Flow patterns induced by hydrophylic surfaces

S. Musa, D. Florea, H. Wyss and J.M. Huyghe

Eindhoven University of Technology, Departments of Biomedical &Mechanical Engineering

When a charged surface comes into contact with water it attracts counterion ions to neutralize. The Double Layer theory, which explain this mechanism, predicts that the charge surface induces order to few layers of water molecules next to it before the counterion ions layer is formed. The distance between the surface and the counterions layer, called the Debye length, is usually in the range of a few to tens of nanometers. Along this distance there an electric potential which decreases rapidly away from the surface, called the zeta potential.

Recent studies, however, have shown that suspensions are excluded to distances a few hundreds of micrometers away from hydrophilic surfaces [1]. The hydrophilic surfaces include those of various polymers, gels, biological tissues and solids such as zinc [2]. These studies revealed that there is an electric potential and viscosity gradient across the exclusion zone [2, 3?]. Also, a sudden change in the pH is observed at the edge of the exclusion zone [4], indicating the existence of the counterions layer at the end of the zone. All these observations suggest that the Debye length is being extended to hundreds of micrometers instead of tens of nanometers. The reason for the existence of this very large exclusion zone is not completely understood.

We report on peculiar flow patterns that accompany the formation of exclusion zone. We have observed that as the exclusion zone is developing water outside the zone flows towards the charged surfaces and bounces back when it reaches the surface. Although the flow decreases as a function of time, but it lasts for a number of hours. The energy driving this flow is not obvious as there is no pressure or electric field applied. Studying this flow can help in understanding the underlying physical principles of exclusion zone formation. Moreover, this flow has a potential for a wide range of applications where flow needs to be generated or controlled.

To investigate these flow patterns we have conducted multi-particle tracking measurements using video microscopy. With this method we determined the flow velocities and water viscosity around the exclusion zone. We have also tracked the exclusion zone expansion using a microscope to determine to the speed with which it is developing. The results reveal the flow dynamics associated with the formation of the exclusion zone.