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Enhancing PVDF-TrFE Properties with Fe3O4 via Electrospinning for Multiferroic Applications

Multiferroic materials, capable of exhibiting multiple order parameters such as magnetic, electric, and elastic properties, are at the forefront of quantum material research due to their transformative potential in next-generation technologies. Among these, polymeric multiferroic materials offer unique advantages, including lightweight, flexibility, and ease of processing, which make them highly desirable for applications in sensors, energy harvesting, and data storage devices. Polyvinylidene fluoride-trifluoroethylene (PVDF-TrFE) stands out as a promising polymer matrix for multiferroic composites due to its superior ferroelectric properties, high spontaneous polarization, and ability to form the β-phase crystalline structure crucial for piezoelectricity. However, its lack of inherent magnetic properties necessitates doping with magnetic nanoparticles, such as ferrites, to develop composites that respond to both electric and magnetic fields. This study investigates the fabrication and characterization of PVDF-TrFE/Fe3O4 nanocomposite fibers and particles prepared via electrospinning with varying Fe3O4 concentrations (1, 3, and 5 wt%). Controlled electrospinning parameters (14 cm needle-to-collector distance, 15 kV applied voltage, 24-gauge needle) yielded uniform fibers with SEM and TEM analyses revealing reduced average diameters (from 0.258 μm to 0.109 μm) with increasing nanoparticle loading. EDS confirmed successful Fe3O4 incorporation, while piezoelectric measurements (d33 coefficient) demonstrated the enhancement of piezoelectric properties in doped composites. This research highlights the potential of PVDF-TrFE-based multiferroic nanocomposites as versatile and multifunctional materials, advancing their viability for industrial applications. The integration of magnetic and electric order parameters in polymeric matrices represents a significant step forward in the development of flexible, scalable multiferroic systems for emerging quantum material applications.