# A Lattice Boltzmann Kinetic Model for Simulation of Micro Flows

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**Abstract:** Micro-electromechanical systems (MEMS) have become a subject of active research in a growing discipline. As all the micro devices have to operate in a fluid media, the understanding of flow at micro level is fundamental to the development of MEMS. In spite of its importance, the research of micro flows is still at a preliminary stage although the mechanical properties of some micro devices are reasonably well studied. The main reason behind this is at micro-level, the continuum assumption is no longer valid since the mean free path of gas molecules is the same order as the typical geometric dimension of the device. As a result, the conventional governing equation of motion (the Navier-Stokes equations) and numerical tools that seek to solve this equation are not applicable. The usual ways to study the micro flows are molecular dynamics (MD), the direct simulation Monte Carlo (DSMC) approach and solutions of full Boltzmann equation (BE). However, the computational effort of the MD and the DSMC is usually very huge with the use of most powerful supercomputer and the schemes used for solving the full BE are more complicated than those usually used for the Navier-Stokes equations.

Recently, the lattice Boltzmann method (LBM) has received considerable attention by fluid dynamic researchers [1]. Although the LBM is intrinsically kinetic, a very few application of it in micro flows were carried out. The reasons may be due to the difficult determination of relaxation parameter for collision and boundary conditions. In our previous work [2], we assumed that the collision of two particles in the LBM happens and relaxes toward equilibrium within a mean free path $\lambda$ of gas molecules in a collision interval, and we established a relationship between the relaxation parameter $\tau$ in the LBM and the local Knudsen number as $\tau = Kn / \bar{\delta t}$. In this work, we further present a theoretical foundation of the above assumption based on the kinetic theory [3] and the LBM theory [1]. On the other hand, to correctly consider effects of fluid-solid interactions on the boundary, we present a diffuse-scattering boundary condition (DSBC) for the LBM to simulate micro flows according to the classic Boltzmann assumption [1]. This boundary condition has considered the wall equilibrium information and is suitable for any kind of boundary geometries. To check theoretical validity, a numerical analysis for a simple flow is also presented. Using the LBM with present efforts, the two-dimensional (2D) pressure-driven isothermal micro-channel flows, the 2D shear-driven isothermal micro flows and the thin-film gas bearing lubrication are investigated. The numerical results obtained are found to be in good agreement theoretical analysis, available experimental data and numerical simulations.

References

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