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Colloid-Based Biodetection at Aqueous Electrical Interfaces Using Fluidic Dielectrophoresis

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Abstract : Portable diagnostic methods have become increasingly important for a number of different purposes: point-of-care screening in developing nations, environmental contamination studies, bio/chemical warfare agent detection, and end-user use for commercial health monitoring. The cheapest and most portable methods currently available are paper-based – lateral flow and dipstick methods are widely available in drug stores for use in pregnancy detection and blood glucose monitoring. These tests are successful because they are cheap to produce, easy to use, and require minimally invasive sampling. While adequate for their intended uses, in the realm of blood-borne pathogens and numerous cancers, these paper-based methods become unreliable, as they lack the nM/pM sensitivity currently achieved by clinical diagnostic methods. Clinical diagnostics, however, utilize techniques involving surface plasmon resonance (SPR) and enzyme-linked immunosorbent assays (ELISAs), which are expensive and unfeasible in terms of portability. To develop a better, competitive biosensor, we must reduce the cost of one, or increase the sensitivity of the other. Electric fields are commonly utilized in microfluidic devices to manipulate particles, biomolecules, and cells. Applications in this area, however, are primarily limited to interfaces formed between immiscible interfaces. Miscible, liquid-liquid interfaces are common in microfluidic devices, and are easily reproduced with simple geometries. Here, we demonstrate the use of electrical fields at liquid-liquid electrical interfaces, known as fluidic dielectrophoresis, (fDEP) for biodetection in a microfluidic device. In this work, we apply an AC electric field across concurrent laminar streams with differing conductivities and permittivities to polarize the interface and induce a discernible, near-immediate, frequency-dependent interfacial tilt. We design this aqueous electrical interface, which becomes the biosensing “substrate,” to be intelligent – it “moves” only when a target of interest is present. This motion requires neither labels nor expensive electrical equipment, so the biosensor is inexpensive and portable, yet still capable of sensitive detection. Nanoparticles, due to their high surface-area-to-volume ratio, are often incorporated to enhance detection capabilities of schemes like SPR and fluorimetric assays. Most studies currently investigate binding at an immobilized solid-liquid or solid-gas interface, where particles are adsorbed onto a planar surface, functionalized with a receptor to create a reactive substrate, and subsequently flushed with a fluid or gas with the relevant analyte. These typically involve many preparation and rinsing steps, and are susceptible to surface fouling. Our microfluidic device is continuously flowing and renewing the “substrate,” and is thus not subject to fouling. In this work, we demonstrate the ability to electrokinetically detect biomolecules binding to functionalized nanoparticles at liquid-liquid interfaces using fDEP. In biotin-streptavidin experiments, we report binding detection limits on the order of 1-10 pM, without amplifying signals or concentrating samples. We also demonstrate the ability to detect this interfacial motion, and thus the presence of binding, using impedance spectroscopy, allowing this scheme to become non-optical, in addition to being label-free.

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