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Triboelectric Nanogenerators, A Study of Sliding Mode Mechanism

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***Abstract*—This experimental abstract focuses on investigating the surface electric potential of two dielectrics within a Triboelectric Nanogenerator (TENG) and elucidating the resultant open circuit voltage and short circuit current. The study explores the intricate triboelectric effect, where contact and separation between materials lead to the generation of electric charges. Using a TENG setup, the experiment measures and analyzes the surface electric potential of two dielectric materials in contact, examining their interaction dynamics.**

The primary objective is to quantify the open circuit voltage and short circuit current generated by the TENG in response to the triboelectric effect. By employing precise instrumentation and methodologies, the study aims to provide a comprehensive understanding of the relationship between surface electric potential and the electrical output of the TENG. This experimental exploration contributes valuable insights into the fundamental principles governing TENG operation and offers practical data for optimizing its performance.

The results obtained from this investigation hold significance for the advancement of TENG technology, providing a basis for refining material selection, design strategies, and applications. This abstract encapsulates the experimental approach, emphasizing the quantification of surface electric potential and its direct correlation with the open circuit voltage and short circuit current in the context of triboelectric nanogenerators.

***Keywords*—TENG, surface electric potential, TENG operation**

I. INTRODUCTION

The study of the triboelectric effect, a phenomenon in which two materials become electrically charged in opposite signs after contact, has been a subject of interest for centuries. Everyday experiments, such as rubbing a plastic rod on common fabrics, demonstrate this effect, leading to the development of a fundamental understanding of measurable electric charges. The triboelectric effect is not only limited to solid-solid contacts but extends to non-solid interactions, including solid-liquid, solid-gas, and liquid-gas contacts. However, despite its long-known existence, a comprehensive understanding of the triboelectrification process remains limited, leading to controversies in material design, especially for devices like Triboelectric Nanogenerators (TENGs). Efforts have been made to establish a universal pattern of triboelectricity between different materials, often attributed to the flow of electrons during contact. The triboelectric series, a well-accepted reference, categorizes materials based on their electronegativities, forming a basis for the development of charged states. These charges, typically stable on insulator surfaces, can be harnessed for energy conversion using generators such as the Van de Graaff generator. In the realm of TENGs, the correct exploitation of triboelectrification is crucial. Four working modes—contact-separation, linear sliding, freestanding, and single electrode—have been identified, each offering distinct advantages and applications. The understanding and effective utilization of these modes contribute to the development of TENGs for energy harvesting. Despite millennia of awareness about the triboelectric effect, ongoing research seeks a deeper understanding of the mechanisms involved, particularly in diverse material interactions. This quest for knowledge aims to refine applications, enhance material design, and unlock the full potential of the triboelectric effect in various technological advancements.

II RELATED WORKS

As the demand for sustainable power in electronic devices continues to grow, researchers are actively exploring various innovative solutions in the realm of triboelectric nanogenerators (TENGs). This section reviews several noteworthy studies that contribute to the evolving landscape of TENG technology, spanning versatile applications, cost-effectiveness, materials exploration, and novel designs.

The pressing need for sustainable power in electronic wearables, introducing a cylindrical-fiber-based triboelectric nanogenerator (CFTENG) with 140% elasticity. The emphasis on real-world applications underscores the potential for versatile integration into wearables, offering a promising solution for autonomous power in self-powered devices [4],an In-Out cylindrical TENG as a versatile solution for autonomous power in self-powered devices. The research employs rigorous modeling and evaluation to demonstrate the feasibility and efficiency of this innovative TENG design, highlighting its transformative potential in real-world applications[5].Cost-effective TENG utilizing readily available household materials—paper, PET, and a graphite pencil. The streamlined fabrication process presents a sustainable solution for power generation, especially in resource-constrained environments, showcasing promising electrical outputs[6]. Copper Tape-Based TENG as a Self-Powered Humidity Sensor,versatile copper tape-based triboelectric nanogenerator (CCT-TENG), this research innovatively integrates it as a self-powered humidity sensor. The study demonstrates cost-effectiveness and sustainability, providing a unique application of TENG technology in environmental sensing[7].

Switchable Textile-Triboelectric Nanogenerator, by overcoming accuracy limitations through switchable modes. It offers continuous and detailed profiles of mechanical variations, paving the way for transformative applications in self-powered sensors and wearable technologies[8]. Multilayered Cylindrical TENG for Forest Fire Detection, multilayered cylindrical triboelectric nanogenerator (MC-TENG) for self-powered forest fire detection. The research demonstrates the feasibility and efficiency of this innovative TENG design, contributing to sustainable prevention measures[14]. Mechanical Nanogenerator (MNG) Combining PENG and TENG, explores the MNG, combining Piezoelectric (PENG) and Triboelectric (TENG) technologies. The resulting cost-effective and flexible solution holds promise for self-powered, high-performance smart technologies, enhancing efficiency across various applications[13]. Silicon Rubber-Based TENG for Wearables, silicon rubber-based single electrode triboelectric nanogenerator (TENG), this study achieves high efficiency with a user-friendly design. The innovation advances self-powered sensors, emphasizing transformative potential in wearables and personalized health monitoring[1]. Rotary TENG for Small-Scale Wind Energy Harvesting, small-scale wind energy harvesting, this study introduces a rotary TENG with high efficiency and multifunctionality. It marks a significant stride toward practical renewable energy applications, especially in challenging environments[18].

These diverse works collectively contribute to the expanding knowledge base in the field of triboelectric nanogenerators, offering insights into materials, designs, applications, and sustainability, and laying the foundation for future innovations.

III METHODOLOGY

COMSOL Multiphysics Model

COMSOL Multiphysics is a versatile finite element analysis, solver, and Multiphysics simulation software designed to operate across different platforms. It enables users to interact with conventional physics-based interfaces and handle systems involving coupled partial differential equations. The software provides an integrated development environment (IDE) and a cohesive workflow for a range of applications. In the context of triboelectric nanogenerators (TENGs), COMSOL is employed to model the coupled effects of contact electrification and electrostatic induction. The simulation focuses on electrostatics physics within COMSOL to extract critical parameters such as open circuit voltage and short circuit charge.

A.Environment Setup

a. Space Dimension

In the model wizard, the space dimension is set to 2-D symmetric, as the sliding mode triboelectric nanogenerator which we intend to simulate is symmetric and has thin film layers.

b. Physics Interface

For the triboelectric system, the physics interface is set to electrostatics. The electrostatic interface is used to compute the electric field, electric displacement field and potential distribution in dielectrics where the electric charge distribution is explicitly prescribed.

The physics interface solves Gauss Law for the electric field using the scalar electric potential as the dependent variable.

c. Type of Study

The type of study we conducted is stationary, as our model is not time dependent. Time dependent studies are complex as the results depend upon the behaviour of the system over time. Stationary studies are used in electromagnetics to compute static electric or magnetic field, both of which are field variables which do not change over time.

B.Physical Parameters

The unit of measurement used is millimetre(mm), as the design deals with thin layers.
Sliding distance (x1) = 0.1 mm
The top and bottom layers are constructed using the rectangle tool and has the following dimensions:
Width (w) = 100mm
Height (h) = 0.22 mm

The bottom layer is placed at x= -100mm, y=0 mm and is fixed. Motion across both the dimensions are locked. The top layer is created by duplicating the bottom layer and is placed on top of the bottom layer, with a gap between the two layers, ‘d’ = 0.22mm. The motion of the top layer is arrested in the y-axis. The top layer can slide over the bottom layer across the x-axis.

SIMULATION RESULTS

When the dielectric films come into contact and undergo relative sliding parallel to their surfaces, triboelectric charges are generated on both film surfaces. To completely neutralize the field created by these triboelectric charges, a lateral polarization is introduced along the direction of sliding. This polarization initiates the flow of electrons between the top and bottom electrodes. Consequently, the top electrode develops a positive electric potential, while the bottom electrode acquires a negative potential, a result of the electrostatic induction caused by the triboelectric charges.

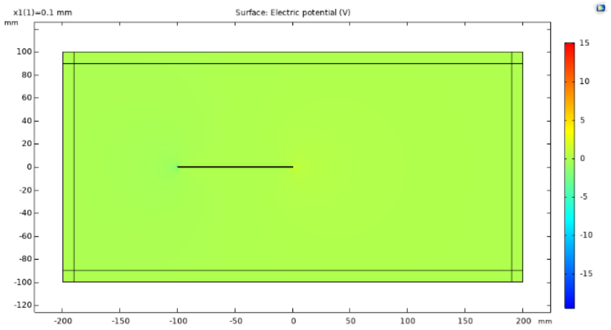

Figure.1.1

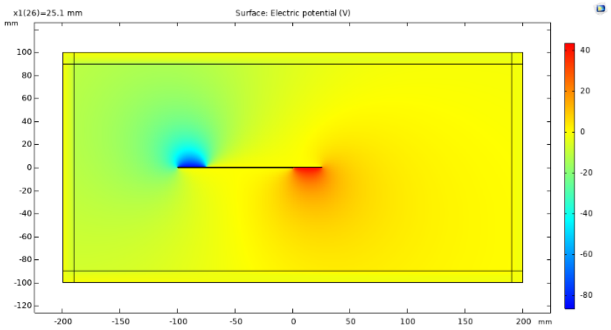

Figure.1.2

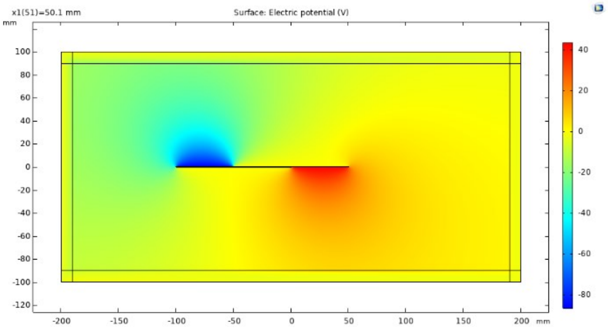

Figure.1.3

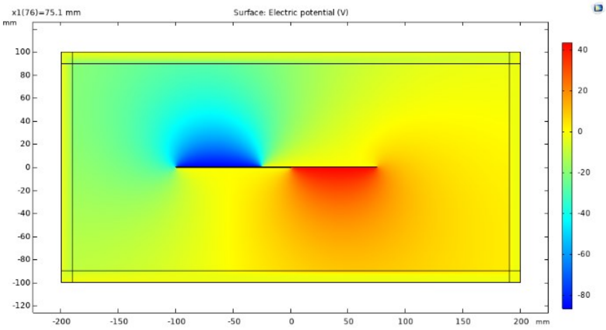

Figure.1.4

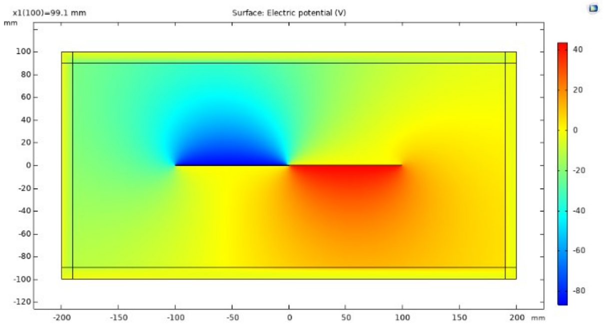

Figure.1.5

Figures (1.1) to (1.5) shows the change in the surface electric potential of the electrodes with increase in sliding distance (x1). Each of the figures has a linear increase in sliding distance, at a rate of 25mm per instance

V.CONCLUSION

The COMSOL Multiphysics model successfully simulates the behaviour of a sliding mode triboelectric nanogenerator (TENG) with a focus on the electrostatic effects. The 2-D symmetric space dimension was chosen to match the characteristics of the TENG, and the electrostatic physics interface was employed to compute essential parameters such as electric field, electric displacement field, and potential distribution in dielectrics. The stationary study type was selected, considering that the model is not time-dependent. This choice is justified by the nature of electromagnetics involved in computing static electric fields, which remain constant over time. The physical parameters, all measured in millimetres, include the sliding distance (x1), dimensions of the top and bottom layers, and the gap between them. The simulation results reveal the generation of triboelectric charges upon contact and sliding between dielectric films. To neutralize the field created by these charges, a lateral polarization is introduced, initiating the flow of electrons between the top and bottom electrodes. As a consequence, the top electrode develops a positive electric potential, while the bottom electrode acquires a negative potential due to electrostatic induction. The provided figures (x.1 to x.5) illustrate the change in surface electric potential of both electrodes as the sliding distance (x1) increases. The linear progression in electric potential with sliding distance is evident in each figure, highlighting the correlation between the two variables. Overall, the simulation provides valuable insights into the electrostatic behaviour of the TENG, demonstrating its potential to generate positive and negative electric potentials through controlled sliding. This modelling approach can serve as a useful tool for further optimizing the design and performance of triboelectric nanogenerators for energy harvesting applications.

REFERENCES

[1] Shamsuddin , Saeed Ahmed Khan , Abdul Qadir Rahimoon , Ahsanullah Abro , Mehran Ali , Izhar Hussain , Farooq Ahmed-“Biomechanical Energy Harvesting by Single Electrode-based Triboelectric Nanogenerator”

[2] Wei Gou, Shiquan Fan , Li Geng-“ Three-layer Structure Triboelectric Electricity Generator with ULP Rectifier for Mechanical Energy Harvester”

[3] Multilayered Cylindrical Triboelectric Nanogenerator To Harvest Kinetic Energy of Tree Branches for Monitoring Environment Condition and Forest Fire -Yaokun Pang, Shoue Chen,]unchi An, Keliang Wang, Yiming Deng, Andre Benard, Nizar La)nef, and Chang ong Cao '.

[4] Dogyun Kim,A Young Choi,Jiwon Park,Chang Jun Lee and Youn Tae Kim-“Stretchable and Flexible Cylindrical-fibre-based Triboelectric Nanogenerator”

[5] Ahmed Zaky , Akram Ahmed1 , Passant Ibrahim , Basant Mahmoud , and Hassan Mostafa-“In-Out Cylindrical Triboelectric Nanogenerators Based Energy Harvester”

[6] Muhammad Umaid Bukhari, Kashif Riaz, Tauseef Tauqeer, Memoon Sajid-“Simple and low cost triboelectric nanogenerator (TENG) for resource limited environment”

[7] KequanXia , Zhiyuan Zhu , Jiangming Fu, Yue Chi, and Zhiwei Xu-“ Multifunctional Conductive Copper Tape-Based Triboelectric Nanogenerator and as a Self-Powered Humidity Sensor”

[8] Hao Wang, Shuting Liu, TianyiyiHe ,Shurong Dong , Chengkuo Lee-“ A switchable fabric-triboelectric nanogenerators (SF-TENGs) profile sensing application”

[9] RenyunZhang , Håkan Olin –“Material choices for triboelectric nanogenerators: A critical review”

[10] SimiaoNiu , Ying Liu , Sihong Wang , Long Lin , Yu Sheng Zhou , YoufanHu,and Zhong Lin Wang-“Theory of Sliding-Mode Triboelectric Nanogenerators”

[11] Simiao Niu1and Zhong Lin Wang-“Theoretical systems of triboelectric nanogenerators”

[12] WenlinLiu , Zhao Wang , Gao Wang , Guanlin Liu , Jie Chen , Xianjie Pu , Yi Xi , Xue Wang , Hengyu Guo, Chenguo Hu & Zhong Lin Wang-“Integrated charge excitation triboelectric nanogenerator”.

[13] SaichonSriphan,NaratipVittayakorn,“Hybridpiezoelectric-triboelectric nanogenerators for flexible electronics: Recent advances and perspectives”

[14] Multilayered Cylindrical Triboelectric Nanogenerator To Harvest Kinetic Energy of Tree Branches for Monitoring Environment Condition and Forest Fire-YaokunPang,ShoueChen,]unchiAn,KeliangWang,YimingDeng,AndreBenard,NizarLa)nef,andChangongCao'

[15] Sihong Wang, Long Lin, Yannan Xie, Qingshen Jing, Simiao Niu, and Zhong Lin Wang- “Sliding-Triboelectric Nanogenerators Based on In-Plane ChargeSeparation Mechanism”

[16] Zong-Hong Lin , Gang Cheng , Ya Yang , Yu Sheng Zhou , Sangmin Lee, and Zhong Lin Wang –“Triboelectric Nanogenerator as an Active UV Photodetector”.

[17] Cun Xin Lu, Chang Bao Han, Guang Qin Gu, Jian Chen, Zhi Wei Yang, Tao Jiang, Chuan He, and Zhong Lin Wang-“Temperature Effect on Performance of Triboelectric Nanogenerator”

[18] Yannan Xie, Sihong Wang, Long Lin,QingshenJing,Zong-Hong Lin,Simiao Niu, ZhengyunWu,and Zhong Lin Wang –“Rotary Triboelectric Nanogenerator Based on a Hybridized Mechanism for Harvesting Wind Energy”