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Development of Biomorphic Magnesium-Zinc Oxide Nanofibrous Using Eggshell Membrane as Bio-Template

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Structured Abstract

Background: Nanostructured metal-oxide composites exhibit adjustable optical, antimicrobial, and photocatalytic properties; however, methods enabling controlled dopant incorporation while maintaining a three-dimensional biomorphic morphology remain limited. This study introduces an environmentally friendly bio-templating approach that transforms eggshell membrane (ESM) waste into biomorphic magnesium-zinc oxide (Mg–ZnO) nanofibrous materials. It further examined the impact of precursor immersion time (1–4 hours) on phase formation, morphology, and composition.

Methods: Eggshell membranes were extracted from fresh chicken eggs, subsequently cleaned and air-dried. An aqueous precursor solution of 0.2 M $Zn(NO_3)_2 \cdot 6H_2O$ with 1.5% w/w $Mg(NO_3)_2 \cdot 6H_2O$ was prepared. The membranes were impregnated for durations of 1, 2, 3, and 4 hours (designated as samples Z1–Z4), rinsed with deionized water, dried at 100°C, and then calcined in air at 500°C with a ramp rate of 5°C/min and a dwell time of 1 hour. The calcined powders were characterized using ATR-FTIR spectroscopy to identify the Zn–O and Mg–O vibrational modes, and SEM-EDX was employed to examine the microstructure, fiber preservation, and elemental composition.

Results: ATR-FTIR spectra confirmed the presence of Zn–O stretching bands within the 400–600 cm^{-1} range and Mg-O features near 800–900 cm^{-1}. The bands associated with organic residues diminished with extended immersion times, indicating enhanced precursor conversion after the immersion. SEM imaging revealed that the hierarchical interwoven fibrous network of the ESM, with fiber diameters of approximately 1–5 µm, was largely preserved, while oxide nanoparticles were deposited along the fiber surfaces. SEM-EDX quantification identified the 3-hour immersion sample (Z3) as optimal, exhibiting the highest Zn content (69.32 wt. %), a favourable Zn:O atomic ratio (0.830), and the lowest residual carbon content (8.88 wt. %). The incorporation of magnesium was minimal (0.12–0.46 wt%) and peaked in the 2-hour sample. A 4-hour immersion resulted in an elevated oxygen signal and particle agglomeration, consistent with oversaturation.

Conclusion: Eggshell membrane (ESM) biotemplating facilitates the production of hierarchical, magnesium-modified ZnO nanofibrous materials that preserve the morphology of the template and enable compositional adjustment through variations in immersion time. A 3-hour immersion in the precursor solution offers an optimal balance between precursor conversion, compositional uniformity, and minimal organic residue. These sustainable materials, derived from waste, demonstrate potential for antimicrobial and photocatalytic applications.

Keywords: Biomorphic Mg–ZnO, Eggshell Membrane, Bio-template, FTIR, SEM-EDX

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