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Microfluidic particle trapping and separation using combined hydrodynamic and electrokinetic effects

Fernandez Poza, Sergio

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Summary (English)

This thesis describes a new methodology for particle trapping and fractionation using flow-induced electrokinetic trapping (FIET). FIET is a particle-trapping mechanism that relies on bidirectional, recirculating flow profiles generated by opposition of pressure-driven (PF) and electroosmotic (EOF) flows in straight channels that expand at both ends. Micrometer-sized particles are captured in the closed recirculating streamlines and fractionated according to differences in surface charge (zeta potential, ζ) and size.

First, the behavior of trapped particles inside the straight, narrow channel was characterized under conditions of constant pressure and varying applied voltage. For this, we propose a Gaussian model that accurately describes the spatial distribution of particles along the trapping channel length as a function of the applied voltage. This model provides valuable information about the trapping process, such as the range of applied voltage within which particles of a particular size and charge are caught inside the channel and the specific voltage at which a maximum number of particles experience trapping. FIET enrichment of polymer particle suspensions is also evaluated using the optimal trapping parameters determined experimentally.

Second, we evaluate the implementation of this distribution model for quantitative fractionation of binary mixtures of polymer microparticles in FIET microfluidic channels. For this, particle distributions of beads having different size or charge were registered as a function of applied voltage. A comparison of the fractionation capacity for each mixture was subsequently conducted at different applied pressures based on the acquired distribution curves. Particles having different sizes exhibited better separation rates (clearer collected fractions for both particle types) at lower applied pressures, whilst particles having different zeta potentials could be fractionated at higher pressures. This fact evidenced a clear distinction between two well-defined mechanisms (hydrodynamic and electrokinetic) co-existing in the FIET process.

Lastly, the applicability of this model is further extended to the fractionation of ternary mixtures of particles having different size and zeta potential. The synergistic exploitation of the hydrodynamic and electrokinetic mechanisms described above was

accomplished by a stepwise increasing voltage program applied at two different pressures. Two separation dimensions were clearly revealed, with one based on size, and the other based on charge. The simultaneous occurrence of these two mechanisms in the same FIET microfluidic device leads to a unique orthogonality, described here for the first time in the realm of microfluidic particle separations.