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HABILITATION THESIS

Biotechnological applications of metal and metal oxide nanoparticles

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Abstract

The habilitation thesis focuses on the surface modification of metal nanoparticles (NPs) to enhance their plasmonic properties for various applications in biotechnology and chemistry. It also examines the environmental impact of engineered metal oxide NPs by studying their effects after being taken up by plant models.

Chapter I presents the synthesis and characterization of different types of colloidal NPs , based on our ten years of research. It discusses the surface modification of gold nanoparticles (AuNPs) with polyethylene glycol (PEG) and bovine serum albumin (BSA), highlighting their potential for biomedical applications. The chapter also introduces a novel synthesis route for silver nanoparticles (AgNPs) capped with chloride ions, which allows for high-intensity surface-enhanced Raman scattering (SERS) spectra of cationic molecules at low concentrations.

Chapter II focuses on molecular processes at the metal surface and explores the role of chemisorbed ions (adions) in the SERS activity of AgNPs. It investigates the specific adsorption mechanism of different adions for anionic analytes, providing insights into the mechanism of SERS. The chapter also examines the impact of tetrahydroxyborate ($B(OH)_4$) anions on the surface plasmon resonance (SPR) band of colloidal AuNPs, considering factors such as chemical interface damping, refractive index changes, and variations in charge density. The last study in Chapter II delves into the dissolution of Ag and Au metal NPs by repetitive oxidative steps. A method to increase the chemisorption rate of iodide ions (I^-) is proposed by using adsorbed Mg^{2+} or Zn^{2+} ions as catalysts. The study demonstrates the enhancement of NP dissolution and tracks the increase in electron density in AuNPs due to charge transfer from chemisorbed I^- ions.

Chapter III introduces SERS liquid biopsy, a novel approach for clinical diagnosis based on molecular profiling from biofluids using competitive adsorption of metabolites on AgNPs and SERS detection. It highlights the potential of SERS as a tool for molecular profiling of biofluids in clinical applications and compares the performance of different machine learning algorithms for disease classification based on SERS datasets.

Chapter IV investigates the impact of titanium dioxide (TiO_2) and zinc oxide (ZnO) NPs on soybean plants. The study evaluates the effects of these NPs on plant morphology and metabolic changes, with a focus on potential environmental and health impacts. ZnO NPs

were found to be more toxic than TiO_2, causing ultrastructural changes in chloroplasts and reduced plant growth. The study emphasizes the importance of assessing the impact of engineered nanomaterials on the environment and human health.

Finally, Chapter V presents the author's proposal for university career development. It discusses her professional experience, teaching responsibilities, and scientific research conducted within the Department of Food Science at the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.

Overall, the comprehensive exploration of surface modification of metal NPs and the impacts of metal oxide NPs on morphology and metabolic changes of plant models, provide insights into the mechanisms underlying NP behavior and their applications in various fields such as biotehnology, chemistry or medicine.