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# Ag- and Li-Doped ZnO Nanostructures: Morphological Features and Piezoelectric Applications

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## INTRODUCTION & AIM

**The pursuit of sustainable and lead-free alternatives for piezoelectric materials has motivated the development of new synthesis strategies with minimal environmental impact. In this study, we report an eco-friendly approach for fabricating piezoactive nanostructures based on zinc oxide (ZnO) doped with silver (Ag) and lithium (Li).**

**Comprehensive morphological characterization was performed using atomic force microscopy and scanning electron microscopy, confirming the successful growth of well-aligned doped ZnO nanostructures. The piezoelectric performance of the samples was evaluated through measurements of the direct piezoelectric coefficient ($d_{33}$).**

**The results demonstrated that the incorporation of dopant ions not only preserved but also enhanced the piezoelectric activity of the ZnO structures, indicating that the synthesis route is both efficient and environmentally responsible. This work highlights the potential of Ag- and Li-doped ZnO nanostructures, prepared under green processing conditions, for obtaining large-area piezoelectric materials. The combination of low-cost synthesis, ecological benefits, and functional piezoelectric response suggests that this approach represents a promising pathway toward sustainable materials design for applications in energy harvesting.**

## METHOD

**The nanostructures were synthesized via a low-temperature hydrothermal method directly on metallic substrates (platinum and titanium foils) previously coated with a ZnO seed layer obtained through sol-gel spin coating. The hybrid system was further encapsulated with a polymer layer to ensure mechanical stability and compatibility for device integration.**

## RESULTS & DISCUSSION

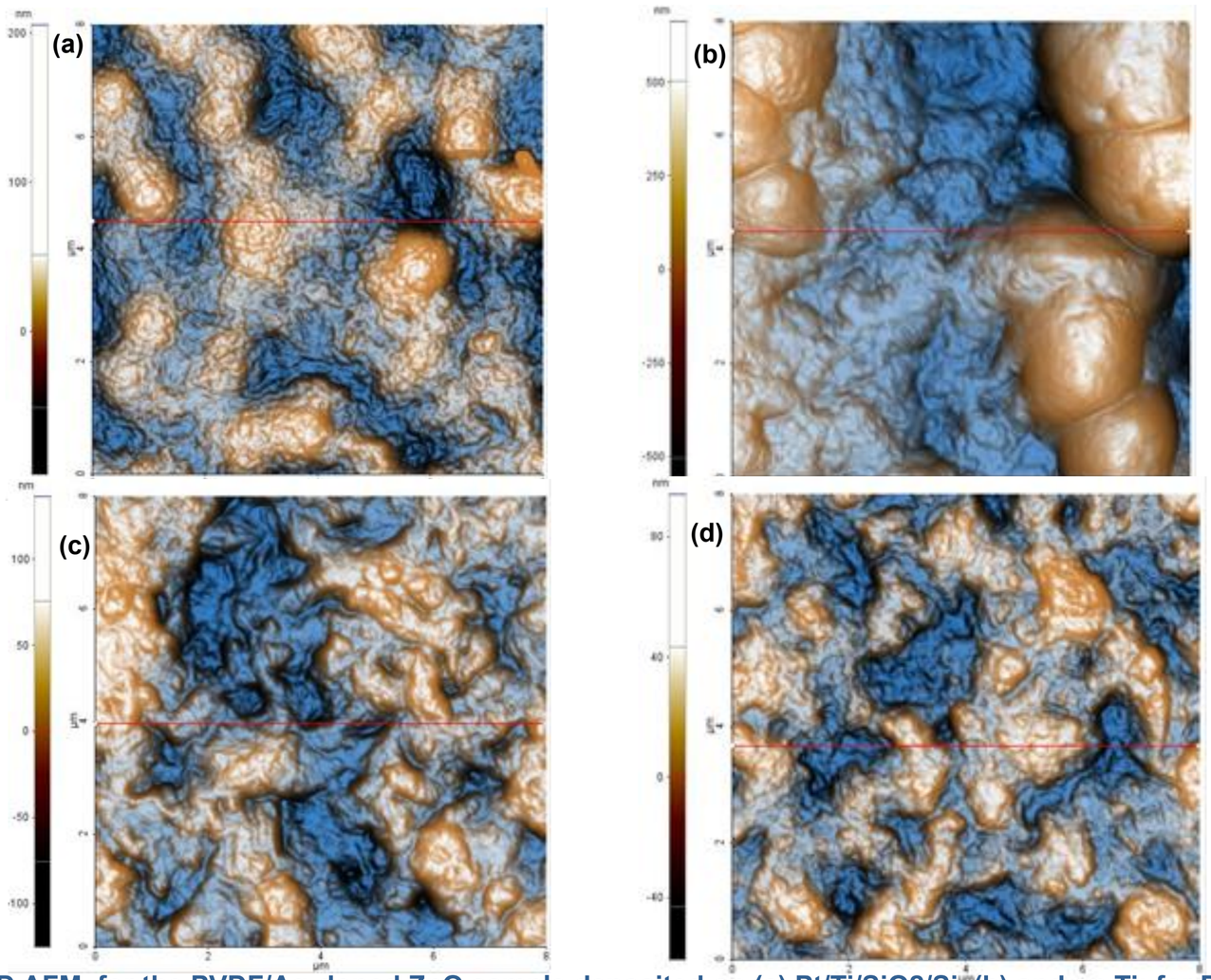
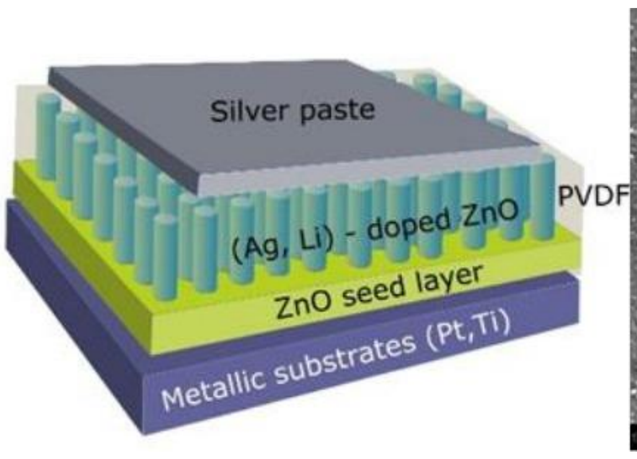



**Fig.1 2D AFM for the PVDF/Ag-doped ZnO sample deposited on (a) Pt/Ti/SiO2/Si (b) and on Ti; for PVDF/Li-doped ZnO sample deposited on (c) Pt/Ti/SiO2/Si and (d) onTi.**



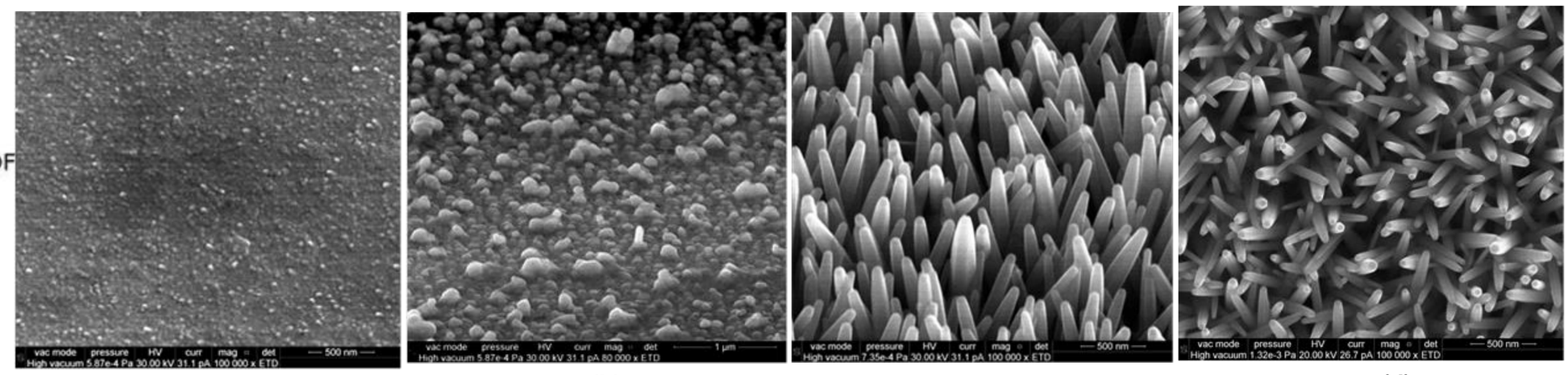




**Fig.2 SEM images for ZnO seed layer (a) and the Ag-doped ZnO sample deposited on Pt/Ti/SiO2/Si substrate (b); and for the ZnO samples doped with Li deposited on Pt/Ti/SiO2/Si (a) and Ti (b) substrate.**

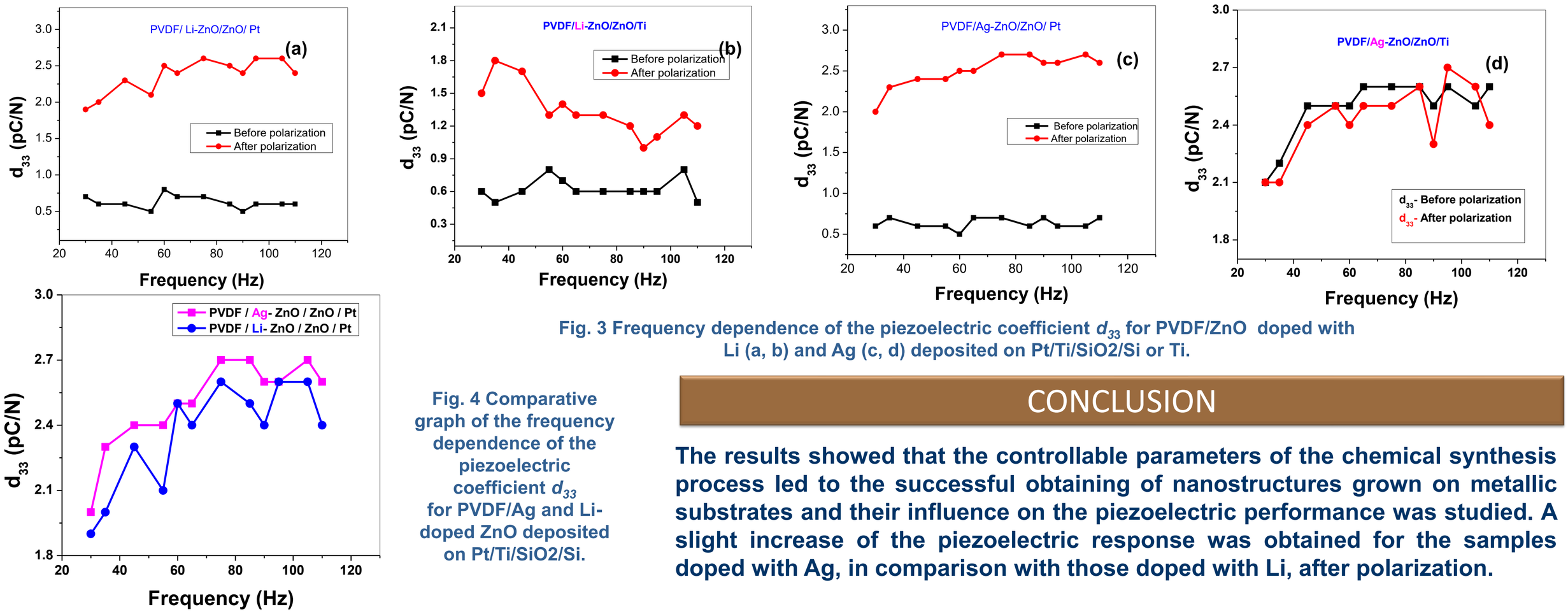



**Fig. 3 Frequency dependence of the piezoelectric coefficient $d_{33}$ for PVDF/ZnO doped with Li (a, b) and Ag (c, d) deposited on Pt/Ti/SiO2/Si or Ti.**

**Fig. 4 Comparative graph of the frequency dependence of the piezoelectric coefficient $d_{33}$ for PVDF/Ag and Li-doped ZnO deposited on Pt/Ti/SiO2/Si.**

## CONCLUSION

**The results showed that the controllable parameters of the chemical synthesis process led to the successful obtaining of nanostructures grown on metallic substrates and their influence on the piezoelectric performance was studied. A slight increase of the piezoelectric response was obtained for the samples doped with Ag, in comparison with those doped with Li, after polarization.**