Electrofluidic Self-Assembly with Molecular Control of Orientation

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We have developed a technique for assembling nano-scale molecules with controlled orientation on solid-state surfaces using electric field. This self assembly method can be used for enhancement of sensitivity of both affinity based biosensors and probe-free sensing platforms and even self assembly of metallic nanoparticles for plasmonic substrates. In this presentation we discuss our use of this technique for assembly of protein molecules. Using atomic force microscopy we verified that electric field modulates antibody (IgG molecules) orientation. In addition to this, we also will discuss how we apply this technique to improving the performance of fluorescent affinity biosensors.

Previously Talasaz et. al. [1] developed a modeling tool for predicting protein orientation and showed that the orientation during immobilization is affected by the intrinsic electric field at the surface of a sensor due to the debye layer. Our focus here was to exploit the dipole property of IgG and the fact that it can be oriented with field.

We use microfabricated rectangular microchannels as our testbed to generate a uniform electric field and study the behavior of the immobilized antibodies. During the step where we physically adsorb antibodies to the base of the channel, we apply an electric field across the channel. Ag-AgCl electrodes at the inlet and outlet ports of the microchannel were excited with DC voltages. Using atomic force microscopy (AFM), we characterized the orientation of the antibodies on the surface. Our results show that the application of electric field results in uniform orientation and lining up of the antibodies during self-assembly on the surface. When electric field is off, the molecules become randomly oriented on the surface.

In this talk, we will also discuss how we used this method to improve biosensor sensitivity for affinity-based sensors [2-8]. In this class of sensors, the probe protein has specific sites or epitopes where binding occurs. Probe antibody orientation during immobilization onto the surface affects efficiency of target analyte capture. As an example, we studied the interaction of fluorescently tagged (FITC) anti-IgG with surface immobilized IgG, where only the immobilization process is controlled by electric field. Our study demonstrates that the use of electric field can result in up to 40X enhancement in signal to noise ratio compared to normal physical adsorption. The improvement in sensitivity results from favorable orientation of the antibody.

This method has shown promise for improving sensitivity in affinity based immunosensors, but also has potential capability for improving performance of probe-free sensors[8]. Additionally, this technique can be used for fabricating various biomaterials and even control of protein adsorbtion kinetics during assembly. This can also be a promising approach for depositing nanostructructures (nanotubes, nanorods, nanowires) on solid-state surfaces with controlled orientation, opening up a new horizon for bottom-up nanofabrication.

References

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