A method to design highly reliable Piezoelectric nanogenerator based on Graphene/PVDF ink with good energy harvesting performance

1.Abstract

The various composites materials with high flexibility and electrical conductivity have been widely employed as a functional material in a flexible nanogenerator. It can be mounted on to the human skin or mesh into the clothing or e-skin. In this work, Polymer material especially PVDF and their nanocomposites have attracted more attention due to their good flexibility, high durability, and high thermal stability properties. The flexible piezoelectric nanogenerator was developed by Graphene/PVDF ink while the graphene acts as a nucleating agent to increase the electroactive β phase. The Graphene/PVDF ink was filled in between the PDMS substrate to make a sandwich structure film. Consequently, this device is capable of producing energy from accessible biomedical and human motion such as hand folding, jogging, walking, etc., and machine vibration.

2. Introduction

Nowadays, the limitations of fuel availability and energy concerns have encouraged the study and development of new eco-friendly technology for accumulating energy from our human motion [1]. Several approaches have been developed to harvest mechanical energy from different sources such as human motions (talking, breathing, walking, etc.,) vibrations and hydraulic forces (blood flow) to power up various portable electronic devices [2-5]. Thus, the energy harvesting technology based on human motion has great concern due to its emergent trends to power up small electronic devices [6]. Recently piezoelectric nanogenerator has attracted great consideration for producing mechanical energy under different small mechanical actions. Moreover, the polymeric materials have excellent flexibility, compatibility, withstand higher mechanical deformation, nanomaterial formability which is suitable for polymeric nanogenerator. Therefore, the use of piezoelectric polymeric material in the nanogenerator has been developed rapidly.

Polymer materials, especially PVDF is one of the most important polymers which generate piezoelectricity when a mechanical force or pressure applied to it. PVDF polymer can harvest mechanical energy and output voltage/current signals through the piezoelectric effect. Accordingly, PVDF based nanogenerator with high durability, excellent sensitivity in small force and high electrical output is desirable. Depending on the chain conformation structure PVDF has four crystalline phases such as α (TGTG'), β(TTTT), γ (TTTG'TTTG') [7]. Among them α induced non-polar phases. β and γ polar phases highly desirable phases due to their piezoelectric properties. Above all phases, β is the most important due to the polarization of excellent piezoelectric properties [8-9]. There are several methods to induce the electro-active β phases to achieve the piezoelectric properties. The electrical poling process was used to stabilize the polar phases in PVDF which done through the alignment of CH2/CF2 dipoles to achieve better output performance. The various applications reported in the literature suggest that the flexible and easy to implement material is required as a sensor substrate. PDMS is a silicone-based elastomer to improve the piezoelectric applications including flexibility, bio-compatibility, permeability to water and low electrical conductivity.

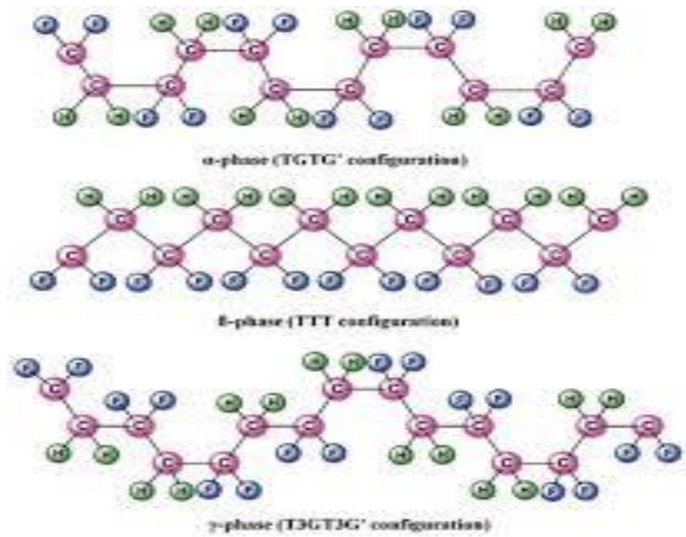

Fig 1. α, β and γ phase formation in PVDF material

3.OBJECTIVES

* To design a Graphene/PVDF composite solution for improve the piezoelectric performance.

* To design a Graphene/PVDF-PDMS nanogenerator sandwich structure for device application such as hand folding, jogging, walking, etc., and machine vibration

3.1. **Fabrication process of graphene/PVDF-PDMS nanogenerator sandwich structure**

Initially, PDMS pre-polymer and its curing agent was mixed with the ratio of 10:1 and stirred well for 5mins. Then the resultant solution was kept at an oven for 15min to remove the air bubbles. The glass substrate was surrounded by the sticking tape, the dimensions of 50mmx30mmx2mm and the PDMS solution (layer 1) was casting on the substrate area and dried at 80^{o}c for 4Hrs. Consequently, PDMS layer 2 was casted by following the same procedure before that the PLA Stamp was kept on the top of the PDMS layer 1. After fully cured, remove the PLA Stamp and fill the Graphene/PVDF ink then cure it for 30mins under 60^{o}c for 1Hr. Moreover, the sticking tape was placed on the top of the already attached tape (2mm thick), then coated the PDMS solution (Layer 3) on the substrate area and kept 85^{o}c for 4hrs. Finally, peeled off the Graphene/PVDF-PDMS sandwich structure composite film from the glass substrate which was examined for the physicochemical properties and piezoelectric applications.

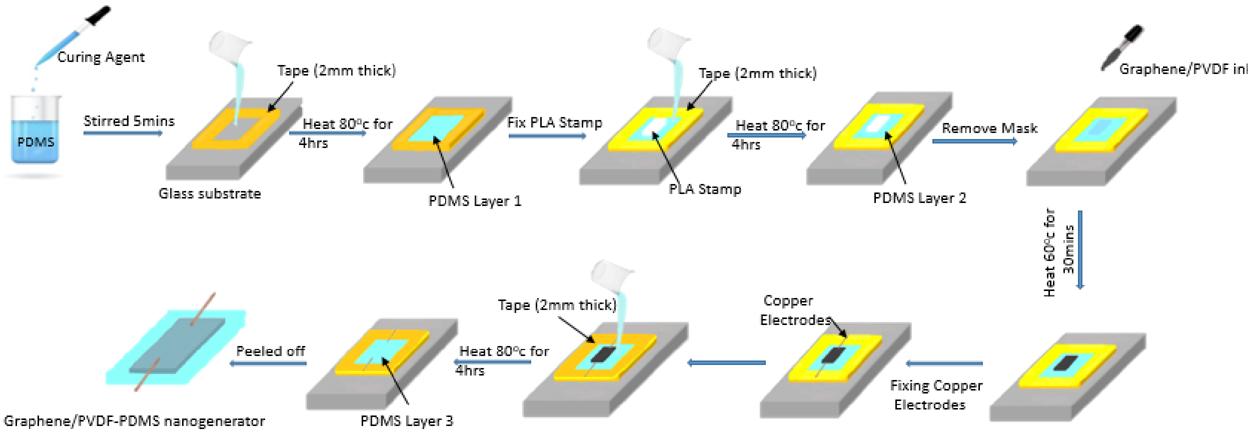

Fig.2.Fabrication process of graphene/PVDF-PDMS nanogenerator sandwich structure

4.Piezoelectric Measurement

The transmit pressure or load is an important factor for the generation of output voltage as the deformation of a sandwich structure depends on applied mechanical pressure. Therefore, we are measure the output signal generated from the Graphene/PVDF-PDMS nanogenerator by finger imparting and releasing conditions at different pressure and loading and unloading condition at a different frequency. Furthermore, different types of body movements are available in our daily life such as jogging, finger typing, running, walking, arm movements, eye blinking, blood flow, and heartbeats, The Graphene/PVDF-PDMS composite film exhibits the biomechanical energy for developing human-based self-powered devices. The prepared piezoelectric nanogenerator was placed below the foot and analyzed the electrical output for various movements including foot pressing, jogging and walking. Meanwhile, the device was attached above the throat to measure the electrical signal of swelling behavior and also to detect human breathing. The Graphene/PVDF-PDMS composite film was also employed to detect the signals of the masticatory movement and record the electric output under continuous chewing activities. The prepared device was fixed on the wrist to distinguish different kinds of wrist movements, including upward bending, downward bending, and torsion and analysis of the output voltage response. Finally, the stability and durability of the nanogenerator were tested under cyclic pressing and releasing with imparting frequency. The excellent stability of the devices is applicability as effective and robust energy harvester that might be very much appropriate for energy harvesting applications.

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