Polymer Nanocomposite for Energy Harvesting Applications

Students names: Salwa Al-Kuwari & Fajr Al-Shamari
Supervisor: Eng. Ruba Ali

Research Problem

The annual report published by the Statistical Review of World Energy indicates that fossil fuels make up 84% of the world's energy consumption in 2019. Qatar is a state that depends on non-renewable energy sources for electricity production in all major power generation stations. However, the government is fostering new projects and initiatives for clean energy production to lower the negative impact on the environment. The prime vision of this research is prepare nanofiber composite that will provide eco-friendly alternative for energy harvesting.

.

Hypothesis

1. Nanofibers composite can be fabricated from PVDF base.
2. PVDF/BaTiO3-NiFe2O4 nanocomposite can generate electric charged when mechanically deformed.
3. The addition of nanofiller enhanced the piezoelectric output performance of the pure PVDF.

Materials

Poly(vinylidene fluoride)- PVDF, Dimethyl formamide (DMF), Acetone, Barium acetate, titanium butaoxide, Nickel acetate and Iron chloride were purchased from sigma Aldrich.

Equipment used

Figure 1 SEM

Figure 2 XRD

Figure 3 Electrospinning apparatus

Procedure

Preparation of BaTiO3/NiFe2O4 solution

BaTiO3/NiFe2O4 composites were prepared by the hydrothermal method. Nickel acetate and iron chloride were mixed together. Then, titanium (IV) n-butoxide was dissolved in ethanol, and then barium acetate was added into it. Both solutions were mixed and stirred well for 2hr. The resultant solution was then transferred into Teflon autoclave at a temperature of 180 °C for 24 hrs. Finally, the precipitate obtained was dried at 80 °C for 6 hrs.

Preparation of pure PVDF and PVDF/BaTiO3-NiFe2O4 solutions

PVDF solution was prepared by the addition of PVDF pellets to DCM and Acetone (20ml solvent) and stirred for 3h at 70 °C. The BaTiO3/NiFe2O4 nanopowder (2wt%) was dispersed in the same solvent mixture (5 ml). The dispersed solution was combined with the PVDF solution.

Preparation of pure PVDF and PVDF/BaTiO3-NiFe2O4 composite nanofibers

The polymer and particular nanofiller (BaTiO3/NiFe2O4 composite) is dispersed in a common solvent and thereafter mixed well using a magnetic stirrer bar. The solution was used for electrospinning, and the nanofibers were collected in a rotator.

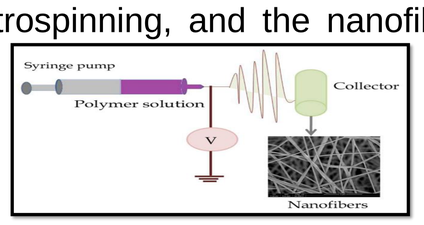

Figure 4 Electrospinning set-up

Results

X-Ray diffraction analysis

XRD diffractograms for PVDF/BaTiO3-NiFe2O4 was used to study the structural property. The XRD pattern shows the distinct peaks for both BaTiO3 and NiFe2O4, which confirms the formation of the composite structure. The presence of sharp diffraction peaks indicating that the prepared samples have an excellent crystalline nature. Diffraction peaks observed for PVDF/BaTiO3-NiFe2O4 in the 30-50° range

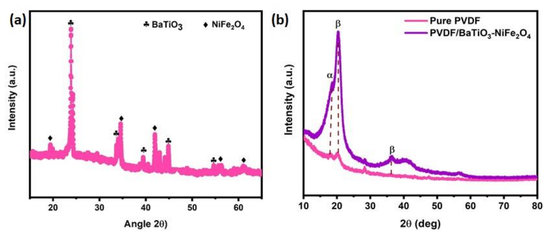

Figure 5. X-ray diffraction patterns

FTIR Analysis

The crystalline β-phase of PVDF/BaTiO3-NiFe2O4 were identified by FTIR studies. The peaks shown in the FTIR spectra give clear evidence for the presence of α and β crystalline phase of the sample, which is attributed to the nucleation of electroactive β crystalline phase.

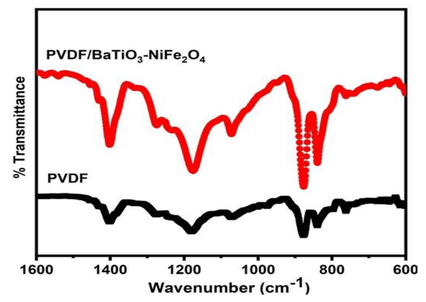

Figure 6. FTIR spectra of PVDF/BaTiO3-NiFe2O4 composite nanofibers

SEM

The morphology of BaTiO3/NiFe2O4 nanocomposite and PVDF nanocomposite fibers were investigated by scanning electron microscopy (SEM) and the images are depicted in Fig.7 (a-c). The nanocomposite shows the agglomerated nanoparticles-like structure as shown in Fig.7 (a). SEM images of neat PVDF and PVDF/BaTiO3-NiFe2O4 nanocomposite fibers are shown in Fig. 7(b&c) and the fiber diameter is reduced for PVDF/2wt% BaTiO3-NiFe2O4 composite nanofibers.

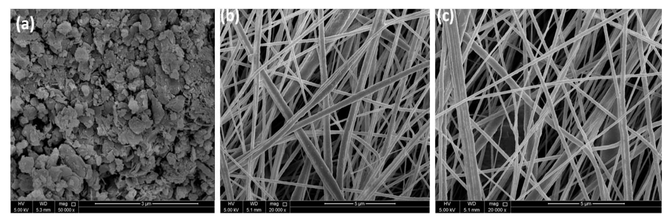

Figure 7. SEM images of (a) pure BaTiO3/NiFe2O4 nanocomposite, (b) pure PVDF and (c) PVDF/BaTiO3-NiFe2O4 composite nanofibers.

Piezoelectric properties

The Piezoelectric nanogenerator was made by wires were attached through aluminium foil electrodes. Conducting carbon tape was used to fix the device to the substrate. Figures 8 shows the piezoelectric properties of Pure PVDF and PVDF/2wt% BaTiO3-NiFe2O4 nanofibers. The peak to peak output voltage was very low; 700mV for pure PVDF and it was high for PVDF/2wt% BaTiO3-NiFe2O4 composite nanofibers and the value was 4.3V.

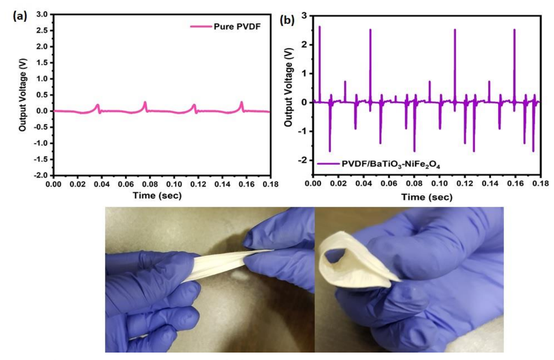

Figure 8. Piezo electrical output voltage of (a) pure PVDF and (b) PVDF/BaTiO3-NiFe2O4 composite nanofibers, (c) flexibility of the film.

Conclusion

In this study, PVDF and PVDF/BaTiO3/NiFe2O4 composite nanofibers were prepared by electrospinning method. The structural property of the prepared PVDF and PVDF/BaTiO3-NiFe2O4 composites nanofibers was investigated, and it indicates that the β- crystalline phase is increased in the BaTiO3/NiFe2O4 composite fibers. The surface morphology of the prepared nanofibers was investigated. The dielectric properties of the composites fibers were investigated and found that the addition of BaTiO3/NiFe2O4 nanofillers increased the dielectric constant of the fibers. This enhancement in the dielectric properties reflects the ability of these nanofibers for energy storage. In addition the good piezoelectric properties were achieved for the PVDF/2wt% BaTiO3-NiFe2O4 composite nanofibers.

Applications

When applied on a larger scale the nanocomposite fibers can be used in wide applications such self-powered sensors and smart skins, wearable electronics and gadgets, medical equipment. The flexible nanocomposite can be used electricity generation on roads and walking tracks and sports facilities as well to make sustainable buildings.

References

1. Research Features. 2019. How population growth impacts energy consumption in Guangdong in China. [online] Available at: <https://researchfeatures.com/population-growth-energy-consumption-guangdong-china/> [Accessed 25 February 2021].
2. Eia.gov. 2021. Fossil fuel production expected to increase through 2022 but remain below 2019 peak. [online] Available at: <https://www.eia.gov/todayinenergy/detail.php?id=46496> [Accessed 25 February 2021].
3. International Energy Agency. 2019. World Energy Outlook 2019 – Analysis - IEA. [online] Available at: <https://www.iea.org/reports/world-energy-outlook-2019> [Accessed 25 February 2021].
4. Vaclav Smil (2017). Energy Transitions: Global and National Perspectives. & BP Statistical Review of World Energy.
5. GlobalPetrolPrices.com. 2019. Qatar: energy mix for electricity generation | GlobalPetrolPrices.com. [online] Available at: <https://www.globalpetrolprices.com/energy_mix.php?countryId=144#:~:text=In%20Qatar%20the%20greatest%20share%20of%20electricity%20is,with%20energy%20mix%20data.%20This%20site%20uses%20cookies.> [Accessed 25 February 2021].
6. Cavallo, A. J. (2004). Hubbert's petroleum production model: an evaluation and implications for world oil production forecasts. Natural Resources Research, 13(4), 211-221.
7. Cao, X. (2006-12). Effect of TiO2 nanoparticle size on the performance of PVDF membrane. Applied surface science, 253(4), 2003-2010.doi:10.1016/j.apsusc.2006.03.090.
8. V. Nguyen, D. Rouxel, B. Vincent, L. Badie, F. D. Dos Santos, E. Lamouroux and Y. Fort, Appl. Surf. Sci., 2013, 279, 204–211.
9. Parangusan, Hemalatha & Ponnamma, Deepalekshmi & AlMa'adeed, Mariam. (2017). Flexible tri-layer piezoelectric nanogenerator based on PVDF-HFP/Ni-doped ZnO nanocomposites. RSC Adv.. 7. 50156-50165. 10.1039/C7RA10223B.
10. Uchino, K., 2017. Advanced piezoelectric materials. 2nd ed. pp.353-382.