GEOMETRICALLY PROGRAMMABLE BIDIRECTIONAL PUMP USING ROTATING MAGNETIC MICROSPHERES

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ABSTRACT

We report geometrically programmable bidirectional pumping in microchannels using magnetic microspheres which rotate around magnetic disks under influence of an external rotating magnetic field. Geometric programming of the pumping direction is obtained by locating the magnetic disks on the inside or the outside curve of a microchannel as shown in Figure 1. A second degree of freedom in pumping direction is offered by the rotation direction of the external field. Pumping rate is controlled by the rotational frequency.

KEYWORDS: Magnetic Microspheres, Pumping, Permalloy, Closed Microsystem, Rotating.

INTRODUCTION

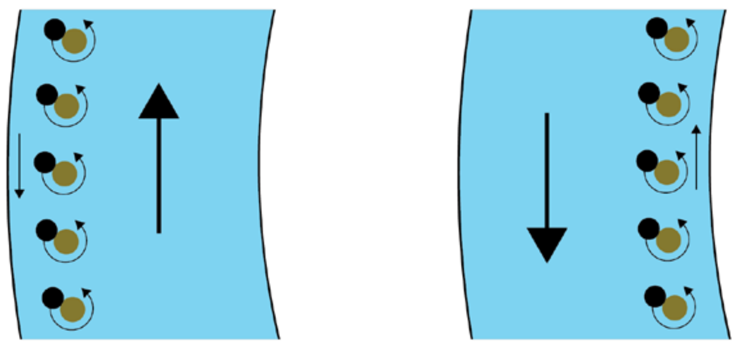


Figure 1: An example showing geometrical programming of the flow direction by placing the magnetic disks on the inside or outside of the channel. Note that in both cases the beads rotate in the same direction.

In μTas 2012 we reported monodirectional liquid displacement by microspheres rotating around magnetic permalloy disks in a microfluidic channel [1]. Here we show that this technique can be used to locally pump in opposite directions by a single magnetic field, when we position the disks either close to the inner or close to the outer wall of a circular microfluidic channel as shown in Figure 1. Due to the positioning of the disks near the edge of the channel, the drag caused by the channel wall caused an asymmetry in liquid displacement, resulting in a net pumping motion, with a pumping direction determined by the closest wall.

MANUFACTURING

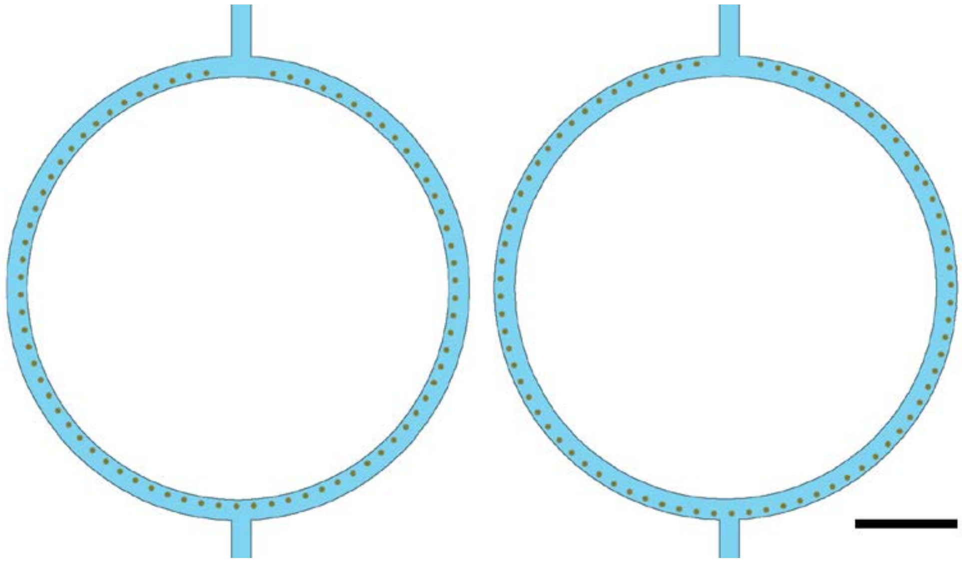


Figure 2: The design of the two tested chips, on the left the design with the disks on the inside and on the right the disks on the outside of the microchannel (scale bar is 500 µm).

The permalloy disks are fabricated by sputtering of a 480 nm permalloy layer on a silicon wafer, patterned using conventional lithography and etching. The permalloy disks were coated with 425 nm of silicon oxide, capping the chip, therefore creating a fully biocompatible chip. The microchannels were defined by a SU8 lithography process. Lastly the channels are sealed by bonding the silicon wafer to a borofloat wafer. In Figure 2 the two types of fabricated chips are shown, with disks on the inside and outside curve of a circular channel.

EXPERIMENTAL

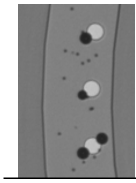
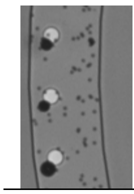
To obtain strong magnetic particles, polystyrene microspheres of 17 µm [3] were dried on a silicon substrate, and subsequently sputter-covered with 100 nm of permalloy. In a later stage, the coating with magnetic material could be followed by the sputtering of a capping layer, making the complete system suited for biological experiments. By means of sonification and centrifuging, the coated microspheres are prepared for the pumping experiment. During the experiments, no permanent magnetic clustering was observed. Polystyrene tracing microspheres of 3 µm diameter [4] were added to visualize the flow under a microscope.

The chips were filled with the magnetic coated microspheres and tracking microspheres, and placed on top of an inverted microscope stage. A permanent rare-earth magnet was rotated with a rotational frequency of 15 Hz above the chip using an electric motor to generate the rotating magnetic field.

RESULTS

In the experiments the two independent control methods (geometrical and external field rotational) resulted in a set of four possible pumping configurations, shown in Table 1, demonstrating the versatility of the concept. The pumping principle can be the basis for an easy-to-use pumping platform for lab-on-a-chip applications, demanding on chip pumping with controllable and spatially and temporally variable flow rate and direction, and allowing pumping in closed systems, especially suited for flow controlled medium circulation in culture chambers [2].

Table 1: Particle tracking results of the tracing particles, showing a quadrant of pumping directions enabled by both geometrical programming and rotational direction of the externally applied magnetic field (positive pumping is defined as clockwise direction).

	Clockwise magnetic field rotation	**Counter clockwise magnetic field rotation**
Inside curve 	+8 μm/s	-7 μm/s
Outside curve 	-8 μm/s	+9 μm/s

REFERENCES

[1] W.T.E. van den Beld, E.L. and de Weerd, L. and Abelmann, and J.G. Bomer, and A. van den Berg, and J.C.T. Eijkel, (2012) "Microfluidic pump based on arrays of rotating magnetic microspheres." In: The 16th International Conference on Miniaturized Systems for Chemistry and Life Sciences, Oct 28 - Nov 1, 2012, Okinawa, Japan. pp. 1453-1455. microTAS. Chemical and Biological Microsytems Society. ISSN 1556-5904

[2] P.J. Hung, P.J. Lee, P. Sabounchi, R. Lin, and L.P. Lee. Continuous perfusion microliquidic cell culture array for high-throughput cell-based assays. Biotechnology and bioengineering, 89:1-8, 2005.

[3] Thermo Scientific, catalog number: 7516A. http://www.thermoscientific.com/content/tfs/en/product/7000-series-copolymer-microsphere-suspensions.html

[4] Polyscience, Inc. http://www.polysciences.com/Core/Display.aspx?pageId=98&categoryId=346&productId=827

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