments," *Nano Energy*, vol. 44, pp. 228–239, Feb. 2018.

[7] W. He *et al.*, "Recent progress of flexible/wearable self-charging power units based on triboelectric nanogenerators," *Nano Energy*, vol. 84, p. 105880, June 2021.

[8] X. He, H. Guo, X. Yue, J. Gao, Y. Xi, and C. Hu, "Improving energy conversion efficiency for triboelectric nanogenerator with capacitor structure by maximizing surface charge density," *Nanoscale*, vol. 7, no. 5, pp. 1896–1903, 2015.

[9] J. Chen *et al.*, "Enhancing Performance of Triboelectric Nanogenerator by Filling High Dielectric Nanoparticles into Sponge PDMS Film," *ACS Appl. Mater. Interfaces*, vol. 8, no. 1, pp. 736–744, Jan. 2016.

[10] X. Pu *et al.*, "A Self-Charging Power Unit by Integration of a Textile Triboelectric Nanogenerator and a Flexible Lithium-Ion Battery for Wearable Electronics," *Adv. Mater.*, vol. 27, no. 15, pp. 2472–2478, Apr. 2015.

[11] G. Zhu, P. Bai, J. Chen, and Z. Lin Wang, "Power-generating shoe insole based on triboelectric nanogenerators for self-powered consumer electronics," *Nano Energy*, vol. 2, no. 5, pp. 688–692, Sept. 2013.

[12] Y. H. Ko, S. H. Lee, J. W. Leem, and J. S. Yu, "High transparency and triboelectric charge generation properties of nano-patterned PDMS," *RSC Adv.*, vol. 4, no. 20, p. 10216, 2014.

[13] R. L. Ward, "Mechanism of poliovirus inactivation by ammonia," *J. Virol.*, vol. 26, no. 2, pp. 299–305, May 1978.

[14] S. S. Kwak, H. Yoon, and S. Kim, "Textile-Based Triboelectric Nanogenerators for Self-Powered Wearable Electronics," *Adv. Funct. Mater.*, vol. 29, no. 2, p. 1804533, Jan. 2019.

[15] R. Cheng *et al.*, "Flame-Retardant Textile-Based Triboelectric Nanogenerators for Fire Protection Applications," *ACS Nano*, vol. 14, no. 11, pp. 15853–15863, Nov. 2020.

[16] C. Qian *et al.*, "All-printed 3D hierarchically structured cellulose aerogel based triboelectric nanogenerator for multi-functional sensors," *Nano Energy*, vol. 63, p. 103885, Sept. 2019.

[17] C. Yao, X. Yin, Y. Yu, Z. Cai, and X. Wang, "Chemically Functionalized Natural Cellulose Materials for Effective Triboelectric Nanogenerator Development," *Adv. Funct. Mater.*, vol. 27, no. 30, p. 1700794, Aug. 2017.

[18] J. Chen and Z. L. Wang, "Reviving Vibration Energy Harvesting and Self-Powered Sensing by a Triboelectric Nanogenerator," *Joule*, vol. 1, no. 3, pp. 480–521, Nov. 2017.

[19] S. Kim *et al.*, "Transparent Flexible Graphene Triboelectric Nanogenerators," *Adv. Mater.*, vol. 26, no. 23, pp. 3918–3925, June 2014.

[20] C. Wu *et al.*, "Enhanced Triboelectric Nanogenerators Based on MoS_2 Monolayer Nanocomposites Acting as Electron-Acceptor Layers," *ACS Nano*, vol. 11, no. 8, pp. 8356–8363, Aug. 2017.

[21] M. Seol *et al.*, "Triboelectric Series of 2D Layered Materials," *Adv. Mater.*, vol. 30, no. 39.

[22] H. Yang, F. R. Fan, Y. Xi, and W. Wu, "Bio-Derived Natural Materials Based Triboelectric Devices for Self-Powered Ubiquitous Wearable and Implantable Intelligent Devices," *Adv. Sustain. Syst.*, vol. 4, no. 9, p. 2000108, Sept. 2020.

[23] R. Wang *et al.*, "Engineered and Laser-Processed Chitosan Biopolymers for Sustainable and Biodegradable Triboelectric Power Generation," *Adv. Mater.*, vol. 30, no. 11, p. 1706267, Mar. 2018.

[24] J.-N. Kim *et al.*, "Skin-attachable and biofriendly chitosan-diatom triboelectric nanogenerator," *Nano Energy*, vol. 75, p. 104904, Sept. 2020.

[25] Y. Bao, R. Wang, Y. Lu, and W. Wu, "Lignin biopolymer based triboelectric nanogenerators," *APL Mater.*, vol. 5, no. 7, p. 074109, July 2017.

[26] Y. Han *et al.*, "Fish Gelatin Based Triboelectric Nanogenerator for Harvesting Biomechanical Energy and Self-Powered Sensing of Human Physiological

Signals," *ACS Appl. Mater. Interfaces*, vol. 12, no. 14, pp. 16442–16450, Apr. 2020.

[27] S. An, A. Sankaran, and A. L. Yarin, "Natural Biopolymer-Based Triboelectric Nanogenerators via Fast, Facile, Scalable Solution Blowing," *ACS Appl. Mater. Interfaces*, vol. 10, no. 43, pp. 37749–37759, Oct. 2018.

[28] J. Son *et al.*, "Recycled, Contaminated, Crumpled Aluminum Foil-Driven Triboelectric Nanogenerator," *Adv. Sci.*, vol. 10, no. 28, p. 2301609, Oct. 2023.

Nomenclature

PDMS	Polydimethylsiloxane
TENG	Triboelectric Nanogenerator
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene Fluoride
PVA	Polyvinyl Alcohol