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Tailoring Structural and Optical Properties of Metal-Doped ZnO Nanoparticles for Optoelectronic and Consumer Applications

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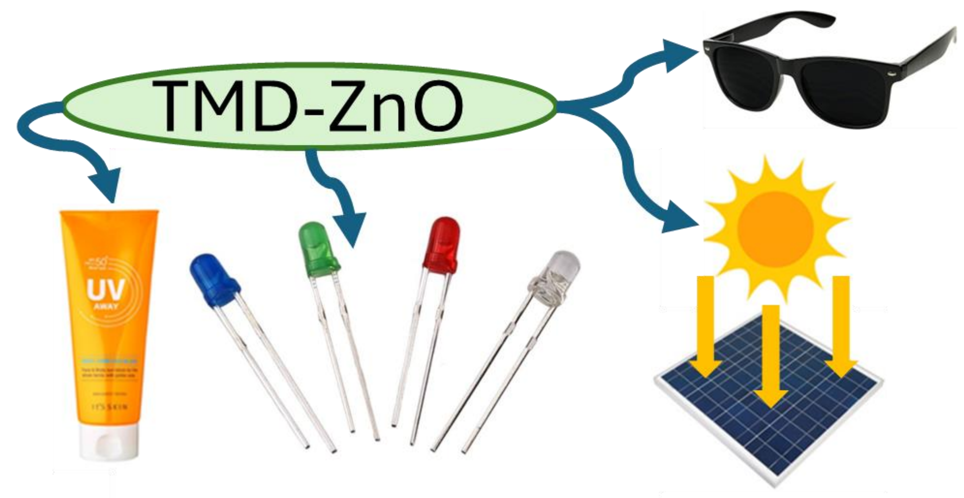
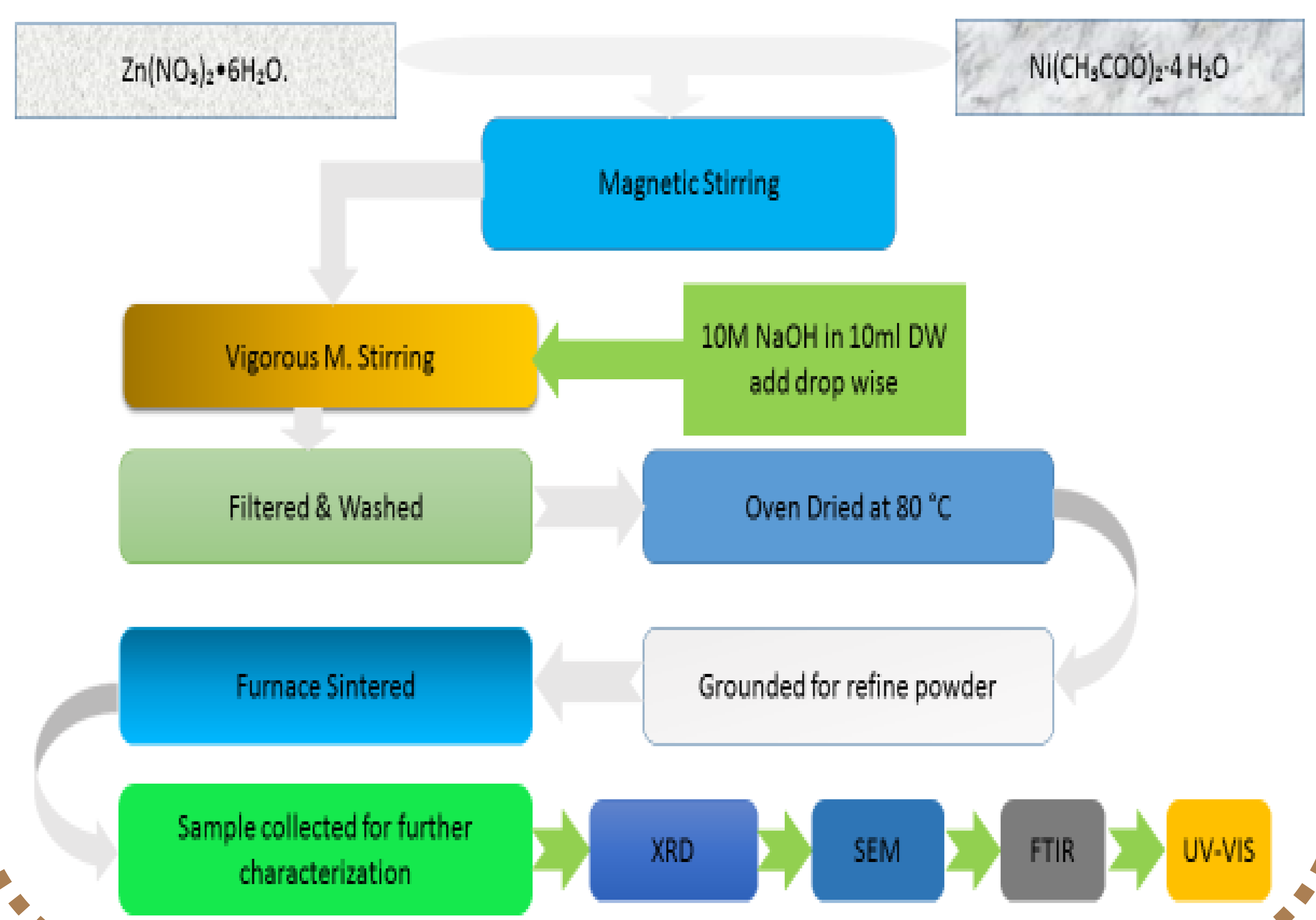
Abstract

ZnO is a II-VI semiconductor with a direct band gap of 3.37 eV and a high exciton binding energy of ~60 meV, making it suitable for UV-based devices such as LEDs, lasers, and transparent electronics [1] .Incorporating transition metals into the ZnO lattice introduces new functionalities, allowing controlled modification of its electrical and optical behavior, thereby expanding its application scope [2].

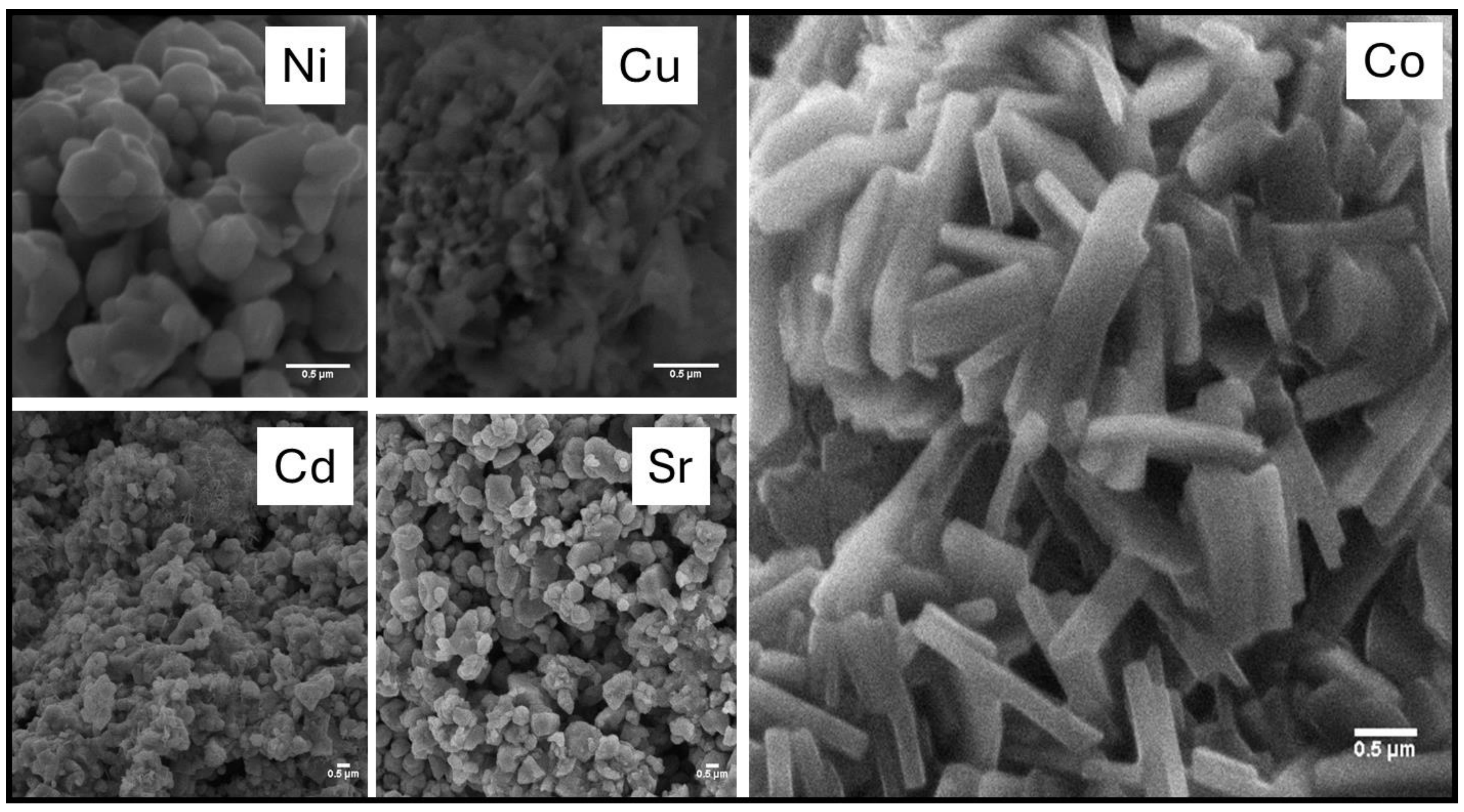
In the present study, transition metal-doped ZnO (TMD-ZnO) nanoparticles were synthesized by the co-precipitation method to investigate their structural and optical properties. Five samples with the formula $A_xZn_{1-x}O$ (A = Ni, Cu, Co, Cd, Sr; X = 0.01) were prepared with identical doping levels. Characterization results demonstrate that metal doping significantly modifies the optical and structural properties of ZnO, enhancing its suitability for applications in transparent electronics, UV LEDs, photocatalysis, and UV-protective coatings.



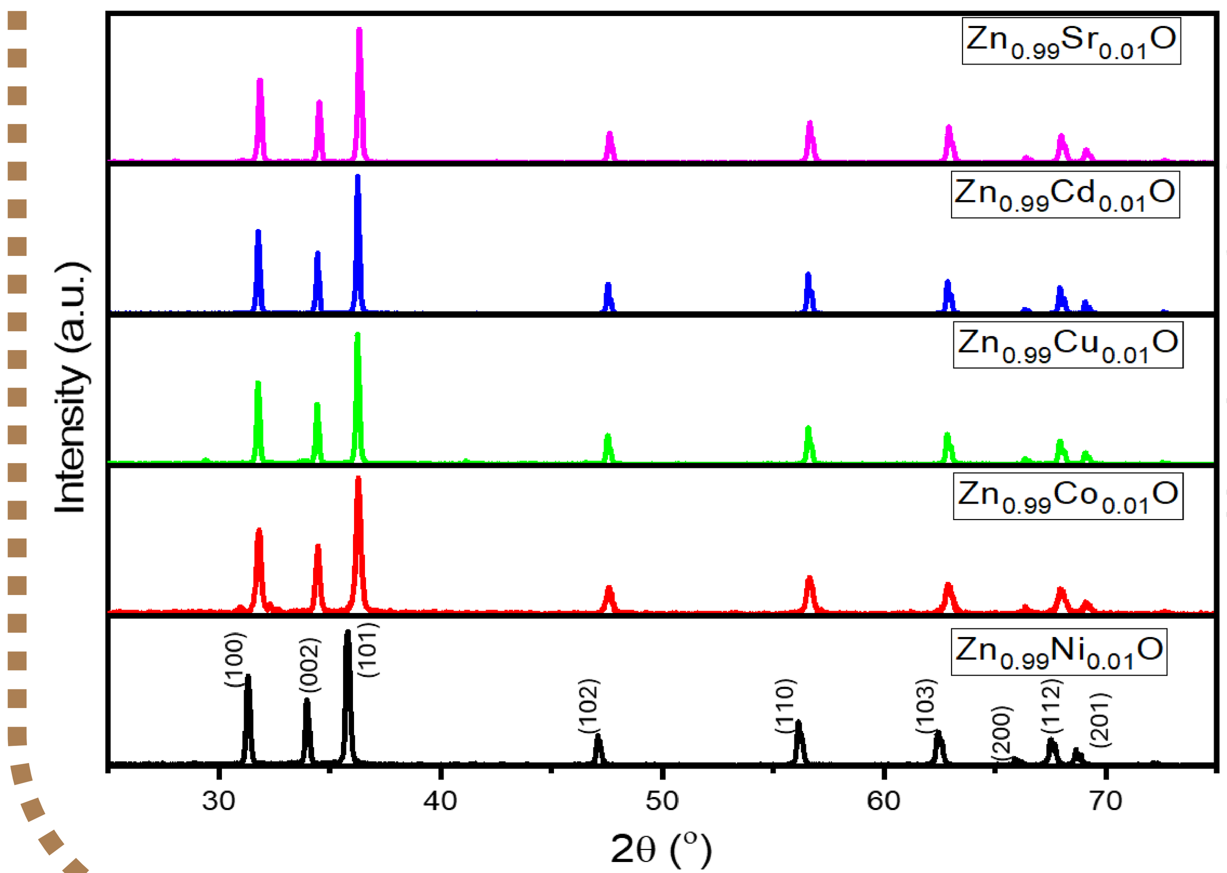
Experimental



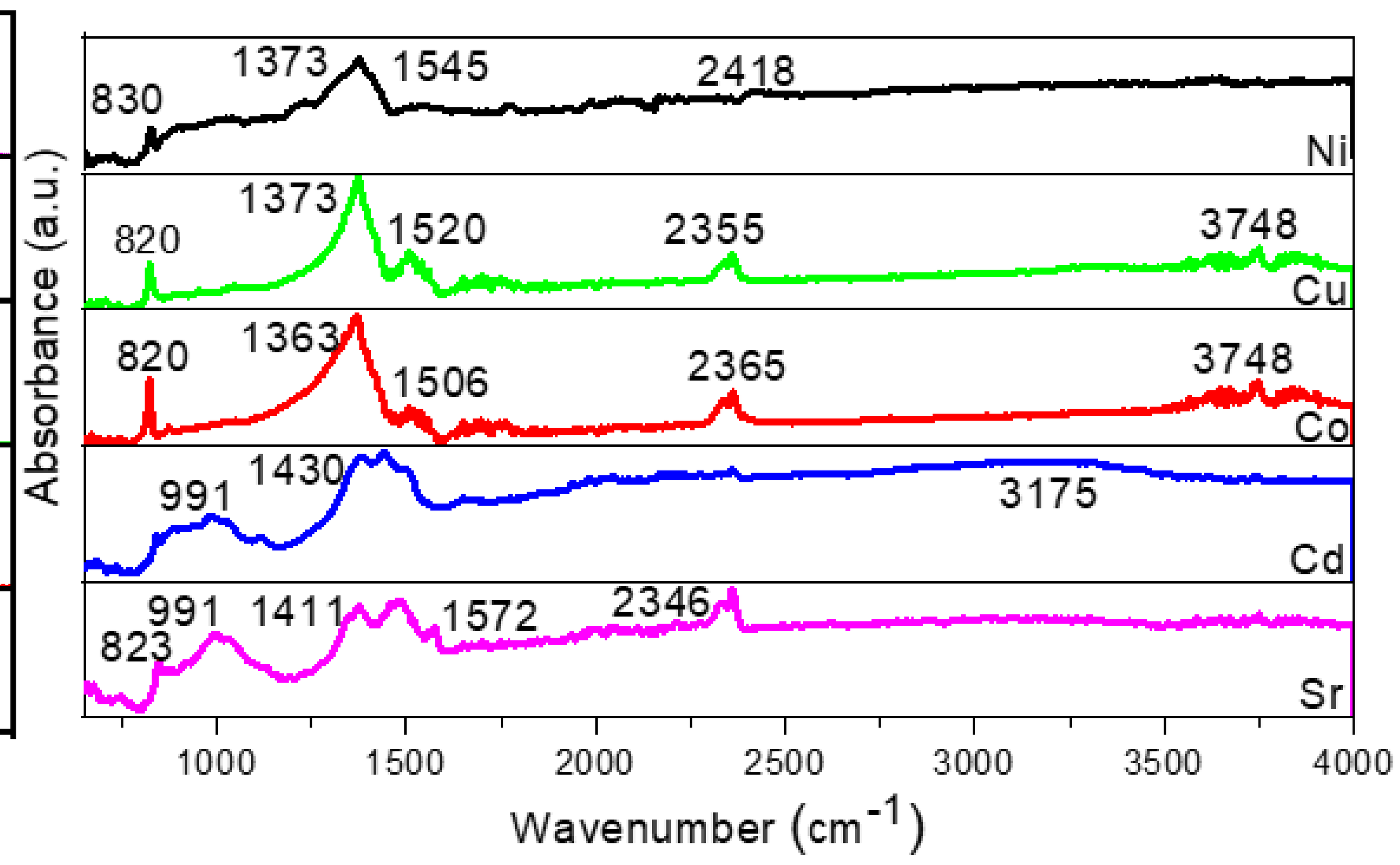
SEM Analysis



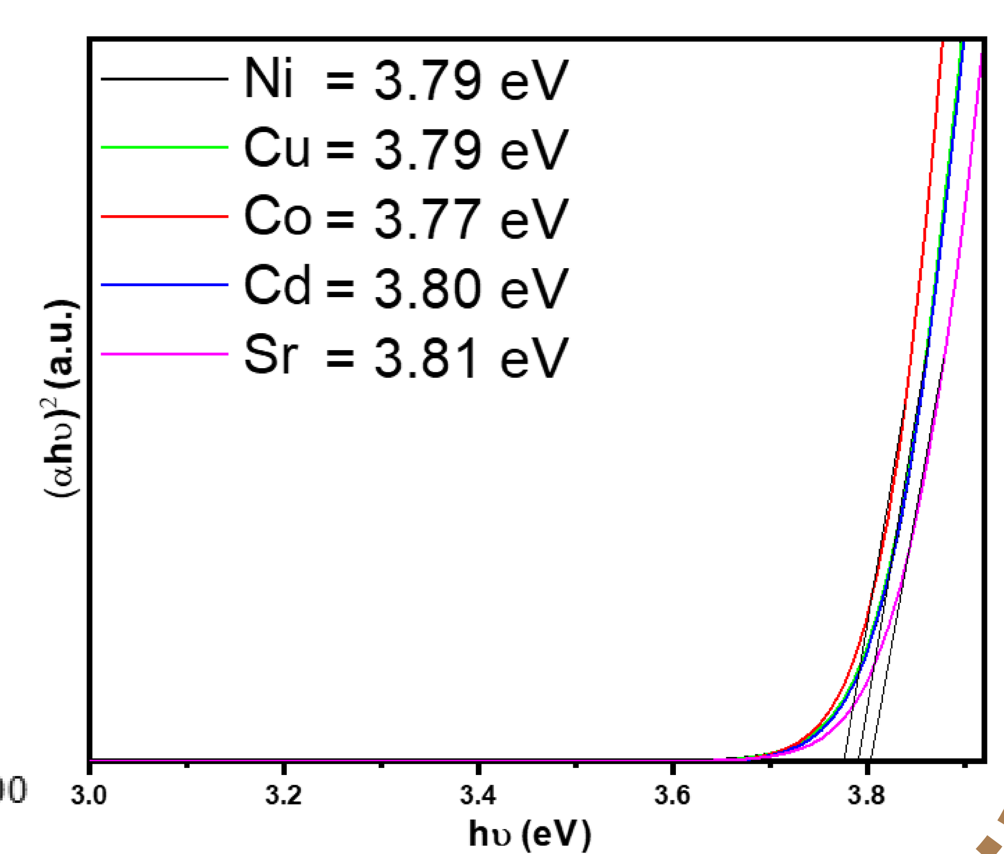
XRD Analysis



FTIR Analysis



UV-Vis Analysis



Conclusions/Future Work

Transition metal-doped ZnO nanoparticles with a 1% doping concentration were successfully synthesized using a co-precipitation method. Doping with different metals led to notable changes in both optical and structural properties. UV-Vis absorption spectroscopy revealed a band gap variation between 3.77–3.81 eV, influenced by the nature of the dopants. XRD analysis confirmed the wurtzite crystal structure in all samples, while FTIR spectroscopy indicated the presence of functional groups such as atmospheric CO_2, carboxylate ions, and C–H bending vibrations. SEM imaging revealed the formation of nanoparticles and nanorods, with noticeable agglomeration in some samples.

These findings suggest strong potential for applications in optoelectronic devices, including solar cell electrodes, UV detectors, and photodetectors. Future integration of these nanoparticles into functional devices, such as UV sensors, low-voltage air quality sensors, sunblock creams, and components in high-efficiency heterojunction lasers and LEDs, may further enhance their applicability.

References

[1] K. Radzimska, et al., (2014). *Materials*, *7*(4), 2833-2881. [2] M. Khan, et al., (2023). *Molecules*, *28*(24), 7963.