Energy Generation using Bombax Ceiba Fibres based Triboelectric Nanogenerator

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Abstract

Triboelectric nanogenerators are promising sources of energy that can harvest energy from variety of materials. Bombax ceiba also known as silk cotton tree has white fibres which are present in its ovary shaped fruit. This paper proposed fruit fibres-based contact separation mode triboelectric nanogenerator which is fabricated in combination with PTFE. Manual tapping at approximately 4Hz has generated sufficient power that can power 62 green LEDs which shows that this combination has the capability to produce 124V. Also, this material is highly electropositive in nature as compared to PTFE. Thus, variety of waste materials can be explored that can be utilised to harvest green energy. The power exploited from such materials can be used to run numerous small devices especially in monitoring human health systems or remote sensing.

Keywords

Natural material, Triboelectric effect, Green energy, Energy Harvesting

1. Introduction

Triboelectric nanogenerators are the simple and easy way to harvest mechanical energy to electrical energy using two basic principles that are electrostatic induction and contact electrification[1]. According to this, whenever two different materials having different electron affinities are brought in contact, it results in the production of charges on their surfaces and through induction electrodes collects this charge. So, material selection plays a vital role in the current or voltage production in TENG[2]. As there are numerous research papers in which synthetic polymers were used for production of current/voltage and energy was harvested from various sources or motions[3]–[10] But recycling of these polymers and their non-biodegradable nature made researchers to explore new materials that solve these problems. So various natural materials based TENG was proposed by several researchers and range of voltage was generated. Feng et al. harvested the energy from green leaves and their powder which produced 430V and 15µA voltage and current respectively. Further this TENG was modified by using poly-L-lysine (PLL) in the leaf powder that enhanced the performance to 1000V voltage production[11]. Zhong and his group prepared fully biodegradable TENG using chitin (from carb or shrimp), silk fiber (from cocoon), egg white (from eggs) and rice paper (from wheat or rice) and also proposed a tribo series for these materials[12]. Researchers also proposed the relationship between cellulose content present in material used for charge generation and the output voltage produced. It was concluded that the material with more carbohydrate content resulted in more voltage creation but role of roughness of surface was also important[13]. Variety of leaves such as Hosta leaf, L. Chinese, Populous

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leaf etc. werealso explored for the TENG fabrication and range of voltage was generated[14]. Along with these, dog hair[15], egg shell membrane[16], spider silk[17], orange peel[18], rose petal[19] etc. based TENGs were also proposed by researchers. This paper proposed a TENG fabricated from cotton like white fibers which are collected from bombax ceiba tree as one active material and PTFE as another active material.

2. Materials and TENG setup

Bombax ceiba is deciduous tree which is an important medicinal plant and mostly grows in tropical and subtropical regions of India. It belongs to a family known as Bombacaceae which represents silk cotton tree[20]. It grows up to 40 meters in height and it bears flowers in the months of January to march. Its fruit is ovary shaped, 5 valved and seed are embedded with white silky fibres[21] as shown in figure 1. Theses fibres are collected and washed with DI water for several times and dried at room temperature overnight. Further, these fibres are used as charge generating material and applied on aluminum tape which acts as an electrode. Other material is Polytetrafluoroethylene (PTFE), which is a flexible synthetic polymer, is applied on electrode and connecting wires are attached to these electrodes. The full setup diagram for TENG fabrication is described in figure 1.

The working mechanism is such that both materials are placed facing each other having electrodes on their back which are further connected to connecting wires to complete the circuit. Initially when both materials are pressed against each other it results in production of charge on their surfaces because of different electron affinities. But the charge so produced is equal so no potential difference is created. Further when this pressure is released, the potential gradient appears and consequently current will flow in the outer circuit. This gradient tries to achieve the equilibrium with increase in distance and once this balance is achieved, the current flow ceases. Up to this one peak of output is generated and next but opposite peak is observed when force is applied on these active layers and brought in contact. Thus, ac output is generated from the TENG that can be stored or rectified and utilized in any application. The working of contact separation mode TENG using Bombax ceiba and PTFE is described in figure 2.

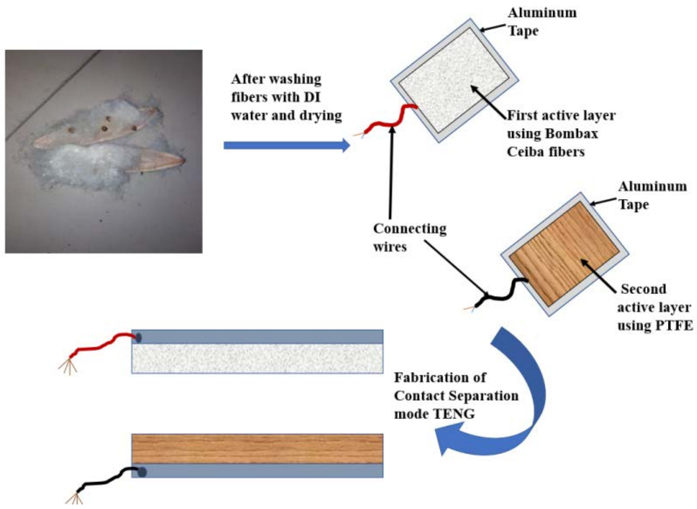

Figure 1: Fabrication process of contact separation mode TENG

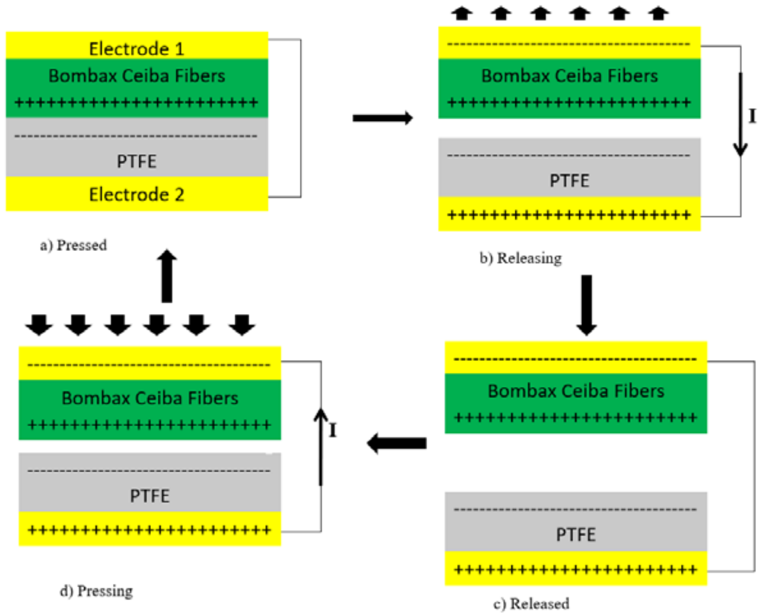

Figure 2: Working mechanism of TENG

3. Results and Discussions

To study the functional groups, present in bombax ceiba fibres, FTIR using Agilent Canny 630 is performed and result is shown in figure 3a. The prominent peak at 3339.7 cm^{-1} represents the presence of stretched O-H bond while C-H group is denoted by peak at 2922.2 cm^{-1}. Further peaks at 1729.5 cm^{-1} and 1595.3 cm^{-1} signifies the presence of carbonyl group (-C=O) and carboxyl group respectively. Stretched mode of carbonyl aldehyde group is observed at 1237.5 cm^{-1} and stretched C-O group at 1028.7 cm^{-1}. The presence of carboxyl group, which is an electropositive material as mentioned in tribo series, makes this material to exhibit static charge when brought in contact with other material. In case of PTFE[15], the presence of various modes of CF_2 group are observed at prominent peaks of 1207.7, 1148, 633.6 and 499.5 cm^{-1} as shown in figure 3b.

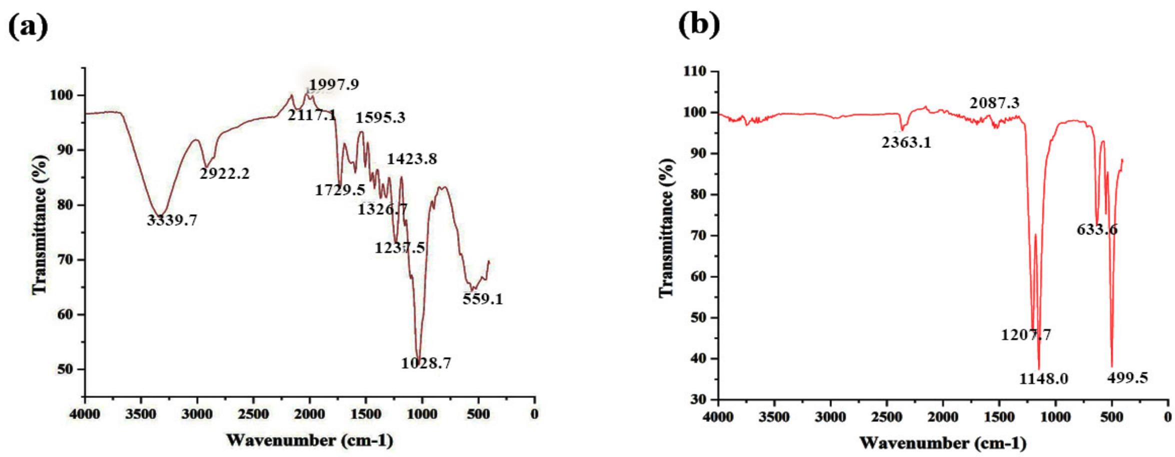

Figure 3: FTIR a) Bombax Ceiba fibres b) PTFE

The output from TENG is observed using manual tapping at 4HZ frequency over the area of 6x8 cm^2. The bombax ceiba based layer is connected to negative probe of DSO (Keysight EDUX 1002G) and PTFE to positive probe. When tapping is applied it is observed that this combination has the capability to generate approximately 98V. Moreover, while pressing (p) positive peak is observed and negative peak on releasing (r) as shown in inset figure 4. It is concluded from the aforementioned reason that bombax ceiba fibres are more electropositive as compared to PTFE. Lastly, the output voltage so produced from this combination is utilized in powering green LEDs. The output collected from TENG is connected to array of green LEDs which are arranged in series and when tapping is performed 62 LEDs are powered as shown in figure 5. As each green LED requires 2V for its working, thus this TENG has generated 62 x 2 = 124V.

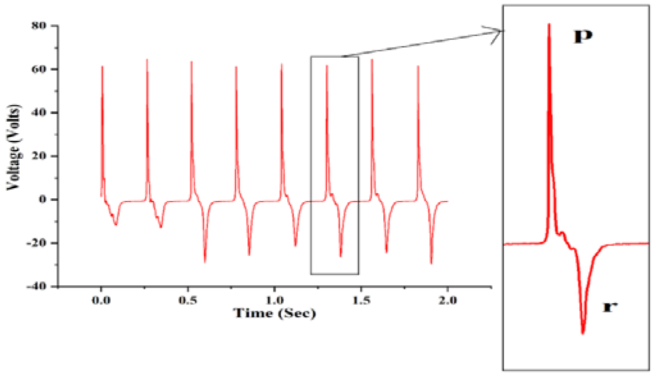

Figure 4: Output observed from Bombax Ceiba and PTFE based TENG. Inset: enlarged version of one peak.

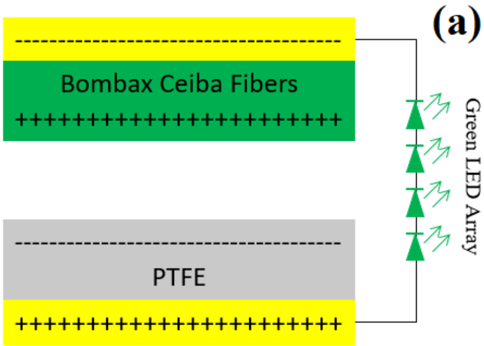

Figure 5: a) Setup for powering LEDs b) Powered green LEDs

Thus, it can be concluded that the fibres of bombax ceiba fruit can be used for power generation that is otherwise a waste material. This voltage produced can be changed to DC voltage using rectifier and further utilized in powering small electronic devices through capacitor.

To further extend this work, the material's biodegradability should be tested so as to check the time for which its content maintains its electron affinity. Another point is verifying the durability of material so as to calculate the time for which it will provide constant output.

4. Conclusion

In this paper, a waste material based TENG is proposed that is prepared using Bombax Ceiba fibres and PTFE. These fibres are available in the months of march and April and appears like cotton. These fibres contain carboxyl group that makes it more electropositive than PTFE. Also, this electropositive nature is verified by the output waveforms obtained from DSO. Further the output voltage obtained from TENG was utilized to power 62 green LEDs thus resulting in the production of 124V. Thus, this naturally available and eco-friendly material can be utilized to harvest green energy that can run small electronic devices or network of small IOT based sensors.

5. References

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