GRADUAL CAPACITANCE FOR PARTICLE TRACKING IN MICRO-CHANNELS

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ABSTRACT

Here we report a new technique to detect the position of cells/particles using impedance spectroscopy in micro-channels by applying a gradual capacitance in a parallel electrode array. With this technique, both the 2D position and the dielectric properties of the particles can be measured. For validation, a microfluidic chip with a gradual capacitance was fabricated experimentally demonstrating its feasibility.

KEYWORDS: Particles tracking, Impedance spectroscopy, Gradual capacitance, Microfluidics

INTRODUCTION

Tracking the position of cells and particles in micro-channels is of great importance, amongst others, to characterize microfluidic separation techniques and track the cell position in cytometry studies [1]. Normally, the position of cells is investigated by optical means which provides a low throughput and it is very computing power consuming. Recently, 3 different approaches have used impedance spectroscopy (IS), which allows high throughput analysis, to track the position of cells/particles in one axis [2-4]. Here, we present a system that uses two parallel electrodes to detect the position of particles in one axis using a gradient in capacitance at both electrodes. Our technique differs from others because, first, it uses the impedance information at low frequencies which normally is ignored in cytometry studies and second, it allows both cells/particles position detection and dielectric properties analysis at lower ($\approx 10^3$ Hz) and higher frequencies ($\approx 10^5$ Hz) respectively. At lower frequencies, the electrode's double-layer capacitance dominates the overall impedance, whereas at higher frequencies, the dielectric properties of the medium plus particle are dominant. Figure 1 shows electric field lines of a 2D simulation at 2 different frequencies of two parallel electrodes with a gradient in capacitance, showing that at lower frequencies the non-homogeneous electric field allows for the position detection while at higher frequencies the electric field is homogeneous.

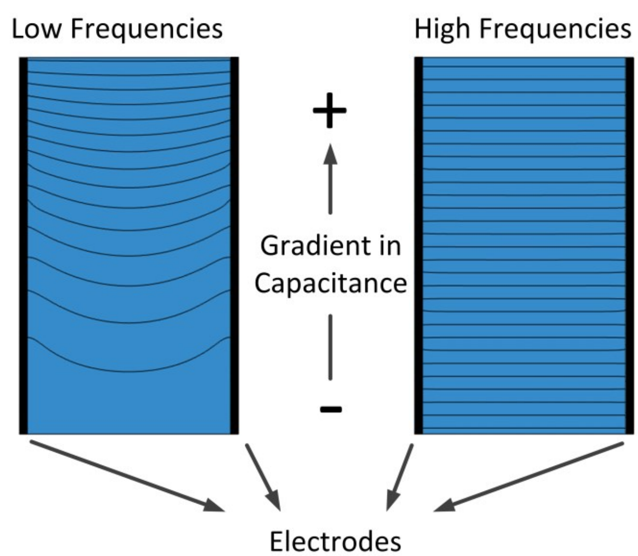

Figure 1. 2-D Comsol simulation at low and high frequencies of two parallel electrodes with a gradient in capacitance.

EXPERIMENTAL

In order to provide an experimental validation a glass-SU8-glass chip was developed using standard photolithography. Before bonding both wafers, the gradient in capacitance was developed by applying positive photoresist on both electrodes and exposing an increasing area along the axis of detection. Thereafter, the electrodes were cleaned by performing a cyclic voltammetry with a 0.1 M H_2SO_4 solution and subsequently electrodeposited with a 2.4 mM of H_2PtCl_4 and 0.8 mM $Pb(CH_3O_2)_2$ solution. Figure 2, shows the increasing effective area which provides an increasing capacitance along the same axis. Figure 2c shows the thickness of the porous layer being *≈1μm* which is less than *0.5%* of the total height of the channel.

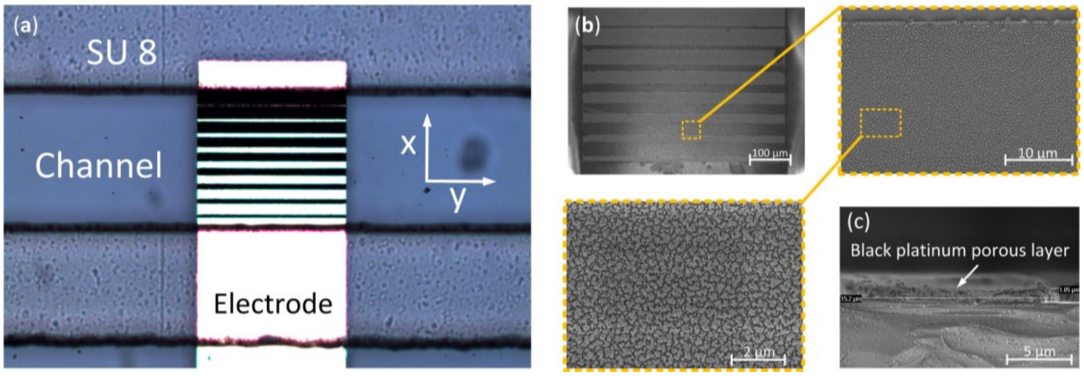

Figure 2. (a) Optical image of one of the electrodes electrodeposited with platinum-black, (b) SEM images of the electrode and porous layer and (c) perpendicular SEM image, thickness, of the black platinum.

RESULTS AND DISCUSSION

The trajectories of 80-µm polystyrene spheres were recorded with a camera and their impedance at lower and higher frequencies were measured. Figure 3 shows a typical experiment where two particles flow at two different positions in the channel. As can be seen, when a particle flows in the top region, the area with a larger capacitance and thus current density, the particle generates a larger impedance difference. On the other hand, when a particle flows in the lower region the impedance difference is smaller. Figure 4 presents the experimental difference in impedance when a particles flow between the electrodes at lower and higher frequencies showing the position dependence at lower frequencies. This position dependence is absent at higher frequencies. Also, Figure 4 shows a big spread of impedance which could be caused by small differences in particle's size or position in z-directions which was not tracked in this study.

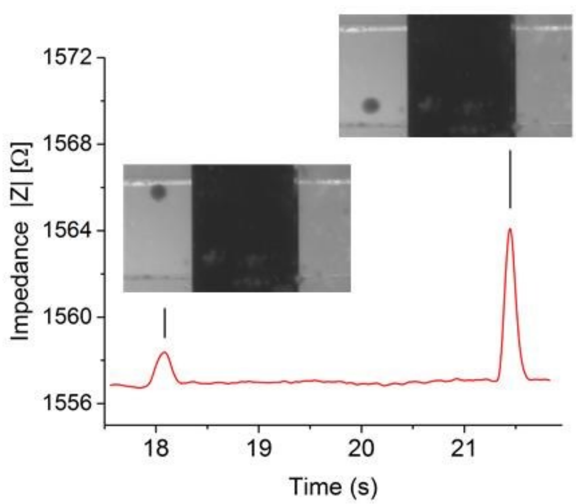

Figure 3. Experimental data of two particles passing at two different position of the channel at low frequencies.

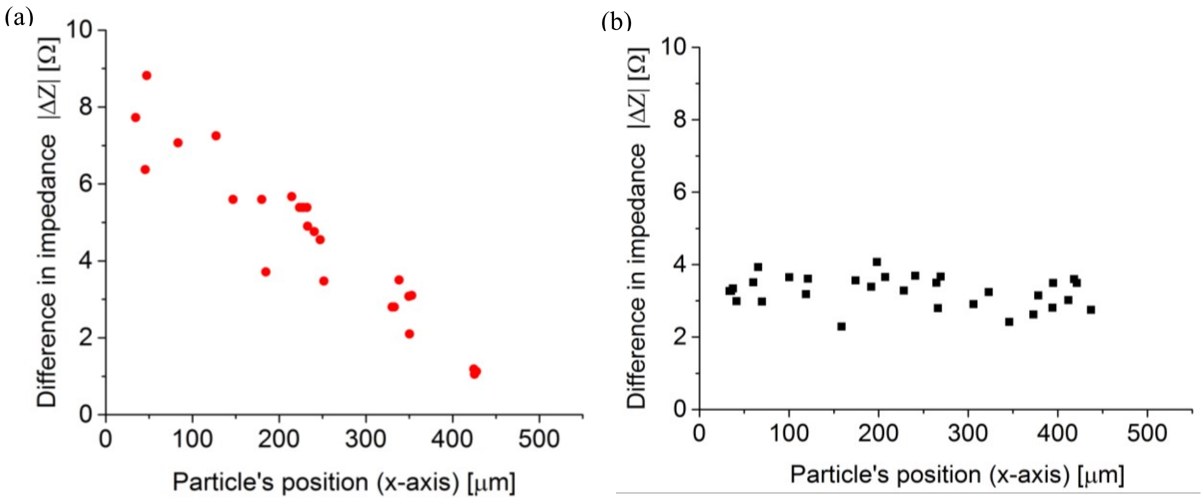

Figure 4. Experimental data (a) at low and (b) high frequencies of particles passing the parallel electrodes.

CONCLUSION

A new technique that uses a gradual capacitance to track microparticles in microchannels has been developed. This method has the extra benefit of measuring the dielectric properties of the system at higher frequencies. Experimental validation shows the feasibility of using this method to track the particles position however the spread in impedance difference is still big. Next steps will focus on detecting and measuring the position and dielectric properties of the same particles.

ACKNOWLEDGEMENTS

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