CIFRE Thesis Proposal

Study of the Interaction Mechanisms of Power Ultrasound with Natural Deep Eutectic Solvents: Application to Plant Extraction

Organic solvents, widely used in industry, present challenges in terms of cost, toxicity, and environmental impact. To address these issues, bio-based solvents—particularly natural deep eutectic solvents (NaDES)—are increasingly being investigated. In line with the principles of green chemistry, NaDES are composed of plant-derived metabolites and are stable at room temperature. They show strong potential for the extraction of biomolecules from plant biomass or microalgae, especially in the cosmetics sector. Extraction efficiency can be enhanced through the use of ultrasound, via a phenomenon known as acoustic cavitation. This technique breaks down plant matrices and promotes solvent diffusion. It is typically performed using low-frequency ultrasound (20–50 kHz). Several studies have explored the combination of NaDES and ultrasound to improve the valorization of natural products. However, the effect of high-frequency (MHz-range) ultrasound in this context has not yet been investigated.

This thesis project aims to innovatively investigate the impact of high-frequency power ultrasound (500 kHz to 5 MHz) on the extraction of valuable molecules using natural deep eutectic solvents (NaDES). The objective is to assess how power ultrasound affects NaDES in order to enhance their extraction performance and explore the potential deployment of this technology in the field of extractive sciences.

The proposed research is structured into three main components. First, an ultrasonic cell will be designed, manufactured, and characterized to enable the treatment of biomass using ultrasound-assisted extraction. In parallel, suitable NaDES will be selected based on the target biomass and subsequently characterized in terms of their acoustic and physicochemical properties—both before and after insonification. Structure–property relationships of these NaDES will then be established.

Finally, an extraction experiment using plant compounds will be carried out to demonstrate the potential of ultrasound-assisted extraction in NaDES.

To achieve this goal, the project brings together a multidisciplinary consortium:

- **GREMAN**, a team specializing in the design and instrumentation of ultrasonic devices and the characterization of complex media,
- **SIMBA**, a team focused on developing eco-friendly extraction processes using NaDES, and
- **GeniAlis**, a company specialized in designing and integrating laboratory equipment—such as high-frequency ultrasound systems—for the agri-food, cosmetics, and healthcare industries.

Presentation of the laboratories and the company

The activity will be shared between the GREMAN laboratory, the SIMBA laboratory and the company GeniAlis

GREMAN (University of Tours, CNRS, INSA Centre Val de Loire) is a laboratory specialized in materials and devices for the conversion and management of electrical energy, with a strong focus on energy efficiency. The DISCUS team, involved in the project, is an expert in the characterization of piezoelectric materials and in the modeling of acoustic transduction devices.

The laboratory has advanced equipment for electrical and acoustic measurements, especially at high power. He also masters numerical simulation tools (analytical and finite elements) to model radiated sound fields, relying in particular on the Cascimodot computing center. The work will be carried out on the acoustics and piezoelectricity pole of the laboratory located at the INSA centre Val de Loire in BLOIS

SIMBA (University of Tours) is a research laboratory focused on the discovery of molecules with therapeutic potential, resulting from chemical synthesis or extracted from plants and microalgae. He is developing two main axes: (1) natural eutectic solvents (NaDES) for sustainable development, and (2) the design of new molecular structures. In this context, SIMBA designs NaDES via in silico tools such as COSMO-RS, and has an eco-extraction and analysis platform to characterize plant extracts, supported by strong local collaborations.

GeniAlis is first and foremost an innovation engineering company, whose know-how has been developed: around the methodology for conducting innovative projects in the field of food, cosmetology, particularly from benchtop to industrial scale, and associated products and applications. Since its creation, GeniAlis has been interested in ultrasound with frequencies between 1MHz and 5MHz. The company has thus developed real expertise in the design of equipment, particularly in terms of the electronics necessary to power the piezoelectric elements emitting the said ultrasounds.

Recruitment Profile –

Training and expected skills:

- Engineering degree or Master 2 with specialization in electronics, mechanics, acoustics or related fields.
- Solid knowledge of wave physics, acoustics, piezoelectricity and ultrasonic transduction.
- Numerical modeling skills (finite elements, acoustic field simulation, etc.) highly appreciated.
- Interest in experimental characterization of materials (electroacoustic response, free-field measurements, etc.).

Complementary skills appreciated:

- Notions of organic chemistry or physico-chemical analysis techniques.
- Sensitivity to interdisciplinary approaches combining physics, chemistry and engineering.
- A strong interest in teamwork, scientific rigor, autonomy, and the ability to communicate effectively in both French and English, both orally and in writing.

Application: send by email a file consisting of a detailed CV, a cover letter to

Contacts:

guy.feuillard@insa-cvl.fr
GREMAN, A&P Pole
INSA Centre Val de Loire
Rue de la chocolaterie
CS 23410
41034 Blois CEDEX

Guillaume Gillet
GeniAlis
20 Rte d'Achères, 18250 Henrichemont
g.gillet@genialis.fr