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On the Electromechanical Properties of Hybrid Piezolectric Nanocomposites by Scanning Probe Microscopy

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The energy crisis demands urgent exploration of new methods for electricity production and storage. A promising approach involves the development of systems made of materials exhibiting piezoelectric properties for charge generation. Although some materials such as PZT exhibit excellent piezoelectric properties, the presence of toxic lead hinders their applicability, necessitating the exploration of alternative materials. Organic materials such as poly(vinylidene fluoride)-b-triflluoroethylene (PVDF-TrFE) possess inherent piezoelectric properties, although their coefficients are lower than those of their inorganic counterparts. However, the addition of piezoelectric nanoparticles such as $BiFeO_3$ (BFO) nanoparticles can enhance their overall piezoelectric response.

This study aims to prepare and characterize a hybrid composite system of PVDF-trFE copolymer with BFO nanoparticles, combining the organic flexibility with the inorganic piezoelectric sensitivity. We investigated those systems using Piezoresponse Force Microscopy (PFM), a local probe microscopy mode based on the inverse piezoelectric effect, coupled with a resonance frequency tracking device. Although PFM is still widely used to quantify piezo and ferroelectric properties, recent studies have revealed that there is a significant signal contribution of different artifacts, mainly due to electrostatic interactions between the surface and the tip. We ensured to minimize these effects by using different approaches, such as identifying the Electrostatic Blind Spot (ESBS), positioning the laser on the cantilever to minimize this electrostatic contribution.

In addition to conventional PFM, we employed more advanced modes, such as switching spectroscopy PFM (ssPFM). This mode is based on a script where the electromechanical response is continuously monitored while alternating between a polarization step (on-field) and a non-polarization step (off-field). From these data, the ferroelectric hysteresis of the material can be extrapolated. We also verified the true ferroelectric nature of our samples by analyzing the results of cKPFM produced with the same set of techniques. We show how important this double check is by illustrating them on a well-known non-ferroelectric sample of ZnO.

Through these research efforts, we aim to contribute to the development of piezoelectric hybrid materials with improved electromechanical properties. These materials hold significant potential for addressing the energy crisis and driving advancements in electricity generation.