Modeling chemotactic forces

In this project an intriguing and still not completely understood physical phenomenon will be investigated. The problem originates from the observation that when a hydrophylic surface is immersed into an aqueous solution a particle free exclusion zone, which extends to several hundreds of micrometers is formed. Double layer theory which explains the interactions between charges surfaces and surrounding solutions predicts that the surface is surrounded by a diffuse layer of counter-ions which shields it completely from the bulk solution. The thickness of this diffuse layer of counter-ions, called Debije length, is in the range of a few to tens of nanometers, which is orders of magnitudes less than the exclusion zone. Recently, it has been observed that the formation of exclusion zones are always accompanied by convection flow. The cause of the exclusion zone and the associated convection flow is generating an intense debate in the literature. Understanding this phenomenon could have interesting implications in various fields including biology, chemistry and physics. It could potentially lead to many applications.

Recently, chemotaxis has been proposed as a possible cause for the exclusion zone formation. Chemotaxis hypothesis assumes that certain materials induces concentration gradients around their interfaces with aqueous solutions. Particles existing in a concentration gradient will experience a force proportional to this gradient and will be driven away from the interface. As a consequence, a particle free exclusion zone will be created. This theory also predicts that the concentration gradient will lead to a gradient in the concentration of the counter-ions in diffuse layer of the double layer forming around the glass making the sample chamber. The concentration gradient in the diffuse layer will result in a chemotactic force acting on the fluid at the interface and generate a fluid flow. The particle flow induced by the hydrophilic surface and the fluid flow at the interface with the glass are in opposite direction as depicted in the figure.

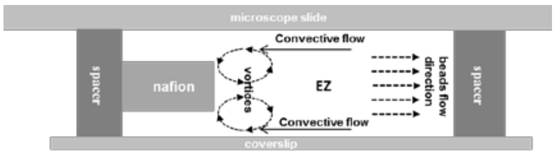

Figure 1: An illustration depicting the cell with hydrophilic material (Nafion), exclusion zone and the beads flow directions

It has been shown that migration of particles away from the interface can be predicted with high accuracy using a chemotactic force proportional to the concentration gradient of the electrolyte at the interface. The concentration gradient is modeled using the diffusion of ions in and out of the hydrophilic material. This model does not take into account convection flow at the glass interface, which is predicted by the model and has been experimentally shown. This flow mixes the different electrolytes concentrations in the cell and might level off the gradient, which the underlying cause of the particle flow.

In this project we would like to develop a mathematical model which accounts for the convection flow and examine whether the particle migration can still be predicted by the chemotactic forces.

If you are interested in this project you could contact dr. Sami Musa (s.musa@tue.nl) or dr. Jacques Huyghe (j.m.r.huyghe@tue.nl) for further information.

References:

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