

Supporting information

Fabrication of Rare Earth Doped ZnO-PVDF Flexible Nanocomposite Film for Ferroelectric Response and their Application in Piezo-responsive Bending Sensor

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S1. XRD analysis of Er³⁺ doped ZnO and ZnO:

The X-ray diffraction (XRD) pattern depicted in Figure S1 reveals that the peaks observed in the case of EZ are shifted towards lower 2θ values compared to the standard ZnO (ICSD#145869). This indicates a broadening of the lattice. Two specific mechanisms can occur during the doping process. The first one is the substitution of the host ions by the dopant ions and second one is the occupation of the dopant ions at the interstitial sites. As observed in the present study, the XRD patterns do not exhibit any significant impurities associated with the formation of a different phase. Although the ionic radius of cationic dopant Er³⁺ is greater than that of host cation Zn²⁺, the substitution of Zn²⁺ (3d) ions by Er³⁺ (4f) ions inside the host lattice structure of ZnO has been reported to occur in previously published literatures [1,2]. Therefore, it can be concluded that the Er³⁺ ions have substituted the Zn²⁺ ions inside the host lattice.

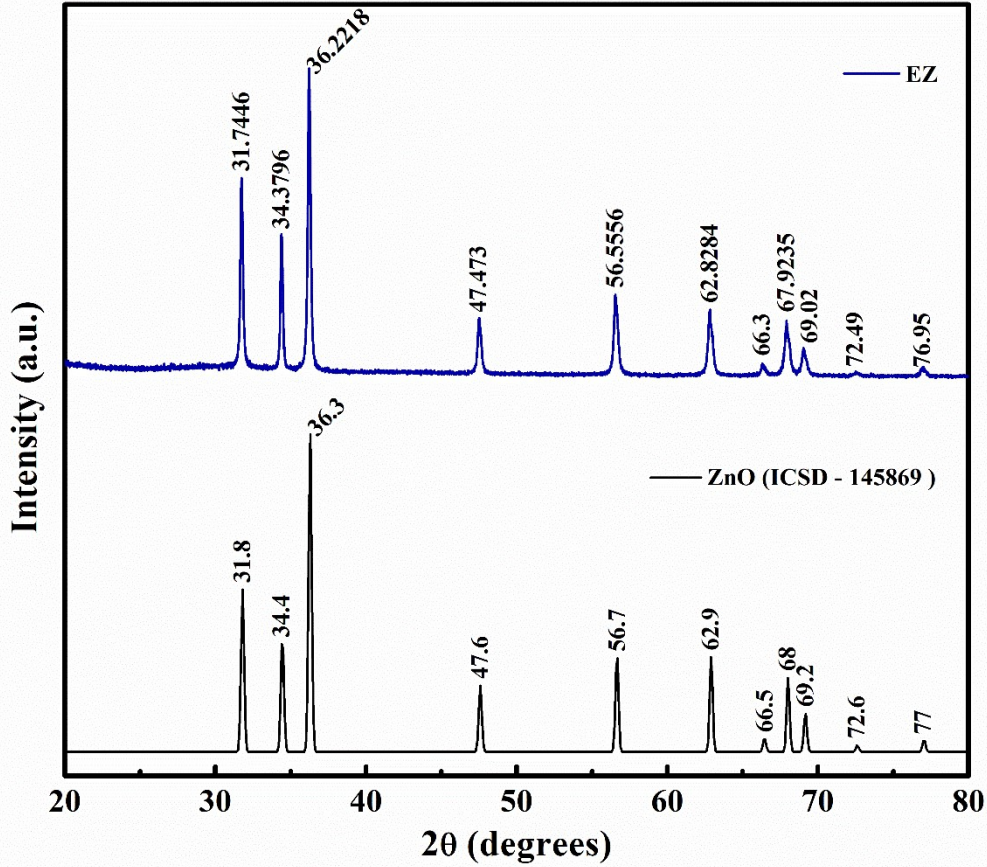


Figure S1. XRD pattern of EZ and ZnO (ICSD-145869).

S2. Calculation of force for the determination of piezoelectric coefficient (d_{33}):

The force imparted on the film is estimated from the laws of conservation of energy.

$$mgh = \frac{1}{2}mv^2 \quad (1)$$

Where m is the mass of dropped object, g is the acceleration due to gravity, v is the final velocity before striking, and h is the height of the object from where it is dropped. Velocity has been found 1.71 m/s using equation (1) for the height of 15cm.

Therefore, the net applied force F on the nanocomposite film is given by

$$F = m\left(\frac{v}{\Delta t} + g\right) \quad (2)$$

where Δt is the full width at half maxima (FWHM) of the voltage vs the time graph of piezoelectric response [3]. The piezoelectric voltage has been obtained by exerting force by hand where m is 0.0185 kg, v is 1.71 ms^{-1} , h is 0.15 m, g is 9.8 m/s^2 , and Δt is 0.00159 s from Figure S2. From these values using equation (2), the applied force on the device is found to be 20.077 N.

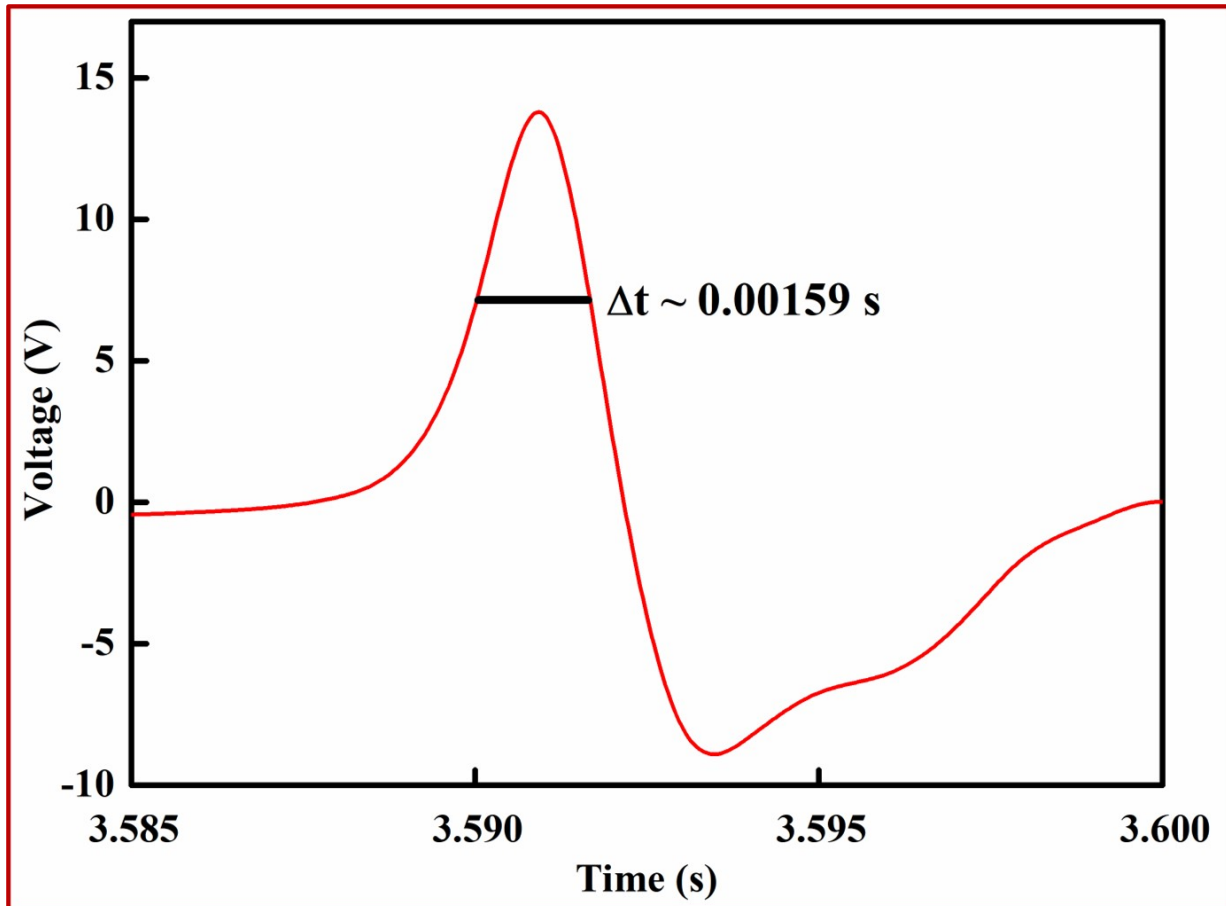


Figure S2. FWHM (Δt) from the voltage vs time plot of the piezoelectric response.

S3. Video of piezoelectric voltage response due to bending of nanocomposite film:



Piezoelectric bending sensor.mp4

S4. Thermal property study:

For better understanding of thermal stability of EZ-PVDF nanocomposite films (EZP1, EZP2) as compare to pure PVDF system, thermogravimetric (TGA) and differential thermal analysis (DTA) has been performed for all the nanocomposite films. The weight loss profile and the differential thermal analysis of all the nanocomposite films (PVDF, EZP1 and EZP2) has been shown in Figure S4. Before going to start the experiment all the nanocomposite films had been heated and the moisture is removed if present in the samples at 100 °C for 20 min. Then, the experiment was run at the range of 30-600 °C temperature with the continuous flow of liquid nitrogen at the rate of 80 ml/min. using aluminium crucible and the rate of increasing temperature 10 °C/min. For the pure PVDF system Figure S4 from the DTA observation we have seen that the smoothing temperature was started at ~169 °C and at around ~459 °C its completely degrade, also, the major weight loss on its TGA curve observed at ~459 °C. In case of EZP1 and EZP2 nanocomposite films for both the system the smoothing temperature was started at ~170 °C (observed from DTA analysis) and the nanocomposite films degrade at ~461 °C and ~463 °C respectively which is more than that of pure PVDF film. Thus, it has been quite clear that with the increase of weight percent (10 and 20 wt.% EZ nanoparticles) inside the PVDF matrix has increase the thermal stability of the nanocomposite films gradually as compare to PVDF. So that,

with the increase of EZ nanofillers inside the PVDF matrix will be more the declination temperature of the EZ-PVDF nanocomposite films. This happened due to the well distribution of EZ nanoparticles inside the matrix of PVDF and the formation of interface between them also improved their thermal stability [4]. The nanocomposite films were nucleated by the interaction of surface electrostatic charge presented in the EZ nanoparticles which can remarkably nucleate and enhance β -phase of the EZ-PVDF nanocomposite films. Those are mainly responsible for the considerable increment of the thermal sustainability of the composite films containing 20 wt.% rather than 10 wt.% EZ nanoparticles. The TGA observation for all weight percentage represents the weight loss and the DTA curves indicating a phase change.

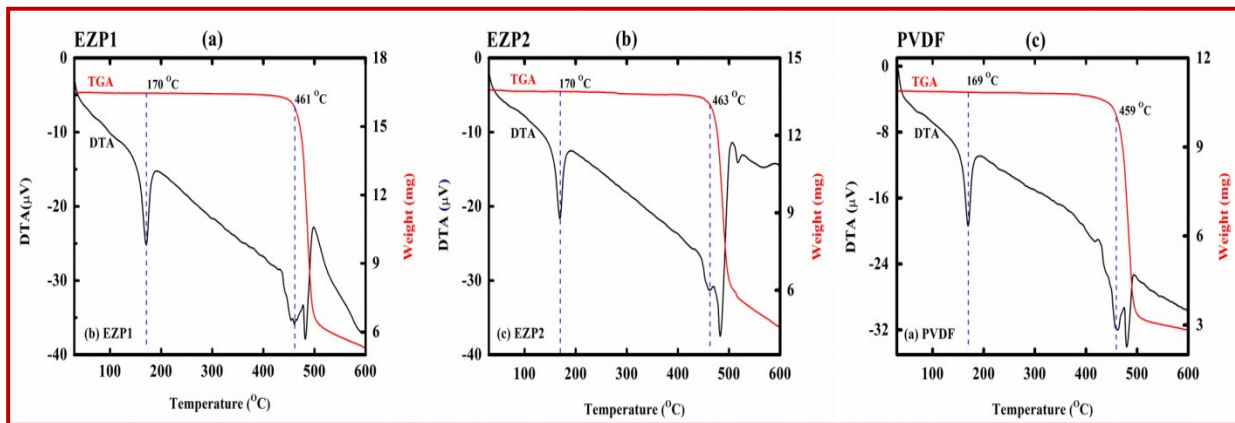


Figure S4. DTA and TGA study of (a) EZP1 and (b) EZP2 and (c) PVDF nanocomposite films.

References

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