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Designing, Fabrication and Performance Review of Triboelectric Nanogenerated (TENG) Tile for Sustainable Energy Harvesting

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Abstract:- There is an increase in the need of sustainable energy harvesting sources as the world is on the verge of exhausting all the non-renewable sources of energy. Hence, there is developed focus on development of new harvesting devices with the view of decreasing the dependency of energy on non-renewable sources. One of the methods is the development of energy using triboelectric nanogenerator. It has gained significant attention due to the high energy output, low cost, and eco-friendliness. Development and use of triboelectric nanogenerator is in different forms, one of which is use of it in tile form. The tile will harvest the waste mechanical energy from various mechanical forces, vibrations or pressure and convert it to electrical energy. In this paper an attempt is made to develop and review the performance of a low-cost [1], small scale triboelectric nanogenerator tile which will harvest energy from the pressure applied on it via different mechanical forces, for example, walking, vibrating machines or rain drops. There is also an attempt to integrate the tile with solar panels to increase the efficiency of the device when there is no mechanical force applicable on it. Materials using are Kapton (C22H10N2O5), Aluminum (Al) for electrodes and copper wires for the electrical conductivity.

Keywords:- *Triboelectric Nanogenerator, Sustainable Energy, TENG, Mechanical Energy Conversion.*

I. INTRODUCTION

As the world faces interrelated challenges of climate change, energy security and environmental degradation there is a pressing need for renewable energy. There is a finite source of fossil fuels which have been more or less the dominant source for energy. Different problems have arisen due to the extensive use of the non-renewable sources like rising sea levels, extreme weather events, loss of biodiversity, etc. Renewable energy is a great alternative and sustainable energy available which can replace the fossil fuels. Energy sources like the solar, wind, hydro, geothermal, etc. do not deplete over time and produce minimal harmful effects on the ecosystem. This will also reduce the carbon footprint to a greater extent by harnessing the abundant inexhaustible sources. With the rise in sustainable energy sources, innovative technologies have also been on a rise which harness energy from different sources. There are over 200 billion sensor projects in use till date and the number is on a rise. One of the sensors use to harness energy is the triboelectric nanogenerator. This technology has emerged as a promising solution of generating electricity and energy from waste mechanical energy, the best part it offers is that it does not require any recharging and replacement is required only when there is any damage to sensor.

Now the question arises is what is triboelectric nanogenerator and how does it work? The TENG can be compared to a normal piezoelectric crystal that converts mechanical stress to electricity. But unlike piezoelectric property which is exhibited by a handful of known components TENG capabilities can be found in materials which have tendency to gain and loose electrons. There is exchange of electrons between two electrodes of a TENG when there is mechanical stress applied [2]. They can be used in different modes to exchange electrons like the contact separation tap mode, sliding mode or single electrode tap mode (refer fig. 1) [3].

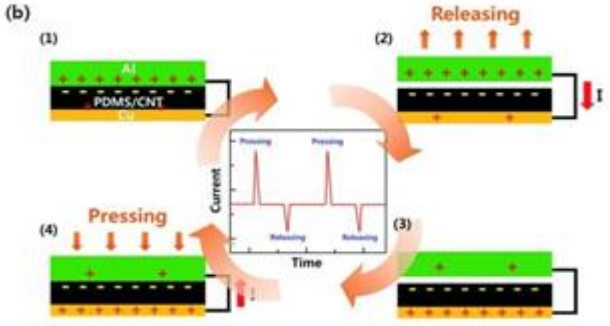

Fig 1. Tap mode separation mode

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The basic principle is that when the electrode is tapped onto one another there is exchange of electrons this phenomenon is called as contact electrification [4], this causes a flow of electrons and hence an electrical flow is generated. By repeated cycle of contact making a and breaking there is more and more electron loos and gain and hence electrical flow is maintained. Coming to manufacturing the TENG in small scale working form it can be used in the form of a tile which has an electrode at the base and second electrode on top of it separated by the spring on the edges. At rest the springs are in uncompressed state which keeps the two electrodes separated and when the mechanical force greater than stiffness (K) of spring is applied the contact of the electrodes causes the exchange of electrons.

II. AIM AND OBJECTIVE

The following study was conducted in order fabricate and implement an integrated energy harvesting system using TENG and to find the output of energy developed by the small wasted mechanical forces which are available in environment with an aim to harness these waste energies. The aim is to develop a small scale, low cost device which can be installed on the foot walks or railway stations or high traffic areas which will harness the energy from the human walking over the tile, the integration of solar panel is secondary aim to improve the output of the tile when not in use [5].

Main objective remains the same i.e. to lower the cost of the device hence it can be used in daily life. Secondary objective is to optimize the energy conversion efficiency by changing the parameters like size, thickness, surface texture, etc. The output received and the challenges faces is discussed in the paper ahead in the section V of the paper.

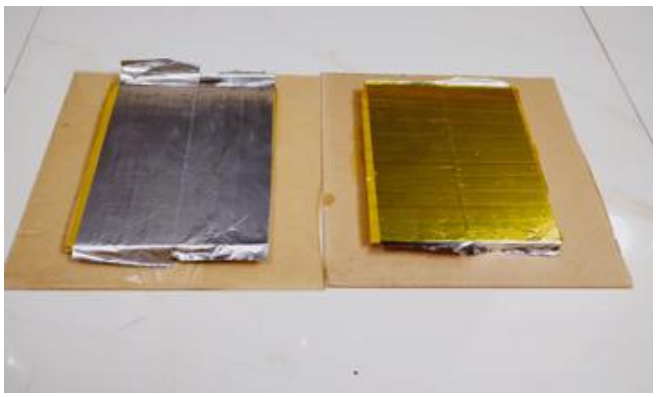

Fig 2. Layer formation

III. MATRIAL SELECTION [6]

Generally, materials with high capability to transfer and exchange electrons are used for triboelectric layers. The material available for fabrication of triboelectric nanogenerator is as follows -

- Polydimethylsiloxane (PDMS) – This is the most abudent used material for TENG as it can gain and loose electrons easily
- Polyimide (PI) – This material posses excellent mechanical and thermal properties hence it is used as dielectric layer in TENG
- Teflon (PTFE) – It is a non conductive polymer having low frictional properties, it has comparable capabilities with PDMS to gain and loose electrons [7]
- Metals – Metals like aluminium, copper, zinc can be used as TENG materials when used with proper secondary material.

For this study the material selected for triboelectric layers is Teflon (PTFE) and commercial Aluminum (Al) obtained by different processes or even from food packaging [8], with a layer of copper wires in between the electrode layers.

IV. METHODOLOGY AND MANUFACTURING

A systematic approach will be followed to design the tile like done by U. Bukhari et.al. [9] and integrate it with solar panels for higher energy generation. The compressive knowledge gathered from the literature review helped in selection of material and method of production.

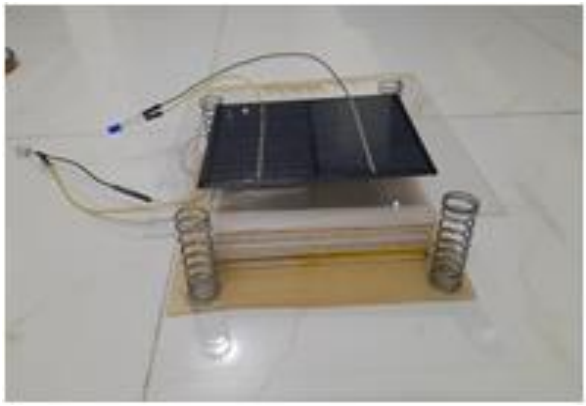

Fig 3. 15x15 Tile Prototype

The manufacturing process of TENG tiles integrated with solar panels will involve several steps, they are as follows-

- Layer fabrication – A substrate is coated with the triboelectric layer, aluminum and Teflon is used as a triboelectric layer. Aluminum is manufactured by either sputtering or evaporation or by chemical vapor deposition. Teflon is coated by spray coating or by spin coating (refer fig. 2).
- Integration of copper wires – Between aluminium and Teflon copper wires are integrated to establish electrical conductivity and connections. The electricity will be collected by these wires and they act as a conductive pathway. Uniform distribution of copper wires is necessary for proper output of the device.
- Spring placement – There are two such layers of triboelectric made one with aluminium on top and other with Teflon on top, both are coated on a balsa wood which acts as a substrate. The two layers are separated by springs

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on four corners to ensure that the two layers don't come in contact unless mechanical force is applied.
- Quality Control – Quality control measures will be implemented through out the manufacturing process to ensure consistency and reliability. Testing must be performed while manufacturing to know the strength of the tile.
- Connections – The copper wires are connected to jumper wires and the wires from solar panels are also connected to a common point of wires, which is divided as positive and negative. A multimeter can be used to measure the current or an LED can be installed to check the connectivity of the wires.

A 15 x 15 cm tile is manufactured by the above process (refer fig. 3). The materials are selected as per availability hence it must not be difficult to get the materials.

V. FINDINGS, CONCLUSION AND FUTURE SCOPE

TABLE 1 OBSERVATIONS

Sr. No.	**OBSERVATIONS**		
	FORCE VALUE (N)	ELECTRICAL OUTPUT W/O SOLAR PANEL	ELECTRICAL OUTPUT WITH SOLAR PANEL
1.	45	54mW	98mW
2.	55	68mW	111mW
3.	65	72mW	123mW
4.	75	79mW	129mW
5.	85	85mW	134mW

*THE FOLLOWING WAS MEASURED USING A CALIBRATED MULTIMETER *THE SURFACE AREA USED FOR THE TILE IS 15X15 CM * THE OBSERVATIONS WERE FOR A SINGLE CONTACT SEPERATION CYCLE

As per the observations it can be concluded that integrating the solar panel with the device aids in increasing the output of the overall system. But a drawback of it is that the integration of the solar panel makes the circuit more complex. The increase in output when increase in force is due to the fact that the layers are in contact with each other for a longer period of time compared to less force and also that higher force causes more surface area to come in contact within the device within the layers. Hence, it can be inferred that to increase the efficiency and output more surface area contact is required hence more the area more the electricity production. There is minor effect on the overall cost but the increasing of complexity of circuit causes it to have skilled mind working and installing the TENG tile. The strength of the tile is also compromised seeing the low strength of the solar panel which will lie on top of the triboelectric layer.

To conclude it can be said that the use of TENG tile in high foot fall places will help in generation of energy but at a certain cost. The energy developed by the tile may be less compared to the other sources but it can help harness the waste energy.

There must be further studies conducted on TENG tile in order to optimize the design and increase the efficiency. The further studies require the formation of high strength tile with the solar panel, increasing the efficiency by either increasing the surface area or by changing the material and observe the findings.

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