Biomechanics of single cells using a microfluidic device to correlate transients of flow impedance and electrical impedance

O. Alalul[1]; J. Liu[2]; M. Böl[2]; A. Al-Halhouli [3] and A. Dietzel[1]

[1]Technische Universität Braunschweig, Institute of Microtechnology; Braunschweig (Germany)
[2]Technische Universität Braunschweig, Institute of Mechanics and Adaptronics, Braunschweig (Germany)
[3]German Jordanian University, Department of Mechatronics Engineering, Amman (Jordan)
osama.alalul@tu-braunschweig.de

Understanding cellular mechanics is fundamental for advancing developmental biology and reproductive medicine. However, conventional techniques such as atomic force microscopy and micropipette aspiration, while informative, are constrained by limited throughput [1]. To address this, we present a novel microfluidic device that enables real-time, impedance-based biomechanical characterization of single oocytes under flow. The system integrates three coplanar microelectrodes (E1, E2, E3) (Figure 1) within a constriction microchannel, allowing simultaneous mechanical deformation and electrical impedance measurement as cells transit through the chip. Impedance signals were acquired using a lock-in amplifier and current amplifier across a range of frequencies at 0.700 Vrms. Differential impedance readings between electrode pairs (E1–E2 and E2–E3) reflected variations in cell deformation and depth of penetration into the constriction channel. System calibration was performed using deformable hydrogel spheres, with impedance responses validated relative to distilled water. The use of SU-8-based microfluidic chips provided smooth channel surfaces and stable electrode performance, ensuring reproducibility and signal integrity under varying pressure conditions. This platform enables dynamic, label-free, and non-invasive assessment of oocyte biomechanics, establishing correlations between mechanical deformation and impedance responses. Unlike previous studies that focused on somatic cells, our system is specifically designed to accommodate the sensitivity of reproductive cells, broadening the applicability of impedance cytometry in reproductive biology. Our findings highlight the potential of this technique as a high-throughput screening tool for evaluating oocyte mechanical properties, with implications for diagnostics and assisted reproductive technologies.

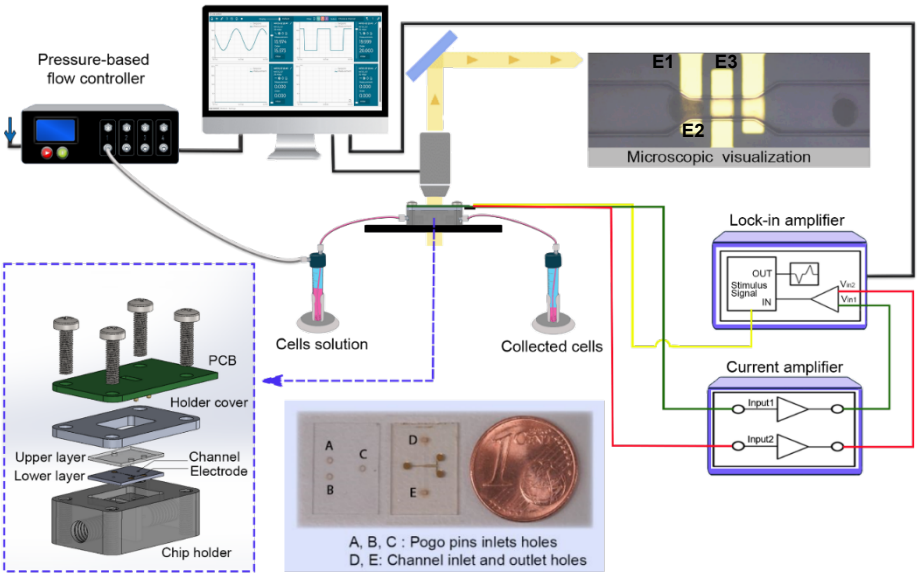

Figure 1: Schematic of the experimental setup.

References:

[1] Y. Chen, K. Guo, L. Jiang, S. Zhu, Z. Ni, and N. Xiang, "Microfluidic deformability cytometry: A review," Talanta, vol. 251, p. 123815, 2023, doi: 10.1016/j.talanta.2022.123815.