STUDY OF THERMO-MICROFLUIDIC PHENOMENA IN MICROCHANNELS

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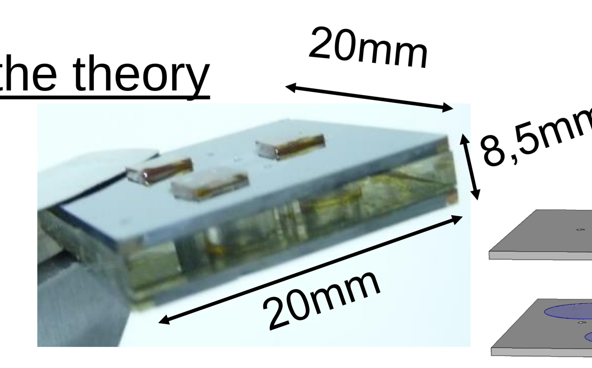
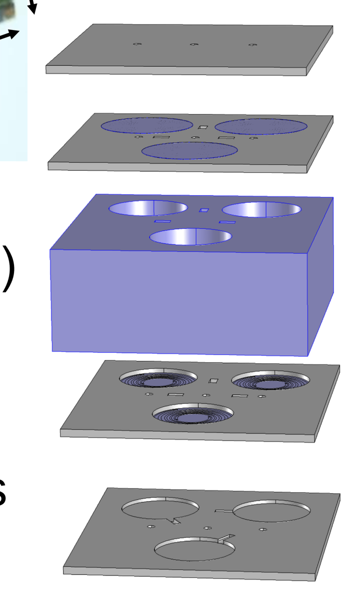
CONTEXT AND OBJECTIVES OF THE STUDY

Context of the study

Miniaturization of a Stirling engine for low temperature recovery and energy conversion → Energy losses higher than predicted by the theory

Effect of roughness and 90° angle bends on flow in channel with D_h < 1mm ?





In the literature

- Alternate flow at sub-millimetrical scale → Almost nothing
- Permanent flow at sub-millimetrical scale → Conflicting results

Roughness	Compressibility
Wu *et al.* 1983, Cryogenics.	Ying-Tao *et al.* 2002, Chinese Physics.
Turner *et al.* 2004, Journal of Heat Transfer.	
Yuan *et al.* 2016, Chinese Journal of Aeronautics.	Morini *et al.* 2009, Microfluid and Nanofluid.
Shen *et al.* 2006, Energy conversion and management.	Yang et al. 2012, Experimental Thermal and fluid science.

Objectives:

Influence of geometrical and thermo-fluidic parameters (hydraulic diameter (D_h), aspect ratio, compressibility, temperature gradient…)

- Permanent flow
- Alternate flow

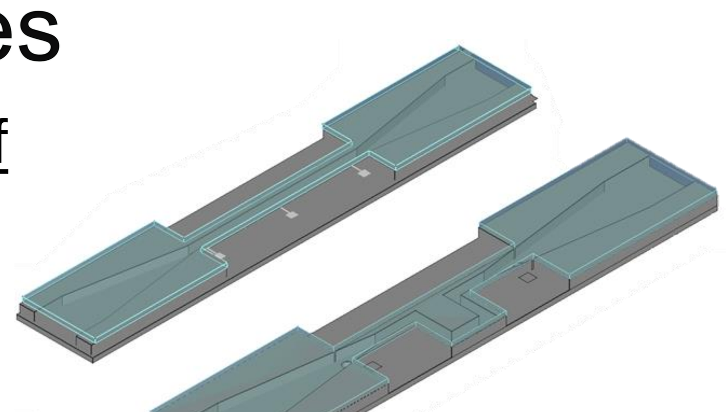
→ Investigation for straight channels and channels with bends

EXPERIMENTAL SETUP AND NUMERICAL SIMULATIONS

Experimental setup and microfabrication of the devices

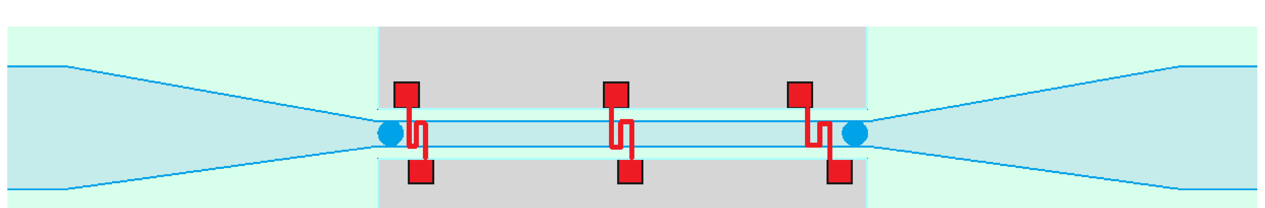
Design of the samples for the study of major and minor losses:

Straight channels / Channels with bends



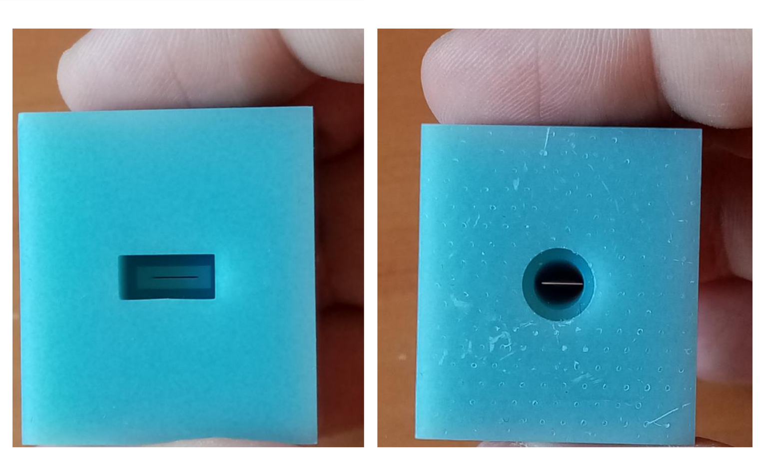
Measurements:

- Pressure (inlet / outlet / inside the channel)
- Temperature (inlet / outlet / inside the channel)
- Mass flow sensor
- Velocity



Adaptation section part ①:

- Devices connected to microchannels
- Adapt square/rectangular cross-section to circular cross-section



Microfabrication :

Fabrication of the channel

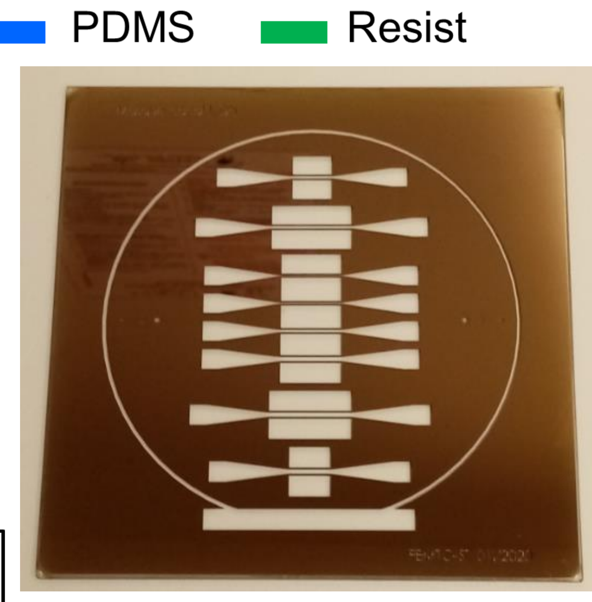
→ Etching on the whole wafer

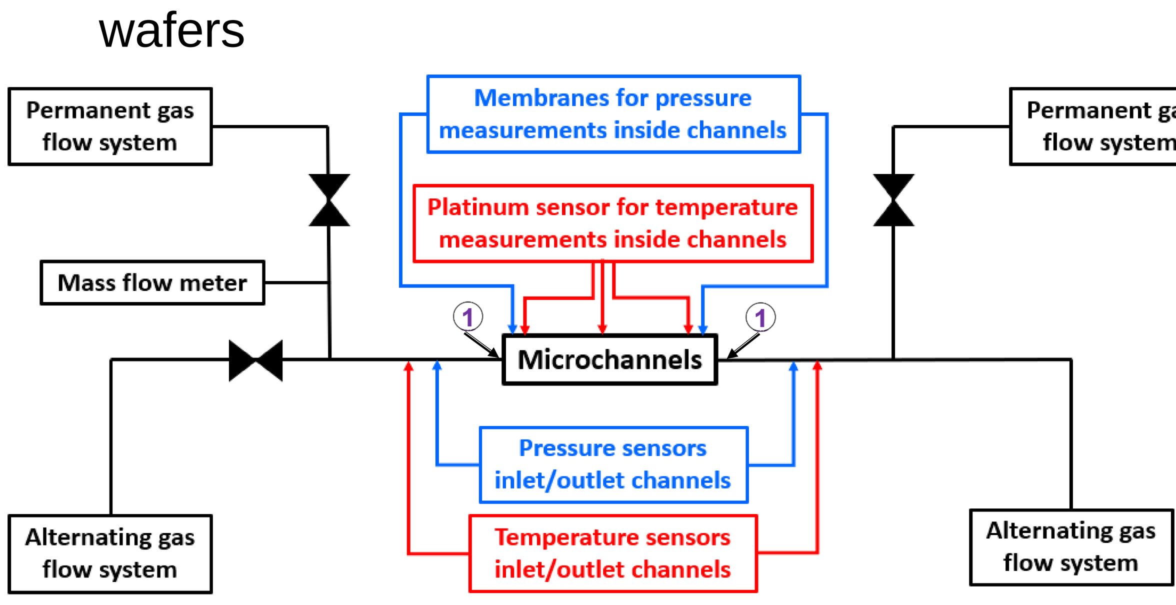
Sensors

- Platinum sensor : Platinum deposition
- Membrane fabrication : Etching and deposition of PDMS
- Etching on back side → optical access

Assembly of the device

- Bonding of the Glass and top Silicium wafers
- Bonding of the top Silicium and bottom Silicium wafers





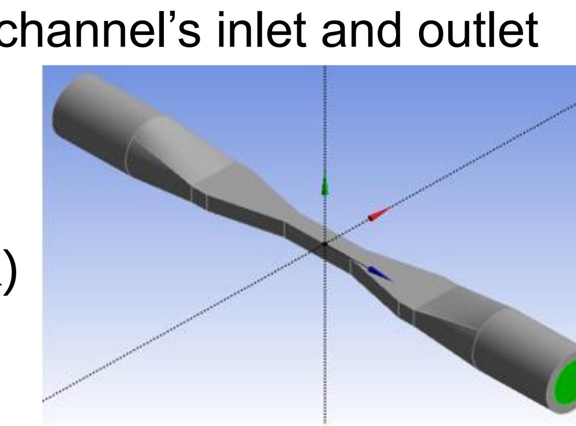
Geometry and boundary conditions of simulation

Numerical simulation for microchannels and adaptation part with different D_h

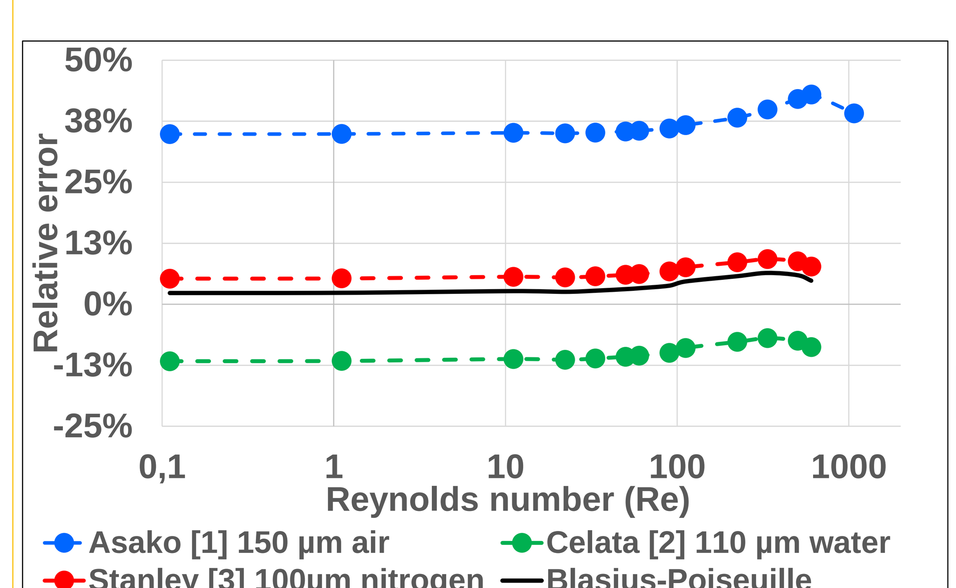
→ With / Without temperature gradient between the channel's inlet and outlet

Boundary conditions:

- Inlet velocity and temperature (300K – 450K)
- Outlet pressure (P_{atm}) and temperature (300K)
- Adiabatic wall

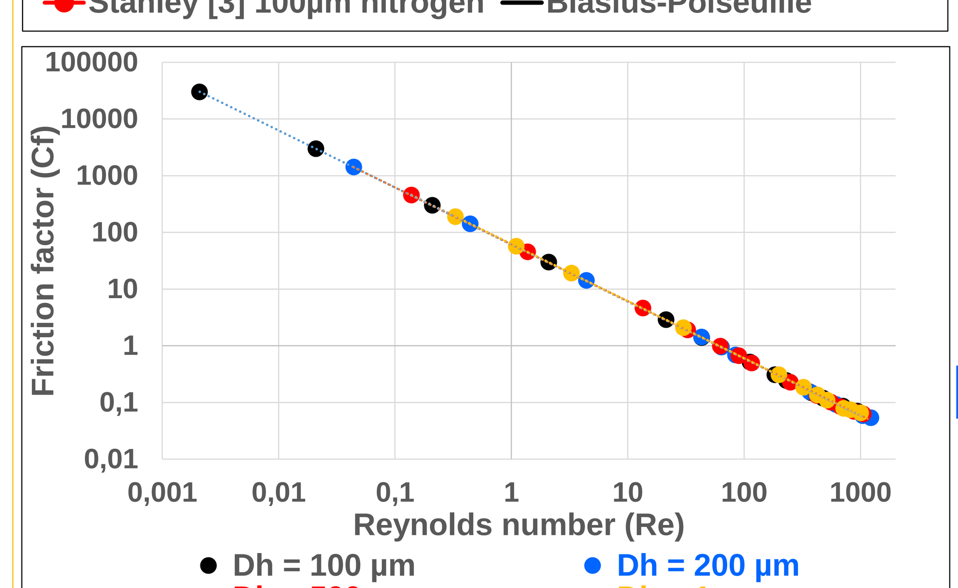


Numerical results



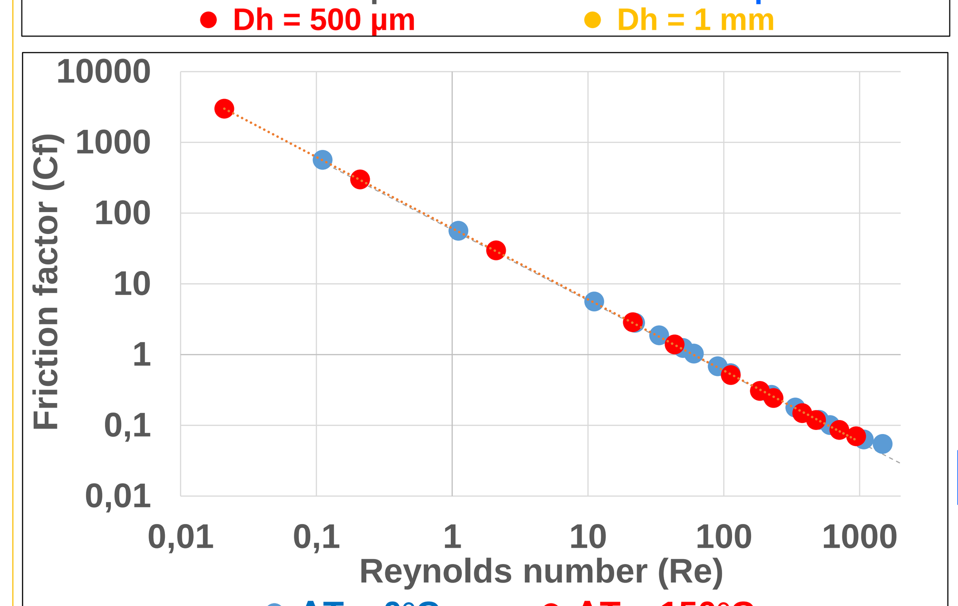
Comparison for friction factor with literature, experimental and numerical results

Numerical simulation show differences with experimental results → roughness not taken into consideration in the simulation



Friction factor versus Reynolds number for different channel diameters for air flow

No significant influence of diameter on friction factor



Correlation of friction factor versus Reynolds number with and without temperature gradient

DT = 0°C: C_f = 59,5 Re $^{-0,914}$

DT = 150°C: C_f = 61,5 Re $^{-0,914}$

No significant influence of temperature difference between the inlet and outlet of the channel on the friction factor

[1] Y. Asako, K. Nakayama,T. Shinozuka, 2005, International Journal of Heat and Mass Transfer.
[2] R.S. Stanley, 1997, Two-phase flow in microchannels, PhD, Louisiana Tech University.
[3] G.P. Celata, M. Lorenzini, G.L. Morini, G. Zummo, 2009, International Journal of Heat and Fluid Flow.

RESUME & PERSPECTIVES

Resume

- ❑ Numerical results have been compared with experimental results from the literature:
  - Simulations results for different D_h show no significant influence of D_h on the friction factor
  - No significant influence of temperature gradient on friction factor
- ❑ Microdevices currently in fabrication

Perspectives

- ❑ Experimental study of both permanent and alternate flows in microchannels
- ❑ Numerical investigation on the influence of bends on permanent and alternate flows
- ❑ Comparison between numerical and experimental results

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