NUMERICAL AND EXPERIMENTAL CHARACTERIZATION OF A PIEZOELECTRIC ACTUATOR FOR MICROFLUIDIC APPLICATIONS

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Introduction

Microfluidic impedance cytometry [1] is increasingly used for the high-throughput label-free electrical characterization of single cells. Adding a cell-sorting functionality to impedance cytometry systems represents an attractive opportunity (Fig. 1(a)). This requires the development of tailored approaches for the online processing of impedance signals, coupled with a suitable microfluidic cell sorter. In this work, we present the numerical and experimental characterization of a sorting system based on piezoelectric actuation.

Methods

As shown in Fig. 1(b-c), the main channel of the microfluidic device is 150 µm wide, while the width of the three collection channels is 50 µm. Channels height is 40 µm. Two lateral regions are designed on the sides of the sorting region. One of them houses the actuator, that consists of a cylindrical chamber (13 mm diameter, 5 mm height) above which a circular ceramic transducer (lead zirconate titanate, PZT) is bonded. The PZT element has a diameter of 15 mm and a thickness of 110 µm, while its metal substrate (stainless-steel) is 20 mm in diameter and 100 µm thick.

To analyse the fluid flow and the particles displacement induced by the PZT actuation, a 3D finite element model of the device was implemented (Fig. 1(d)) based on: the linear theory of piezoelectricity, the Navier-Stokes equations for laminar incompressible flow, and the Khan and Richardson's model [2] for particle tracing.

Furthermore, an image-based approach was developed for the experimental characterization of particle deviation. Specifically, the time course of the rotation angle of the sample stream was automatically extracted from high-speed video recordings using a custom Matlab script.

Results

Figure 1(e) shows an example of the simulated displacement of the central point of the metal plate as a function of time, under voltage stimulation at 3 Hz and an inward flow rate of 10 µl/min at the main channel inlet (no sheath flows). The overall outward flow rate through the outlets is also reported.

Figure 1(f-g) shows an example of image-based characterization of the rotation angle of the sample stream.

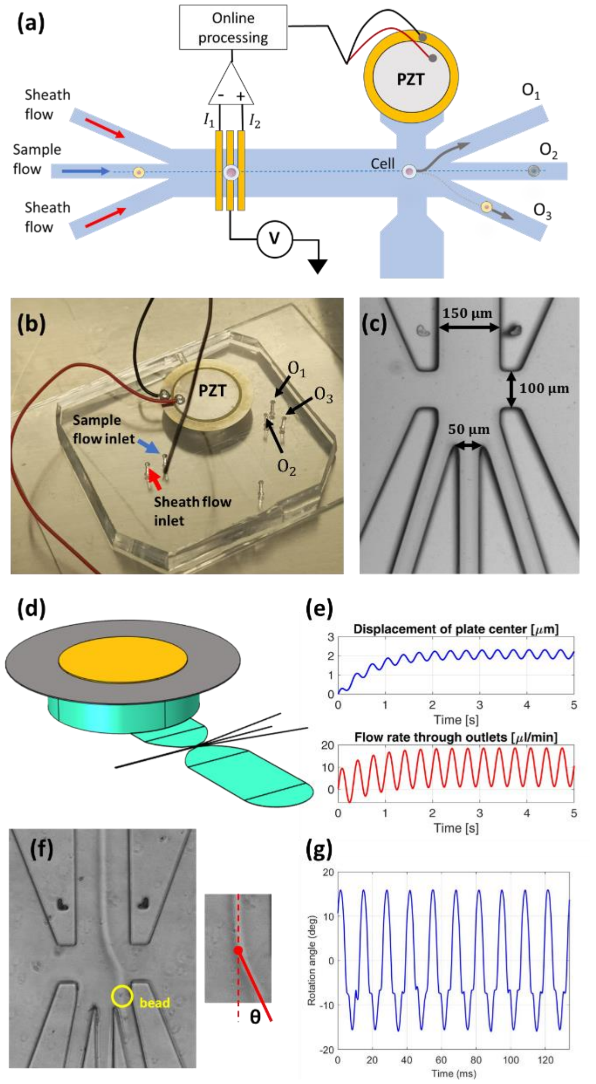

Figure 1: (a) Principle of impedance-based single-cell sorting. (b) Device photograph. (c) Microscopy image of the sorting region. (d) Model geometry. (e) Simulated displacement of plate central point (10 V, 3 Hz). (f) Microscopy snapshot showing an example of particle deviation (5 µm bead). (g) Rotation angle, θ, of the sample flow upon sinusoidal actuation (5 V, 75 Hz).

References

1. Honrado et al, Lab Chip, 21(1): 22–54, 2021.
2. Richardson et al, Chemical Engineering, vol. 2. 2013.

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