

LABO - Axe et Equipe : **INSTITUT PASCAL** - M3G – Experimental Mechanics

Thesis supervisor: **Xavier Balandraud** (PU), xavier.balandraud@sigma-clermont.fr

Co-supervisor: **Geneviève Chadeyron** (PU), genevieve.chadeyron@sigma-clermont.fr

Co-supervisor: **Antoine Jury** (MCF), antoine.jury@uca.fr

Title of PhD subject: **Development of bio-based luminescent materials for the additive manufacturing of functional objects designed for anti-counterfeiting marking: physicochemical and thermomechanical characterization**

Summary: Counterfeiting has become a major economic, industrial, and societal issue, affecting both everyday consumer goods and high value-added sectors such as the automotive and aerospace industries. In this context, the development of innovative, durable, and difficult-to-reproduce anti-counterfeiting marking solutions, directly integrated into the product, has become a necessity. At the same time, **additive manufacturing** by polymer extrusion is emerging as a key technology for the industry of the future, offering unique possibilities in terms of customization, geometric complexity, and traceability of manufactured parts. The integration of luminescent materials directly within printed objects thus represents a particularly promising approach for volumetric anti-counterfeiting marking, inherently impossible to remove without damaging the part. Within this framework, the FABULEU project (led by Geneviève Chadeyron) aimed to develop luminescent polymer materials for additive manufacturing, capable of generating specific optical signatures for secure marking applications. This PhD project is fully aligned with this dynamic and aims to **explore the formulation of bio-based polymers incorporating phosphors** (in the form of filaments intended for 3D printing machines, with the objective of producing printed objects integrating anti-counterfeiting marking functions), and to **evaluate the mechanical properties of both the filaments and the printed objects** (in order to ensure the integrity, durability, and functionality of the marked products). This work therefore aims to establish clear relationships between material formulation, additive manufacturing process, and optical and mechanical properties, with a view toward industrial applications. Particular attention will be paid to **mechanical properties, both static (stiffness, strength, etc.) and dynamic (creep, fatigue, etc.), especially at the interfaces with zones containing phosphors, in order to ensure the long-term durability of the marking solution**. Instrumented tests using cameras (optical and thermal full-field measurements) will be employed to monitor the spatiotemporal evolution of deformations and self-heating in the materials. Finally, a multifunctionality aspect will be added to the study through the use of “mechanoluminescent” powders, paving the way for novel applications in the mechanical testing of polymers.

Scientific objectives of the PhD:

- Formulation aspect: develop bio-based luminescent polymer matrices; produce luminescent polymer filaments compatible with their use as feedstock for 3D printing; study polymer/phosphor compatibility (dispersion, thermal stability, and photostability);

- Additive manufacturing aspect: produce test specimens (for mechanical characterization) and printed objects incorporating volumetric luminescent marking (visible under specific excitation);
- Optical characterization aspect: characterize the optical properties associated with the marking (spectral signature, long-term stability);
- Mechanical characterization aspect: evaluate the thermomechanical properties of composite filaments (polymer + phosphors); assess the mechanical properties of luminescent composite materials obtained by additive manufacturing; evaluate the mechanical properties at the interfaces between luminescent composite zones and non-composite zones (pure non-luminescent polymer); assess the mechanical integrity of final products (parts incorporating anti-counterfeiting marking).

Planned work program:

1. Formulation of luminescent polymer materials and filaments:

- Selection of bio-based polymers compatible with additive manufacturing;
- Choice and integration of phosphors suitable for anti-counterfeiting marking;
- Optimization of formulations (loading rate, dispersion, compatibility);
- Processing into filament form;
- Study of their thermal and optical stability;

2. Additive manufacturing of test specimens and marked objects:

- Conversion of filaments into feedstock for 3D printing;
- Production of test specimens for mechanical characterization and objects incorporating volumetric luminescent marking;

3. Optical and mechanical characterizations:

- Study of photoluminescent properties related to the marking;
- Mechanical characterization of filaments and test specimens, with a focus on properties at the interfaces between pure polymer and luminescent polymer;
- Correlation between formulation, process, and final mechanical performance of printed parts;

4. Final demonstrator to validate the concept of anti-counterfeiting marking integrated into objects manufactured by 3D printing.