Fabrication of Stretchable PVDF Piezoelectric NanoGenerator

Amel D. Hussein, Raad S. Sabry, Osama Abdul Azeez Dakhil

Physics Department, College of Science, Mustansiriyah University, Baghdad, Iraq

amldeshar@yahoo.com
drraad_sci@uomustansiriyah.edu.iq

dr.osama@uomustansiriyah.edu.iq

Abstract:

A piezoelectric layer process of heighten plasticity lightweight besides firstly self-controlled using one topic persistent in electrospinning technique. Piezoelectric layers device shows a three-layer assembly that PVDF. The poly (vinylidenefluoride) nanofiber layer fabricated to be between two Aluminum layers foil as electrodes as a sandwiched shape. Then the completed generator was totally coated by a thin layer of polydimethylsiloxane (PDMS) to keep it in situation of packaging a device. Here, established highly piezoelectric in which flexible layers and increased the output voltage from (600 -800 mV) by using the same force and frequency. The fiber layer of structure crystal for PVDF was characterized by using XRD in range between (5-35°), FTIR in range between (500– 4000) cm^{-1}, and using liquid nitrogen for cross sections by wetted the three membrane layers of the device in addition beforehand imaging (SEM) the samples coated by gold as a thin layer. Finally by means of oscilloscope the output voltage for devices were indicated on behalf of piezoelectric membrane.

Keyword: PVDF; Electrospinning; Piezoelectric; Nanofibers; NanoGenerator (NG).

Introduction:

PVDF and the situation as copolymers are the largely investigated organic piezoelectric materials aimed at great piezoelectricity. Large influences have been consumed to make electro effective into PVDF β phase crystalline and many suggested was designed on behalf of methodologies devising for piezoelectric polymer devices [1-4].

A number of researchers used electrospinning approach to creations PVDF nanofiber membrane by improved β-phase crystalline, significant flexibility and wherever the electrohydrodynamic conversion besides electrical field was decided towards achieve capable for obviously chief on the way to a special orientation. PVDF Electrospun nanofiber membrane has effective on unsupplied piezoelectricity other behaviors is poling, and may perhaps formed piezoelectric procedure soon [5-8].

Activating technique electrospin is designed to production of a stretchable piezoelectric device on behalf of polymer constructed from piezoelectric materials. While other study devises to improve the energy harvester's stretchability around 110% through using the electrospinning PVDF fibers based on prestressed PDMS substrate [9, 10].

Among many classes of the polymers the PVDF which contains a high piezoelectric affect besides the superlative each about electroenergetic assets. In general, polymorphs for PVDF denoted to subsists in five popular altered phases (α, β, γ, δ and ε) phase's subject proceed by treating situations [11].

Behaving of PDMS is a smooth and flexible material; it was predictable totally of the surface area be able to in a correct touching base between the electrodes therefore this work enhances that electric indicators that established the piezoelectric perhaps coupled in increasing a different method for improving a notable generator mechanical energy collecting device.

Materials and Method:

PVDF in powder form with (Mw = 534 000), Dimethyl Sulfoxide (DMSO) and (Acetone) in 99% purity, Merck were gained from Sigma

Aldrich which the starting chemicals were performed. The polymer solution PVDF in 18 (Wt. %) was structured through melting the powder PVDF in (1:3 v/v) mixed solvent of Acetone and DMSO. Then the perfect polymer solution afterward dissolution was put in (6 mL) plastic syringe with inner diameter (0.7mm) steel needle. At a room temperature the electrospinning was performed by applied (18 kV) electric field, while the polymer solution with feed rate (0.3 mL/h) was used to feed into the needle tip for syringe pump, and random fibers were gathered on a grounded collecting in (400 r.p.m) at a plate foil Aluminum placed from the needle tip on (15 cm). At last on room temperature for (24 h) the constructed fiber mats were dried.

PDMS perhaps attained into a thickness of micrometer, thin films through spin coating method that poses to displayed a high ability on uses as an electrical method for covering and wearable. The PDMS film occupied by spin coated with a complete thickness for assimilated generator in (167 Ϻm) can able to recognized, PDMS layers through a thickness of around (400 Ϻm) were established through achieve a special pre-polymer PDMS resin: curing agent (10/1) consuming to the device. Then curing and degassing in 100˚ C at (2 h) in (r. p. m =4000), for (30 s) through (2 times).

Result and Discussion:

Crystalline structure:

Pure powder and mat of PVDF fiber peaks furthermore the special styles XRD for three phases α, β, and γ of PVDF film by way of a reference in [11] were illustrations in Fig. 1 (a and b). Firstly Fig. 1 (a) for pure powder PVDF at [2θ=18.4° (020), 19.9° (110)] and [26.4° (021)] that approving the origin α phase for pure powder PVDF that agree with reference [12]. Then it approves in Fig.1 (b) for electrospun 18%PVDF fiber mat with three phases ɣ-phase, α-phase and β-phase. The peak at [2θ = 18.3° (002)] which approves the perfection of ɣ-phase besides a central peak at [2θ=20.14◦ (110)] showcases attributed for α phases. While that the peak at [2θ = 20.78° (200)], as well as at [2θ=31.9◦ (001)] which approves that by electrospunininng for PVDF fiber mat perfection creation of β-phase.

The crystalline β-phase of PVDF moreover they realized without any heat treatments or poling methods which agreement with [13]. This is capable of appointed for the actuality for used the electrospinning technique by applied high voltage which achieved to present the electric dipoles current through degree of alignment in solution PVDF which organism the relational for the practical electric field with quantity.

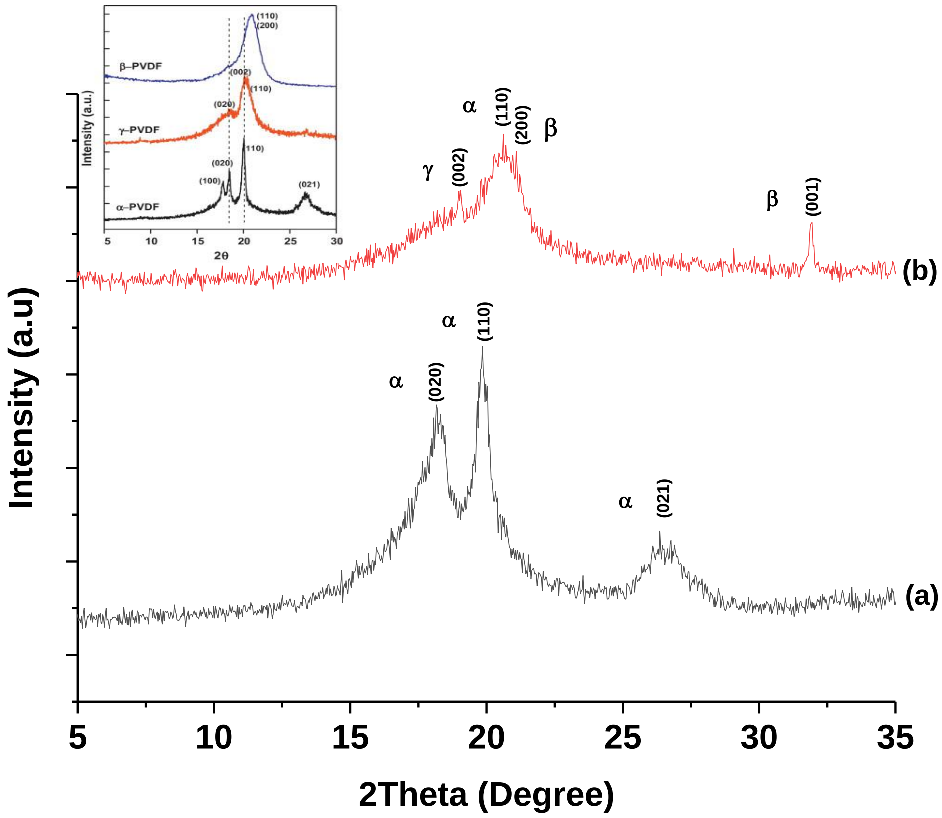

Fig. 1 XRD pattern for as-spun:

(a) Powder PVDF and (b) Nanofiber PVDF with 18 Wt. %.

Membrane morphologies:

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The morphologies besides the surface topographies for cross section of PVDF electrode membrane and the nanofiber PVDF membrane were investigated through SEM. Fig. 2 (a and b) appearance that no bead or beaded fiber was checked in addition the electrode membrane is combined of interpenetrating layer of PVDF nanofiber in Fig. 2 (b).

Then again to the SEM which presented in Fig. 2 (b) that a good form for PVDF nanofibers with composes membranes were with diameters in range between (200-500) nm. Also the device which fabricated for piezoelectric was consistent of structure with three layers where the energetic layer for membrane PVDF nanofiber is putted among two Aluminum Al electrodes layers, and the complete piezoelectric devices were with thicknesses in (Mm) roughly at 167 before and 400 after covered by PDMS, were measured by using OSK (Ogawa Seiko. LTD) tool which completed to measure thickness from 10 points of the samples.

The cross section of device was exhibited the structure and by software image J the mean diameter of the image fiber on behalf in SEM at Fig. 2 where can see that the layer piezoelectric without boundary as well as the connection is in a good way between them. Agreeing to the SEM image and the diameter distribution histogram which shown here of the nanofibers, with diameters of the fibers are between (200-500) nm. While from Fig. 3 can appearance the structured of the device when used PDMS for covered it's towards the tow side of the device.

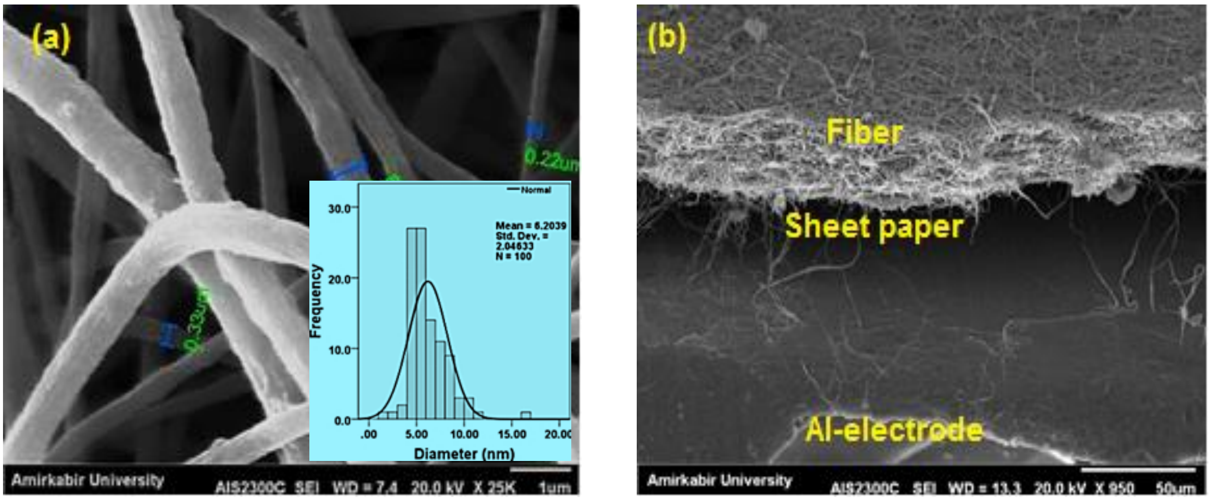

Fig. 2 Schematic illustration and SEM image of (a) PVDF fiber, (b) Image of the cross-section of the integrated nanofiber.

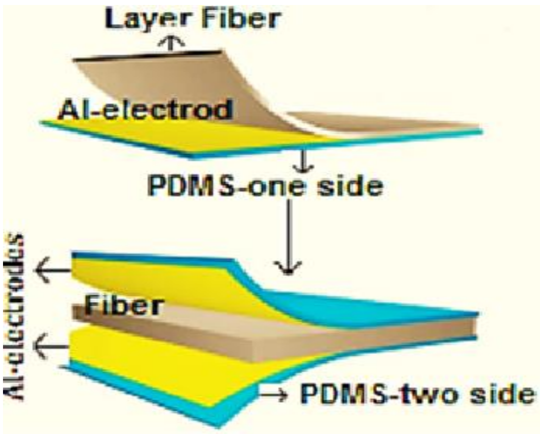

Fig. 3 Characteristic patters for generator covered by PDMS.

Fourier transforms infrared spectroscopy analysis:

Fig. 4 (a and b) illustrates the FTIR analysis, in Fig. 4 (a) of powder PVDF the absorption bands at [449, 614, 763, 841, 877, 976, 1070, 1186, 1404 and 3025 cm^{-1}].

The distinguishing absorption peaks of powder PVDF for α-phase indication at (449, 614, 763, 877, and 1186 cm^{-1}) correspond to α-phase whereas the bands at (976, 1404, 1070 cm^{-1}) correspond to β-phase.

There are several effects on the crystalline phases of the PVDF, such as the polarity of the solvent, which with high polar solvents due to the dipoles of molecular chain C–F bond in the PVDF is great for reduce the energy barrier for forming and rotate,) further totally trans conformation (TTT) expanded for (β-phase), while solvents with a lower dipole moment all time benefits alternating trans besides gauche conformation (TGTG) of (α-phase).

On the other hand, a variety phases can products when using polar solvent, by adjusted the temperature conditional for preparation also the evaporation of the solvent. As well as vibrational bands inclusive of at ($841cm^{-1}$) in both γ and β-phases which agreement with indication for [14-18]. While the band at ($3025\ cm^{-1}$) was small which back to the moisture and the interface between the air/solid in addition the noise relation which as showed in reference [١٩] .

The crystalline phase of the constructed membrane may be categorized as ɣ [α + ɣ] β and α and β [α + β] α and α, β and ɣ [α + β + ɣ] and ɣ [β + ɣ] phases for curves indicating that those bands cannot be used completely or used exclusively for α or β and ɣ-phases for descriptions [20].

Due to the vibrational stretching of molecular dipoles ($-CH_2-/-CF_2-$) in PVDF so the transformation of α-phase to β-phase (or γ-phase). As well as that very essential on this study at for the reason that β and γ-phases of PVDF are favorable for correct piezoelectric properties [21].

The FTIR analysis organized in Fig.4 (b) for electrospun PVDF nanofiber mat illustrations the absorption bands on [487, 510, 601, 762, 841, 882, 1074, 1188, 1278, 3018 and 1403 cm^{-1}].

The broad FTIR signifies the altogether grouping of three phases α, β, and ɣ at peak(882 cm^{-1}) and since in this work used the DMSO as polar solvent due to that (β and ɣ) together phases as (ferroelectric phase) which agreement with reference [17].

The bands at (487, 762, and $601cm^{-1}$) related for α-phase, while the bands located in (1074, 1188, 1278, and 1403 cm^{-1}) were related for β-phase. Whereas the band in ($510\ cm^{-1}$) related through together the β & γ-phases in addition to amorphous phase for PVDF was seen at the band (3018 cm^{-1}).

As well as from the Fig. 4 (b) can be supported that when used the technique electrospinning advantage to enhances the creation of β-phase crystalline PVDF. Through benefit from the relation in (1) can calculated the percentage of β phase [22].

$$\mathbf{F(\beta) = A_\beta / (K_\beta/K_\alpha) X A_\alpha + A_\beta \ldots\ldots.. 1}$$

Anywhere, A_β and A_α attend to absorption while the absorption coefficients K_β and K_α at the corresponding wavenumber (6.1×10^4 and 7.7×10^4 $cm^2 mol^{-1}$), respectively [23, 24].

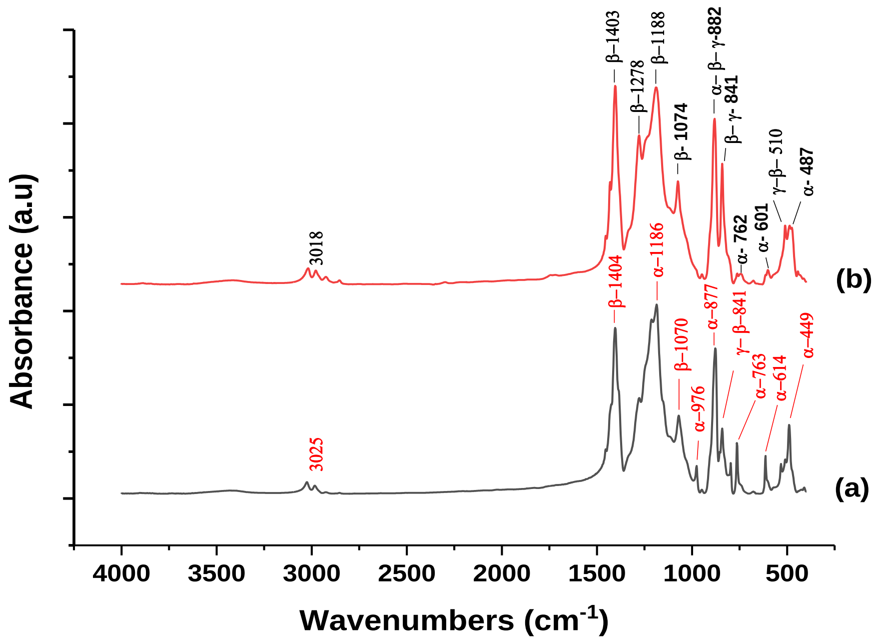

Fig. 4 FTIR Spectrumof: (a) Powder PVDF (b) Electrospun PVDF fiber mat.

Output Voltage:

The principally piezoelectric was calculating in compared way between tow samples for the response to electrical effects by an oscilloscope to indicate the output voltage from the circuit it is attained of PVDF nanogenerators. In relation to the investigation of the result when affected by PDMS through practical stretches force on PVDF nanofabric which causes to distinctive the output voltage, from (3.2-3.8) V without and with, used PDMS respectively. Proposed for certifying the dependability of these products, all samples were calculated four times at the similar testing situation. As observed, in Fig. 5 (a and b) was significantly would increase the electrical response of samples in Fig. (a) when covered by PDMS was higher than without due to the flexibility, stretchability and significant output behaving in Fig. (b).

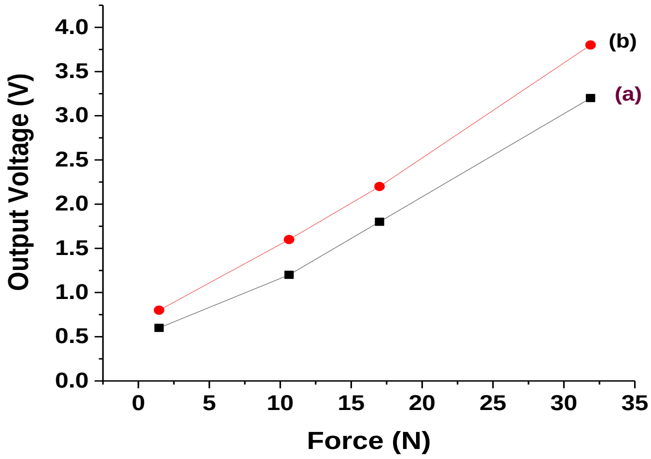

Fig. 5 Graph relationship between PDMS and output energy of PVDF nanofabrics power mechanism under 1.9 Hz (a) without PDMS and (b) with covered by PDMS.

Conclusions:

In this work it was improved a simple and suitable technique electrospun to produce β-phase of PVDF. The effects of surface covered by PDMS on the performance of PVDF were analytically calculated through behaving for two types of nanogenerators. PVDF fibers layers including of 200-500nm of an average diameters generally were formed through performing electrospinning technique. Where from XRD besides FTIR can benefit of presence α and β-phase's polymorphs and to be certain of an enhanced of β-phase.

Therefore an effected for used PDMS as a rubber to cover the device which fabricated from pure polymer PVDF was appearance in the output piezoelectric voltage when compared with second device which uncovered by PDMS there is an increasing due to increasing in the stress when applied force from the oscilloscope to the device which covered by PDMS.

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The Abbreviations; Poly (Vinylidene Fluoride) (PVDF); PDMS; polydimethylsiloxane; (Scanning Electron Microscopy) SEM; and (X-ray diffraction) XRD;

The Ourthure: Used software for drawing: Origin, Spas, Image J and EndNote for arranged the references.

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