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A MICROFLUIDIC MAGNETIC HYBRID ACTUATOR FOR ADVANCED HANDLING FUNCTIONS AT CELL RESOLUTION

M. FOUET^{1,2*}, R. COURSON^{1,2}, X. DOLLAT^{1,2}, D. MÉDALE^{1,2}, A.-M. GUÉ^{1,2}

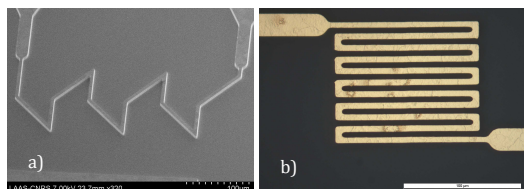
¹LAAS-CNRS, Toulouse, FRANCE

²Université de Toulouse, Toulouse, FRANCE

*email : mfouet@laas.fr

In microfluidics, the use of super-paramagnetic microparticles (SMPs) has experienced a dramatic increase over the last decade, but control of the magnetic field at micro scale is still a topical issue. Permanent magnets don't offer a programmable approach, external coils require a certain power, and neither are usually integrated. Coils were thus integrated to microfluidic chips, but obviously a limitation has been reached when it comes to the size of planar coils with five, ten or more turns: their use is generally in bulk mode rather than aiming for cellular resolution. Hybrid systems, which include external magnets to generate a high and homogeneous magnetic field, and integrated coils that produce a high gradient, are seemingly a promising way to reach a higher precision in magnetic actuation, not mentioning the forces they create on SMPs can be attractive or repulsive.

The goal of our work, for one part, is to develop a simple solution for the micro-fabrication of this kind of devices, but also to delve into the design possibilities, for instance to create a separation stage or investigate



more exotic functions like focusing (without leading to a dilution or an increase in the flow rate, unlike most hydrodynamic focusing techniques).

Figure 1: a) SEM image of a coil designed to perform focusing. b) Optical microscope picture of a micro fabricated shift register.

Common micro-technology processes (metallization and electro-chemical growth) have been used to create the coil (they are 5 μm wide and high wires). As for the microfluidic channels, two layers of low cost dry film (DF 10-20) were laminated then structured with photolithography. It is also important to stress that this technique (if piling more layers) can plainly lead to 3D microfluidic structures.

The experimental setup comprises a pressure controller for fluid handling, a bright field fluorescence microscope, an EMCCD camera, two rectangular NdFeB magnets (with a 1.3 T remanence) and a chip holder (see Fig. 2). We developed an electronic board that is able to deliver positive and negative currents to the coils (to change the sign of the magnetic force). For the magnetic carriers, we used 5 μm diameter Spherotech (fluorescent) beads, and THP1 monocytes labeled with Invitrogen anti-CD14 Dynabeads.

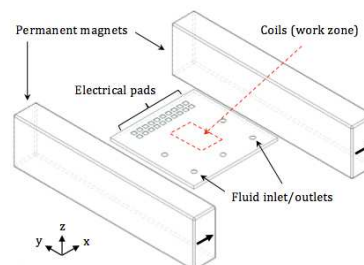


Figure 2: Scheme of the hybrid magneto-fluidic chip set up.

Two different designs were tested for the focusing function, and led to promising results. On Fig. 3, we can see two 5 μm Invitrogen particles (their velocity is about 560 $\mu\text{m/s}$) experiencing a deviation of 22 μm in 140 ms. In other series of tests, we obtained the same range of deviation at much higher velocities (about 2 mm/s), and we also made sure we can achieve focusing on the whole width of the channel.

Currently we are working on the characterization of other types of coils we built (for separation and a shift register to control the SMPs flow). Introducing tridimensional microfluidic structures would open new avenues for the realization of complex lab on chips. A very intriguing lead lies in achieving the integration of the homogeneous magnetic field source, which is quite weak so far but work is still in progress, especially in the field of NMR on chip analysis.

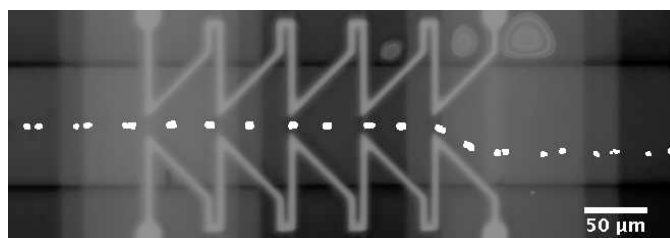


Figure 3: Stacked microscope images of two particles being deflected and aligned by the micro coils.