

DES SCIENCES

FACULTÉ

D'ORSAY

M2/PhD internship proposal



Title: Human bone pathologies investigated by electron spectroscopy at the nanoscale

Keywords: spectromicroscopy, multimodal approaches, advanced instrumentation and methods, biomineralization mechanisms, health-related topics

Scientific description: Biominerals are materials produced by living organisms, such as animal bones and teeth, mollusc shells, and pathological calcifications. They are composed of organic and inorganic species organized in a multi-scale structure that gives them remarkable properties. Understanding the formation mechanisms and properties of these complex systems requires analyzing their chemical structures at the nanoscale. This is highly challenging to achieve with traditional characterization methods. Recent studies illustrate the capabilities of Electron Energy Loss Spectroscopy (EELS) for investigating biomaterials and biological systems (1-3). This approach is based on analyzing the signals resulting from the interaction between the electron beam of a scanning transmission electron microscope and the material. For biominerals, EELS provides nanoscale chemical maps of the organic and inorganic fractions with a nanometer resolution (Figure 1). This unique information is essential for the elucidation of the physicochemical processes involved in their formation and it is inaccessible by other spectroscopic approaches.

The proposed internship aims to study healthy and pathological human bones (including osteoporosis and osteosarcoma) using STEM-EELS approaches. The candidate will actively participate in the different aspects of the project. He/she will be trained in electron spectromicroscopy approaches on a latest generation microscope (<u>https://equipes2.lps.u-psud.fr/stem/chromatem/</u>). He/she will conduct measurements on the samples and will be in charge of the data processing using statistical analysis approaches to extract the spectral signatures of interest.

The internship will take place at the Laboratoire de Physique des Solides within the STEM team (https://equipes2.lps.u-psud.fr/stem/) as part of a collaboration with Nadine Nassif (LCMCP, Sorbonne University).



Figure: Chemical and structural maps from EELS study on a biomineral (mollusk shell): (a,b) distributions of carbonate (in red) and organic compounds (in green) are shown. (c,d) Maps of the crystalline vs amorphous nature of the mineral phase. Amorphous areas represented in green and crystalline ones in purple (from de Frutos et al, ACS Nano (2023) 17, 2829-2839). **Techniques/methods in use**: Electron Energy Loss Spectroscopy (EELS) in a Scanning Transmission Electron Microscope (STEM). Data processing by statistical analysis approaches.

Applicant skills: A solid background in physics is required together with a marked interest in experimental aspects and a strong motivation for interdisciplinary physics-biology subjects (not prerequisite knowledge).

Industrial partnership: No

Internship supervisor(s) Marta de Frutos, marta.de-frutos@universite-paris-saclay.fr

Internship location: Laboratoire de Physique des Solides, Université Paris-Saclay 1 rue Nicolas Appert, 91400 Orsay

Possibility for a Doctoral thesis: Yes. ANR funding (request submitted) or PhD scholarship from ED 2MIB.

- (1) Inorganic phosphate in growing calcium carbonate abalone shell suggests a shared mineral ancestral Precursor. Ajili et al, Nat. Comm. (2022) 13, 1496; DOI: 10.1038/s41467-022-29169-9
- (2) Nanoscale Analysis of the Structure and Composition of Biogenic Calcite Reveals the Biomineral Growth Pattern. de Frutos et al, ACS Nano (2023) 17, 2829-2839; DOI: 10.1021/acsnano.2c11169
- (3) Nanoscale Multimodal Analysis of Sensitive Nanomaterials by Monochromated STEM-EELS in Low-Dose and Cryogenic Conditions. Chaupard et al, (2023). ACS Nano 17, 3452. 10.1021/acsnano.2c09571