



**HAL**  
open science

# AN INTEGRATED MAGNETOFLUIDIC DEVICE ENABLING NOVEL ACUTATION FUNCTIONALITIES

Marc Fouet, Rémi Courson, Sylviane Baster, Anne Marie Gué

► **To cite this version:**

Marc Fouet, Rémi Courson, Sylviane Baster, Anne Marie Gué. AN INTEGRATED MAGNETOFLUIDIC DEVICE ENABLING NOVEL ACUTATION FUNCTIONALITIES. 18th International Conference on Miniaturized Systems for Chemistry and Life Sciences, Oct 2014, San Antonio, United States. hal-01086525

**HAL Id: hal-01086525**

**<https://hal.science/hal-01086525>**

Submitted on 24 Nov 2014

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# AN INTEGRATED MAGNETOFLUIDIC DEVICE ENABLING NOVEL ACUTATION FUNCTIONALITIES

Marc Fouet<sup>\*12</sup>, Rémi Courson<sup>12</sup>, Sylviane Baster<sup>12</sup> and Anne-Marie Gué<sup>12</sup>  
<sup>1</sup>CNRS, LAAS, Toulouse, FRANCE  
<sup>2</sup>Univ. de Toulouse, Toulouse, FRANCE

## ABSTRACT

We report a simple solution for implementing a new set of reconfigurable magnetophoretic functions in a highly integrated hybrid magnetofluidic device. Using a dry film lamination technique, we designed and built a device enabling magnetic actuation of superparamagnetic beads at cell resolution, with attraction and repulsion possibilities, for essential functions such as focusing and trapping.

**KEYWORDS:** Magnetic actuation, Magnetofluidic, Micro-coils, Focusing

## INTRODUCTION

Magnetic hybrid systems include external permanent magnets for the generation of a high and homogenous magnetic field, and integrated micro-coils locally producing a high gradient. Thinking about all the design possibilities those systems can offer is quite intriguing, and depending on the strength of the homogeneous magnetic field, we can either control single beads, or play with chains and clusters [1].

Our interest resides in controlling single cells and particles with high precision, and our work on planar coils [2] paved the way regarding the fabrication process and bulk separation functions. Hybrid devices seemed like a promising choice to deal with magnetic actuation at micro scale, that we achieved with two different focusing systems, a shift register and a trapping array.

## EXPERIMENTAL

Microfabrication technology consists in a simple two-step process. Glass substrates (500  $\mu\text{m}$ , Schott AF32) were chosen for imaging purposes during experiments.

The micro coils are wires of 5  $\mu\text{m}$  width and height, and were obtained with standard micro-technology processes (Ti/Au metallization and electro-plating of copper or gold), then encapsulated with SU8 (10  $\mu\text{m}$ ) for protection. For the microfluidic channels, two layers of low cost dry film photoresist (20  $\mu\text{m}$ , DF-1020, EMS Inc, Ohio) were laminated on top of the micro-coils, and structured with photolithography according to a technique we developed (3D structures can be achieved if piling more layers) [3].

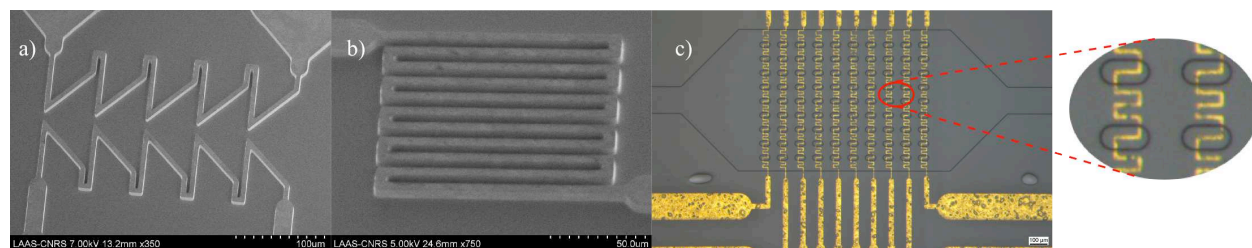


Figure 1: a) b) SEM images of microfabricated focusing and shift register units, respectively. c) Optical microscope picture of a cell trapping array (with coils and microfluidic channel). Cells or beads can be trapped on the coils between the pillars.

The permanent magnetic field value in the working zone is tuned by the distance between two permanent magnets (NdFeB, 1.3 T remanence) and the chip, from 40 to 70 mT with this setup. In order to control this distance, we built a chip holder (Fig. 2) that also comprises electrical and fluidic connection features (with a spring loaded connector and a manifold). The experimental setup is based on a fluorescence microscope (with an EMCCD camera), a pressure controller, and we developed an electronic board based on an Arduino/Labview solution to power the coils with positive or negative currents.

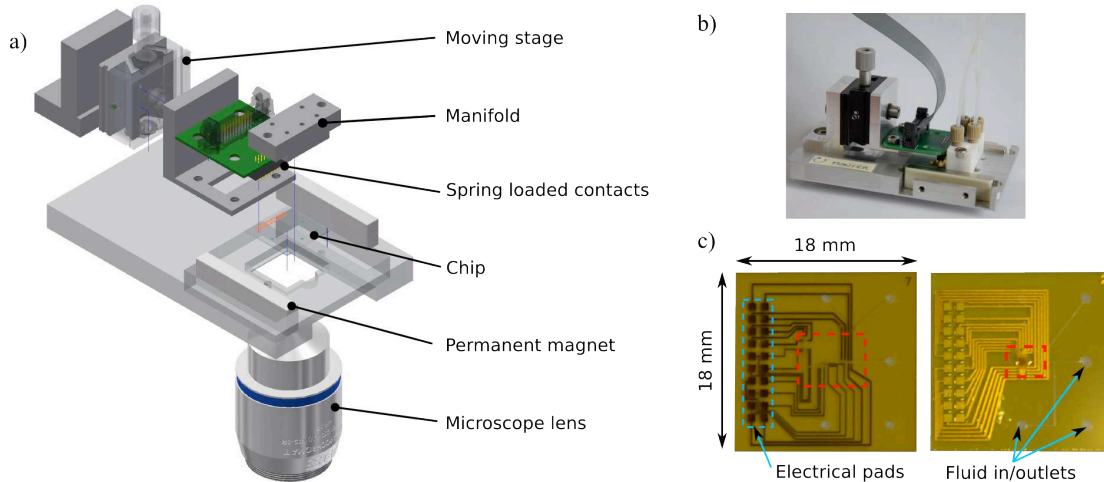


Figure 2: a) CAD drawing of the chip holder setup. Chosen materials were aluminum and PTFE (for the manifold). b) Actual built setup (connected), with mounted magnets and chip. c) Pictures of magneto-fluidic chips. Coils are made of copper (left) and gold (right). The red dashed lines represent the magnetic working zone (external field considered to be homogeneous).

Solutions of superparamagnetic beads were flowed through the system while recording the motion and trajectories of the beads for a given electrical current. We used  $4.5 \mu\text{m}$  and fluorescent  $8 \mu\text{m}$  diameter beads from Invitrogen and Spherotech respectively.

## RESULTS AND DISCUSSION

Focusing  $4.5 \mu\text{m}$  magnetic beads was achieved with two different designs (Fig. 3). Working in a stronger permanent field, we even showed deviation on a small chains of 2-3 beads. Beads velocity in Fig. 3 a) is  $560 \mu\text{m/s}$ , and we observed the same range of deviation at higher velocities (up to  $2 \text{ mm/s}$ ), for a  $85 \text{ mA}$  current.

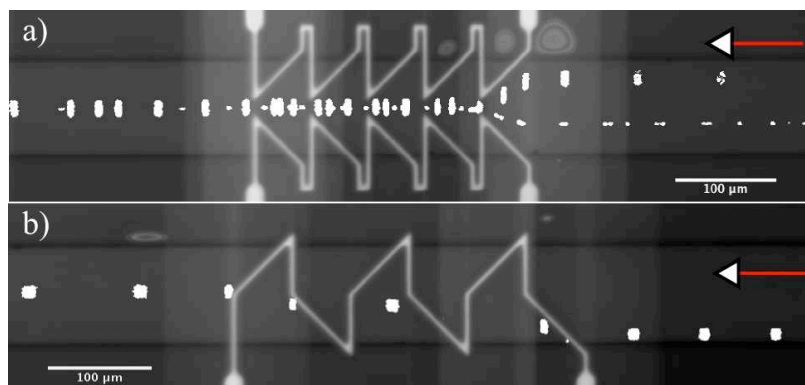


Figure 3: a) Two coils focusing device performing a deflection on two single beads (bottom) and a chain of 4 beads (top). b) Single coil focusing system centering a single bead. For both images, the electrical current was  $85 \text{ mA}$ . Red/white arrows point in the direction of the flow.

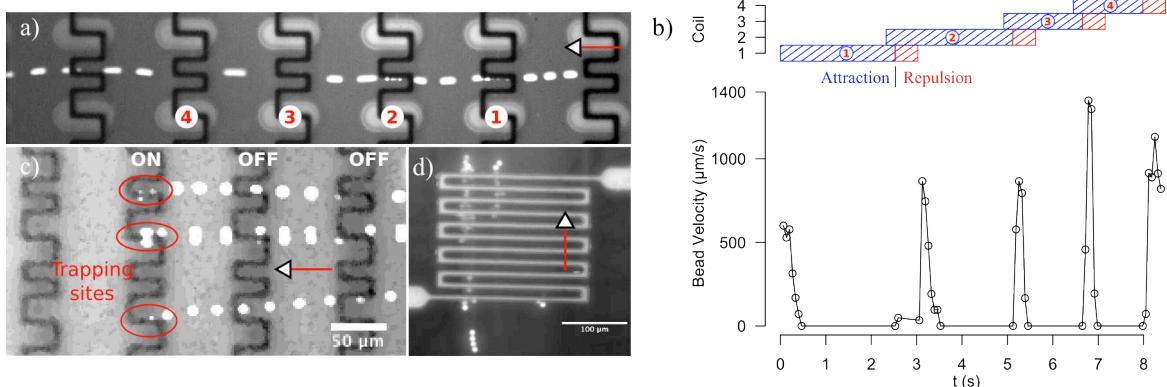


Figure 4: a) Trajectory of a  $8 \mu\text{m}$  diameter bead being captured and released 4 times with a trapping array. b) Coils actuation and bead velocity for experiment shown in a). c) Trapping of several beads simultaneously (trajectories shown). d) Possibility for the shift register to stop and trap beads and clusters. Red/white arrows point in the direction of the flow. Current of 100 mA was used for all these experiments.

Magnetic traps are based on the attraction of a middle wire and repulsion (or focusing) of side wires; to release the particle quickly we invert the current polarity for a short amount of time. We demonstrated single bead trapping with  $8 \mu\text{m}$  diameter fluorescent beads (Fig. 4) at velocities above 1 mm/s, as well as trapping (and release) of bigger objects on the same chip (shift register). We therefore proved that cell arrays can be organized dynamically and reversibly.

## CONCLUSION

Albeit this study only shows a few design possibilities of magnetic hybrid systems, our results show we are able to achieve key operations like trapping and focusing single magnetic beads (and small chains) at cell resolution. Dynamic cell trapping arrays find applications in co-culture and screening systems, as we intend to design and test new functions as tools for single cell biology experiments. Further developments are needed to explore beads concentration regulation (e.g., with a shift register) or automated capture and sorting of single cells coupled to analysis systems, but this would be the early stage of highly integrated complex magnetofluidic systems.

## ACKNOWLEDGEMENTS

This study was supported by the French National Research Agency (ANR) in the frame of the PIA - Nanobiotechnology project Digidag.

## REFERENCES

- [1] B. Eickenberg, F. Wittbracht, P. Stohmann, J.-R. Schubert, C. Brill, A. Weddemann, and A. Hütten, "Continuous-flow particle guiding based on dipolar coupled magnetic superstructures in rotating magnetic fields," *Lab Chip*, vol. 13, no. 5, pp. 920–7, Mar. 2013.
- [2] R. Fulcrand, A. Bancaud, C. Escriba, Q. He, S. Charlot, A. Boukabache, and A.-M. Gué, "On chip magnetic actuator for batch-mode dynamic manipulation of magnetic particles in compact lab-on-chip," *Sensors Actuators B Chem.*, vol. 160, no. 1, pp. 1520–1528, Dec. 2011.
- [3] R. Courson, S. Cargou, V. Conédéra, M. Fouet, and A.-M. Gué, "Low cost integration of multilevel lab-on-a-chip using a new generation of dry film photoresists," in *Smart System Integration*, 2014.

## CONTACT

\* M. Fouet; phone: +33-56-133-6418; mfouet@laas.fr