Coupling AC dielectrophoresis with DC ion concentration polarization in nanochannels for ultrafast biomarker enrichment

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The charge selective transport characteristics at the entrance of nanochannels under conditions of ion concentration polarization (ICP) that arise due to the non-linearities in surface charge and field can cause sharp field gradients. In prior work these field gradients have been combined with electro-osmosis or electrophoresis, to cause exceptionally high degrees of biomarker enrichment [1]. However, since the trapped biomarkers are co-localized within a tightly confined region, the degree of selectivity is limited [2]. Dielectrophoresis (DEP) enables highly selective trapping of bio-particles based on the characteristic frequency response of the dielectric permittivity of the bio-particle versus that of the medium, and can be applied in principle towards frequency-selective biomarker enrichment [3]. However, DEP of nanoscale biomarkers is limited by the cube-fold drop in trapping force with particle radius and its disruption by electrothermal flow due to localized Joule heating within physiological media of high conductivity. While micro- and nanoscale constrictions can enhance the local field to enable frequency-selective trapping of ss-DNA [4] and proteins [5, 6] in physiological media, the highly localized nature of DEP behavior limits the spatial extent of biomarker depletion. Herein we explore the coupling of DEP behavior with concentration polarization for enhancing the spatial extent of biomarker depletion and thereby cause ultra-fast biomarker enrichment. We elucidate how the surface charge assymetry under DC fields within a nano-constriction device can be enhanced within physiological media through the application of AC fields to cause localized accumulation of counter-ions, thereby driving the ultra-fast enrichment of dielectrophoretically trapped biomarkers. This methodology has been applied towards enhancing the detection sensitivity of streptavidin, prostate specific antigen and neuropeptides [7].

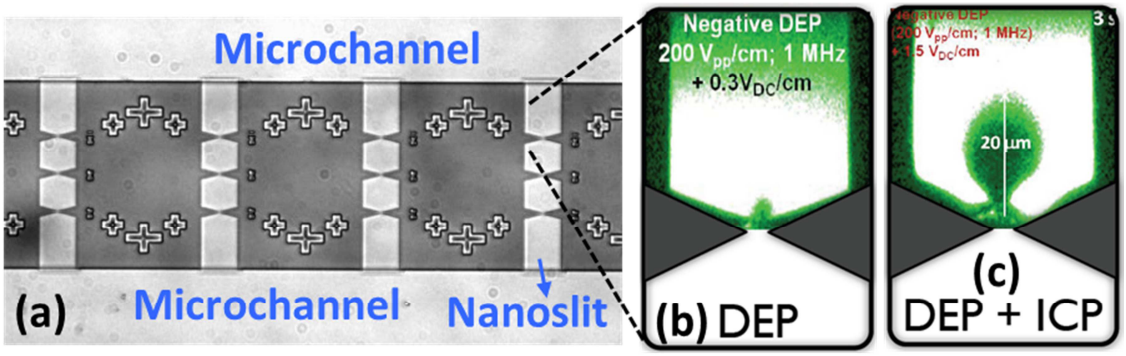


Figure 1: (a) Nano-slit channel with 50 nm constrictions; (b) DEP (200 V_{pp}/cm, 1 MHz) plus sub-critical DC field; (c) DEP with a critical DC field of 1.5 V/cm to initiate ion concentration polarization (ICP).

References

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