

Liquids: The Holy Grail of Microfluidics Modeling

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Interest in microelectromechanical systems (MEMS) has experienced explosive growth during the past few years. Such small devices typically have characteristic size ranging from 1 mm down to 1 micron, and may include sensors, actuators, motors, pumps, turbines, gears, ducts and valves. Microdevices often involve mass, momentum and energy transport. Modeling gas and liquid flows through MEMS may necessitate including slip, rarefaction, compressibility, intermolecular forces and other unconventional effects. The continuum-based Navier–Stokes equations—with either the traditional no-slip or slip-flow boundary conditions—work only for a limited range of Knudsen numbers above which alternative models must be sought. These include molecular dynamics simulations (MD), Boltzmann equation, Direct Simulation Monte Carlo (DSMC), and other deterministic/probabilistic molecular models. The kinetic theory of gases defines well the boundaries for which the no-slip Navier–Stokes equations can accurately model the flow of a dilute gas. The same cannot be said about dense-gas and liquid flows where intermolecular interactions play a dominant role. Neither type of fluid has a well-advanced molecular-based theory, as is the case for dilute gases. The concept of mean free path is not very useful for liquids and the conditions under which a liquid flow fails to be in quasi-equilibrium state are not well defined. Such complex fluids can only be treated via hybrid continuum–molecular approaches, which approaches are still far from satisfactory at the present time. The present talk will address such issues and outline a blueprint for future developments.