Formation Mechanisms of Nano Ferrite/Biopolymer Hybrid Materials: Interaction with Heavy Metals

Ferrite Nano-Particles (NPs) represent a versatile class of materials with numerous applications in health sciences[1], catalysis[2], information storage[3], and, more recently, in water depollution treatments [4]. In the latter case, the magnetic properties of NPs, used as adsorbents, allow to separate them from the treated water.

At the LCPME (Laboratoire de Chimie Physique et Microbiologie pour les Matériaux et l'Environnement), it has been demonstrated that the preparation of magnetite in the presence of a polysaccharide (starch) leads to the formation of a hybrid material composed of functionalized NPs. Functionalization inhibits particle aggregation, preserving a high specific surface area to maximize pollutant adsorption. Additionally, functionalization results in a modulation of structural properties (size reduction) and magnetic properties (superparamagnetism) of NPs.[5,6] However, while the impact of polysaccharide functionalization on NP properties is well-established, the role of these polymers in NP formation and the underlying mechanisms remain largely unexplored. Existing literature only hints at hypotheses regarding the influence of polymers on the nucleation and growth of iron oxide particles, involving 1) polymer/Fe ion interactions, 2) polymer/Fe oxide interactions, 3) reduced diffusion of Fe ions in the presence of polymer.

The proposed thesis aims to make a significant contribution to understanding these mechanisms for the rationalization of functionalized nano-ferrite development and optimization for water depollution. The strategy will involve linking synthesis conditions, structure, and properties (magnetic, adsorption) of the obtained materials. Functionalization with polysaccharides such as alginate, chitosan, or κ-carrageenan will be implemented to assess the respective roles of their carboxylate, amine, or sulfonate functions in obtaining ferrites. The influence of synthesis parameters, including polymer quantity and molecular weight, will evaluate the role of NP interconnection via polymer chains. It will also involve modulating the nature of polymer/cation and polymer/oxide interactions by adjusting the solvent nature, ionic strength, or the presence of complexants in the reaction medium. Obtaining ferrites with varied compositions ($M_xFe_{3-x}O_4$, M: Fe, Mn, Cu, Zn, etc.) will be considered.

The materials obtained will be characterized using structural and spectroscopic tools (XRD, FTIR, Raman, XPS, ^{57}Fe Mössbauer spectrometry) of the Spectroscopy and Microscopy of Interfaces (SMI) platform at LCPME. Finally, the reactivity of ferrites towards environmentally relevant probe species such as chromate ions will be evaluated.

The proposed thesis will take place within the Laboratory of Physical Chemistry and Microbiology for Materials and the Environment (LCPME, UMR 7564, CNRS / University of Lorraine). The candidate will conduct research in the SIMAVI team. We are seeking a candidate with Master's degree in chemistry, physics, materials, or geosciences.

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