A novel coplanar layout enabling accurate microfluidic impedance cytometry

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Single-cell impedance cytometry is a non-invasive method for characterizing individual cells and particles [1, 2]. A microfluidic impedance chip typically consists of a microchannel equipped with microelectrodes and filled with a conductive buffer. An AC voltage is applied to a pair of electrodes, which causes a current to flow between them. The current change upon passage of a cell between the electrodes is measured and then analysed to determine cell properties. Coplanar chip layouts are especially attractive, because coplanar electrodes can be easily patterned yielding miniaturized, reproducible, and ultimately low-cost devices. However, their accuracy is challenged by the dependence of the measured signal on particle trajectory, which manifests itself as an error in the estimated particle size, unless any kind of focusing system is used.

The aim of this work is to present a new, easy-to-realize microfluidic impedance chip able to provide high-accuracy size estimation without the need for focusing [3, 4]. The device uses a chip with coplanar electrodes, and its operation mode is conceived such that a peculiar electric field distribution is generated within the sensing region. Consequently, the signal trace recorded upon the passage of a particle exhibits a characteristic shape, from which a new metric can be extracted correlating with particle trajectory height (Figures 1 and 2).

As proved by numerical and experimental campaigns, the new metric can be used to compensate for the spurious spread in the measured electrical size, thus achieving high accuracy (Figures 3 and 4).

The easiness of fabrication of coplanar electrodes coupled with the increased accuracy achieved by the proposed methodology make the resulting device a simple and effective tool for label-free particle analysis, with potential applications in medicine, life science and quality control.

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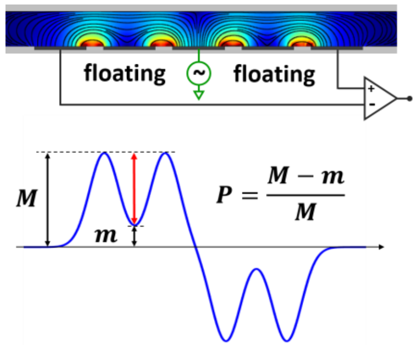

Figure 1. AC excitation signals are applied to the central electrode, and the difference in current flowing through the lateral electrodes is measured, with intermediate electrodes floating. Weak-field regions are generated in front of the floating electrodes, yielding a bipolar double-Gaussian profile of the measured current. The definition of relative prominence P is shown.

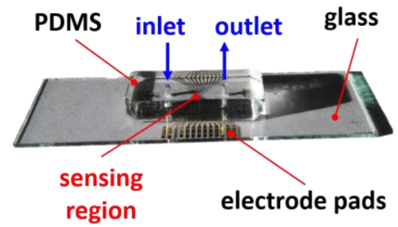

Figure 2. Microfluidic impedance chip, consisting of a PDMS fluidic top layer and patterned coplanar microelectrodes on glass. In the sensing region, the microchannel cross-sectional area is 40 µm (w) × 21 µm (h). The sensing electrode width is 30 µm, and the spacing between them is 10 µm.

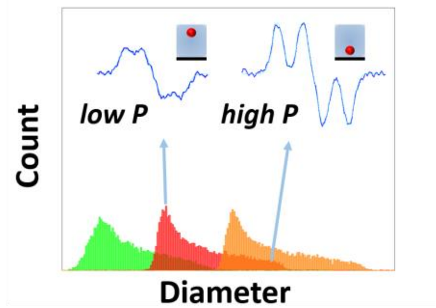

Figure 3. The histogram of the electrical diameters of 5 (green), 6 (red), and 7 (orange) um beads exhibit spread and asymmetry. Particles traveling near the electrodes (having high prominence P) provide larger diameters than particles traveling far from the electrodes (exhibiting low prominence P).

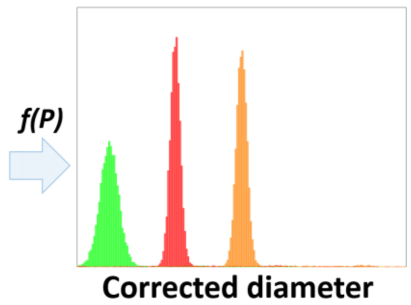

Figure 4. After applying a compensation procedure based on the relative prominence P, 5 (green), 6 (red), and 7 (orange) um beads exhibit low CV Gaussian electrical diameter distributions, and therefore can be properly discriminated by size.