PhD contract offer

Start: January 2026

Multiphysics modeling and experimental validation of dielectric barrier discharge in a liquid medium for advanced water treatment

General information

Place of work: Nancy, France (Institute Jean Lamour)
Type of contract: PhD contract (ANR funding)
Duration of the contract: 36 months, **Proportion of work:** Full time
Expected date of employment: January 1, 2026
Remuneration: 2,044.12 €/month
Desired level of studies: Master's degree in plasma physics-chemistry or equivalent
Director of the thesis: Dr. Thierry Belmonte, **Co-supervisor:** Dr. Nguyen Truong Son

1. Subject

Dielectric barrier discharge (DBD) has emerged in recent years as a highly promising technology for advanced water treatment. Its efficacy stems from the generation of a rich reactive oxygen species (ROS), which drive essential processes including chemical oxidation, microbial sterilization, and the degradation of recalcitrant pollutants. Despite its potential, a fundamental mechanistic understanding of DBD-based water treatment remains incomplete. Key knowledge gaps persist concerning the formation pathways of ROS within the gas phase plasma, the complex physicochemical phenomena governing their transfer across the dynamic plasma-liquid interface, reaction kinetics, and the reaction within the aqueous phase. Addressing these gaps necessitates the development of a comprehensive, predictive model that rigorously integrates plasma discharge physics, interfacial transport phenomena, and detailed liquid-phase reaction chemistry. Such a physics-based framework is critical for elucidating the underlying mechanisms and enabling the rational design and optimization of high efficiency plasma reactors.

This PhD project aims to bridge this knowledge gap by developing and experimentally validating a complex multiphysics simulation framework using COMSOL. The main objectives are:

- To simulate the non-equilibrium plasma chemistry within a DBD reactor operating in water, predicting the formation kinetics and concentrations of key reactive species (e.g., $\cdot OH$, O_3, H_2O_2).
- To model the dynamic processes governing the transfer of these ROS across the plasma-liquid interface, incorporating effects of plasma filaments, gas-liquid hydrodynamics, and interfacial reactions.
- To simulate the dissolution, diffusion, reaction kinetics, and evolution of ROS and their reaction products within the aqueous phase.

The computational modelling will be tightly integrated with targeted experimental investigations to ensure model fidelity. Experimental techniques will include:

- Optical Emission Spectroscopy (OES): For quantifying transient gas-phase species concentrations.

- High-Speed/High-Resolution Imaging: To characterize plasma filament dynamics, morphology, and interface interactions.

Liquid phase Chemical Analysis: Utilizing UV-Vis spectrophotometry, and potentially mass spectrometry (MS), HPLC to identify and quantify stable reaction products (e.g., O_3, H_2O_2) and measure oxidant concentrations under varying conditions.

These experiments will provide essential data for calibrating kinetic parameters and rigorously validating the simulation model across a range of operational parameters (applied voltage, frequency, gas composition, flow rate).

By synergistically combining advanced multiphysics modelling with targeted experimental validation, this project will deliver a deeper mechanistic understanding of the coupled interfacial physics and chemistry in plasma-liquid systems for water treatment. A validated computational framework capable of simulating DBD reactor performance under diverse operating conditions. Essential knowledge and tools to guide the rational design, optimization, and future scale-up of DBD reactors for industrial water treatment applications.

2. Works plans

Within the framework of the project, the PhD student will carry out the following tasks:

Development of the multiphysics modelling framework

- Construct a detailed COMSOL-based simulation of dielectric barrier discharge (DBD) plasma operating at the gas-liquid interface.
- Simulate non-equilibrium plasma chemistry to predict the formation of key ROS (e.g., ·OH, O_3, H_2O_2).
- Implement interfacial transport models to describe the flux of reactive species into the aqueous phase, considering effects of plasma filaments, gas composition, and fluid dynamics.

Experimental characterization of the plasma

- Design and optimize a lab-scale DBD reactor suitable for optical diagnostics.
- Use optical emission spectroscopy to identify and quantify transient species in the plasma phase.
- Use high-speed camera to investigate filament dynamics for different operating regimes.

Liquid phase chemical analysis and model validation

- Perform UV-Vis spectrophotometry and potentially MS, HPLC to analyze the concentrations of ROS under varying plasma conditions.
- Calibrate and validate the numerical model using experimental data across a range of operating parameters (voltage, frequency, flow rate).

Publication and knowledge dissemination

- Compile and publish research findings in peer-reviewed journals and present at conferences.

3. Requirements for candidates

We are seeking a highly motivated and enthusiastic PhD candidate with a strong interest in plasma science, multiphysics modeling, and environmental applications. The ideal candidate should meet the following requirements:

Educational background:

- Master's degree (or equivalent) in plasma physics, chemical Engineering, or a related field.

Technical skills:

- Solid knowledge of plasma physics or fluid mechanics, with a particular interest in cold atmospheric plasmas.
- Prior experience with numerical simulation tools (e.g., COMSOL Multiphysics, Fortran, or similar program) is highly desirable.
- Familiarity with spectroscopic techniques (such as optical emission spectroscopy) and/or chemical analysis methods (e.g., UV-Vis, MS) is a plus.

Analytical and research abilities:

- Strong analytical thinking, problem-solving skills, and ability to work independently and collaboratively in a multidisciplinary team.
- Good scientific writing skills and the ability to present research findings clearly.

Language Skills:

- Good written and oral communication skills in English (knowledge of French is an advantage but not mandatory).
- Ability to write research articles and present findings at international conferences.

Teamwork and collaboration

- Ability to work both independently and as part of a **multidisciplinary team**.
- Willingness to collaborate with other research groups for practical applications.

Keywords

Non thermal plasma; plasma liquid interactions; modeling; dielectric barrier discharge; advanced oxidation technologies;

Work context

The PhD student will work within the Plasmas Processes Surfaces (PPS) team of the Jean Lamour Institute (IJL), in the ARTEM campus in Nancy. It will be fully funded by a ministerial grant for a period of 36 months. Visits to external laboratories with which we collaborate are possible, depending on funding.

About the Jean Lamour Institute

The Jean Lamour Institute (IJL) is a joint research unit of CNRS and the University of Lorraine. It is affiliated with the CNRS Institute of Chemistry. Specialized in materials science and process engineering, its research areas cover the following fields: materials, metallurgy, plasmas, surfaces, nanomaterials, and electronics. The IJL has 183 researchers and faculty members, 91 engineering, technical, and administrative staff, 150 PhD students, and 25 post-doctoral researchers. It collaborates with more than 150 industrial partners, and its academic collaborations extend across approximately thirty countries. Its exceptional instrumental facilities are spread across 4 sites, with the main site being a new building located on the ARTEM campus in Nancy, which will be the primary location for the PhD work.

Constraints and Risks

The open position is in a sector that falls under the protection of the Nation's scientific and technical potential and therefore requires, in accordance with regulations, that the recruitment be authorized by the competent authority of MESRI (Ministry of Higher Education, Research and Innovation).

Application procedures

The application file includes the following elements:
- Curriculum Vitae.
- Cover letter.
- Copy or certificate of the master's degree.
- Grades and ranking of the two years of the master's degree (M1 and M2).
- Letter(s) of recommendation.
- Copy of the identity card or passport.

Applications must be sent before **September 30, 2025** by e-mail to:

- Dr. Thierry Belmonte: *thierry.belmonte@univ-lorraine.fr*
- Dr. Nguyen Truong Son: *truong-son.nguyen@univ-lorraine.fr*