

## Contrat doctoral – ED Galilée

**Titre du sujet :** Development of multifunctional bismuth-lanthanide nanocomposites for near-infrared luminescence thermometry applications

- Unité de recherche : Laboratoire des Sciences des Procédés et des Matériaux (LSPM), CNRS UPR-3407 (Axe MINOS).
- Discipline : Chemistry / Materials Science
- Direction de thèse : **PhD supervisor** : Frédéric SCHOENSTEIN (PU) et **Co-supervisor** : Virgile TRANNOY (MCF)
- Contact : virgile.trannoy@lspm.cnrs.fr
- Domaine de recherche : Materials chemistry and functional nanomaterials
- Mots clés : Core-shell nanocomposites, luminescent materials, soft chemistry, bismuth, lanthanides, luminescence thermometry, near-infrared (NIR), upconversion nanoparticles (UCNPs), NIR-to-NIR conversion.

### Summary and objectives of the PhD project:

Luminescence thermometry is a promising approach for remote temperature sensing at the nanoscale, particularly in biological environments where conventional techniques are limited by their invasive nature, low spatial resolution, and incompatibility with submicron scales (<10  $\mu\text{m}$ ).<sup>1</sup>

It relies on the use of nanomaterials whose emission properties depend on temperature. Among these systems, lanthanide-doped nanophosphors are of particular interest due to the upconversion process, which enables the conversion of near-infrared (NIR) excitation into higher-energy emission (visible or NIR). This property is especially suitable for biomedical applications, as both excitation and emission in the NIR allow for deeper tissue penetration.<sup>2</sup>

However, current systems still suffer from limited NIR emission efficiency, insufficient control over structural properties, and an incomplete understanding of energy transfer mechanisms, highlighting the need to develop more efficient NIR-to-NIR nanothermometers. In this context, bismuth-based lanthanide-doped materials emerge as promising candidates due to their low toxicity, moderate cost, tunable bandgap, and the ionic radius of  $\text{Bi}^{3+}$  being compatible with  $\text{Ln}^{3+}$  ions, enabling fine modulation of emission properties and opening the way to multimodal imaging applications.<sup>3</sup>

**The objective of this PhD is to develop new NIR-to-NIR luminescent nanothermometers based on bismuth-lanthanide nanocomposites, and to establish structure-composition-optical and thermometric property correlations, in order to achieve efficient NIR emission, high thermal sensitivity, and high-resolution detection under low excitation power.**

PhD work plan:

#### 1. Synthesis of bismuth-lanthanide nanocomposites

The PhD candidate will synthesize nanoparticles using soft chemistry approaches (polyol, solvothermal, microwave-assisted methods), with precise control over size, morphology, and chemical composition. Advanced architectures such as core-shell or multilayer structures will be developed to optimize energy transfer and minimize quenching effects. Surface functionalization strategies will also be implemented to improve colloidal stability, preserve emission properties, and ensure physiological compatibility in aqueous and biological environments.

#### 2. Structural and chemical characterization

The synthesized materials will undergo comprehensive characterization to determine their crystalline structure, composition, and local structural organization. The candidate will use a range of complementary techniques such as X-ray diffraction, pair distribution function (PDF) analysis, electron microscopy, and spectroscopic methods to establish structure-property relationships in these complex systems.

#### 3. Optical and thermometric properties investigation

The PhD candidate will investigate the photoluminescence properties of the nanocomposites in relation to their structure and composition. The performance of the luminescent nanothermometers, as well as their reproducibility, will be evaluated.

### Candidate profile:

The position is open to candidates with a background in chemistry, physical chemistry, or materials science, who are motivated and dynamic. The candidate should demonstrate strong adaptability, both scientifically and interpersonally, as well as good communication skills, which are essential for working in a multidisciplinary research environment.

### References:

(1) Brites, C. D. S. *et al.*, Spotlight on Luminescence Thermometry: Basics, Challenges, and Cutting-Edge Applications, *Adv. Mater.*, **2023**, 35, 2302749; (2) Puccini, A. *et al.*, Lanthanide-based nanomaterials for temperature sensing in the near-infrared spectral region: illuminating progress and challenges, *Nanoscale*, **2024**, 16, 10975-10993; (3) Back, M. *et al.*, Tuning the upconversion light emission by bandgap engineering in bismuth oxide-based upconverting nanoparticles, *Nanoscale*, **2017**, 9, 6353-6361.