Study on a Ring-shaped Interdigitated Electrode Controlled by AC Electrokinetic for Concentrating Bio-particles

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Introduction

1. When the AC voltage is applied to the electrode, the bacteria in the sample will be dragged to the center of the electrode by AC electroosmotic flow (ACEO).
2. From the results, samples (~100 µL) were dropped on the micro-concentrator platform, and applied an appropriate AC voltage and frequency. Escherichia coli (E. coli) were dragged toward the center of the electrode and adsorbed on the electrode due to the interaction of AC electroosmotic flow and dielectrophoretic force.
3. In the future, the platform may be applied to the low concentration detection, such as rapid test on urinary tract infection, etc.

System configuration

Different Concentration of E. coli

Sample: 100 µL E. coli (ATCC 25922)
Buffer: 300 mM sucrose solution (conductivity: 2 µS/ cm)
Voltage: 120 Vpp
Frequency: 1 kHz
Time: 10 min

Different Capture Time of E. coli

Sample: 100 µL E. coli (ATCC 25922)
Buffer: 300 mM sucrose solution (conductivity: 2 µS/ cm)
Voltage: 120 Vpp
Frequency: 1 kHz
Concentration: 10^6 CFU/mL

Theory of Dielectrophoresis Force (DEP)

\[ F_{DEP} = 2 \pi \alpha^3 \varepsilon_a \text{Re} \left[ f_{CM} \right] V E^2 \]

\[ f_{CM}(\omega) = \frac{\varepsilon_p - \varepsilon_m}{\varepsilon_p + 2\varepsilon_m} \]

\[ \text{Re} \left[ f_{CM}(\omega) \right] = \frac{(\sigma_p - \sigma_m)}{(1 + \omega^2 \tau^2)(\sigma_p + 2\sigma_m)} + \frac{\omega^2 \tau^2 (\varepsilon_p - \varepsilon_m)}{(1 + \omega^2 \tau^2)(\varepsilon_p + 2\varepsilon_m)} \]

Theory of AC Electroosmosis (ACEO)

\[ \nu_{EOF} = \frac{1}{8} \frac{\varepsilon_m V_0^2 \Omega^2}{\eta \pi (1 + \Omega^2)^2} \]

\[ \Omega = \frac{\varepsilon_m}{\sigma_m} \frac{\pi}{2} \kappa \]

\[ F = -qE_i \]

\[ F = qE \]

Ring-shaped Interdigitated Electrode (RIDE) Design

Conclusions

1. We proposed a novel microfluidic system combining AC electrokinetic and image analysis for highly concentration and quantitation of bacteria.
2. The difference concentration of bacteria such as Vibrio and E. coli could be distinguished (from 10^6 to 10^4 CFU/mL) in few minutes.
3. For aquaculture, the result of quantification of bacteria from circulating water system by using RIDE system compared with conventional method are all less than 10^6 CFU/mL.