ECOLE DOCTORALE
ED468
« «Mécanique, Energétique, Génie Civil, Procédés »

Open PhD position at INSA Toulouse, France

Title	**Thermally driven non-equilibrium micro gas flows**
Supervisors - contacts	COLIN Stéphane Stephane.colin@insa-toulouse.fr ROJAS-CARDENAS Marcos Marcos.rojas@insa-toulouse.fr
Laboratory	Institut Clément Ader (ICA – FRE CNRS 3687), Team Microfluidics (http://www.institut-clement-ader.org/axe.php?eq=ism) Toulouse, France

Duration: 3 years. Starting date: September 2015

Application deadline: 22 May 2015

Requirements:

The successful candidate should have the following qualifications:

- a Masters-level degree in Applied Mathematics, Physics, Computational Science, or Engineering with high standard results;
- a good background in fluid mechanics and knowledge on experimental work;
- excellent communication skills and written/verbal knowledge of the English language;
- high autonomy and adaptability skills;
- if the candidate has some experience in microfluidics and/or in experimental or numerical techniques adapted to fluid flows, this would be a benefit.

Application procedure: http://www.ed-megep.fr/contrats_doctoraux_33.php

Description of the project

Background and Scientific Topic

Nowadays fluidic micro-electro-mechanical systems (fluidic MEMS) are employed in a large spectrum of industrial and laboratories applications. In the environmental and health domains for example, there is a crucial need to develop gas micro-analyzers able to detect and measure in situ the concentration of volatile organic compounds (VOCs) such as formaldehyde inside buildings or gas molecules such as trichloramine in public pools, which negative impact on human health has recently been clearly demonstrated. To develop such compact and innovative microsystems - which can include micropumps, microseparators and micro heat exchangers- it is therefore of great importance to be able to model at the micrometric or sub-micrometric scale the behavior of the gas in contact with the MEMS substrate. Extremely important issues that are needed to be dealt with are the thermal management of the microsystem and the precise control of gas mass transport inside the microsystem. The gas flows in these microsystems are rarefied because the molecular mean free path of the molecules is of the same order of magnitude than the characteristic dimensions of the system under consideration. This rarefaction leads to local thermodynamic non-equilibrium, which also allows a convenient transport of the gas by means of controlled thermal gradients.

Scientific difficulty and innovation

In a rarefied gas, the Navier-Stokes equations with classic boundary conditions are not able to correctly describe the gas flow [1]. At these scales the continuum assumptions fail. It is thus necessary to investigate the fluid flow from a microscopic perspective, i.e. to use a molecular description of the fluid flow using for example statistical models such as the Direct Simulation Monte Carlo technique. The subject of the thesis is more specifically focused on the thermal transport and control of gas inside microsystems. There are a reduced number of publications in the literature concerning the study of the non-equilibrium phenomenon which is generated in rarefied gases by the application of solely a temperature gradient along the walls surrounding the gas. The gas tends to move or to “creep” from cold to hot regions along the walls of the system, creating a macroscopic flow [2, 3]. The so-called thermal transpiration, or thermal creep, phenomenon has not been until present days completely understood and the experimental data are very rare. By mastering the physical mechanisms acting at the solid/gas interfaces for the specific case of thermal transpiration, it will be possible to better understand and model fundamental phenomena (such as slip, thermal slip and temperature jump at the wall) which play a crucial role in gas microflows, and will allow optimal design of innovative gas microsystems.

Objectives of the project

Thermal transpiration will be studied using both experimental and numerical tools.

- Constant Volume Technique (experimental): by following the pressure variation with time in a constant volume reservoir, it is possible to measure the mass flowrate generated by thermal transpiration [2, 3, 4]. At the present state of the art this methodology is suitable to measure fluid flows for different thermal transpiration pump geometries, such as the classic Knudsen pump, the serpentine pump [5], and the ratchet pump [6], but up to now, it has only been implemented in simple circular microtubes geometries [2, 3].
- Molecular Tagging Velocimetry (experimental): an original optical device developed at ICA is capable of tagging and following the movement of fluorescent molecules seeded in the streaming flow [7]. The technique has proved to be functional for non-rarefied gases in micro-systems, it will be necessary to develop this technique in order to make it suitable for the case of thermally driven microflows.
- Atomic Force Microscopy (experimental): through collaboration with Université de Bordeaux it will be possible to test for the first time this promising experimental technique on thermal transpiration. This technique is extremely sensitive to the measurement of forces acting on a micro-sphere at the end of a rigid micro cantilever. It can provide local information on rarefied gas flows [8] and will be adapted and implemented for getting local information inside thermal transpiration flows.
- Direct Simulation Monte Carlo Technique (numerical): it is a numerical tool for analyzing practical non-linear gas flows at the molecular level. The DSMC method is a probabilistic method that contains a physically realistic time parameter which can allow the computation of steady and unsteady dilute gas flows, by computing the trajectories and velocities of a population of model particles after a succession of intermolecular collisions and strikes with the boundaries of the physical domain. The numerical research activities

will be conducted in collaboration with the Aerospace Department of the Politecnico of Milano, Italy.

The DSMC method will be implemented not only to get numerical analysis on the transpiration flows, but also to develop accurate data processing of the experimental data.

Bibliography

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7. Samouda, F., Colin, S., Barrot, C., Baldas, L., and Brandner, J. J., Micro molecular tagging velocimetry for analysis of gas flows in mini and micro systems, Microsystem Technologies-Micro-and Nanosystems-Information Storage and Processing Systems, 2013
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