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Topic of Research: "Preparation, Physico-Chemical and Biological activity of metal-based cellulose films"

Findings

The Ph.D. thesis entitled, "**Preparation, Physico-Chemical and Biological activity of metal-based cellulose films**".

Chapter 1, the findings of this research comprehensively demonstrate that cellulose, owing to its abundance, biocompatibility, and structural versatility, serves as an excellent base material for developing multifunctional films with applications spanning biomedical, packaging, and electronic sectors, and the systematic investigation of cellulose reinforced with natural fibers and metal/metal oxide nanoparticles revealed a spectrum of enhanced Physico-Chemical, structural, and biological properties.

Chapter 2, In the case of spun cotton-thread reinforced cellulose films, characterization through XRD, FTIR, UV-Vis, FE-SEM, AFM, TGA, and DSC confirmed the crystalline nature, structural integrity, optical activity, and morphological features, with the presence of randomly distributed pores on the surface facilitating antifungal activity against *Candida albicans*, and the band gap determination at 4.7 eV indicated suitability in UV-blocking applications,

Chapter III, while thermal stability confirmed its utility in packaging heavy goods. Similarly, embedding silver nanoparticles into cellulose matrices imparted strong antibacterial and antifungal properties, with XRD validating increased crystallinity and distinct Ag peaks, FTIR identifying functional group modifications, and UV-Vis revealing enhanced visible light absorption alongside reduced band gap (2.4 eV), which collectively suggested their potential use not only in biomedical applications such as wound healing and infection prevention but also in photovoltaic devices. Surface analyses via SEM and AFM displayed well-dispersed spherical AgNP clusters on the cellulose films, whereas TGA confirmed thermal robustness, further validating the multifunctionality of the AgNP-cellulose composites.

Chapter IV, The incorporation of ZnO nanoparticles into cellulose films followed by extensive structural (XRD, FTIR), morphological (SEM), and thermal (TGA, DSC) evaluations established that ZnO-cellulose nanocomposites were thermally stable, exhibited crystalline

nanoparticle distribution, and showed pronounced antifungal activity against *Candida albicans*, thus demonstrating their suitability for use as protective wrappers and UV-shielding agents in both food and non-food packaging systems.

Chapter V, Moreover, the synthesis of cobalt nanoparticle-reinforced cellulose films produced semi-crystalline composites with reduced crystallinity upon nanoparticle incorporation, as confirmed by XRD and DSC analyses, while FTIR spectroscopy indicated strong intermolecular interactions between cobalt acetate nanoparticles and cellulose chains, leading to modified chemical bonding environments. FE-SEM and AFM studies confirmed significant surface topography changes with increased roughness, and TGA results highlighted improved thermal stability, while antifungal assays against *Candida albicans* validated their enhanced bioactivity, indicating applicability in heavy-duty packaging and UV-protection. Collectively, these findings converge to establish that cellulose-based nanocomposite films reinforced with natural fiber or embedded with metallic/metal oxide nanoparticles not only retain the inherent biodegradability and film-forming properties of cellulose but also acquire enhanced crystallinity, stability, optical tunability, and broad-spectrum antimicrobial potential, thus opening avenues for advanced applications in sustainable packaging, biomedical materials such as wound dressings and antifungal barriers, and functional devices including UV-protective coatings and photovoltaic components.

The overall study underscores the importance of tailoring cellulose matrices with strategic nanoparticle incorporation, which enables fine control over structure–property relationships, thereby creating multifunctional polymeric systems with strong translational potential for industrial, environmental, and healthcare solutions.