Doctoral seminars at UNIBO "Experimental Techniques for Micro Gas Flows".

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Context: Recent technological developments in micro-fabrication have led to very interesting new applications in several industrial sectors which involve micro-gas-flows, such as micro-sensors for pollutant detection in the atmosphere, aeronautical micro-fluidic-actuators for active flow control, spatial micro-thrusters for propulsion, micro-instrumentation for mass and heat transfer measurements in gas flows, micro-Knudsen-pumps for pressure regulation in vacuum, micro-heat-exchangers for efficient cooling and organs-on-a-chip. An interesting characteristic of gas flows in micro-electro-mechanical systems (MEMS) is related to the fact that gas can be often considered to be in a state of slight or even strong rarefaction. This means that the molecular mean free path of the gas is in same order of dimensions of the characteristic length of the system. The mean free path is the average distance traveled by a molecule before colliding against another molecule and it is inversely proportional to the gas pressure, for example the gas mean free path of air at ambient pressure and temperature is around 70nm. Thus, in systems with characteristic lengths of 1um, air at ambient pressure is already under rarefied conditions. If the gas is rarefied, local thermodynamic disequilibrium may appear in the fluid flow and this may generate phenomena such as slip at the wall, temperature jump at the wall or thermal transpiration. Gas/surface interaction at the solid boundaries of the system plays a fundamental role in respect to these non-equilibrium phenomena and more specifically in respect to the quantitative values obtained of viscous and thermal velocity slip at the wall and temperature jump at the wall. The thermodynamic disequilibrium phenomena are only located in the vicinity of the wall (in the so-called Knudsen layer), which means that the Navier-Stokes-Fourier continuum equations are still valid in the bulk of the flow provided the correct boundary conditions, expressing temperature jump and velocity slip at the wall, are applied. Various models have been developed to depict these specific boundary conditions, but few experimental data are available to discuss their accuracy and range of applicability at a local level. In this context three seminars are proposed:

i) Introduction on Micro Gas Flows: Applications, general theory on gas rarefaction, mathematical models to be used for rarefied gas, differences in respect to the continuum description, focus on the particular phenomena that arise from these specific thermodynamic conditions, general knowledge on status quo experimental techniques to measure rarefied gas flows.

ii) Measurement of Accommodation Coefficients: Due to the practical impossibility of considering each molecule/surface interaction, it is of great interest to study statistical coefficients that can give us information about the global momentum and energy exchange between gas molecules and surface. These so-named accommodation coefficients can vary as a function of the gas molecule and the solid surface material and roughness. In this talk we will treat the experimental measurement of these coefficients which is often achieved by indirect measurement methodologies.

iii) The Molecular Tagging Technique: Molecular tagging (MT) represents a technique in which photoluminescence of tracer molecules seeded into a fluid flow is observed with goal of measuring local fluid properties, such as velocity, temperature, molecular concentration, density or pressure. Through this technique it is possible to obtain velocity and temperature maps in gas flows. A state of the art of the technique will be presented, its applicability to micro-gas flow and its limitations. Furthermore, the most recent results obtained via MT by the microfluidic-ICA team in micro-channels will be presented.

iv) Fabrication of an original pumping device: the Knudsen pump (KP) is a microdevice that acts on the so-called thermal transpiration principle. By solely applying a difference of temperature (no moving parts), one can achieve transport of gas from a cold to a hot region at the micro-scale. An original KP design has recently been proposed by the ICA team. Through rich international collaboration with partners that are experts in new micro-fabrication techniques (KIT), a prototype of such device will be soon manufactured. A state of the art and recent developments on the subject will be presented.