8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

Simulation of Ligands Competing for Binding Sites in a Multi-Solute System

*** Remo M. Winz[1], Eric von Lieres[2] and Wolfgang Wiechert[1]**

[1] University of Siegen
Department of Simulation
Am Eichenhang 50
57068 Siegen, Germany
remo.winz@uni-siegen.de
www.uni-siegen.de/fb11/simtec

[2] Research Center Jülich
Institute of Biotechnology 2
Wilhelm-Johnen-Strasse 1
52425 Jülich, Germany
e.von.lieres@fz-juelich.de
www.fz-juelich.de/ibt/biosep

Key Words: *Microfluidic sensor, adsorbing substances, lab-on-chip technology, multi-solute system.*

ABSTRACT

In recent years, lab-on-microchip technology has become a powerful tool for micro-scale analysis and control of biochemical processes. However, miniaturization significantly increases complexity of the involved processes as compared to lab-scale, due to shorter distances and larger surfaces per volume, resulting in fast kinetics. In a previous publication we studied the interplay of microfluidics, diffusion and adsorption in an experimental set-up, composed of a micro-channel featuring a Y-shaped double-inlet and a functionalized surface [1]. This region is coated with surface-bound receptors in order to immobilize ligands from the liquid flow [2]. The amount of adsorbed molecules can be quantified via attached fluorescence markers. Such functionalized surfaces are of special interest as potential sensor for quantitative detection of multiple substances in lab-on-chip systems. Especially, in competitive binding assays, unmarked components can be indirectly observed by their interaction with marked molecules.

A model is set up for a Y-shaped channel in which two species with different diffusion and sorption rates are introduced at the inlet branches. At low Reynolds numbers, these species flow in parallel and are mixed only by diffusion. The interdiffusion between the parallel streams strongly affects the occupancy pattern of the sensor. In bisolute systems, this occupancy pattern depends not only on the individual diffusion and sorption rates of both species, but also on the competition of both species for free receptors. The microfluidic system is described in three dimensions by sub-models for transport, diffusion and sorption. First, velocity profiles of the carrier fluid are determined by solving the

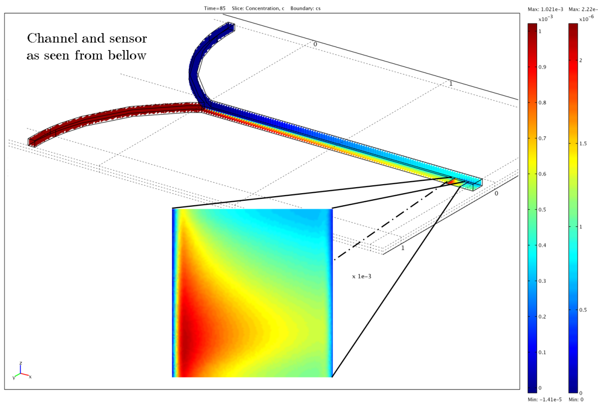
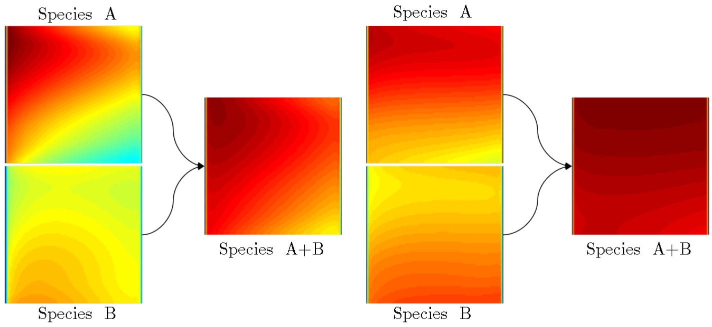


Figure 1: Simulation result of the Y-shaped channel with activated surface for a single–solute system (blue: low load, red: high load).

Navier-Stokes equations for incompressible flow. These profiles are considered invariant, and in particular independent of the variable molecule concentrations. Adsorption and desorption of these molecules at the functionalized surface is then described with the kinetic Langmuir model for competitive multi-component sorption [3].



(a) Sensor load at $t = 70$ sec (b) Sensor load at $t = 120$ sec

Figure 2: Simulation results at the activated surface of a bi–solute system: Adsorption of species A and B illustrated separately and combined. Fluid flows from left to right over the sensor.

Figure 1 shows an experimental setup of a Y-shaped channel with one component adsorbing on an activated surface. Figure 2 illustrates the spatio-temporal patterns of competitive sorption for the same setup, now in a bisolute system. Due to competition the occupancy pattern is much more complex than that of non-competitive single-solute sorption (compare Figure 1): Species A has a lower diffusion rate than B but a larger surface affinity. They are transported with the upper and lower parallel stream, respectively. Initially, both species are mainly adsorbed in the region of their stream. However, desorption of species A later becomes more significant, allowing for a displacement by species B in the upper sensor region. This phenomenon is due to a combination of interdiffusion and competitive adsorption, and requires simulations for the differentiated interpretation of sensor loads as well as for rational design of sensor position and size.

The implemented simulator was applied for the analysis of competitive adsorption of species from two parallel streams of a liquid to an activated surface, for instance in competitive binding assays. Similar set-ups allow to analyze sorption of arbitrary many competing species in systems of microchannels with embedded sensors. The determination of sensitivity characteristics will help to optimize sensor performance. Furthermore, the model geometry can easily be altered such as to analyze miniaturized chromatography systems.

REFERENCES

[1] R.M. Winz, A. de los Ríos Gonzalez, E. von Lieres, M. Schmittel, W. Wiechert. "Simulation of a Micro-Analytical Device for Adsorbing Substances from a Fluid", *in Proceedings of the European Comsol Conference, Grenoble, 2007, edited by J.–M. Petit and O. Squalli*, Vol. **2**, 736–741, 2007.

[2] M. Schmittel, R.S.K. Kishore, and J.W. Bats. "Synthesis of Supramolecular Fullerene-Porphyrin-Cu(phen)2-Ferrocene Architectures. A Heteroleptic Approach towards Tetrads". *Organic and Biomolecular Chemistry*, Vol. **5**, 78-86, 2007.

[3] A.W. Adamson. *"Adsorption of Gases and Vapors on Solids"*. in Physical Chemistry of Surfaces. 6th ed. New York, NY: John Wiley and Sons; 1997:605.