
Internship Proposal 2025-26

Unraveling surface chemistry and reactivity of biodegradable zinc at the protein-material interface

1. Background

Unlike traditional permanent implants, which often require secondary removal surgeries or cause long-term foreign body reactions, biodegradable metals represent a paradigm shift by serving as temporary medical devices designed to dissolve safely as the tissue heals. Among them, zinc is attracting considerable interest due to its physiological relevance and its suitable degradation rate, which lies between those of fast-degrading magnesium and slow-degrading iron [1]. However, the practical application of zinc as a bioresorbable material remains limited by an incomplete understanding of the fundamental chemical processes governing its degradation in biologically relevant environments [2].

When zinc is exposed to a biological medium, its surface undergoes continuous chemical and morphological changes. The oxidation of the metal are accompanied by the formation of new surface species and the adsorption of surrounding biomolecules. Specifically, proteins can interact strongly with the metallic interface, thus altering its surface chemistry, reactivity, and subsequent degradation behavior. Tackling this issue requires accounting for the concept of “real interfaces”, which highlights the discrepancy between idealized assumptions and the complex realities of solid/liquid interfaces [3].

To address these challenges, our laboratory has developed an abiotic cell-free physiological medium designed to mimic the key interfacial reactions occurring immediately after implantation. This project will investigate the surface reactivity of zinc in biologically relevant environments. The aim is to identify and characterize the chemical and physicochemical changes occurring at the zinc/solution interface, and to determine how these changes affect its interactions with surrounding molecules.

Building on these insights, selected surface treatments will also be investigated as a strategy to modulate the degradation behavior of zinc and trigger specific biological responses, such as osteoinductive or antimicrobial properties.

2. Objectives

The main objective of this internship is to **explore the surface dynamic changes of a biodegradable zinc at the nanoscale upon exposure to a biomimetic abiotic cell-free physiological media**. Probing the interface at this resolution is required to investigate the mechanisms by which adsorbed biomolecules, oxidative species, and surface treatments govern local reactivity and degradation behavior.

3. Experimental approach

The experimental strategy relies on tracking the physical and chemical changes of zinc surfaces upon exposure to media of increasing biochemical complexity, from simple model solutions to protein-containing biomimetic environments. **Liquid-phase atomic force microscopy (AFM)** will serve as the primary tool to follow morphological transformations in real time. Based on recent methodological developments [4, 5], complementary AFM force spectroscopy using the colloidal probe technique will be used to quantify local interfacial forces and monitor changes in surface charge density during exposure. These nanoscale physical measurements will be combined with surface-sensitive chemical characterizations, including **X-ray Photoelectron Spectroscopy (XPS)** and **Polarization Modulation-Infrared Reflection-Absorption Spectroscopy (PM-IRRAS)**, to identify surface chemical species and adsorbed molecules. In parallel, ICP-OES will be used quantify Zn^{2+} ion release to assess the dissolution kinetics. Finally, this multi-technique

approach will be applied to selected surface-treated zinc samples to evaluate how initial surface modifications alter subsequent interfacial reactivity. Preliminary microbiological and biological evaluations will also be performed to assess the functional impact of these surface modifications.

4. Interdisciplinary dimension & Applicant profile

This project lies at the interface of materials chemistry, surface science, and biomaterials. Its core objective is to address a fundamental physical chemistry question: how does a reactive metallic surface evolve when exposed to a (bio)chemically complex environment, and how can surface engineering modulate this dynamic interface?

We are seeking a highly motivated Master 2 student in materials chemistry, physical chemistry, surface science, or nanosciences with a strong interest in interdisciplinary research. The candidate should be eager to master advanced nanoscale characterization tools (liquid-phase AFM, force spectroscopy, XPS, PM-IRRAS) to uncover detailed mechanistic insights at the bio-interface.

Note. A Ph.D. position following the completion of this Master 2 internship is envisaged for suitable candidates.

5. Working environment

The host laboratory, Laboratoire de Réactivité de Surface (LRS, Sorbonne Université – CNRS), includes the Biointerface thematic axis, covering biomaterials and biomineralization, with research focused on biomolecule-surface interactions and nanoscale characterization of solid/liquid interfaces. This research environment provides the experimental basis for investigating surface chemistry and local reactivity of metallic materials in physiological environments.

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References

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