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Microfluidic Device for Real-Time Electrical Impedance Measurements of Biological Cells

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Abstract : Dielectric spectroscopy (DS) is a noninvasive, label free technique for a long term real-time measurements of the impedance spectra of biological cells. DS enables characterization of cellular dielectric properties such as membrane capacitance and cytoplasmic conductivity. We have developed a lab-on-a-chip device that uses an electro-activated microwells array for loading, DS measurements, and unloading of biological cells. We utilized from dielectrophoresis (DEP) to capture target cells inside the wells and release them after DS measurement. DEP is a label-free technique that exploits differences among dielectric properties of the particles. In detail, DEP is the motion of polarizable particles suspended in an ionic solution and subjected to a spatially non-uniform external electric field. To the best of our knowledge, this is the first microfluidic chip that combines DEP and DS to analyze biological cells using electro-activated wells. Device performance is tested using two different cell lines of prostate cancer cells (RV122, PC-3). Impedance measurements were conducted at 0.2 V in the 10 kHz to 40 MHz range with 6 s time resolution. An equivalent circuit model was developed to extract the cell membrane capacitance and cell cytoplasmic conductivity from the impedance spectra. We report the time course of the variations in dielectric properties of PC-3 and RV122 cells suspended in low conductivity medium (LCB), which enhances dielectrophoretic and impedance responses, and their response to sudden pH change from a pH of 7.3 to a pH of 5.8. It is shown that microfluidic chip allowed online measurements of dielectric properties of prostate cancer cells and the assessment of the cellular level variations under external stimuli such as different buffer conductivity and pH. Based on these data, we intend to deploy the current device for single cell measurements by fabricating separately addressable N × N electrode platforms. Such a device will allow time-dependent dielectric response measurements for individual cells with the ability of selectively releasing them using negative-DEP and pressure driven flow.

Keywords : microfluidic, microfabrication, lab on a chip, AC electrokinetics, dielectric spectroscopy
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