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Fabrication of Triboelectric Nanogenerator using composite film of PDMS and ZnO nanosheets

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Abstract

A triboelectric nanogenerator is well known ambient mechanical energy harvester. In our study, we have worked for an efficient TENG by tuning its surface morphology and effective surface area. We have introduced PDMS-ZnO nanosheets composite TENG. This paper includes the fabrication and characterization of the fabricated TENG. The surface morphology of each composite film is analyzed by SEM and electrically characterized by data acquisition card with resistance box. The maximum power density delivered by PDMS-ZnO nanosheeets is 13.76 μwatt/cm² at 70M Ω. The TENG is used for lightening 20 commercial LEDs and run self-powered system.

Keywords: Triboelectric Nanogenerator, composite film of PDMS, ZnO nanosheets

INTRODUCTION

Due to the rapid increase in smart and portable electronics, energy at small scale is highly demanded [1]. Generally, batteries are used to run these systems which are expensive and need to replace after a certain period of time. Consequently, there is a need to discover an energy source that benefits in terms of cost and lifespan time. Piezoelectric and Triboelectric nanogenerator are of great significance in this regard and contribute power ranging from milli watt to microwatt [2]. Wang et al. discovered triboelectric nanogenerator (TENG) which is capable to convert mechanical energy into electrical energy. Its working principal is triboelectrification and electrostatic induction [3]. It operates in four modes which are contact separation mode, in plane sliding mode, single electrode mode and freestanding mode [4]. TENGs entertained not only in terms of efficiency, flexibility availability and eco-friendly but it is also cheap and biocompatible [6,7,8]. In meantime various TENGs have been developed. Scientist have worked a lot for the efficiency of TENG by using suitable materials, varying size of the dielectric layer and working on surface morphology through nano or micro structures and addition of chemical functional groups for best efficient TENG [9].

TENG has many applications in lightening LEDs charging capacitors, operating an electronic clock and calculator [10]. It is also used in self-powered system especially biomechanical sensors including pulse rate and breath detection sensors [11]. Some other sensors are velocity, displacement, temperature and humidity [12,13].

In this paper we have worked on a composite TENGs which is PDMS-ZnO nanosheeets and designed it in freestanding mode. Our work is based on fabrication and characterization of composite TENG and then its applications.

MATERIALS AND METHODS:

This portion includes fabrication of composite film of PDMS-ZnO nanosheets and construction of TENG.

Fabrication of composite film

The PDMS-ZnO nanosheets composite film was prepared by hydrothermal method. Al was used as a substrate and it was electropolished 1:4 v/v ratios of per chloric acid and ethanol at potential difference of 12V for getting mirror finishing surface. Then sol gel was prepared by dissolving 0.11g zinc acetate di hydrate in 50g of methanol and 0.03g sodium hydro oxide in 25g methanol. Sodium hydro oxide solution was added drop by drop in zinc acetate di hydrate solutions hence sol gel was prepared. Hereafter it was spin coated on electropolished Al to assist as a seed layer and annealed for 5 mints at 120°C. Then the substrate was placed in the hydrothermal solution of 20mM HMTA and 20mM of Zinc nitrate at 90°C for 24hrs. Later it was washed in DI water and dried at ambient temperature. The PDMS was prepared by mixing the silicone monomer with curing agent by 10:1 wt ratio. The mixture was stirred gently and then degassed in vacuum chamber until all bubbles get disappeared from PDMS. The PDMS was deposited on the sample and annealed for 5 mints. The Al sheet was etched in cupric chloride and HCl solution to get the pristine PDMS-ZnO nanosheets composite film and then Au was sputtered on the sample to serve as back electrode.

Construction of TENG:

The TENG was constructed by using fabricated composite film and designed in freestanding mode. For freestanding mode, two Al electrodes and a kapton sheet was stuck on its top surface as shown in Figure 1.The ZnO-PDMS sheet was used to slide on kapton surface. The composite sheet was attached through a mechanical setup to provide to and fro motion.

For electrical characterization the nanogenerator was attached in parallel with a resistance box and data acquisition card.

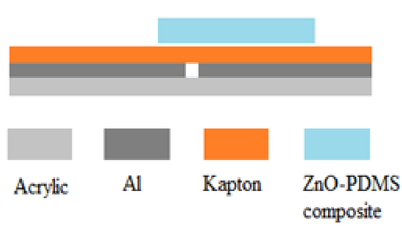

Figure 1: Schematic of fabricated PDMS-ZnO composite FD-TENG

RESULT AND DISCUSSION

1. Surface morphology

The surface morphology of composite film was analyzed by Scanning Electron Microscopy (SEM) from "Centre of Excellence in Mineralogy University of Balochistan, Quetta". The SEM result of 2D-ZnO nanosheets is given in Figure 2. These sheets were grown on Al surface via hydrothermal growth. The grown sheets were interconnected with each other where the sheet thickness was around 20nm.

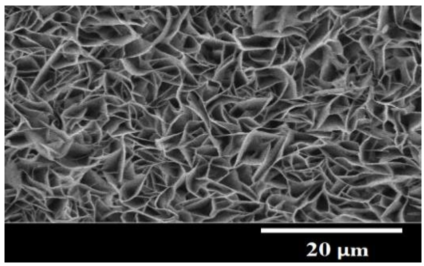

Figure 2: SEM of fabricated Zn nanosheets

2. Electrical characterization

The composite TENG was analyzed with the help of NI data acquisition card and resistance box in parallel. The resistance box was scaled from 1MΩ to 100MΩ.

Output results are investigated at various load resistance. The graph between resistance, voltage and current is shown in Figure 3.

For calculating the device resistance and optimized power the resistance is varied and at every variation the corresponding value of output voltage is recorded and current graph is also established. From Figure 3 it is clear that output voltage and current are significantly dependent on resistance. The maximum value of output voltage is recorded at maximum value of resistance. With the help of voltage and current, power density graph is established as shown in Figure 4. It is evident from Figure 4 that the device gives maximum power density of 13.76 µwatt/cm² at 70 MΩ. The maximum power from the device is achieved when the load resistance is equal to the device resistance which shows that, the fabricated device resistance is 70 MΩ.

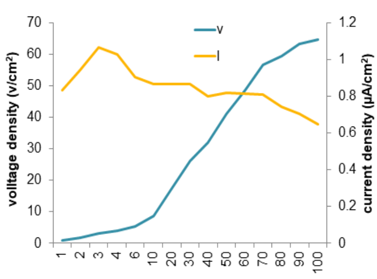

Figure 3: Two axis graph between voltage and current densities with respect to resistances of FD-TENG using PDMS-ZnO nanosheeets composite film

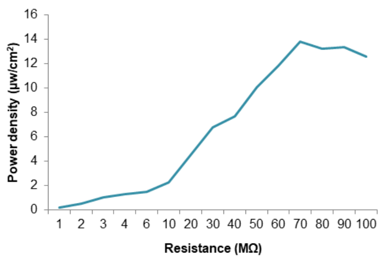

Figure 4: Graph between power density and resistances of FD-TENG using PDMS-ZnO nanosheets composite film

As proof of concept the ZnO-PDMS composite TENG is fabricated on 5x10 cm area for power generation to run 20 LEDs at a time. The LEDs were connected with nanogenerator in series of 10 kΩ resistance. Two set of LEDs were connected in with opposite polarities. By sliding the TENG in left direction the one set of LEDs was energized to run and sliding in right the other set of LEDs was running.

CONCLUSION

A low cost and easy method is developed for making ZnO-PDMS composite material which is used to fabricate TENG. The fabricated TENG has internal resistance of 70 MΩ and maximum power density of 13.76 µwatt/cm^2.The PDMS- ZnO is a good candidate in triboelectric series for making TENG. The maximum output voltage of 64V is recorded at 100 MΩ. The output voltage of TENG is dependent on the load resistance. The device is scaled up and fabricated on 5x10 cm^2 for practical application which is provides 12 V at load resistance of 10 MΩ. This device is used to run a set of LEDs.

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