

Preface

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In an era defined by unprecedented advancements in science and technology, the convergence of nanotechnology and biomedicine has opened up transformative avenues for improving human health and quality of life. The present work, embodied in this Ph.D. thesis, delves into the realm of functional nanomaterial-based composites and their remarkable applications in the field of biomedicine, with a specific focus on the integration of gold nanoparticles. In the realm of nanotechnology, the manipulation of matter at the nanoscale has ushered in a new era of scientific exploration and innovation, unveiling a myriad of possibilities for advancements in various fields. Noble metal nanoparticles, owing to their unique physicochemical properties and versatile surface functionalities, have emerged as frontrunners in the realm of functional nanomaterials. This doctoral thesis delves into the intricate world of functional nanoparticles and their multifaceted applications in the realm of biomedicine.

The remarkable properties of gold nanoparticles, including their tunable size, shape, and surface chemistry, have opened up unprecedented avenues for their utilization in a diverse array of biomedical applications. This thesis embarks on a comprehensive journey through the realms of antibacterial and antibiofilm activities, anti-cancerous potential, antioxidant capabilities, biocompatibility assessment, and their role in the burgeoning field of tissue engineering. The interdisciplinary nature of this research underscores the critical importance of bridging the gap between materials science, biology, and medicine, as we seek to harness the full potential of these nanomaterials.

The thesis is structured into 6 distinct chapters; each contributing to a comprehensive understanding of the research. Chapter 1 establishes the significance of the study and conducts an extensive review of diverse nanomaterials employed in biomedical applications. This chapter expounds on the fundamental concepts and progression of various nanomaterials, including AuNPs, AgNPs, and others. The unique physical, chemical, and optical properties that render gold nanoparticles particularly advantageous for biomedical applications are elucidated, setting the stage for the subsequent exploration. Chapter 2 outlines the methodology encompassing the synthesis of a range of materials such as AuNPs, Cur-AuNPs, CEO-*f*AuNP, Hydroxyapatite (HA), Gold/Silver bimetallic Nanoparticles (Au/Ag NPs), and (1-x)HA - x Au/Ag NPs composites. It also encompasses the detailed characterization of these synthesized materials, involving phase evolution, microstructural analysis, mechanical properties, antibacterial response, and cellular response. Elaborating on the synthesis of highly stable Cur-AuNPs with exceptional water dispersibility, Chapter 3 evaluates their potential as antibacterial and antibiofilm agents, alongside *in vitro* cytotoxicity studies. Characterization techniques including XRD, FTIR, TEM, DLS, and Zeta potential examine the crystalline structure, size, shape, and elemental composition. Antibacterial studies, comprising MIC determination, time-dependent bacterial killing, and antibiofilm activity, are meticulously conducted. The mechanisms underlying their antimicrobial effects, including disruption of cell membranes reactive oxygen species (ROS) generation and interference with biofilm formation, are dissected. The chapter also explores biocompatibility assessment. Biocompatibility evaluation, a critical aspect of any biomedical material, is the focal point of Chapter 4. This chapter sheds light on the integration of Au/Ag NPs within HA, encompassing mechanical properties, microstructure, and elemental composition analysis. Antibacterial efficacy is assessed

against both gram-positive (*S. aureus*) and gram-negative (*E. coli*) bacteria. Additional antibacterial characterizations such as disc diffusion test and ROS generation are undertaken, alongside cytocompatibility evaluations of sintered composites. The synthesis of highly stable CEO-*f*AuNP, water-dispersible and multifunctional, is detailed in Chapter 5. This chapter evaluates its efficacy as an antibacterial, antioxidant, and anticancer agent through in vitro cytotoxicity tests. The research dives into the influence of CEO-*f*AuNP on antibacterial activity and cellular response, enriching insights into functionalized nanoparticles impact. The thesis culminates in Chapter 6, summarizing the findings and highlighting future research avenues. This chapter encapsulates the conclusions drawn from the comprehensive investigations and paves the way for potential expansions of this research trajectory.

This thesis stands as a testament to the intricate interplay between nanotechnology and biomedicine, unveiling the immense potential of functional gold nanoparticles in revolutionizing diagnostics, therapeutics, and tissue engineering. As we navigate the intricate pathways of these applications, we hope to inspire further research, collaboration, and innovation in the relentless pursuit of improving human health and well-being.

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