Looking at cells with electric eyes

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We present an all-in-one electrical impedance-based platform for high-throughput single-cell monitoring and characterization [1]. The heart of the system is a microfluidic channel with embedded electrodes (Figure 1). An electric field is established in the channel and the field perturbations induced by flowing single cells are recorded in the form of electric current signals. The latter signals represent high-content electrical cell fingerprints from which multiparametric information can be extracted, embracing cell count, trajectory, velocity, size and membrane integrity. As illustrative examples, Figure 2 shows the optics-free monitoring of individual flowing red blood cells under different sheath flow conditions (namely, lateral or central focusing), whereas Figures 3 and 4 show red blood cell characterization in terms of electrical volume and opacity (which is an indicator of membrane integrity).

A number of potential application scenarios are envisioned for the proposed device. It could be an effective tool for studying microscale particle motion, for microfluidic sorting and separation applications, and for design and optimization of particle focusing systems. As an example, the proposed approach could be used to investigate viscoelastic focusing of particles and cells. The system, providing accurate cell sizing, is also suited for applications where cell size is a biomarker of underlying cellular processes. Examples include monitoring red cell distribution width (RDW) levels for early detection of cardiovascular and cerebrovascular diseases, as well as monitoring apoptotic cell death, formation of cell aggregates, and leucocyte activation or monocyte differentiation. Moreover, the device is simple from the microfabrication point of view, because it is based on a coplanar-electrode layout, and it is easy to operate, because no focusing mechanisms are required. Therefore, when coupled with a fully integrated electronics, it has the potential for point-of-care testing applications.

[1] R. Reale et al., Lab Chip (2019) doi: 10.1039/C9LC00071B.

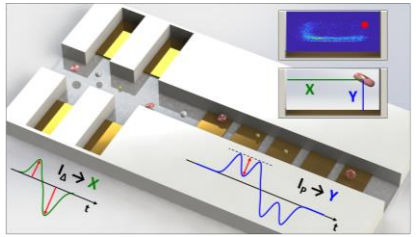

Figure 1. The microfluidic chip is formed by two regions: the first one comprises two pairs of coplanar electrodes housed in side-channels, the second one comprises five coplanar electrodes spanning the main channel width. By proper wiring, two differential current signals are acquired (I_Δ and I_P) yielding a high-content electrical cell fingerprint.

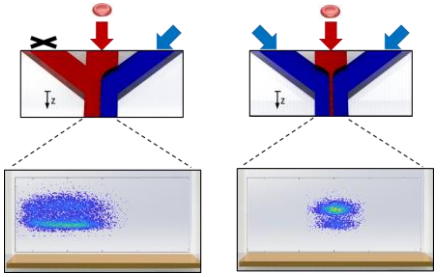

Figure 2. Optics-free monitoring of red blood cells hydrodynamic focusing under different sheath flow conditions (lateral focusing or central focusing). The cell distribution in the channel cross-section (50 µm x 21.5 µm) is visualized. It is noticed that the latter is obtained by an all-electrical approach (i.e., from the features of the signals I_Δ and I_P).

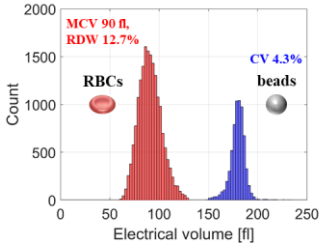

Figure 3. Histogram of electrical volume (in red and blue for erythrocytes and beads, respectively). The red blood cell distribution width (RDW) and mean corpuscular volume (MCV), which are important clinical biomarkers, are also reported.

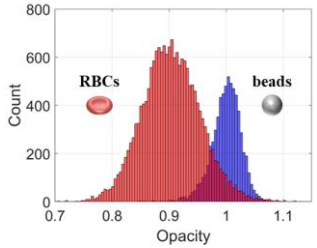

Figure 4. Histogram of electrical opacity (namely, the ratio between the electrical volume at high and low frequency). The opacity is lower for the erythrocytes than for the beads, which is consistent with the capacitive behaviour of an intact cell membrane.