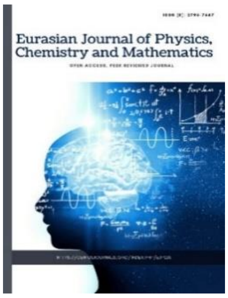

Output Piezoelectric Layers Nanofibers of Nanocomposites PVDF/Ceramic

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ABSTRACT

This study enhances the piezoelectric effects of electrospun nanocomposite nanofibers formed from layers of PVDF-Ceramic nanogenerator. Through the use of several side nanocomposites, the nanogenerator has evolved from a single to a double layer. The outputting piezoelectric is very highly dependent on fabricated performance. A researcher has previously demonstrated interest in mixed nanocomposites (PZB) that are capable of enhancing performance and boosting output voltage to 7,200 V by applying 0.2657 N of force and 2.5 Hz of frequency. Thus, fabricate thin generator companion of nanocomposite materials fibers together with concentrations (16%PVDF–18%ZnO) and (12%PVDF–20%$BaTiO_3$). The phase transition of this generator is detailed using XRD, SEM, and FTIR, and its electrical response characteristics are assessed using an oscilloscope.

Keywords: PVDF; $BaTiO_3$; ZnO; Electro-Spinning.

Introduction:

Instructed high piezoelectricity, PVDF and its copolymers are the organic piezoelectric materials that have been the subject of the greatest research [1-2]. Composite materials, particularly those based on polymeric materials, have developed as a focus of attention within academics and industry throughout the past few decades. The term "composite" refers to a mixture of two or more components, one of which is a rigid and sturdy material known as "filler," and the other of which is a "binder" or "matrix" (polymer) that maintains the filler's position in the mixture. When the various components, known as the filler and the matrix, are combined, the resulting composite material will keep the identities of both the filler and the matrix, and these identities will have a direct impact on the qualities of the composite as a whole [3-4].

It is general knowledge that polyvinylidene fluoride, or PVDF, has qualities that can be categorized as ferroelectric, pyroelectric, and piezoelectric. PVDF is a semi-crystalline material with a nonpolar crystalline δ-phase, crystalline γ-phase, crystalline β-phase, and crystalline α-phase. As a polar crystalline form in PVDF, the crystalline β-phase is an attractive structure, whereas crystalline δ-phase and crystalline γ-phase have inferior qualities compared to the crystalline polar β-phase [5]. In addition, the construction of these purported piezoelectric devices consisted of stacking various layers one on top of the other. Ensuring that there is a proper connection between the piezoelectric layer and the electrodes is a difficult and time-consuming task. Because there is a possibility of sliding between the electrodes and the piezoelectric membrane, there is an increase in wear and contact instability. This has a detrimental impact on the devices' lifetime and output stability. A high-performance piezoelectric device can also be obtained by carefully following the assembly procedure. This is an essential step in the process [6-8].

The author offers an easy method for creating a wearable piezoelectric device using a single step of electrospinning in continuous mode. Nanocomposite ceramics and PVDF nanofibers are arranged in a double -a layers structure in the piezoelectric device. The purpose of the current study is to evaluate and contrast the crystalline structure and output voltage of electrospun PVDF nanofibers composite with a variety of nanoparticles including $BaTiO_3$ and ZnO.

Materials and Methods:

Powder Poly(vinylidene fluoride) (PVDF) with (Mw=534,000 g/mole), Dimethyl Sulfoxide (DMSO), acetone, and $BaTiO_3$ powder with diameter, ≤ 100 nm in spherical shape are purchased from Sigma-Aldrich including purity > 99%.

Fabrication Nanocomposite PVDF nanofibers with different additions:

The initial layer of nanocomposite PVDF/ZnO consists of: A composite of PVDF/ZnO consists of two steps: first, the ZnO is synthetic using a hydrothermal method. Where the chief solutions in this preparation were formed by adding (0.02 M) of zinc nitrate hexahydrate [ZNH; $Zn(NO_3)_2.6H_2O$] (ZNH) and hexamethylenetetramine [$(CH_2)_6N_4$] (HMT) on an equal-molar ratio (1:1) subsequently, are dissolved in deionized water besides continuous stirring.

After that, combined reactants are placed in an autoclave that had been sealed with a Teflon line. This was done to synthesize ZnO powder using the hydrothermal method, which involves heating thermal degradation of the HMT for varying amounts of time.

The second step is to prepare the solution by dissolving PVDF powder (16 %wt.) in solvent mixtures of DMSO/acetone solvent (3/1 v/v) and besides stirring the homogeneous solution using a magnetic stirrer then, add ZnO powder with percentages (18 %wt.) at 50°C for around 2h and sonicated for 15 min by (Cycle 0/5 with frequency 60 Hz). Then, a white heterogeneous solution is established and put in a 6 mL plastic where, a syringe pump which is achieved syringe to electrospinning on aluminum foil with a distance (15 cm), using high voltage (18 Kv), rate flow (0.1mL/ h) and with rotating drum speed 400 rpm.

The nanocomposite of PVDF and BT's second layer is as follows: The solution is made by dissolving PVDF powder at percentages (12% wt.) in solvents combinations of DMSO/Acetone solvent (3/1 v/v) for roughly two hours while using a magnetic stirrer, this process is repeated three times. Then, add the powder $BaTiO_3$with percentages (20 % wt.) at 50°C for around 2 h after that homogeneous solution was sonicated for 10 min by (Cycle 0/5with a frequency of 60 Hz) and with a rotating drum speed of 400 rpm. After everything is prepared, a white heterogeneous solution is produced and transferred into a syringe that has a size of 6 milliliters. Following this step, a syringe is placed in a syringe pump, and the solution is electrospun at top of the first layer while the temperature is kept at room temperature.

Characterization Techniques:

Characterization of the unique form of nanofibres is made possible by the use of a scanning electron microscope (SEM, model: AIS 2100, South Korea). The photographs were utilized using an acceleration voltage of 20 kV in situations in which all of the samples had been gold coated by an Emetic Company machine (model: SC7620 English hulk sputter coater with a thickness of 20 nm and a time of 180 s). After that, methods for image processing are used to estimate the fiber's diameter (Image J).

To analyze the crystalline structure of the nanofiber, X-ray diffractometry with Cu-K radiation (wavelength 0.154 nm) is utilized. This particular model of X-ray diffractometry was developed and manufactured by the INEL France Company. The material is evaluated with two different angles 2θ ranging from (5-60°).

A spectrometer (an instrument manufactured in the United States by Thermo Nicolet; model: NEXUS 670, resolution: 4 cm^{-1}), which is employed within the range of 500–2500 cm^{-1}, can be used to identify FTIR spectra for PVDF nanofiber. A PC Oscilloscope is used to measure the electrical response of piezoelectric material (VDS 1022 I). In addition, a sample is measured at room temperature.

Results and Discussion:

X-ray diffraction analysis:

Results of an XRD analysis of pure PVDF powder, nanocomposites consisting of 16% PVDF–18% ZnO NR and (PZZBB), nanofibers are shown in Figs (1a–d), respectively. These charts, Figs. (1a–c), determined the presence of nanoparticles in the nanocomposite nanofibers as well as the fabrication of β-phase crystal structure as confirmed within [6-8].

While the result in Fig. (1-d) illustrates the crystal structure of double layers spinning in this work possessed a perfect interface interaction that caused special excellent piezoelectric effects. Two peaks are confirmed for crystalline phase PVDF, the first peak at 2θ=20.0° (110) is indicated of ɣ-phase, then, the intensity of the peak becomes decreased at 2θ=26.9° (022) which is indicated by α-phase that agreement with reference [9]. However, the peak located at 2θ=23.1° confirmed for the ZnO.

While high and wide peaks are located at 2θ= [31.32°(110), 38.84° (111), 45.22° (200), 56.57° (211), and 66.22° (200)] were confirmed for BT as compared with Ref. Code: 01-085-1791, Barium Titanium Oxide.

Therefore, enhancing the interference layers could be active for the generation of uniform piezoelectric fiber PVDF/ZnO: PVDF/BT generator. Where the filler matrix relation of interface interaction is modified, through crystallization that was structured to the nucleation β-phase of PVDF with a decrease in the generation of α-phase.

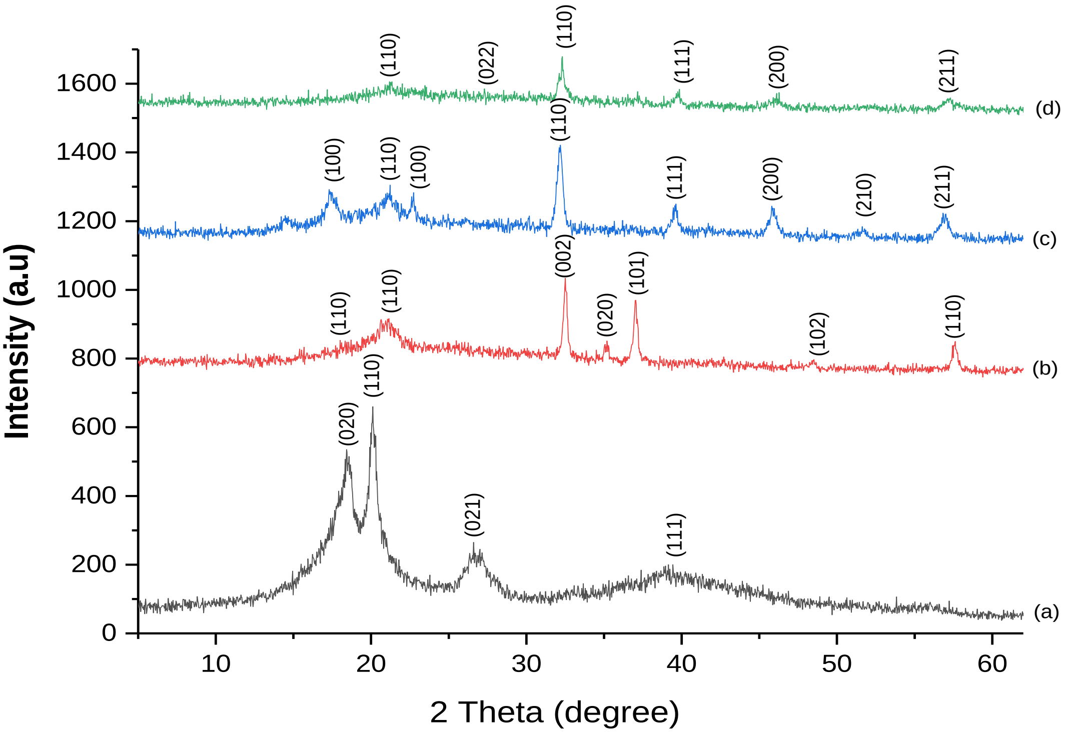

Fig. (1): Illustrate XRD analysis: (a) pure PVDF, (b) ZnO powder, (c) BT powder, (d) nanocomposites layers (PZZBB) nanofibers

Surface Morphology:

Following the discussion of the effect of adding ceramic (ZnO and BT) in the three articles that came before, the researcher indicated that the enhancement β-phase of polymer PVDF increases when adding BT and ZnO (PZB), and then, compounding them in a critical technique, which ultimately results in an increase in the output voltage of nanogenerators in (1, 2, and 3) respectively. Images were acquired with a scanning electron microscope at the locations indicated by Figs. 2 (a-c) nanofiber for pure PVDF with random distribution. While Figs. 2 (a-b) illustrates the nanofiber's diameter and distribution over the figure. A new generator as shown in Fig. 2 (c) composite from the doubled layer with a perfect interface this agrees with [10].

Because increasing the amount of ceramic that is added to PVDF causes the surface of the fiber to become rougher or causes aggregation, as identified in articles [7-8, 11], other techniques, such as using doubled layers of nanofibers, were utilized instead.

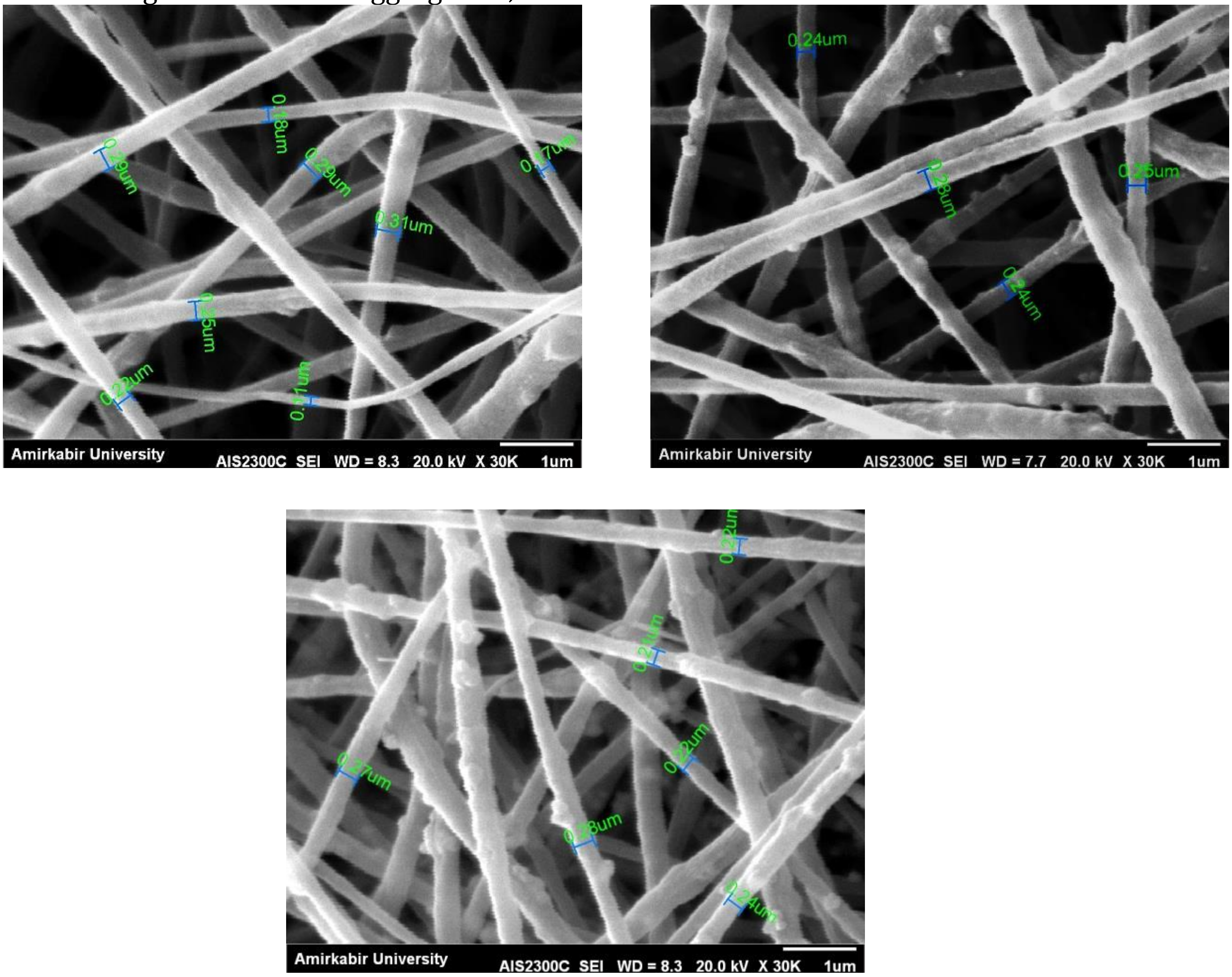

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Fig. (2): SEM (a) 16%ZnO-18%PVDF (b) 12%PVDF-20%BT (c) nanocomposites layers (PZZBB) nanofibers

Fourier Transforms Infrared Spectroscopy (FTIR) Analysis:

FTIR spectrums in Fig. (3) Pure PVDF powder, 16% PVDF–18% ZnO moreover, indicated the phase's structural crystalline in previous work so, the researcher expressed the new composition double layer is confirmed in Fig. (3).

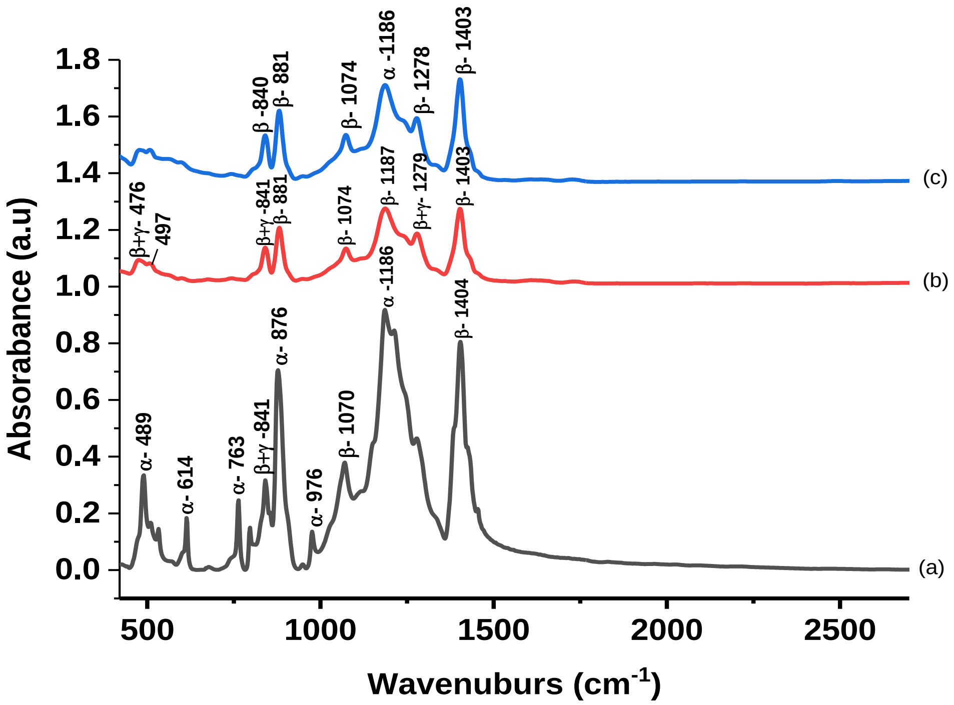

Fig. (3): FTIR (a) Pure PVDF powder (b) 16% PVDF–18% ZnO fiber (c) nanocomposites layers (PZZBB) nanofibers

All peaks are located at [1403, 1278, 1186, 1074, 881, 840] cm^{-1}, in general, a crystal of β-phase is distinguished as a major improvement. This indicates that the mechanism of interference between the two layers of the fibrin structure is distinct, and it is also ideal for converting the separate phases to the -phase responsible for the piezoelectric activity in this study [6-8, 12].

This means that the process of interference between the fibrin structure's double layers is done distinctively, as well as this is perfect for converting the different phases to the β-phase responsible for the piezoelectric property in this work. Sincerely, "rich NH_2 group on poly-dopamine could strongly interact with CF_2 group of PVDF, which would force the CF_2 groups to arrange parallel to each other and perpendicular to the polymer chain, thus increasing supporting the development of β-phases in PVDF" as indicated in references [13].

Fig. (4) Indicates in what approach the nanoparticles BT are seeing as nucleating somewhat, on behalf of improving the β-crystalline phase into PVDF.

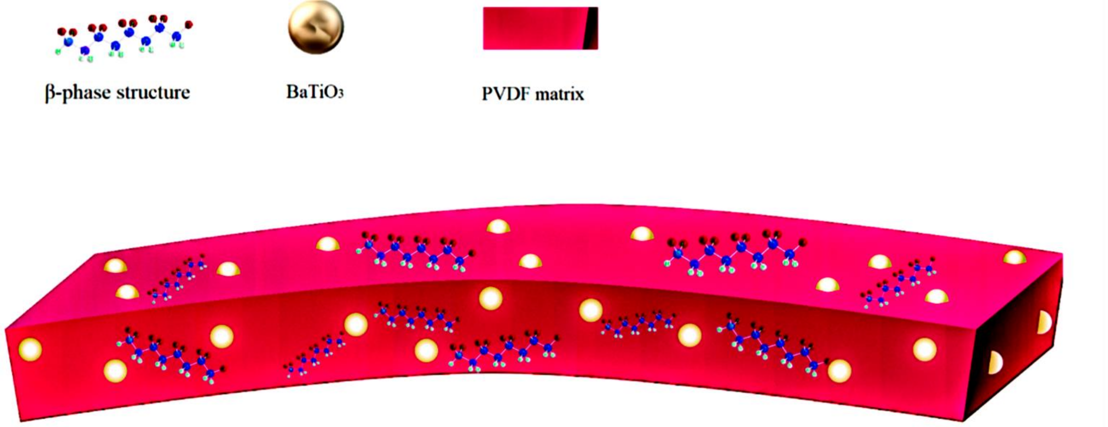

Fig. (4): Representation of improving the β-phase structure of nanoparticles BT into PVDF [12]

Mechanical Output Piezoelectric:

The structure of the output voltage is seen in Table (1) where, it is performed that the piezoelectric increases have been significantly effective, as determined by an analysis of all sample data.

Table (1): Output voltages in different forces and frequencies.

	Forces in (N)	Frequencies in (HZ)	Output voltage in (mV)	Sensitivity in (V/N)
1	0.1328	1.3889	3800	28.60584
2	0.2657	1.3889	4200	15.80849
3	0.5314	1.3889	5200	9.78621
4	0.7970	1.3889	5400	6.77507
5	1.0627	1.3889	6400	6.022282
1	0.1328	1.6667	4800	36.13369
2	0.2657	1.6667	5600	21.07799
1	0.1328	1.9231	4400	33.12255
2	0.2258	1.9231	5600	24.79763
3	0.2657	1.9231	6400	24.08913
1	0.1328	2.5	5600	42.155978
2	0.2258	2.5	6400	28.34015
3	0.2657	2.5	7200	27.10027

The output power voltage of the highest peak-to the peak are fabricated double layers nanogenerator harvester of PVDF/ZnO: PVDF/BT which is higher than only one layer of the PVDF/ZnO or PVDF/BT nanogenerators owing to the related interfaces connecting layers and nanoparticles. In the process of increasing dipole-dipole forces, the PVDF matrix with ceramic nanofillers improved the nucleation of the β-phase of the polymer crystal, hence enhancing its piezoelectric properties.

As a consequence of this, the nanocomposite fiber that was fabricated did not indicate the presence of beads or agglomerated particles on the surface of the fiber. As a result, a preference for the advancement of numerous energies achieves that are renewable and friendly to the environment.

Therefore, the related interaction between the polymer matrix and the ceramic filler is dependent on the size of the filler particle identical to generate the products of differences behaved appearing in the electrical, thermal, and mechanical properties of the composites. These differences can be seen in the composites' electrical conductivity, thermal conductivity, and mechanical conductivity.

Many wearable devices, such as running shoes, bracelets, watches, and medical health detection in addition to environmental and other information-providing devices, will heighten a significant level of advancement in the coming years and become a moderate market, according to recent market analysis [14].

Conclusions:

The nanocomposite layers PVDF/ZnO: PVDF/BT fiber surface did not indicate the presence of beads or agglomerated particles; they were manufactured to enhance piezoelectric performance with high output voltage (7.200 V). There is an inverse relationship everywhere between the relative interaction area of the filler nanoparticle BT and the piezoelectric output voltage. This works as a nucleating agent in polymer phase crystallization and vice versa, which is shown by the mechanical properties, which leads to construction problems. Therefore, nanoparticle BT improves the electric characteristics exhibited by the ferroelectric polarization effect. In addition, as suggested by prior research, an increase in additive filler content results in an increase in aggregate and bead structures in fiber.

Thus, the optimal technique of interference between the composite layers of BT/PVDF and ZnO/PVDF fibers formed as nucleating fillers improves charge transformation through a generator, which is responsible for an increase in output piezoelectric voltage. Therefore, the assembled generator can be used for harvesting bioactive devices or sensors developed for powering small electronics by employing a flexible wearable movement or prototype sensor. This can be done to harvest energy.

Conflict of Interest: The author declares that they have no conflict of interest.

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