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Smart And Robust Nanocomposite Fibers For Self-powering Electronic Devices

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Introduction

Current ways of electricity production have a negative impact on the environment in various ways. Hence, it is necessary to find new environmentally friendly ways for energy generation. Piezoelectric mechanism (through which the mechanical energy is converted to electrical voltage) is considered as an environmentally friendly solution for energy production. Conventional piezoelectric nanogenerators based on ceramic composites of PZT, BaTiO3 etc. limit their applications, because of the chemical reactions, inter diffusion high temperature, and differential thermal expansion in this context polymer based materials. The hybrid combination of nanoparticles –iron oxide (FeO) and titanium dioxide (TiO_2) with the PVDF-HFP using the electrospinning method will result in improving the piezoelectric property and energy storage capabilities.

Experimental Details

- Synthesis of nanoparticles such as FeO by co-precipitation.
- Synthesis of TiO_2 by hydrothermal method.
- Synthesis of hybrid nanomaterials by co-precipitation.
- Fabrication of PVDF-HFP nanocomposites by electrospinning

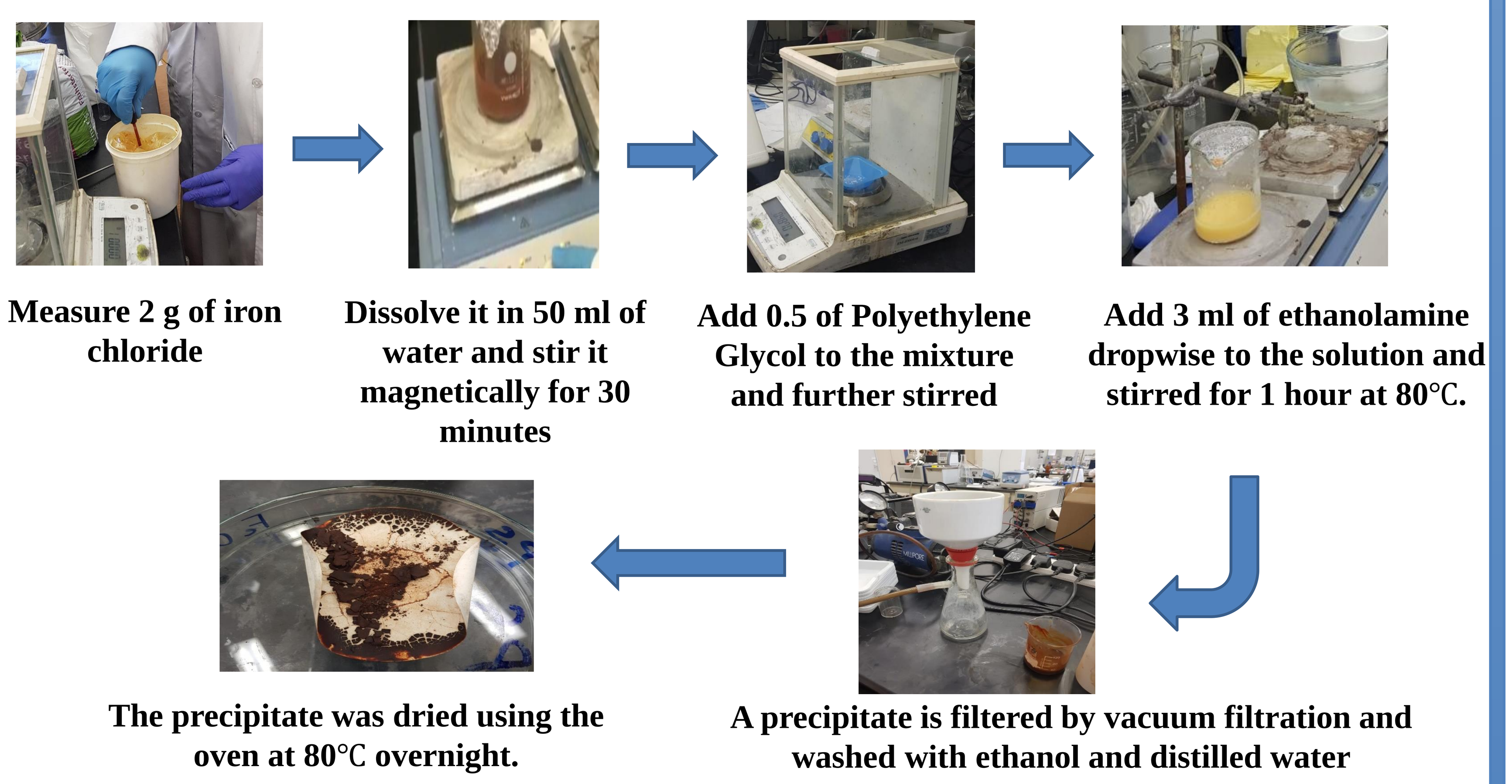

Figure 1: Preparation of nanoparticles

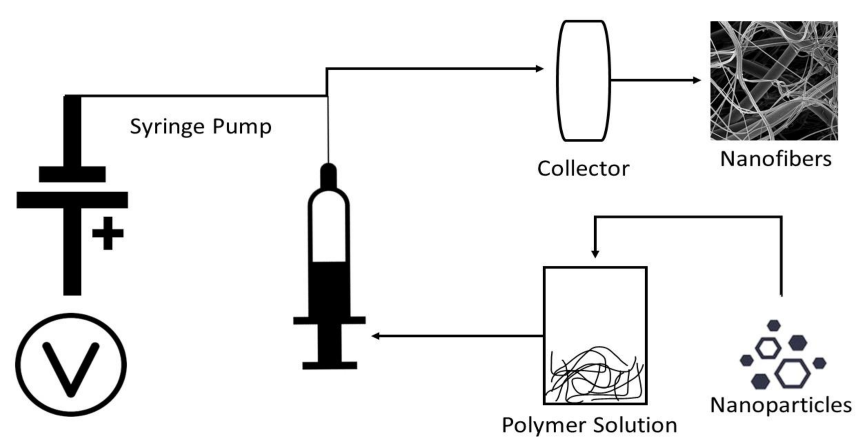

Figure 2: Schematic Representation of Electrospinning procedure

Results and Discussion

1. Characterization of Nanomaterials

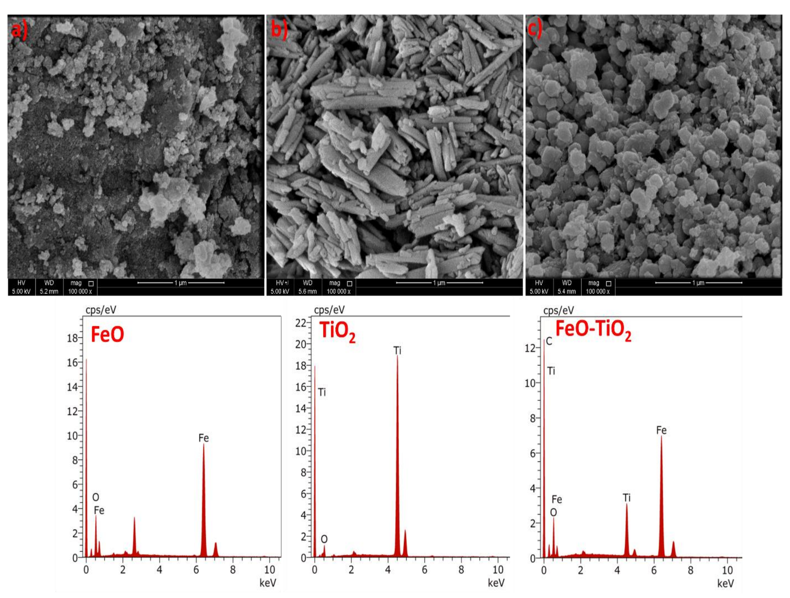

Figure 3: SEM images of a) FeO b) TiO_2 and c) FeO-TiO_2 nanomaterials.

The spherical or smaller platelet like structured morphology is observed for the FeO, whereas tubular morphology is seen for the TiO_2. In the hybrid all elements are seen indicating the formation of hybrid Nano architecture for the nanomaterial.

2. Structural and morphology analysis of the composites

All the nanocomposites show similar peak appearances in the FTIR spectrum, which arises from the various bond vibrations in PVDF-HFP, the base polymer. Nanocomposites shows no additional bonds, which is an indication of no additional chemical bonds in the nanocomposites

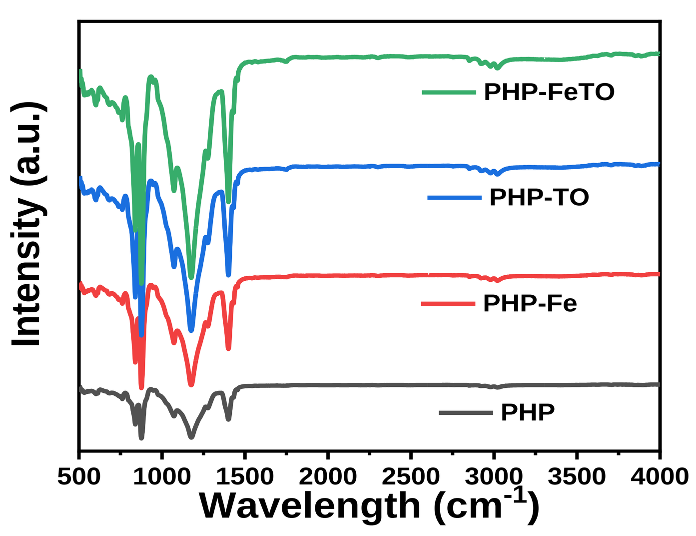

Figure 4: FTIR spectra of PVDF-HFP nanocomposites

3. Crystallinity analysis of the composites

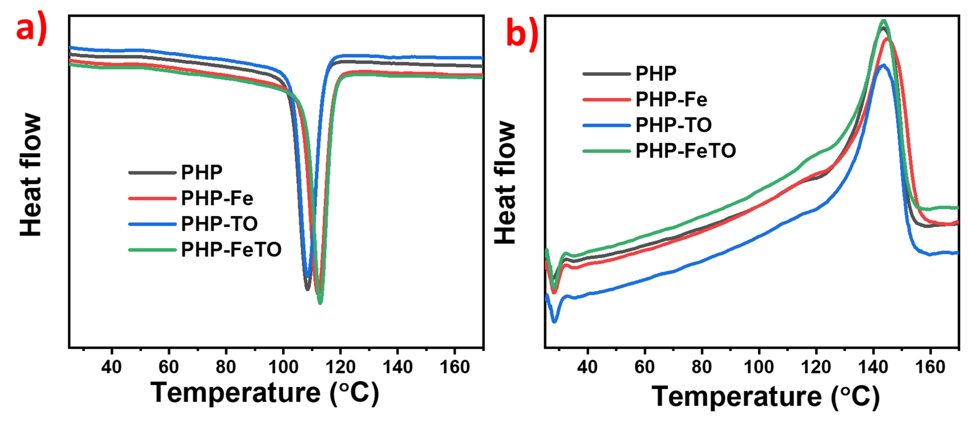

Figure 5: a) melting and b) crystallization curves for the PVDF-HFP and its nanocomposites

The shift in peak position is observed in the case of nanocomposites, which means the nanomaterials affect the melting/crystallization temperature of the polymer. Moreover, in hybrid nanocomposite an increase is observed for the temperature, due to the networking action of the nanomaterials within the polymer chains.

4. Piezoelectric property of the nanocomposite fibers

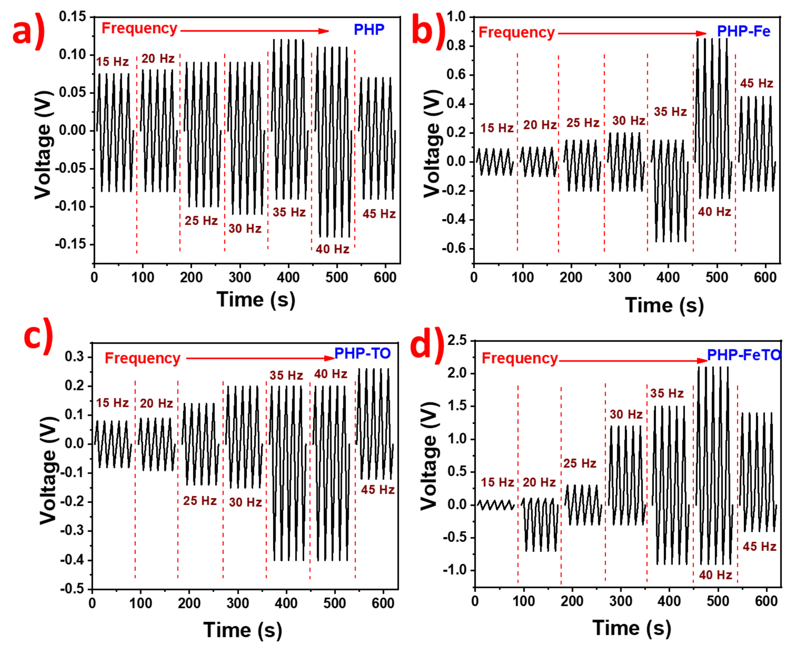

Figure 6: Piezoelectric output voltage of the polymer nanocomposites a) PVDF-HFP b) PVDF-HFP/FeO c) PVDF-HFP/TiO_2 and d) PVDF-HFP/FeO-TiO_2.

For the neat polymer, the piezoelectric output voltage is rather low. However, with the introduction of FeO and TiO_2 nanomaterials, the electric voltage increases reaching a maximum of 3 V at 40 Hz of vibration.

5. Dielectric property of the nanocomposites

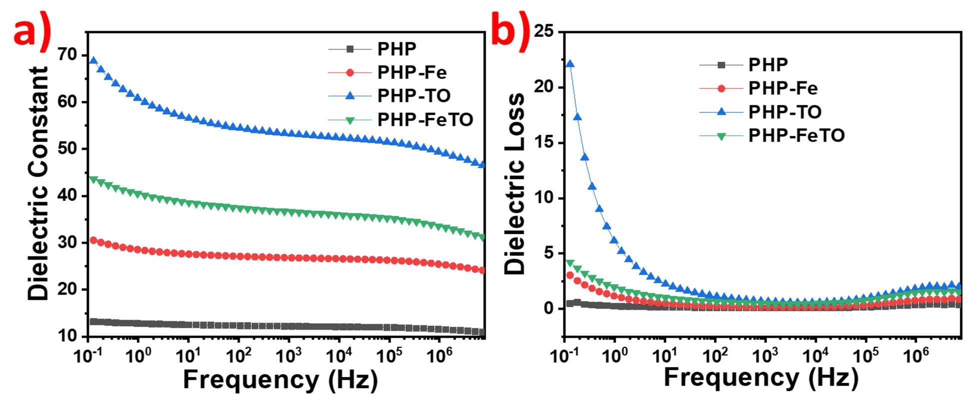

Figure 7: Dielectric properties of the polymer nanocomposites a) dielectric constant and b) dielectric loss versus frequency.

The dielectric constant is the maximum for the TiO_2 composite, but at the same time, its loss value is also comparatively higher. However, for the hybrid nanocomposite, the dielectric constant remains at larger levels when compared to the neat polymer, maintaining the loss values at lower levels.

Conclusion

This research work was done to create a hybrid nanocomposite polymer that has enhanced properties and storage capabilities to produce energy. The synthesized PVDF-HFP\FeO-TiO2 demonstrated good piezoelectricity production in comparison with the other materials. In addition, PVDF-HFP\FeO-TiO2 showed good storage capacity and low energy loss from the dielectric property analysis in comparison with the other materials. In proportion to Qatar 2030 vision of “Balancing between Development Needs and Protecting the Environment”, the developed material has the ability to produce electricity with minimal environmental impact and cost-effective methods, which can contribute to Qatar vision 2030, in minimizing the dependence of non-renewable energy sources.

Recommendations

Additional researches could be directed to test the ability of the developed hybrid nanocomposite to absorb electromagnetic radiation. In addition investigating self-cleaning properties due to the presence of TiO_2 nanoparticles can be a good study. The established material can be used in numerous applications such as smart electronic textiles, biomedical applications, and artificial intelligence.

References

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