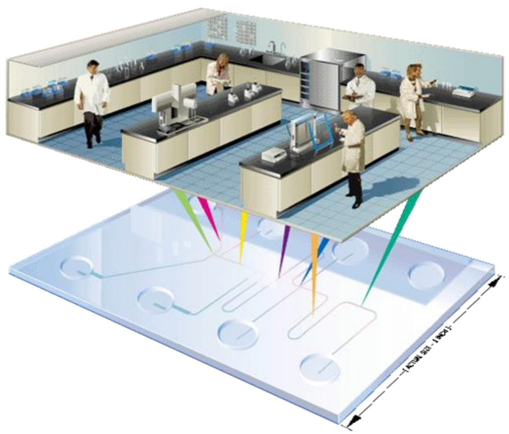
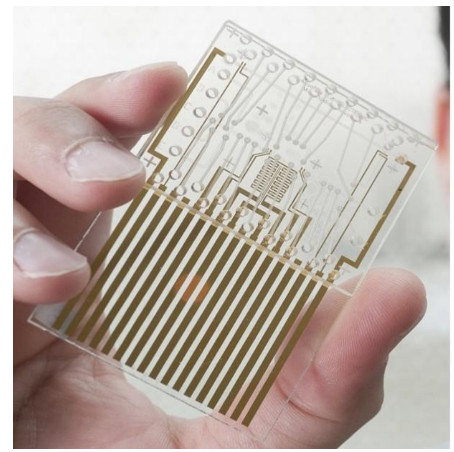
# Converging Artificial Intelligence (AI) and Capillary Microfluidics simulation in Lab-on-a-chip






**Academic Supervisor:** Dr. A. Tarokh, Lakehead University

**Partner organization:** Dr. M. Saboori, Hudson International Consultant and Investment

**Intern:** Dr. A. Amiri Delouei, Lakehead University

# Introduction



Dear Dr. Saboori,

I would like to inform you that I have successfully completed **Stage 1 (literature review)** and **Stage 2 (CFD analysis)** of the project outlined in the Mitacs proposal and will now continue with the next stage.

In the next slides, I will also present results from studies that are published or ready to be published, including the following titles:

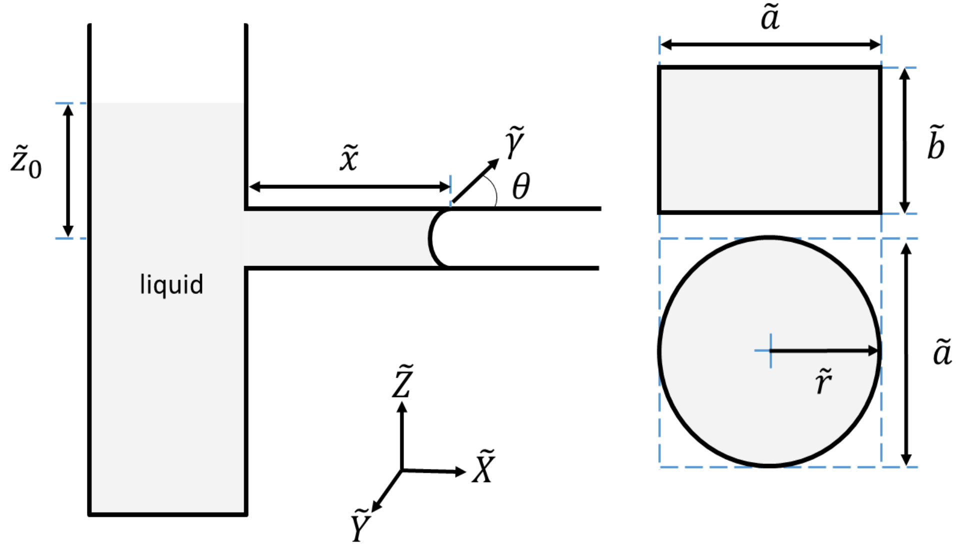
- *A Comprehensive Analysis of Capillary Penetration in Circular and Rectangular Microchannels*
- *Capillary Transport Behavior in Elliptical Microchannels Based on Theoretical Modeling*
- *Direct Numerical Simulation of Capillary Microfluids: Lattice Boltzmann Method*

# A Comprehensive Analysis of Capillary Penetration in Circular and Rectangular Microchannels



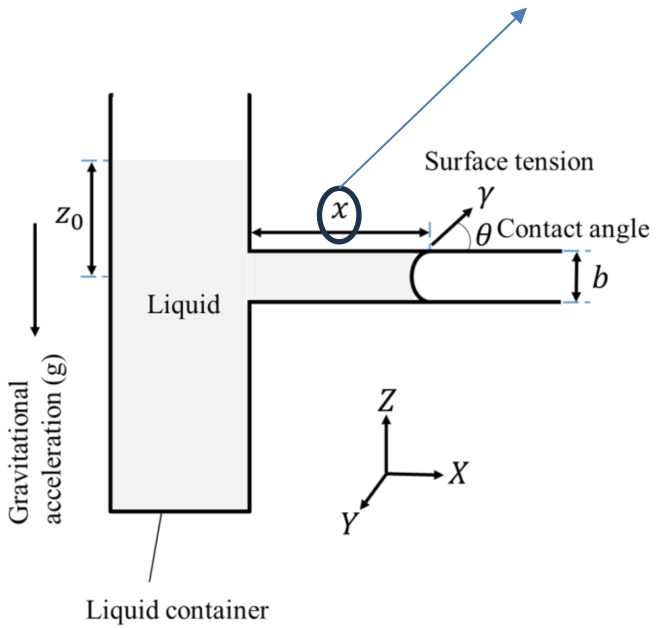
**Introduction:**

This research presents an analytical examination of the capillary penetration phenomenon. In this research, a laminar and incompressible flow in circular and rectangular ducts is considered.

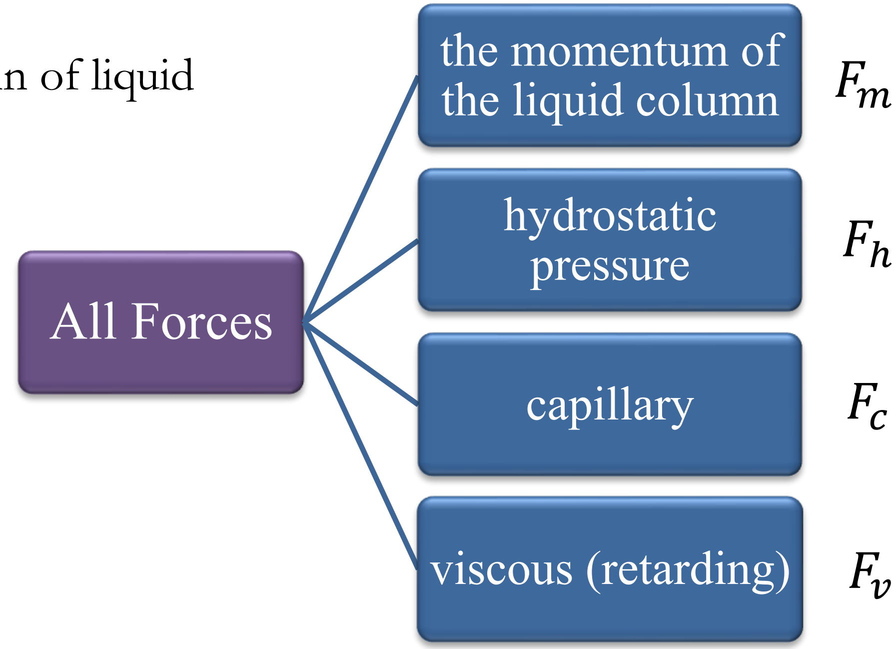


## All Forces:

The length of the column of liquid



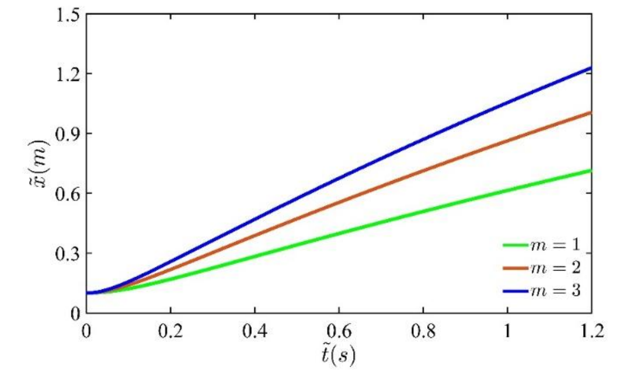

Capillary Penetration in Microchannels.



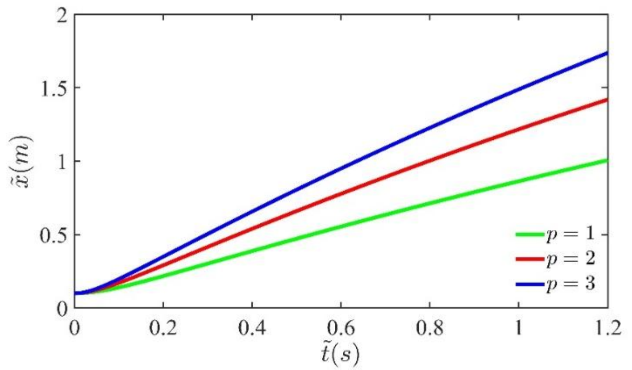

The Motion equation:

$$\frac{dF_m}{dt} = F_h + F_c - F_v$$

# Results:




Variation of the column length versus time for different values of m in circular (n = 1) cross-sections at $\tilde{x}_0 = 0.1(m)$

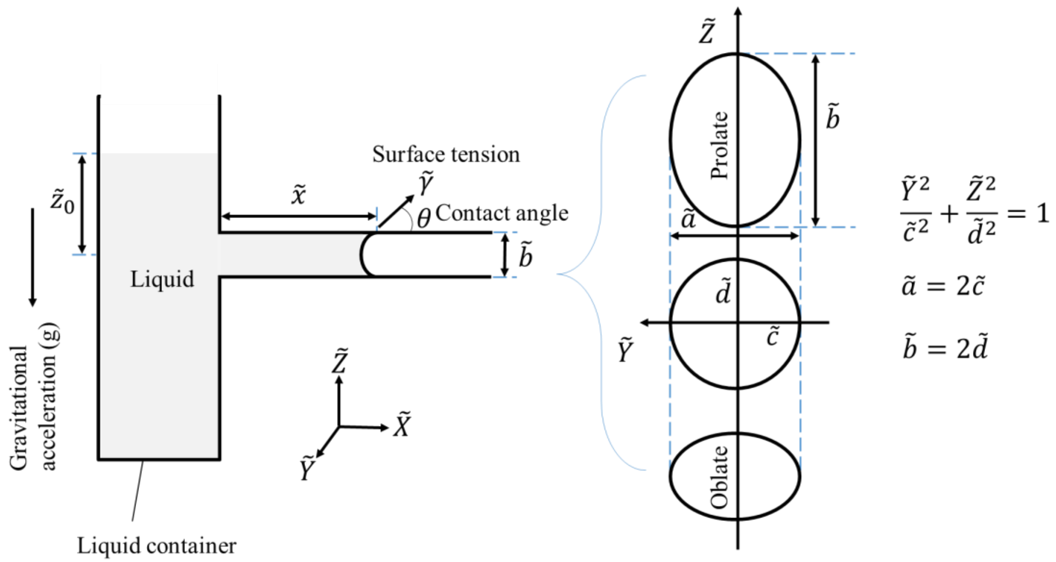



Variation of the column length versus time for different values of p in rectangular (q = 1) cross-sections at $\tilde{x}_0 = 0.1(m)$

# Capillary Transport Behavior in Elliptical Microchannels Based on Theoretical Modeling



**Introduction:** This research presents a comprehensive theoretical investigation into the capillary penetration phenomenon within elliptical microchannels. This study develops a detailed mathematical framework for analyzing the process by focusing on the governing equations, initial conditions, and solution methods within a two-dimensional context.



# Analytical solution:

After considering all the forces, the equation can be analytically solved by considering the initial conditions.

$$x^2 - x_0^2 = \alpha(\beta t + \exp(-\beta t) - 1)/\beta$$

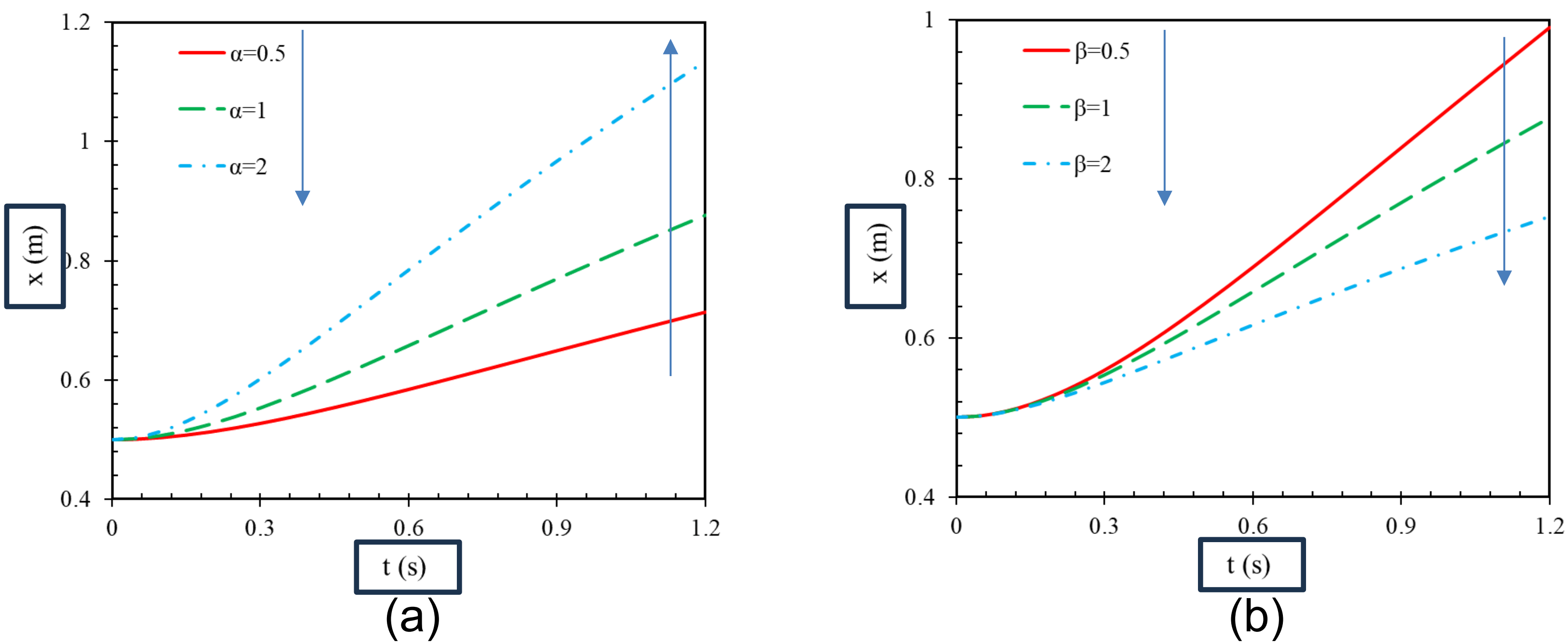
Capillary force

$$\frac{16\gamma \cos\theta \sqrt{a^2 + b^2}}{\sqrt{8}\delta ab} + 2gz_0$$

Viscous force

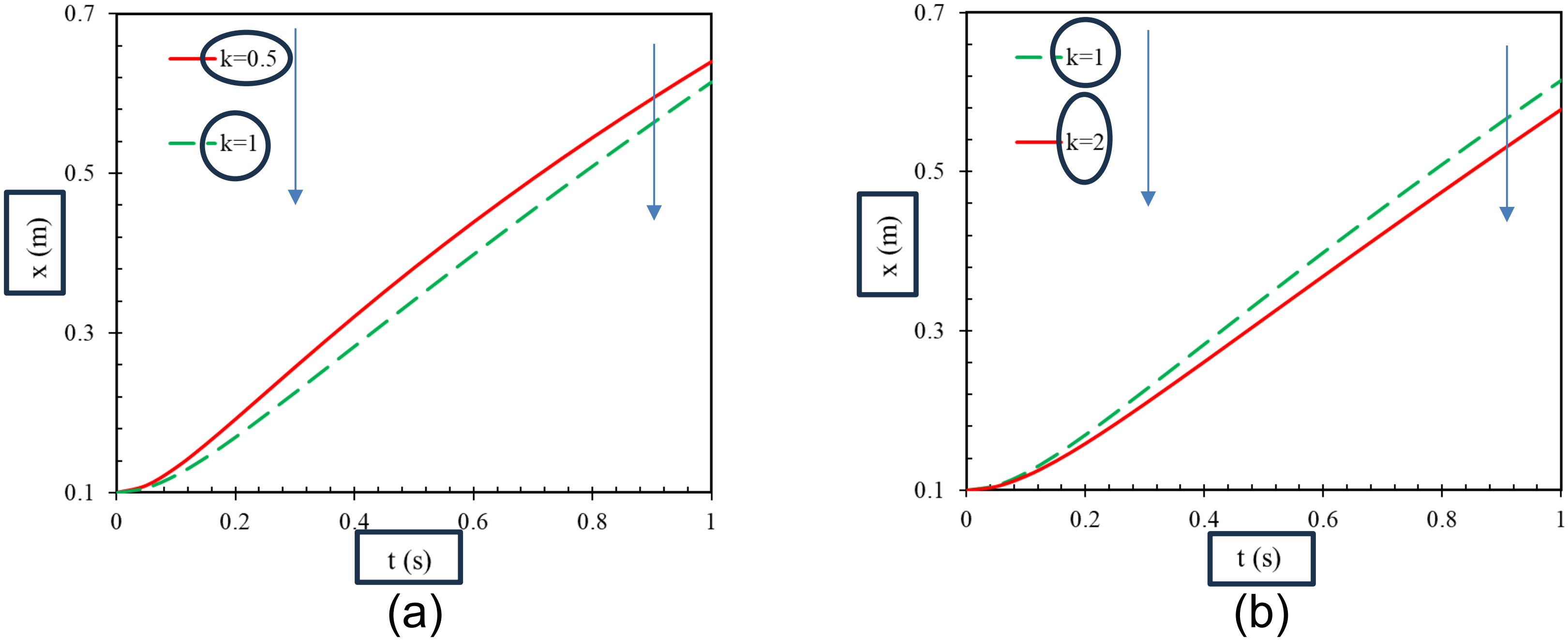
$$\frac{16\mu(a^2 + b^2)}{\delta a^2 b^2}$$

# The effect of capillary and viscous forces on x:




Variation of $x$ versus time for different value of (a) $\alpha$, and (b) $\beta$.

# The effect of aspect ratio (k = b/a) on x:



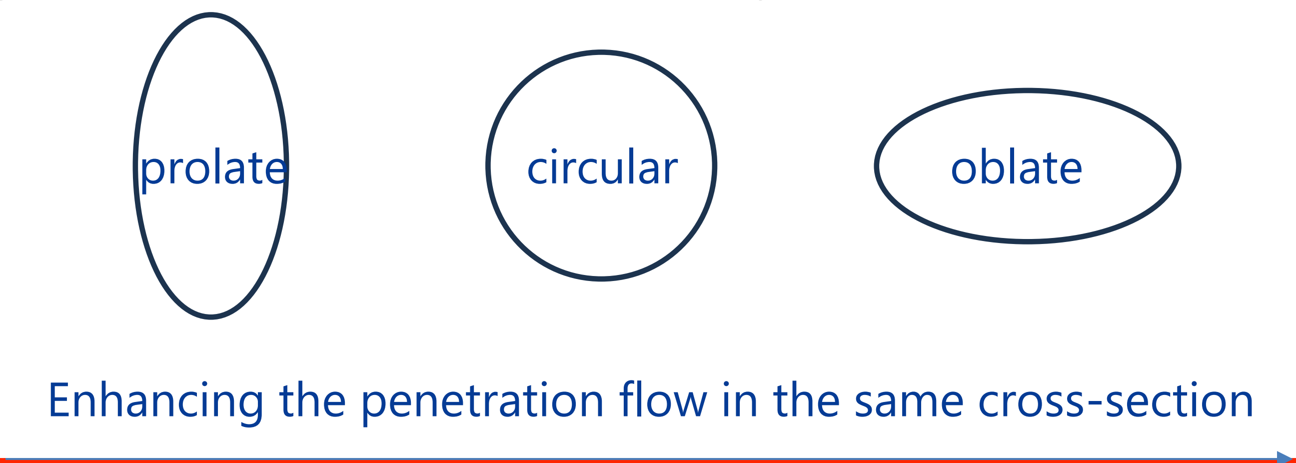

Variation of $x$ versus time for different shape at $x_0 = 0.1$ (a) oblate and circular shapes, and (b) circular and prolate shapes.

# All Findings:

- An increase in the value of $\alpha$ indicates an increase in the capillary force. Consequently, the length of the column increases in response to the surface tension.

- The parameter $\beta$ in the study exhibits as an indicator of the viscous force, and its augmentation results in a reduction of the penetration flow.

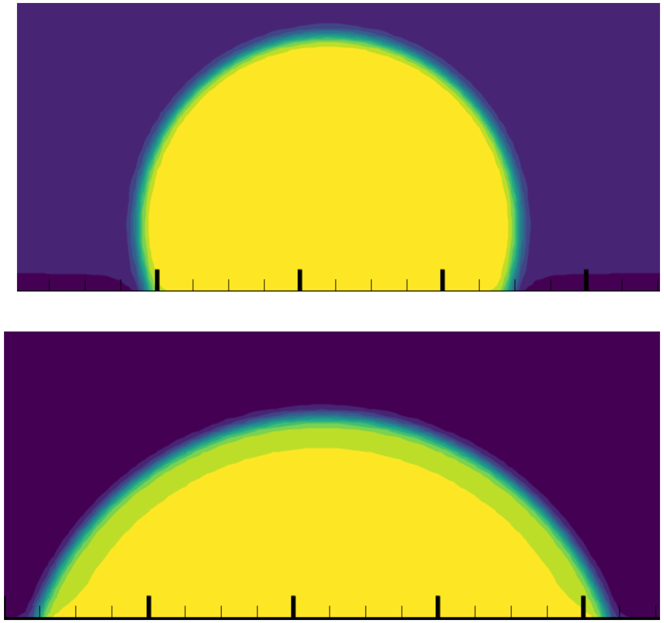
- Enhancing the penetration flow with decreasing the aspect ratio in the same cross-section



# Direct Numerical Simulation of Capillary Microfluids: Lattice Boltzmann Method



**Introduction:** This research employs the lattice Boltzmann method (LBM) to model the motion of a two-phase flow in a microchannel. The fluid flow in this system is primarily driven by surface tension. To validate the accuracy of the developed code, simulations of a droplet on both hydrophilic and hydrophobic surfaces are conducted, yielding successful results. These findings demonstrate the strong capability of the LBM in accurately simulating surface-tension driven flows in microfluidic systems.



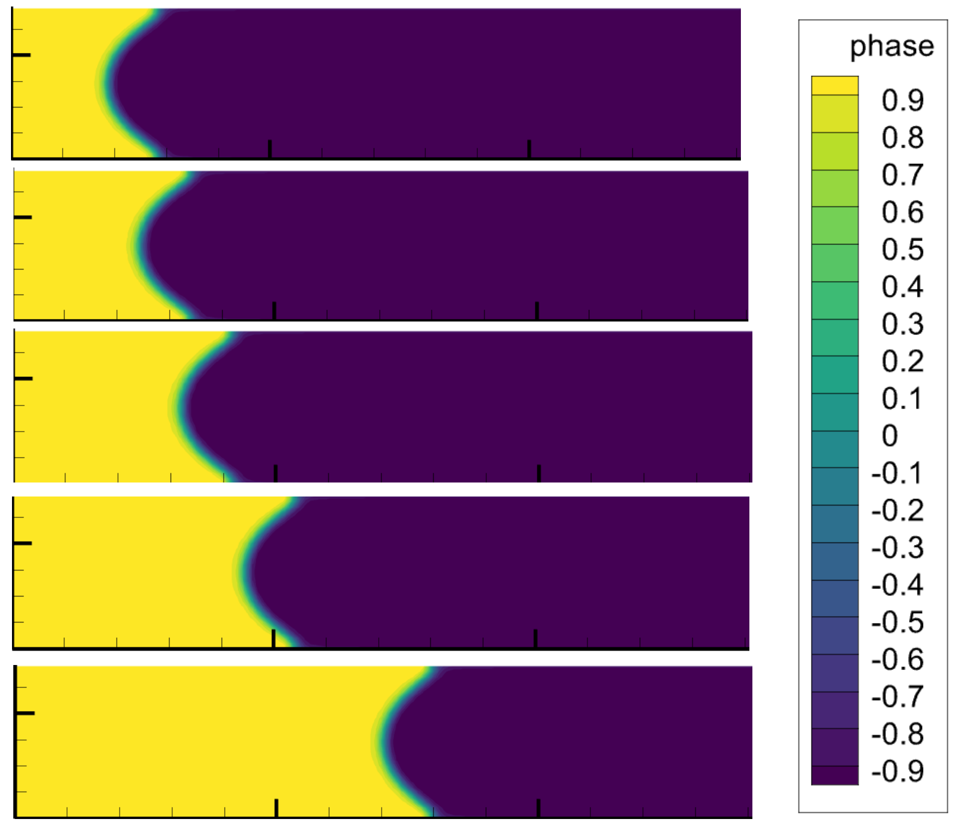
Droplet on hydrophilic and hydrophobic surfaces

# Direct Numerical Simulation of Capillary Microfluids: Lattice Boltzmann Method



Results for two-phase flow interface in a microchannel:

The simulation results demonstrate the effectiveness of the lattice Boltzmann method (LBM) as an efficient approach for conducting Direct Numerical Simulation (DNS) of Capillary Microfluids.




Interface surface in different positions