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Magnetofluidic Conveyor Belt

Stijn van Pelt[1], Arjan Frijns[2], Jaap den Toonder[1]

1 – Microsystems, Department of Mechanical Engineering, Eindhoven University of Technology, The Netherlands
2 – Energy Technology, Department of Mechanical Engineering, Eindhoven University of Technology, The Netherlands

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Introduction – Magnetic beads play an important role in the miniaturization of clinical diagnostics systems. Target biological species can be linked to these beads in order to magnetically manipulate them inside a microfluidic environment, as well as to detect them since the beads can act as labels for optical or magnetic sensing.[1][2] Here, we present a novel method for the linear actuation of magnetic beads in a microfluidic system.

Concept – The actuation method is based on a microfluidic system with integrated soft-magnetic structures and an external rotating field. The rotation angle of an external field translates directly to a linear position along the surface of the microfluidic channel. The method does not rely on microcoils nor does it utilize a discrete control scheme. The method comprises an array of mushroom-shaped soft-magnetic structures just below the surface of a microfluidic channel. When an external rotating field is applied, the magnetic structures focus the field strength and gradient locally. Each structure has a point to which the magnetic beads are attracted which rotates around this structure, following the external field. Because the bead movement is restricted by the microfluidic channel, the rotational motion is converted into a linear motion.

Simulations – We used 2D and 3D finite element simulations of the magnetic field to verify the concept and to optimize the geometry (Fig. a-c). By changing the geometric parameters of the soft-magnetic structures, we were able to tune the force acting on the beads for different orientations of the external field.

Fabrication – The microfluidic chip was made by soft-lithography of PDMS (Fig. d). The soft-magnetic structures were made by mixing PDMS with carbonyl iron particles. The mold was made by excimer laser ablation of polycarbonate.

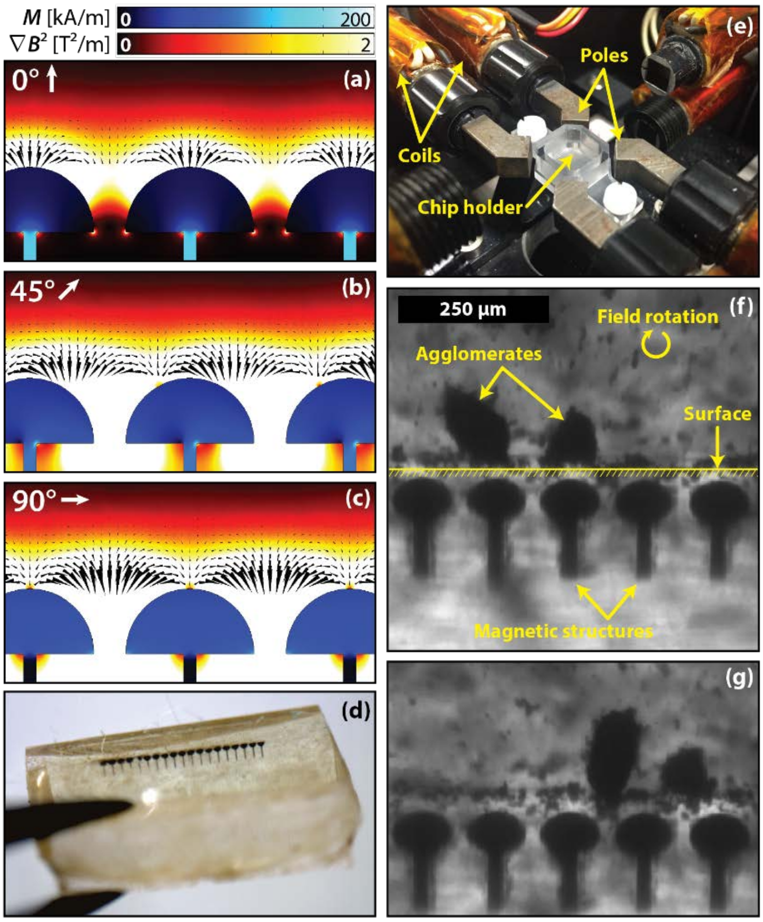
Experiments – We tested our concept using a magnetic setup with 4 poles (Fig. e). The bead motion was observed from above through an optical microscope (Fig. f-g). The rotating field was created by supplying a phase-lagged sinusoidal current to the coils. For frequencies between 0.1-5Hz, bead agglomerates formed and rolled over the surface in phase with the external field at the locations predicted by our simulations. For a frequency of 50Hz, the agglomerates reached speeds of up to 1mm/s.

Conclusion & Outlook – Using a simple geometry of integrated soft-magnetic structures we have shown that we can linearly actuate magnetic beads in a microfluidic system with an external rotating field, creating a magnetofluidic conveyor belt. Our simulations compare well with our experimental results.

In the near future, we will exploit this concept further and show different geometries with different actuation functions like for instance mixing, up-concentration and selection.

[1] A. van Reenen, A. M. de Jong, J. M. J. den Toonder, and M. W. J. Prins, “Integrated lab-on-chip biosensing systems based on magnetic particle actuation – a comprehensive review,” *Lab Chip*, vol. 14, no. 12, p. 1966, 2014.

[2] S. Van Pelt, R. Derks, M. Matteucci, M. F. Hansen, and A. Dietzel, “Flow-orthogonal bead oscillation in a microfluidic chip with a magnetic anisotropic flux-guide array,” *Biomedical Microdevices*, vol. 13, no. 2. pp. 353–359, 2011.



(a-c) Simulations for the magnetic field around the magnetic structures for different orientations of the external field, the arrows show the direction and magnitude of the magnetic force on beads. (d) Photograph of the chip with the magnetic structures. (e) The setup to create the rotating field with 4 magnetic poles and the chip in the center. (f-g) Stills of an experiment at 1Hz for t=0 and t=2s, beads form agglomerates that roll over the surface.