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Optimizing Piezoelectric Performance of ZnO Nanowire Arrays through Integration with Metallic Substrates

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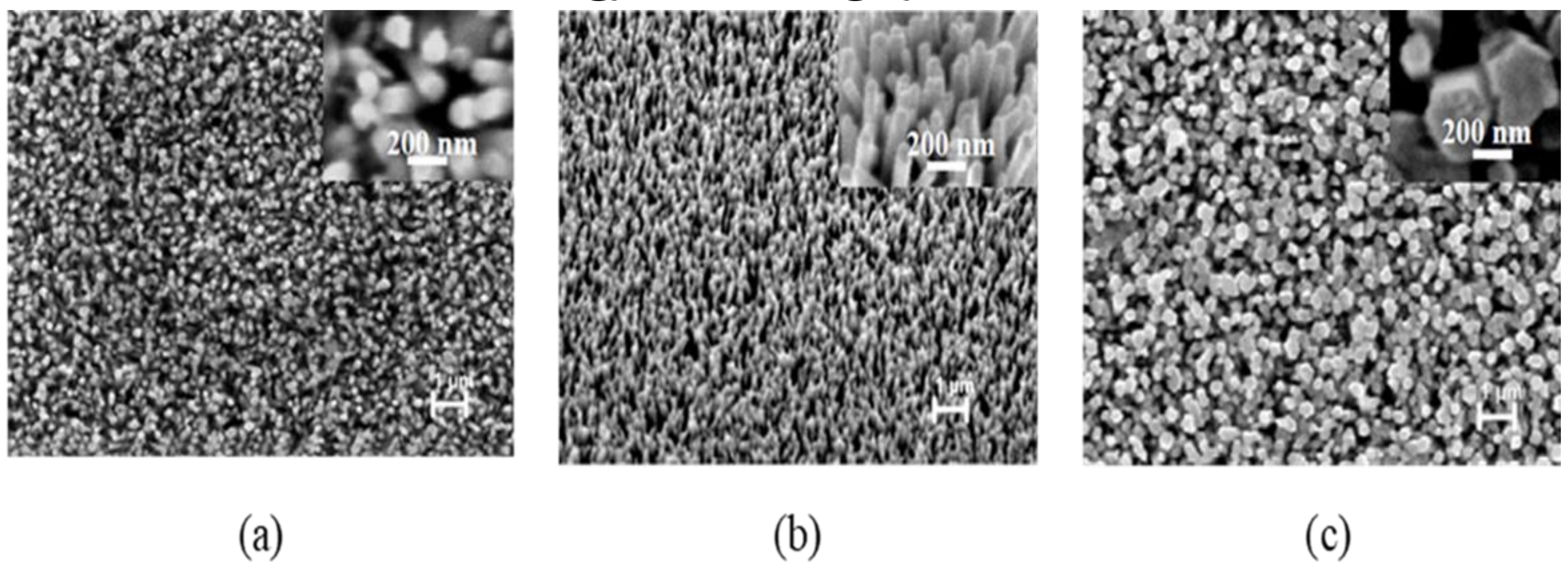
INTRODUCTION & AIM

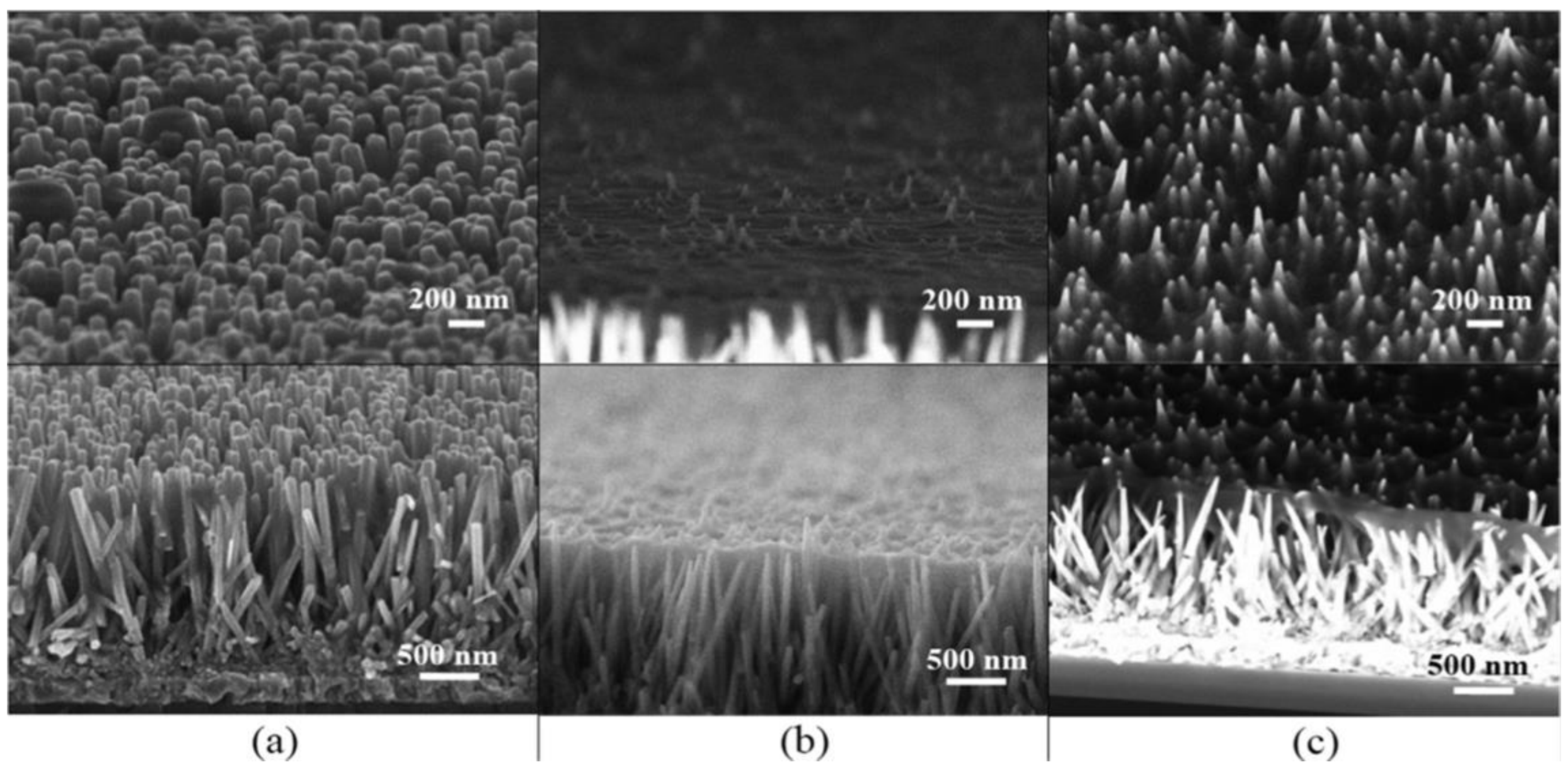
The development of advanced energy harvesting technologies requires piezoelectric architectures that combine high efficiency with mechanical flexibility. In this study, we conduct a comparative investigation of zinc oxide (ZnO) nanowires (NW) arrays grown on rigid Au/Pt-coated substrates and on flexible titanium foils, with the aim of evaluating their potential for integration into next-generation piezoelectric devices.

RESULTS & DISCUSSION

The results revealed a significant enhancement in piezoelectric performance for ZnO NWs integrated on titanium foil compared to those grown on Pt/Au substrates. This improvement is attributed to superior vertical integration and enhanced mechanical adaptability of the NWs when supported by a flexible substrate. These findings highlight the critical role of substrate choice in optimizing nanoscale piezoelectric performance. Moreover, the demonstrated low-cost, solution-processed growth of ZnO NWs on flexible metal foils underscores their potential for scalable fabrication of energy harvesting systems.



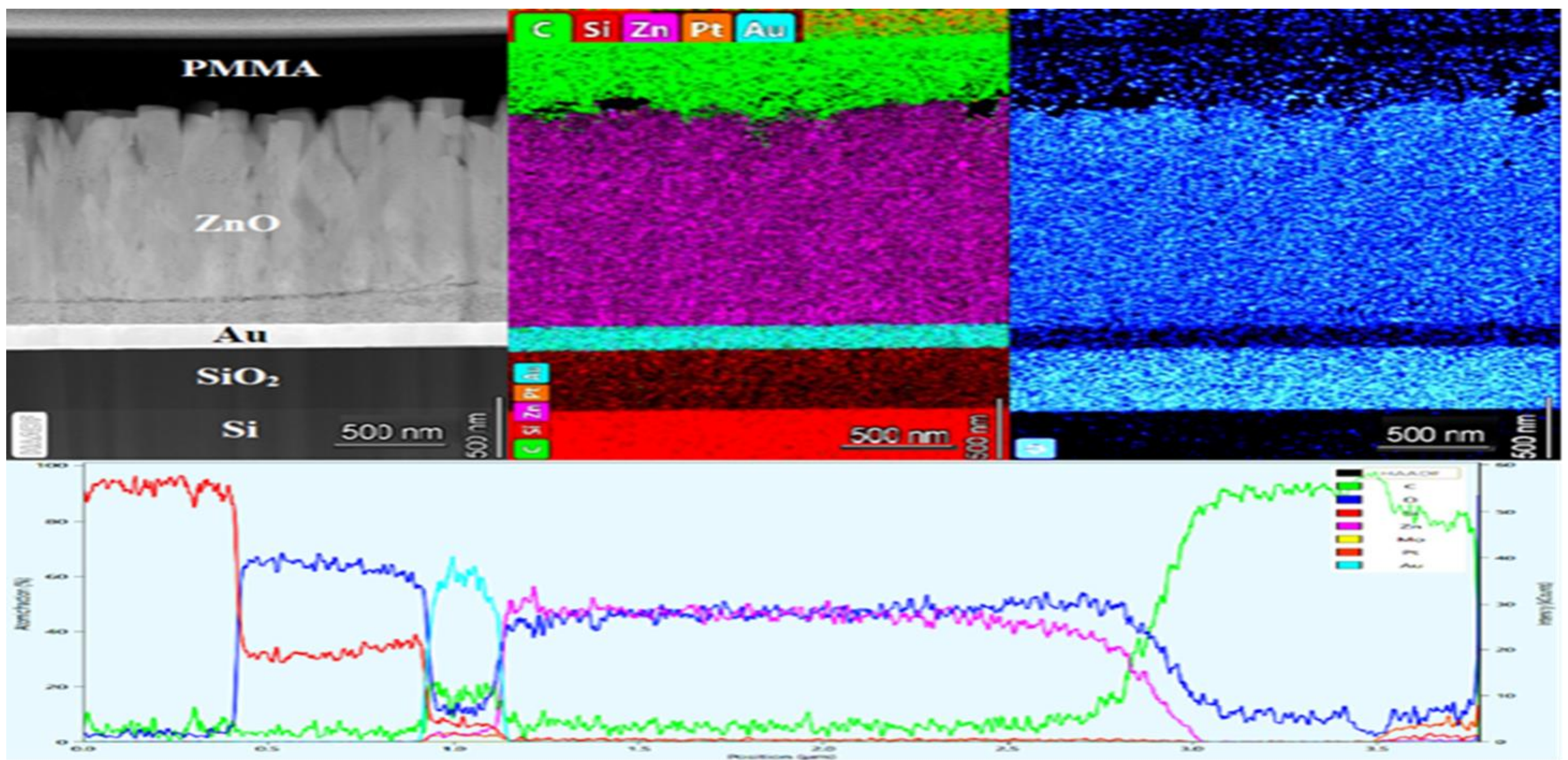
Top view SEM micrographs of well-aligned ZnO NWs before PMMA deposition grown onto different metallic substrates: (a) Pt; (b) Au; (c) Ti.



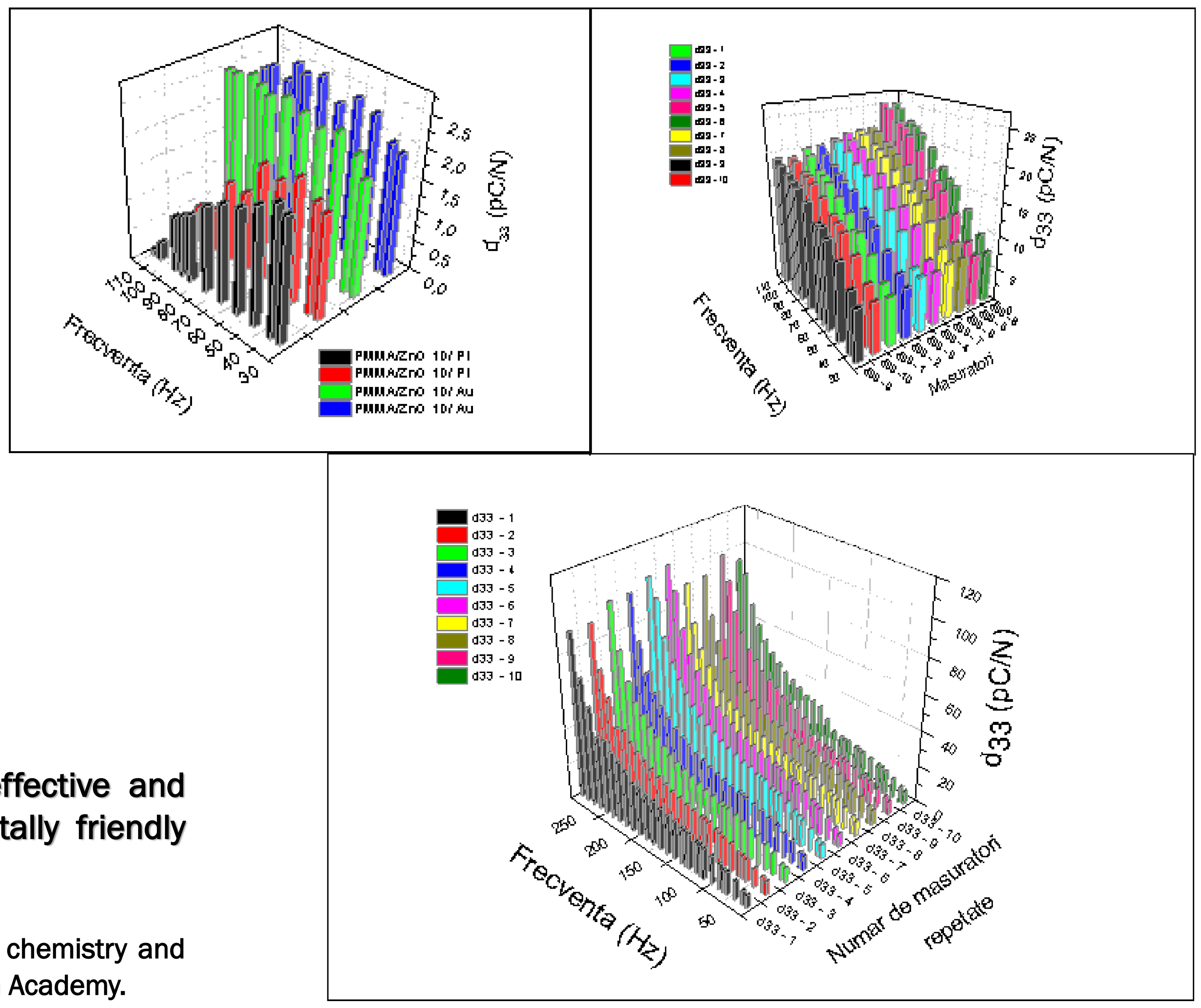
Edge view- SEM micrographs of ZnO NWs after PMMA deposition grown onto: (a) Pt substrate; (b) Au substrate; and (c) Ti substrate.

METHOD

Vertically aligned ZnO NWs were grown via a low-temperature hydrothermal process on a crystalline seed layer prepared by sol–gel spin deposition. To enhance structural integrity and device compatibility, the NW arrays were encapsulated within a polymethylmethacrylate polymer matrix. The nanostructures were characterized throughout fabrication using transmission electron microscopy, scanning electron microscopy, and spectroscopic ellipsometry, confirming uniform morphology, high crystallinity, and consistent alignment. Piezoelectric properties were directly evaluated by measurements of the effective longitudinal piezoelectric coefficient (d_{33}), enabling a quantitative comparison between rigid and flexible device platforms.



HAADF and EDS maps: C-green, Si-red, Zn-magenta, Au-cyan (center) and O-blue (right) from ZnO NWs + PMMA on Au sample.



Frequency dependence of piezoelectric coefficient d33 of the (a) PMMA/(ZnO NWs)/Pt and PMMA/(ZnO NWs)/Au; (b) PMMA/(ZnO NWs)/Ti; c) PMMA/(ZnO NWs)/Ti (over a wide range).

CONCLUSION

Solution-deposited ZnO nanowire networks on metal foils offer a cost-effective and scalable route to the development of high-performance and environmentally friendly energy harvesting technologies.

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