Aerosol particles separation by means of a microfluidic thermophoretic device: 2 graduation projects

Context: This graduation project is part of a French National project ANR AERATOR (2024-2027).

Background

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 to the environment and human health. The separation of particulate matter suspensions (aerosol particles) through a microfluidic device for concentration measurements and analysis is of primary importance for both indoor and outdoor applications. The ANR AERATOR project aims to develop a new aerosol microfluidic separator, which operates utilizing the thermophoretic principle (Figure 1).

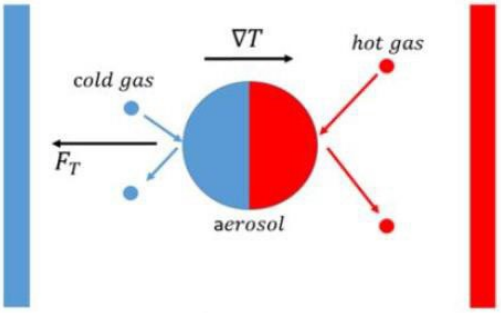

Figure 1. Thermophoretic effect on a particle

The project will focus on the fluid dynamics and micro-fabrication problems 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 at 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 different prototypes will be the first of their kind at the micro-scale (Figure 2).

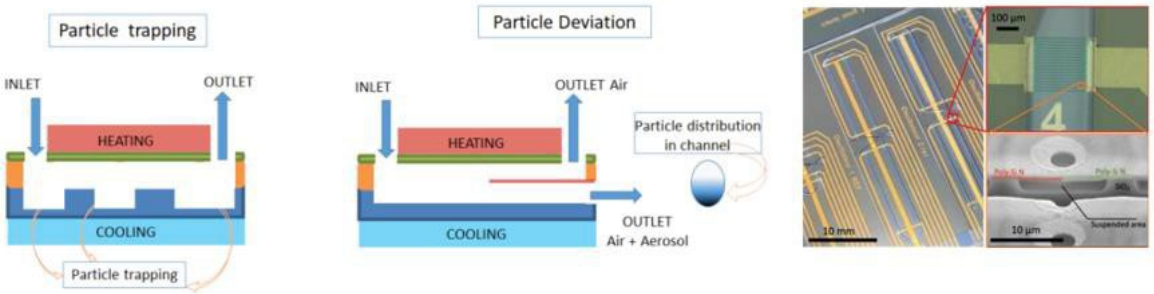

Figure 2. Left: *Illustration of different thermophoretic separator designs. Right:* optical micrograph showing micro-sensors and heaters, their connection lines, and a dry-film microfluidic channel integrated on top.

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Project 1: Numerical analysis

Objective: Development of numerical model of the transport of aerosols in a mini channel subjected to thermal gradients in the perspective of optimizing a microfluidic separator.

Methods: The available CFD tools such as Star-CCM+ and Fluent will be used to simulate the gas flow through the channel submitted to pressure and temperature gradients. The particle tracking will be done in a Lagrangian framework. At the mesoscopic scale, the kinetic model (S-model) to the Boltzmann kinetic equation will be used to obtain the revised expressions of the thermophoretic force and the Cunningham slip correction factor for various types of gas-solid particles interaction laws. The numerical simulations obtained via forementioned approaches will allow the development of new experimental setup to measure the aerosol particles separation via thermophoretic force. This project will allow to make the first steps in the development of the microfluidic separator.

Location: IUSTI, UMR CNRS 7343 Laboratory, Marseille
Collaboration : Institut Clément Ader (ICA), UMR CNRS 5312, Toulouse
Starting date: 15 February 2024
Salary:

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

ICA INSTITUT CLÉMENT ADER

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Université Fédérale Toulouse Midi-Pyrénées

Project 2: Experimental analysis

Objective: 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 and inertial focalization of solid particles immersed in liquid flows.

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.

Location : Institut Clément Ader (ICA), UMR CNRS 5312, Toulouse
Collaboration : IUSTI, UMR CNRS 7343 Laboratory, Marseille
Starting date: 1st of March 2024
Salary:

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

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