End-of-study internship for Engineering school or Master Research students

Aerosol particles separation by means of a microfluidic thermophoretic device: experimental analysis

Context:
This Master internship is part of a French National project ANR AERATOR (2024-2027). This work is a precursor step in order to prepare for a Doctoral work. The grant for the doctoral scholarship is already available.

Localisation : Institut Clément Ader (ICA), UMR CNRS 5312, Toulouse
Collaboration : IUSTI, UMR CNRS 7343 Laboratory, Marseille

Duration: 5 months, starting date 1st of March 2024

Supervisors:
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Candidate profile: Master student in Physics or Mechanical Engineering or Aerospace Engineering. Taste for experimental setup design, experimental testing in fluid mechanics and heat transfer, sense of innovation and autonomy.

Attachments to be provided with the application:

- CV
- Cover letter
- Recommendation letter
- Master grades

Salary:

- 600 €/month
- Financial aid for mobility will be provided for students coming from abroad (1x plane ticket)

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 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

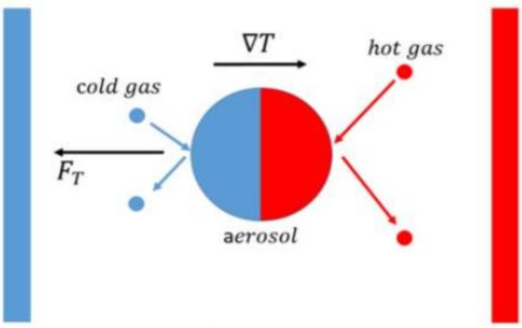

Figure 1. Thermophoretic effect on a particle

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 different prototypes 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.

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). Here 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].

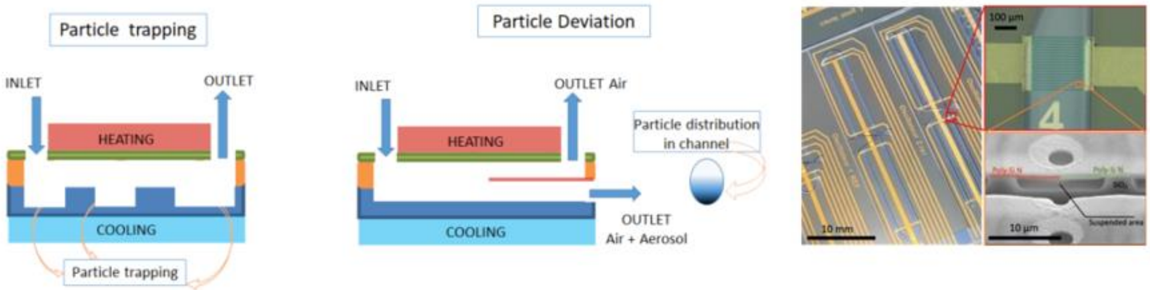

Figure 2. Left: ***Illustration of different thermophoretic separator designs. Right:*** optical micrograph showing micro-sensors and heaters, their connection lines and a dry-film microfluidic channel integrated on top.

Objective of the internship: Development of an experimental setup to test the transport of aerosols in a mini channel subjected to thermal gradients in the perspective of optimizing a microfluidic separator.

Methods: The main goal related to the experimental tasks to be performed at ICA will be to control the thermophoretic effect on a population of nano or micro-particles in order to be able to deviate them from their original trajectory. This will allow us to separate the particles from the main gas stream and to direct them to a predetermined collection tank or plane substrate. We will verify experimentally how the thermophoretic force acts on the particles as a function of the temperature gradient applied on the channel, the size and thermal conductivity of the particles. Furthermore, different separator geometries and configurations will be tested. Method: A new experimental setup will be built by combining the experience accumulated by all partners on thermally driven gas flows [6] and inertial focalization of solid particles immersed in liquid flows [7,8].

Expected results: Experimental data regarding the particle displacement inside the macroscopic channel. Determination of the distance needed to separate particles from the main gas stream. Comparison of particle deposition data with the multiscale simulations. This internship will allow to make the first steps in the development of the microfluidic separator.

References:

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