Synergistic Piezoelectric-Triboelectric Transduction for Enhanced Biomechanical Sensing Efficiency

Nadeem Tariq Beigh[1], Nouha Alcheikh[1]
Department of Mechanical and Nuclear Engineering, Khalifa University, Abu Dhabi, United Arab Emirates
Nadeem.beigh@ku.ac.ae

Abstract

Nanocomposites have accelerated the progress of self-powered sensors into the field of smart healthcare, automation, agriculture, owing to their multidimensional, hybrid, self-powering capability. The interplay of polymer-dopant gives rise to interesting phenomena of dual transduction, resulting in an alternate energy route for sensing/energy harvesting applications [1,2]. This work presents the concept of "triboelectric shift" in a well-known piezoelectric polymer called poly (vinylidene fluoride–trifluoro ethylene) (P(VDF-TrFE)) by a controlled barium titanate (BTO) doping. We employ 20% P(VDF-TrFE) polymer as the base matrix and vary the BTO %weight ratio from 0-20% (Fig. 1(a-e)). Among all, the 15% BTO in 20% P(VDF-TrFE) shows excellent dopant distribution and uniformity with minimal clustering, agglomerations (Fig. 1(f-h)) and piezoelectric crystallinity (Fig. 1i). The absence of clustering and short circuit paths with an optimum BTO content results in a high normalized piezoelectric coefficient of ~10mV/V (Fig. 1j). The addition of optimum BTO dopants enhance the piezoelectric polarization of P(VDF-TrFE), as well as elevates the surface charges by increasing the number of dangling bonds, free electrons and charged particles. Thereby, adding to the surface charge density and modulating the net surface potential from a "tribo-negative" to a "tribo-positive" (Fig. 1k). This phenomenon is called "triboelectric shift". Finally, the dual sensor based on the optimum nanocomposite is tested for a simulated biomechanical excitation (Fig. 1l). The sensor achieves the sensitivities of 21mV.Kpa^{-1} ((Fig. 1m) and 13mV.KPa^{-1}(Fig. 1n). for the triboelectric and piezoelectric modes, respectively. The sensor shows a linear operational range of 60KPa at 4Hz excitations. The initial analysis suggests that the dual transduction sensor based on optimum design nanocomposites has excellent potential in multitude of sensing applications including tactile sensing and smart heath monitoring.

References

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Figures

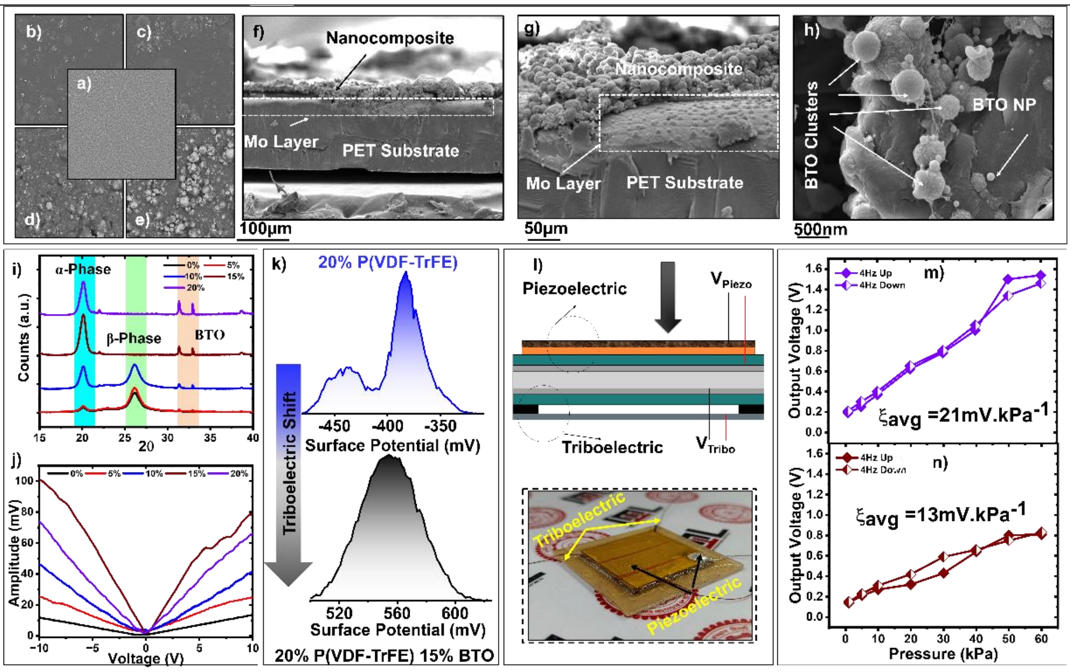

Figure 1: The surface morphology of a) 0% b) 5% c) 10% d)15% and e) 20% BTO in 20% P(VDF-TrFE), cross sectional morphology of 15% BTO in 20% 20% P(VDF-TrFE) at three zoom levels(f-h), i) the XRD evolution of the nanocomposite with 0-20% BTO in 20% P(VDF-TrFE), the PFM evolution of the nanocomposite with 0-20% BTO in 20% P(VDF-TrFE), k) the Triboelectric shift in the 0 and 15% BTO in 20% P(VDF-TrFE), l) device schematics and fabricated device, m) triboelectric pressure response and n) piezoelectric pressure response.