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Submicron flow of polymer solutions: slippage reduction due to confinement

HUGUES BODIGUEL, Univ. Bordeaux

Managing flows of polymer solutions through micro- and nanochannels is important for many applications in various fields, including energy conversion processes, nanotechnologies and flows in porous media. Even above the micron scale, violation of the no-slip boundary condition has been recognized to be very important, especially for high molecular weight polymers for which slip length up to tens of micrometers have been reported. As a consequence, pressure-driven flow of polymer solutions in channels of the order of one micrometer and less should be dominated by slippage. Using micro- and nanofabrication methods to control the geometry and fluorescence photobleaching based velocimetry technique, we developed an experimental approach to investigate flows of polymer solutions in slits of thickness as low as 150 nanometers. In non-adsorbing conditions, and for various polymer solutions (polyacrylamide or polystyrene at different concentrations), our results unambiguously show that the resistance to the flow decreases when the channel height decreases below the micron scale. Besides, the apparent slippage of the solutions is characterized macroscopically on similar surfaces. Though slippage can explain qualitatively the effective viscosity reduction, quantitative comparison fails. The reduction of the effective viscosity is significantly smaller than one could have expected knowing the slippage properties. This shows that the slip length is reduced below the micron scale. This effect is stronger when decreasing the polymer length or when lowering the concentration. Interpretations of these results are based on chain migration due to hydrodynamics interactions, which would explain on the one hand the large macroscopic slip lengths and on the other hand their reduction in confinement.