

Stretchable Piezoelectrics Based on PVDF-Elastomer Blends

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Summary:

In this work, we present the development of a highly stretchable piezoelectric sensor based on a blended polymer system composed of poly(vinylidene fluoride-co-trifluoroethylene) (PVDF-TrFE) and the elastomer nitrile butadiene rubber (NBR), fabricated via bar-coating & vulcanization. A polymer blending approach is employed, in which PVDF-20TrFE is dispersed within an elastomeric NBR matrix, followed by vulcanization of the NBR phase to enhance mechanical stability and elasticity. Furthermore, the polarization–electric field (P–E) hysteresis is investigated, and the material is electrically poled to improve its piezoelectric performance, indicating their potential for stretchable piezoelectric applications.

Keywords: Piezoelectric sensors, Stretchable electronics, PVDF-TrFE, NBR, Bar-coating technique

Background, Motivation and Objective

Stretchable piezoelectric sensors are key components for next-generation flexible and wearable systems, where reliable electromechanical sensing under large mechanical deformation is required. However, achieving an optimal balance between piezoelectricity, mechanical stretchability, higher strain sensing range and long-term durability remains a major challenge in polymer-based systems [1].

Commercial piezoelectric sensors are typically either rigid or flexible but lack sufficient stretchability to withstand high-strain environments [2]. In applications involving large deformation, these sensors often fail due to mechanical fatigue and poor strain accommodation.

In this work, we aim to develop flexible and stretchable piezoelectric blends by blending piezoelectric polymer PVDF-20TrFE and elastomer NBR, targeting improved stretchability, durability and sensing capabilities.

Description of the New Method or System

In this work, we introduce scalable bar-coating approach to fabricate PVDF-TrFE/NBR blend films for stretchable piezoelectric applications. We systematically investigate the polarization–electric field hysteresis behavior for these blends to understand how the elastomer matrix influences the ferroelectric and piezoelectric response. The results highlight the potential of this approach to optimize mechanical properties and

move towards more reliable stretchable piezoelectric sensors.

Results

Mechanical properties were investigated by measuring the stress–strain curves of the blend films. Mechanical characterization reveals a significant reduction in Young's modulus with increasing NBR content, decreasing from 1.6 GPa for pure PVDF-20TrFE to approximately 50 MPa for the 40:60 (PVDF-20TrFE: NBR) blend (Fig. 1). Additionally, the elongation at break increases up to ~16% for the 40:60 blend, indicating enhanced stretchability, compared to only 2% for the pure PVDF-20TrFE film (Fig. 1). These results demonstrate that the incorporation of NBR significantly improves the mechanical compliance and flexibility of the polymer films.

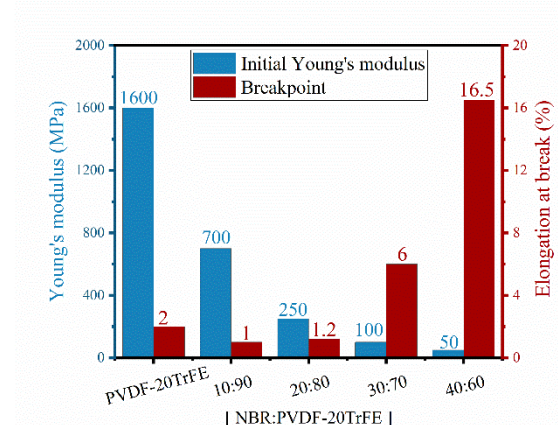


Fig. 1. Graph of Young's modulus and elongation at break for various blend ratios.

Electromechanical measurements confirm clear ferroelectric switching in blends containing $\geq 50\%$ PVDF-20TrFE, with coercive fields in the range of 30–60 V/ μm (Fig. 2), indicating the retention of ferroelectric functionality within the blended system. At higher NBR content, particularly for the 40:60 [N:P] composition, noticeable leakage current are observed, which can be attributed to the increased presence of the elastomeric phase influencing dielectric behaviour.

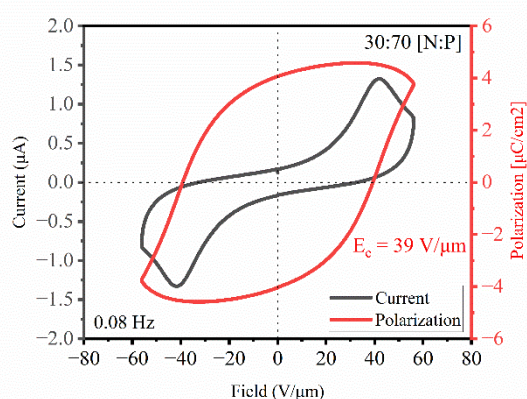


Fig. 2. Polarization-Electric field (PE) hysteresis loop for blend film 30:70

The piezoelectric coefficient (d_{33}) measured using a Berlincourt d_{33} meter for pure PVDF-20TrFE and its blends containing 10 – 40% NBR, provides insight into the effect of polymer composition on electromechanical performance. The d_{33} value gradually decreases from -23 pC/N for pure PVDF-20TrFE to -2.0 pC/N for the 40:60 [N:P] blend ratio, as summarized in Table 1, reflecting the reduced ferroelectric phase contribution with increasing elastomer content.

Tab. 1: piezoelectric coefficient d_{33} of the blends

Samples	d_{33} (pC/N)
PVDF-TrFE	-23
20:80 [N:P]	-9.6
30:70 [N:P]	-2.4
40:60 [N:P]	-2.0

Furthermore, the voltage output was measured using an oscilloscope under repetitive finger-tapping conditions (Fig. 3), which confirms stable and reproducible signal generation across all compositions. The output voltage shows a composition-dependent variation, with values that can be tuned by adjusting the NBR content in the blends, highlighting the compositional control over piezoelectric performance.

Atomic force microscopy (AFM) analysis reveals an elongated distribution of PVDF-TrFE domains within the NBR matrix, which varies with

composition. The large contrast in Young's modulus between PVDF-TrFE (3–5 GPa) and NBR (1–2 MPa) enables stiffness mapping, providing insight into the phase distribution and microstructure of the blends (Fig. 4).

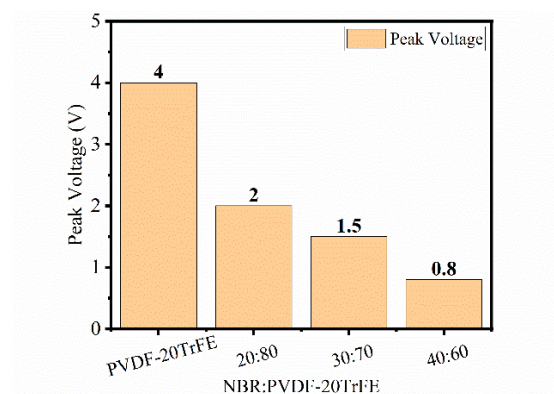


Fig. 3. Graph of peak voltage signal output through tapping mode

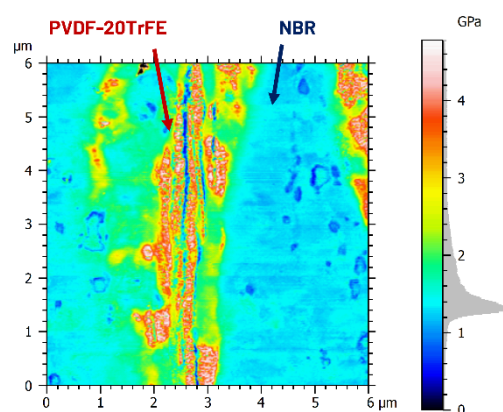


Fig. 4. AFM stiffness mapping: PVDF-20TrFE and NBR phases

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