PhD thesis job offer

# Aerosol particles separation by means of a microfluidic thermophoretic device: numerical and experimental analysis (AERATOR)

**Context:**

This PhD thesis is part of the AERATOR project (2024-2027) financed by the French National Research Agency (ANR-23-CE04-0002). The PhD student will have to realize the numerical work at Aix-Marseille University and the experimental work at University of Toulouse. The project aims to improve the existing databases of atmospheric pollution via the design and manufacturing of an original microfluidic device.

**Consortium:**

- Institut Clément Ader (ICA), UMR CNRS 5312, Toulouse
- Institut Universitaire des Systèmes Thermiques Industriels (IUSTI), UMR CNRS 7343, Marseille
- Laboratoire d'Analyse et Architecture des Systèmes (LAAS), CNRS, Toulouse

**Duration of the PhD thesis**: 36 months, starting date 1st of October 2024

**Application deadline** 1st of June 2024

**Supervisors**:
Prof. Irina Martin-Graur, irina.martin@univ-amu.fr
Dr. Marcos Rojas-Cardenas marcos.rojas@insa-toulouse.fr

**Candidate profile**: Master diploma in Physics or Mechanical Engineering or Aerospace Engineering. An expertise in fluid mechanics and/or heat transfer is requested. Experience in experimental setup design and/or numerical simulation is a plus. The candidate should have also sense of innovation, autonomy and a taste for international collaboration and mobility.

**Attachments to be provided with the application:**

- Curriculum Vitae
- Cover letter
- Master grades
- Recommendation letter and contact of a referent person

**Salary:**

- 2100 €/month gross salary

**Main topic:**

Aerosols are defined as a suspension of particulate matter or liquid droplets in a gas. They come from both natural and human sources, and they can be detrimental for the environment and human health. The separation of particulate matter suspensions (aerosols particles) by means of a microfluidic device for concentration measurements and analysis is of primary importance for both indoor and outdoor applications. The aim of the ANR AERATOR project is to develop a new aerosol microfluidic separator, which operates by means of the thermophoretic principle [1] (Figure 1). The project will focus on the fluid-dynamics and micro-fabrication problematics

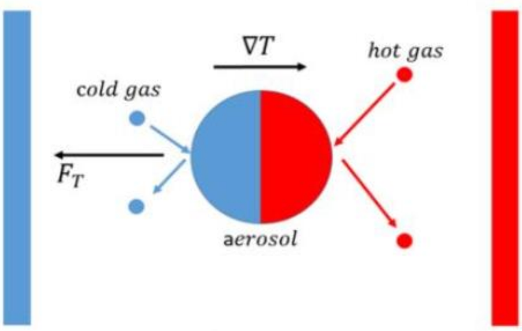

Figure 1. Thermophoretic effect on a particle

involved in creating such a device. The microfluidic device will be able to separate different types of aerosols as a function of size, mass density and thermal conductivity of the particles. A microfluidic separator can be a strong asset to effectuate global and local concentration measurements and sensing of air pollutants or liquid suspensions carrying toxic biological agents in a very cost-effective manner in many strategic points. The obtained results will increase the scientific understanding of the aerosol transport phenomena due to temperature gradient, which will allow improving the efficiency of particle separation equipment for ground and space applications. The prototypes produced in this project will be the first of their kind at the micro-scale (Figure 2).

**Context:**
Aerosols with a diameter less than 2.5 µm (PM2.5) can be deposited deep into the lungs, inducing oxidative stress and respiratory diseases. Several recent studies found that short- and long-term exposure to specific constituents, such as organic carbon, elemental carbon, sulfate, nitrate and sulfur, can be associated with increasing mortality. Studies reveal that ambient air pollution causes more than four million premature deaths per year. Furthermore, particles like black carbon (BC) and brown organic carbon (BrC) can influence climate change by absorbing solar radiation and thus changing the heat exchange balance at the atmosphere, by influencing the cloud processes, and by altering the melting of snow and ice cover. BC particles are formed mainly in flames, the major sources being diesel engines, coal burning for industrial and residential uses. Pure BC exhibits a structure similar to graphite with small-sized spherical particles of 10–50 nm of diameter and is a chemically stable and highly pollutant molecule. BrC is formed mainly by biomass burning, being the major source of burning of agricultural fields, forests and grasslands. These two products of combustion are ubiquitous in outdoor and indoor environments.

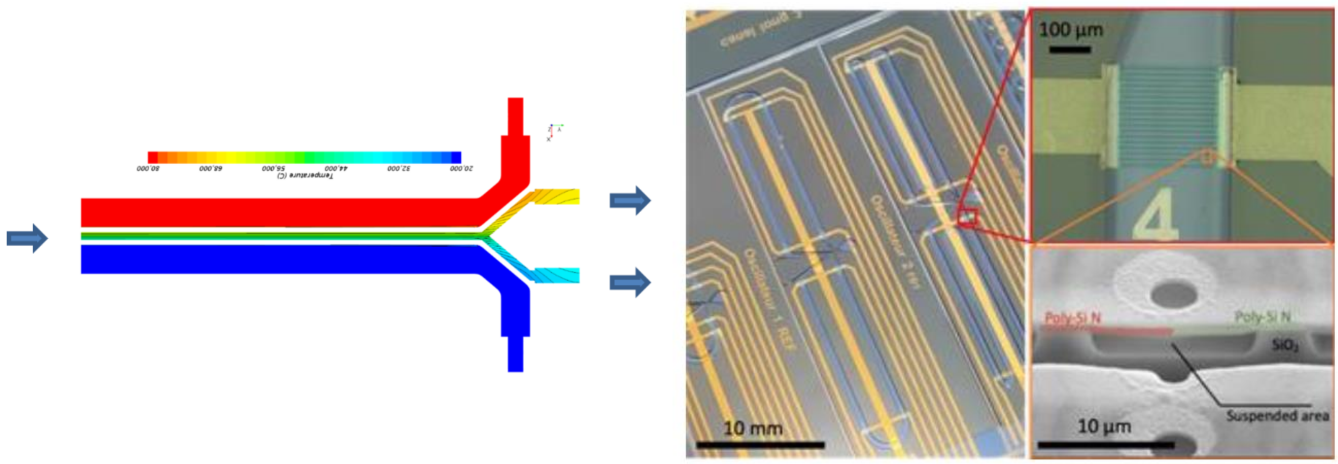


*Figure 2.* Left: ***Illustration of different thermophoretic separator designs. Right:*** optical micrograph showing micro-sensors and heaters, their connection lines and a dry-film microfluidic channel integrated on top.

To our knowledge, efforts related to building a lab-on-a-chip thermophoretic particle separator at the microscale have been realized almost only in respect to liquid flows [2,3]. Nevertheless, very little effort has been carried out to reduce the scale of the working devices to the millimetric or micrometric scales for gas flow separators. The only work performed on the matter was realized by researchers of the University of California, Berkeley, who manufactured an air-microfluidic sensor for airborne particles (25mm x 21 mm x 2 mm footprint). In the latter work, the thermophoretic principle was used to deposit particles onto the surface of a mass-sensitive film bulk acoustic resonator (particle counter). The main stream particle separation was performed via a virtual impactor [4,5].

**Objectives of the project:**

- The fundamental aspects developed in this project will lead to improving knowledge on thermophoresis as well as other non-equilibrium effects that characterize aerosol particle dynamics.
- Based on the general principles of irreversible thermodynamics, the developed models will revise and enhance existing models. Through the developed multi-scale model, we aim to substantially improve the aerosol transport model and find ways to optimize particle separation.
- The models developed at IUSTI, Marseille, will be validated using experimental manipulation on a specifically developed test bench in-situ at ICA, Toulouse.
- Design and manufacture a microfluidic thermophoretic separator for aerosol particles.
- The device will be capable of separating different types of aerosols based on size, density, and thermal conductivity for particles ranging between 10 nm to 1000 nm.
- The micro-separator developed in this project will find applications in two of the main societal challenges identified at the European level (Environmental Transition and Human Health).

**Consortium**

Institut Clément Ader (ICA) - Toulouse (Project Coordinator Marcos Rojas-Cardenas): The Microfluidics team has been highly involved in microfluidics for over 20 years. This group has developed recognized high-level international expertise in modeling, simulation, and experimental analysis of gas flows in microsystems, both from a fundamental and an applied perspective [6,7,8]

IUSTI - Marseille (Local Coordinator Irina Martin-Graur): This team has extensive experience in numerical modeling of multiphysical problems with phase changes. The IUSTI team has developed various models for simulating the behavior of gases at the microscopic scale and under rarefied conditions [9,10].

LAAS - Toulouse (Local Coordinator Vincent Raimbault): This team specializes in Gas and Liquid Phase Analysis Microsystems, with significant scientific achievements in the field of sensors and microfluidics. They are experts in innovative techniques for manufacturing microfluidic systems such as high-resolution stereolithography or advanced processing of laminated dry films [11,12].

**References:**


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