Tailored PVDF-CNC-$BiFeO_3$ electrospun nanocomposites for hybrid energy harvesting: comprehensive investigation into microstructural and electromechanical behavior

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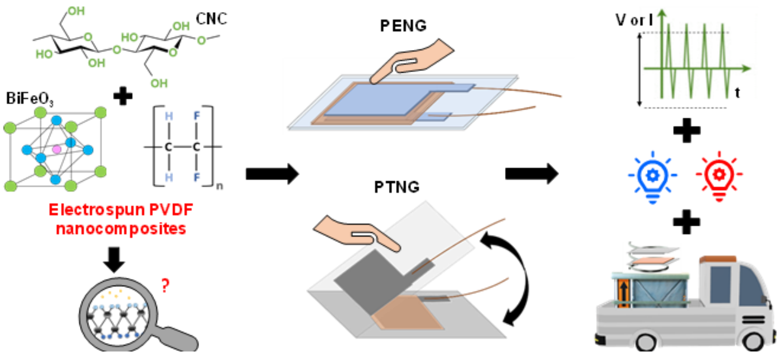
Mots-clés : PVDF, $BiFeO_3$, Electrospinning, Energy harvesting, Hybrid nanogenerators

Résumé :

Polyvinylidene fluoride (PVDF), a semicrystalline polymer with excellent electroactive properties is a promising candidate for developing modern energy harvesters or nanogenerators [1]. The energy harvesting capabilities of PVDF are distinct characteristics of its polar phases, especially the β phase. The fraction of polar phases is significantly influenced by the elaboration techniques and presence of nanofillers. This work investigates electrospun PVDF incorporated with cellulose nanocrystals (CNC) and bismuth ferrite ($BiFeO_3$, BFO) to develop a bi-filler nanocomposite membrane for mechanical energy harvesting and sensing applications [2]. The combined influence of electrospinning and nanofillers on crystallinity ratio and β phase formation is studied in detail using a comparative approach [3]. From the analysis of dynamic dielectric responses, changes were observed in interfacial polarization with filler addition, contributing to a deeper understanding of the complex interactions in triphasic nanocomposites. Additionally, the morphology, and mechanical properties of the nanofibers were also characterized. The practical potential of PVDF-CNC-BFO nanocomposites was demonstrated through the fabrication of piezoelectric and piezo-triboelectric hybrid nanogenerators. The piezoelectric nanogenerator (PENG) based on the bi-filler nanocomposite exhibited a maximum power density of 544 µW/cm^3, excellent durability, and capacitor-charging capability. It responded efficiently to diverse mechanical stimuli, including various human motions and cantilever vibrations. The piezo-triboelectric hybrid nanogenerator (PTNG) generated an average open-circuit voltage of 72 V and a short-circuit current of 15 µA under finger tapping, sufficient to power small electronic devices. When integrated with a spring-based structure under a small-scale vehicle-model test, the PTNG demonstrated potential for applications such as monitoring road conditions and harvesting energy during vehicle motion. This validated its ability to function as a next-generation self-powered sensor and portable energy harvester.



Development of PENG and PTNG from electrospun PVDF-CNC-BFO nanocomposites for energy harvesting

Références :

[1] S. Moozhiyil Purushothaman, M. Fernandes Tronco, B. Kottathodi, D. Rouxel, I. Royaud, M. Ponçot, N. Kalarikkal, S. Thomas, Polymer, 283, 126179, 2023

[2] S. Ponnan, C. Lekha, I. Oh, M. Poncot, S. Thomas, I. Royaud, D. Rouxel, N. Kalarikkal, ACS Appl. Electron. Mater. 2024, 6 (7), 4963–4976. https://doi.org/10.1021/acsaelm.4c00519

[3] S. Moozhiyil Purushothaman, M. Fernandes Tronco, M. Ponçot, C. Lekha, N. Guigo, M. Malfois, N. Kalarikkal, S. Thomas, I. Royaud, D. Rouxel, ACS Appl. Polym. Mater. 2024. https://doi.org/10.1021/acsapm.4c01157