Proceedings

3D Printed Materials Based Triboelectric Device for Energy Harvesting and Sensing †

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Abstract: Energy harvesting and sensing triboelectric module based on 3D-printed materials have been developed. Rapid prototyping, 3D-printing method is used to prepare sheets of triboelectric materials and simple film casting technique is employed to deposit electrically conductive carbon based elastomeric composite on these dielectrics. The device exhibits capability to detect and harvest energy from mechanical deformation. The developed 3D printed triboelectric system, under tapping condition, provides the maximum rms power of 41.2 μW for the optimum load resistance of 6.1 MΩ that corresponds to the power density of 10.6 μW/cm^2. The processing set the building-block towards fully printed triboelectric devices.

Keywords: triboelectricity; 3D printing; energy harvesting; sensing

1. Introduction

The scarcity of the conventional energy sources and their negative effect on environment, drove our attention towards green and sustainable renewable sources of energies. Mechanical/kinetic energy is abundant in nature and is generally wasted is daily life. Scavenging of energy form kinetics, as renewable sources, to power low power consumer electronics is getting greater attention in recent time. Amongst others, triboelectric effect can be implemented to convert mechanical energies to electrical signals [1].

Triboelectric generator (TrEG) uses contact electrification and electrostatic induction mechanisms [1]. Different materials can be used to fabricate TrEG [2]. Such generators can be used to harness mechanical energy from wind/ water wave, movement of objects and even human motion. Verities of triboelectric generators have been reported, to date, for powering consumer devices [1,3,4], and most of these have been fabricated using verities of materials combination and different technology platforms, namely, vacuum based, foil based [5], iterative fiber-drawing process [4], and so on. Recently film casted elastomeric TrEGs have also been reported [6,7]. During this work, we are investigating the possibilities of implementing 3D printed dielectric materials layers as triboelectric functional layers.

In recent time, 3D printing, an additive manufacturing method, has gained substantial interest as rapid procedure to develop prototypes for various applications [4,8,9]. The 3D printing technique allows to develop complex geometries directly from the digital drawing, and can be combined with other manufacturing methods to develop functionalities.

Here, the development of the triboelectric generator based on 3D printed materials, to evaluate their potency as triboelectric materials, in combination with the film casting on electrode materials is presented. The fabricated system shows the potential of sensing of and harnessing power form mechanical deformation.

2. Experimental Procedure

2.1. Design

The fabricated TrEG incorporate vertical contact separation principle in its design, where two 3D printed triboelectric layers having identical active area were placed facing one another separated by a 3D printed sepacer that acts like spring during operation. Figure 1 illustrate the schematic diagram of the design and Table 1 listed the dimensions of the 3D printed material based TrEG.

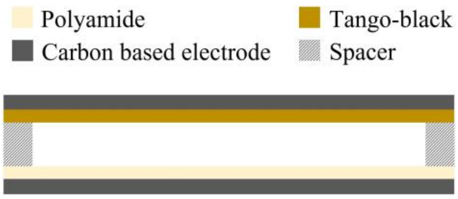

Figure 1. Schematic diagram of the design of 3D printed materials based triboelectric generator.

Table 1. Physical parameter of the 3D printed materials based TrEG.

Physical Parameters	
Active area (cm^2)	25
Spacer thickness (mm)	2.5
Thickness of Tango black layer (μm)	250
Thickness of PA layer (μm)	500

2.2. Materials

Polyamide (PA 2200) and rubber like TangoBlack (TB) dielectric materials were 3D printed using selective laser sintering (SLS) and polyjet 3D printing techniques, respectfully, employing EOSINT P 395 and Objet connex 500. Conductive carbon black pellets Ketjenblack EC-600JD that was used to develop electrode materials was ordered from Akzo-Nobel, and sovents were purched from Sigma-Aldrich. All products were used as received.

2.3. Process Flow

Initially, triboelectric PA and TB layers, were 3D printed, having sligtly different workfunctions. These 3D printed dielectric layers inherent microtextures on their surfaces by default due to the respective 3D printing processes. Thereafter, carbon based conductive eleastomeric material layers were film casted on the one surface of each dielectric layers and cured. Prior to the film casting process, the dielectrid layers were attached on the polyethylene terepthalate (PET) substrate. Finally, both tribelectric layers were assembled facing each other separated by the 3D printed spacer. Wiring was then performed followed by wrapping, using PDMS based adhesive, thin polydimethylsiloxane (PDMS) layer of 20 μm from Wacker on the fabricated struture that acts as a protective layer during operation. Figure 2 presents the photograph of the 3D printed material based triboelectric generator.

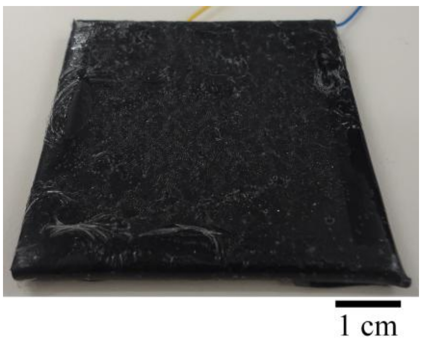

Figure 2. Top view photograph of the 3D printed materials based triboelectric generator.

2.4. Characterizations

The fabricated TrEG was characterized to study their performances under harmonic mechanical deformation of the system by tapping for the operating frequencies of 1.1 ± 0.1 Hz. Open circuit voltage (V_{OC}) and maximum current outpur (I_{Max}) were measured across 10 GΩ and 10 kΩ, respectively. Eventually, the optimum load resistance for the system was identified by characterizing the device for various load resistances. Oscilloscope was used during this measurement. The amount of charges transferred during operation was detected by charging capacitor of 2.2 μF through AC-to-DC full wave bridge rectifier.

3. Results and Discussion

The fabricated device used vertical-contact separation mode. During operation, mechanical force brought two triboelectric layers in contact and spacer which also acts as spring mechanism separate the layers while mechanical force was withdrawn. The open circuit voltage (V_{OC}) and maximum current output (I_{Max}) are presented in Figure 3a,b, respectively. The peak-to-peak V_{OC} and I_{Max} were, respectively, 755.4 V (rms value of 94.8 V) and 14.1 μA (rms value of 2.1 μA). Figure 4a,b illustrate the output voltage, current and corresponding power output of the device with respect to the varying load resistances (R_L). The maximum peak-power (P_p) output of 265.8 μW (rms power (P_{rms}) value of 41.2 μW) for the R_L of 6.1 MΩ (Figure 4c), that corresponds to the peak power density of 10.6 μW/cm^2 (rms power density of 1.65 μW/cm^2).

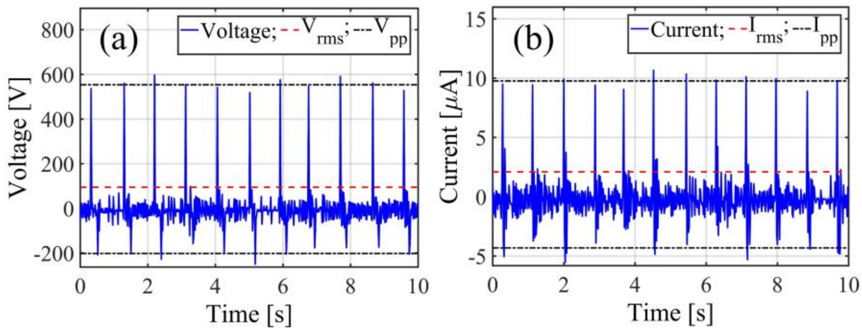

Figure 3. Electrical response of the TrEG (**a**) open circuit voltage (V_{OC}); and (**b**) short circuit current.

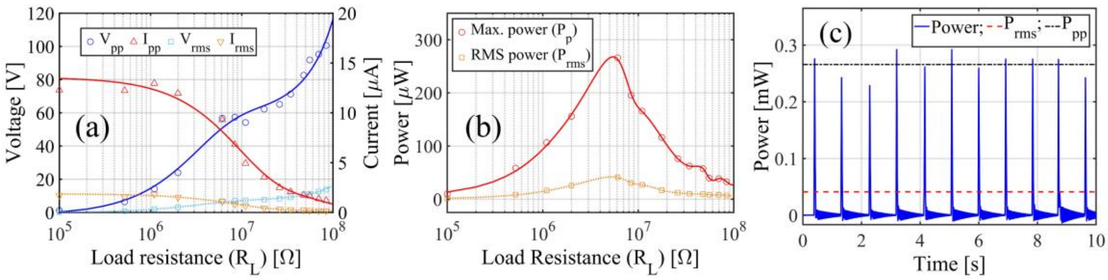

Figure 4. Electrical responses of the TrEG with respect to load resistances (**a**) output voltage and current; (**b**) corresponding power outputs for harmonic tapping motion; and (**c**) power output of the device at optimum load resistances (R_L) of 6.1 MΩ.

Using capacitor charging method, the amount of charges transferred of the system and energy stored under harmonic deformation have also been studied. The 3D printed TrEG provides the amount of charges transferred and energy stored were of 128 ± 5.4 nC/cycle, and 3.7 ± 0.3 nJ/cycle, respectively. As observed, this system can be used to sense/detect individual mechanical deformation, as well as for energy harvesting under harmonic deformation cycles.

4. Conclusions

During this work, a novel approach of manufacturing a triboelectric generator combining commercially available 3D printing techniques and materials, along with film casting approach of electrodes have been introduced. Sheets of 3D printed dielectric PA and soft rubber like tango-black materials have been employed as triboelectric materials. The device consists of simple geometry that utilized vertical contact separation principle for mechanical energy conversion. The generator can be used as sensing and for energy harnessing device at low operational frequency. The fabrication process is easily scalable. The system was capable of producing maximum rms power output of 41.2 μW for the $\boldsymbol{R_L}$ of 6.1 MΩ.

Therefore, 3D printing materials show promises to be used as triboelectric materials. However further study are required regarding process developments and machine for developing fully 3D printed energy harvester.

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Conflicts of Interest: The authors declare no conflict of interest.

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