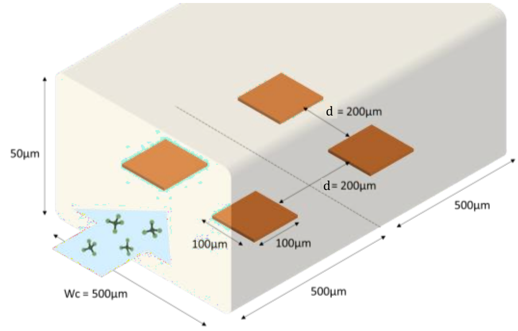
SESSION 4: DESIGN OF A MICROFLUIDIC ANALYTICAL SYSTEM

Exercise 1.

This exercise focuses on the following paper:

Squires, T. M., Messinger, R. J., & Manalis, S. R. (2008). Making it stick: convection, reaction and diffusion in surface-based biosensors. Nature Biotechnology, 26(4), 417–426. http://doi.org/10.1038/nbt1388

Four sensors are arranged in a 2x2 array at the center of the bottom of a microfluidic channel. The distance between the sensors is 200 µm. The sensors are square shaped and their dimensions are: 100 µm × 100 µm. The channel is 1 mm long, 50 µm high and 500 µm wide. The sensors are used to detect a target molecule whose typical MW (molecular weight) is 40’000 g/mole.



Non-specific signal:

The solution containing the target molecules contains also a number of proteins and other non-specific molecules. When the sample solution is driven in the channel where the sensors are placed, the non-specific molecules bind to the surface with a surface density of 10^{10} molecules/cm^2. The MW of the non-specific molecules is on average 60’220 g/mole.

1.a Calculate the overall mass of non-specific molecules on the surface of one single sensor.

The same concentration of these non-specific molecules is found for any target molecule concentration used. This means that the sensors will be subjected to the same non-specific signal at any measurement taken (i.e. for all concentrations of target molecules):

1.b How would you take this type of signal into account in the calibration curve of one sensor?

Depletion region and Péclet numbers:

Consider no convection effects in the channel or a very slow flow rate. If the target molecules have a diffusion coefficient of 102 µm^2/s:

1.c Calculate the time for the depletion region to extend, first, over the entire height of the channel and subsequently, along the entire length of the channel.

1.d Given a flow rate of 2 µL/s, calculate the Péclet numbers Pe_H and Pe_s of the system.

Given a concentration of target molecules of c_0=10 nM, a dissociation constant (K_D) of 1 nM, and a maximum density of target molecules on the surface (Γ_0) equal to 5×10^{11} target molecules/cm^2:

1.e Calculate the collection rate on one sensor (J_D) and the theoretical density of target molecules at equilibrium (Γ_{eq}).

1.f Calculate the minimum time needed to reach equilibrium disregarding the specific reaction kinetics.