Effect of Area of the Reaction Surface on the Capture Efficiency of Immunosensors

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Abstract

With the progress of immunosensing technology, the detection of diseases at early stages is feasible using surface based heterogeneous immunosensors [1]. Literature contains few reports where it is verified that reaction spot of smaller size leads to high fractional occupancy of targets, specifically applicable to the microarray technology [2]. Such enhancement in capture efficiency by the concept of miniaturization can be crucial while designing sensors. The present work is undertaken to study the effect of size of the reaction patch on the capture efficiency of heterogeneous immunosensors for the detection of prostrate specific antigens.

USE OF COMSOL MULTIPHYSICS®: The transport and reaction equations were solved to model the detection of PSA molecules in COMSOL Multiphysics using the finite element method. Two physics interfaces namely "transport of diluted species" and "surface reaction" were used, and we have used the "PARDISO" solver in the minimal residual iterative mode.

RESULTS: The amount of PSA captured was quantified for the patches of radii from 0.5 mm to 3.5 mm sequentially. Figure 1 shows capture efficiency as a function of size of reacting patch and with the variation of different values of diffusivity, where other parameters remain constant. The plot shows the capture efficiency decreases with increase in the area of the reaction patch. We obtained maximum efficiency, around 27% for the smallest patch having radius 0.5 mm and the least efficiency, around 17% for the largest patch of radius 3 mm, for a D value of 16e-11. The novelty of our work lies in the fact that we have obtained a uniform distribution of the concentration of the capture (antibodies) molecules immobilized experimentally, and we have solved the model by considering uniform surface density of reacting sites (immobilized antibodies). In order to understand the mechanism of the monotonic increase in the capture efficiencies with decrease in the radial size, we further explore the model and conduct parametric study on important transport, reaction, and geometrical parameters. One of the representative plots for the effect of D has been shown in figure 1, and it is observed that with increase in diffusivity curves shifts towards right, equivalently the efficiency obtained at larger path size for higher D can be obtained for smaller patch size for lower value of D.

CONCLUSION: In the present work, we have obtained the capture efficiencies of the heterogeneous immunosensors as a function of the radial size of the reaction patch. Since the governing equations indicate a dependency of the capture efficiency on the transport, reaction and geometric parameters, we obtained parametric variations with D, KD and R. This is useful in

the design of the heterogeneous immunosensors to detect PSA, and can for the design of microfluidic immunosensors.

Reference

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