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A Bioparticle Detection Platform using Integrated Insulator-Based Dielectrophoresis and Bioimpedance Measurements

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Abstract

We have developed a bioparticle detection platform which combines insulator-based dielectrophoresis (iDEP) with impedance feedback. The system allows for particles to be continuously and selectively accumulated while electrical responses of the suspension at the trapping site are recorded. The operating conditions for trapping are determined by the physical and electrical properties of the target particle type. Recordings of phase offset, relative to the reference sensing signal, act as the principal monitoring signals. Fluctuations in these measurements determine the presence and concentration of contaminants. We demonstrate and discuss results obtained from the manipulation of fluorescent beads and viable *B. subtilis* spores.

Introduction

Applications that detect microbiological particles must be sensitive to very dilute concentrations. This is especially crucial in systems used for detecting deadly pathogens. This system can process extremely dilute samples by accumulating particles prior to detection through analysis of impedance measurements.

Particle/Solution Interaction

The presence of microparticles in solution affects the electrical properties of the bulk suspension. This phenomenon can be exploited for trapping and detection.

$$f(n) := \frac{n \cdot V_c}{V} \qquad \frac{\sigma_e - \sigma}{2\cdot\sigma_e + \sigma} = f(n)\cdot\frac{\sigma_e - \sigma_p}{2\cdot\sigma_e + \sigma_p}$$

σ_e: *Effective conductivity of trap* — σ_p: *Conductivity of particle*

σ: *Solution conductivity* — f(n): *particle:solution volume ratio*

V_C: *Volume of particle* — V: *Volume of trap*

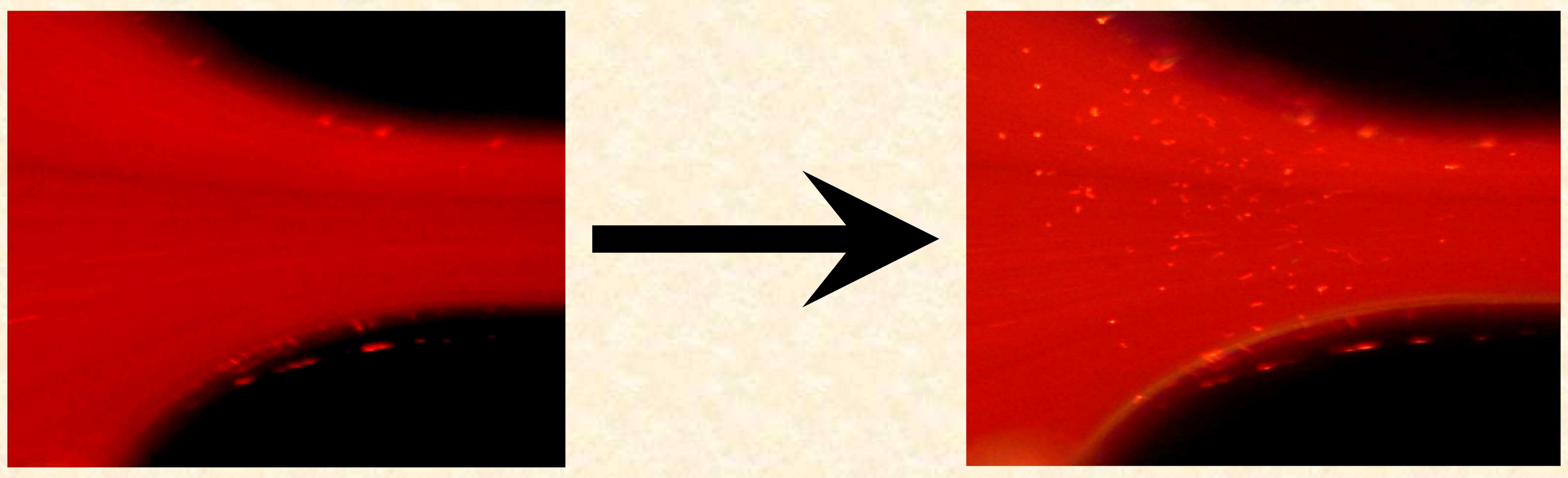
Insulator-based Dielectrophoresis

Trapping occurs when DEP attractive force overcomes other forces applied onto the particles. *iDEP* works by inducing this force when a DC electric field is applied across an array of insulating structures.

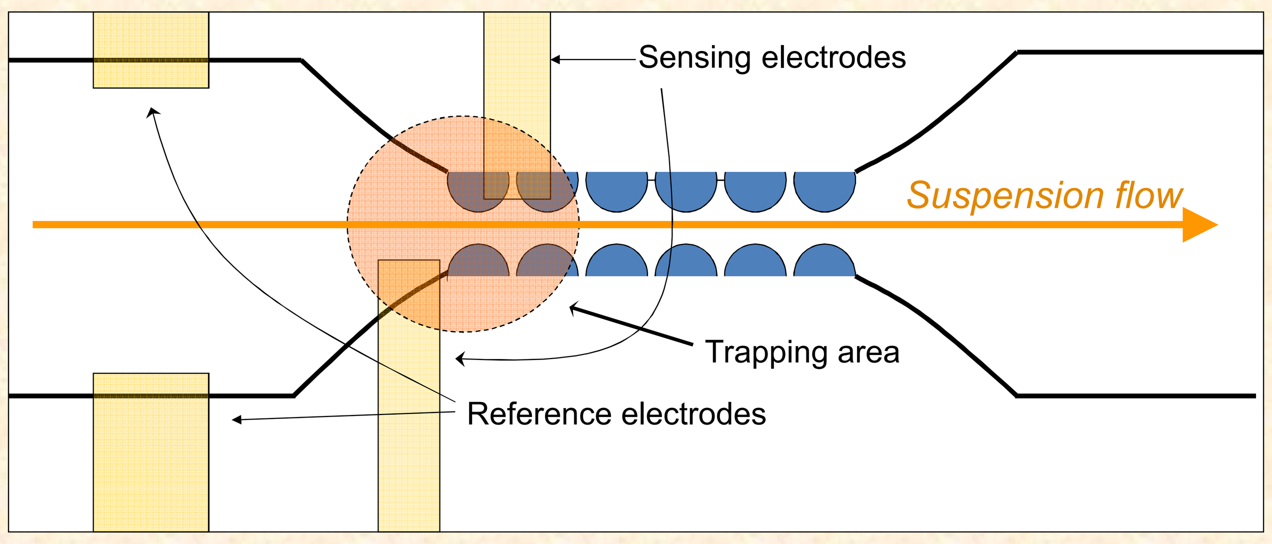
$$F_{DEP} = 2\pi\varepsilon_0\varepsilon_m r^3 \,\mathrm{Re}\left\{\frac{\sigma_e - \sigma}{2\sigma_e + \sigma}\right\}\nabla(E\cdot E)$$

r: *particle radius* — E: *electric field*

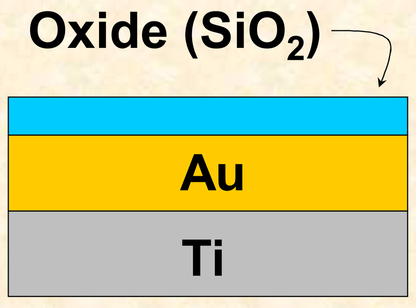
Particles (2-µm fluorescent beads) are shown here being trapped and concentrated through iDEP as solution flows.

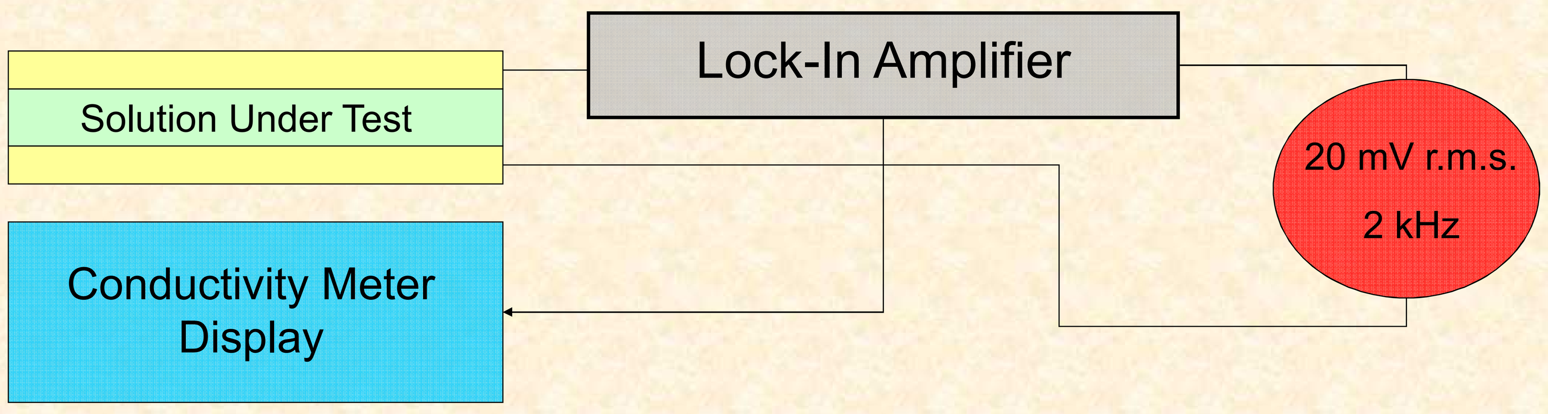


System Overview

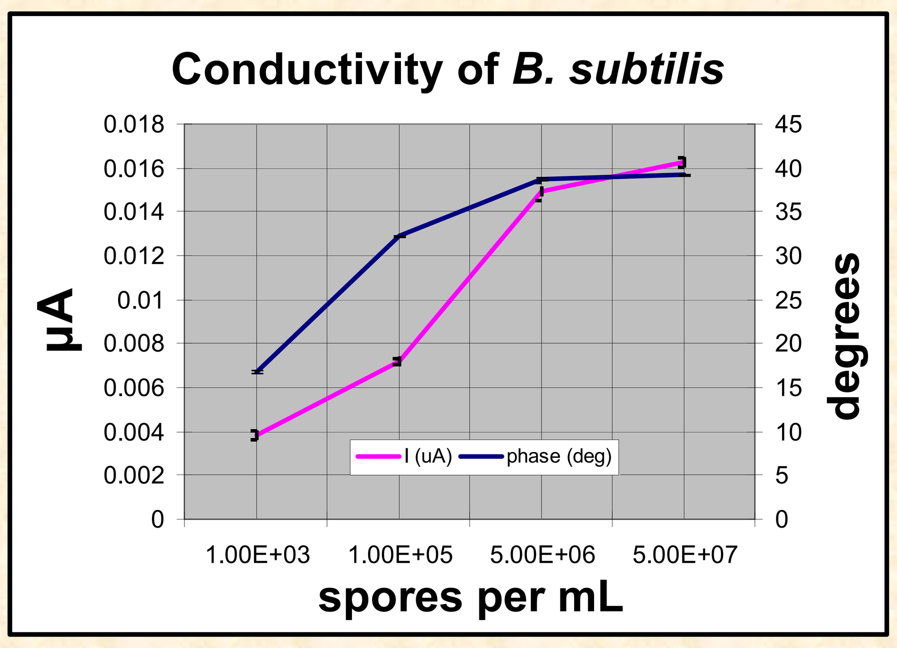


Electrodes in the detection area are passivated with SiO_2 to prevent air bubble formation in the fluid samples.





Different concentrations of B. subtilis were tested to obtain impedance profiles. Phase offset measurements reliably correlated with larger densities of bacterial spores.



Conclusions and Future Work

Detection with impedance feedback allows for very dilute concentrations of particles to be detected reliably by measuring relative phase offsets. Increased concentrations of spores correlated to higher phase offset. This enables the capability of estimating spore concentration through impedance measurements. System improvements through design of differential circuits, alternative geometries for insulating structure arrays, and frequency dependencies in detection are currently in progress.

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