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RESEARCH PAPER

# Simultaneous electrokinetic flow and dielectrophoretic trapping using perpendicular static and dynamic electric fields

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**Abstract** Microfluidics is a rapidly growing field that offers great potential for many biological and analytical applications. There are important advantages that miniaturization has to offer, such as portability, shorter response times, higher resolution and sensitivity. There is growing interest on the development of microscale techniques. Among these, electrokinetic phenomena have gained significant importance due to their flexibility for handling bioparticles. Dielectrophoresis (DEP), the manipulation of particles in non-uniform electric fields due to polarization effects, has become one of leading electrokinetic techniques. DEP has been successfully employed to manipulate proteins, DNA and a wide array of cells, form bacteria to cancer. Contactless DEP (cDEP) is a novel dielectrophoretic mode with attractive characteristics. In cDEP, non-uniform electric fields are created using insulating structures and external electrodes that are separated from the sample by a thin insulating barrier. This prevents bioparticle damage and makes cDEP a technique of choice for many biomedical applications. In this study, a combination of cDEP generated with AC potentials and electrokinetic liquid pumping generated with DC potentials is employed to achieve highly controlled particle trapping and manipulation. This allows for lower applied potentials than those used in traditional insulator-based DEP and requires a simpler sytem that does not employ an external pump. This is the first demonstration of electrokinetic (EK) pumping in which the driving electrodes are not in direct contact with the sample fluid. Multiphysics simulations were used to aid with the design of the system and predict the regions of particle trapping. Results show the advantages of combining AC-cDEP with DC EK liquid pumping for dynamic microparticle trapping, release and enrichment.

**Keywords** Microfluidics · Numerical model · Electrokinetic micropump · Electro-osmosis · Contactless dielectrophoresis

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## 1 Introduction

Microfluidics is rapidly becoming the tool of choice for many complex biological applications. The small length scale allows for high control over convection and diffusion transport, reduced volumes decrease the quantity of sample and reagents consumed, and higher resolution and sensitivity are obtained. The low Reynolds number due to device dimensions ensures laminar flow in all, but the most extreme circumstances. This produces predictable flow patterns that are ideal for separations and analysis, since low to negligible mixing is induced (Whitesides 2006).

Electrokinetic (EK) techniques are one of the main pillars of microfluidics as analytical systems. These techniques have great potential for handling bioparticles, from macromolecules to cells. Isotacophoresis and isoelectric focusing have found important applications in protein separations (Ugaz and Christensen 2007). One important