Fluid-particle coupling induced micro-magnetic trapping of highly diffusive magnetic nano-particles

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Millimeter sized magnets are often used to trap magnetic particles in microfluidic setups for the manipulation of biological elements (cells, molecules...) [1]. As the field gradient values emitted by such magnets are somewhat limited (10^3-10^4 T/m), particles of relatively large volume (1 µm diameter or more) have typically been used to overcome Brownian force. In this work, we propose the use of micro-magnets producing magnetic field gradients as high as 10^6 T/m [2] have been used to efficiently trap nanoparticles with a magnetic core of just 12 nm in diameter, with previous studies suggesting that such particles cannot be permanently captured [3].). Particle capture efficiency increases with increasing particle concentration. Comparison of measured capture kinetics with numerical modelling reveals that a threshold nanoparticle concentration exists below which capture is diffusion-driven and above which it is convectively-driven. It also shows that two-way fluidparticle coupling is responsible for the formation of convective cells, the size of which is governed by the height of the droplet. Our results indicate that for a suspension with a nanoparticle concentration suitable for bioassays (of the order of 0.25 mg.ml^{-1}), all particles can be captured in less than 10 minutes. The efficient capture of nanoparticles having a significantly higher surface to volume ratio than the more widely used microparticles, should contribute to the development of next generation digital microfluidic Lab-on-Chip immunoassays.

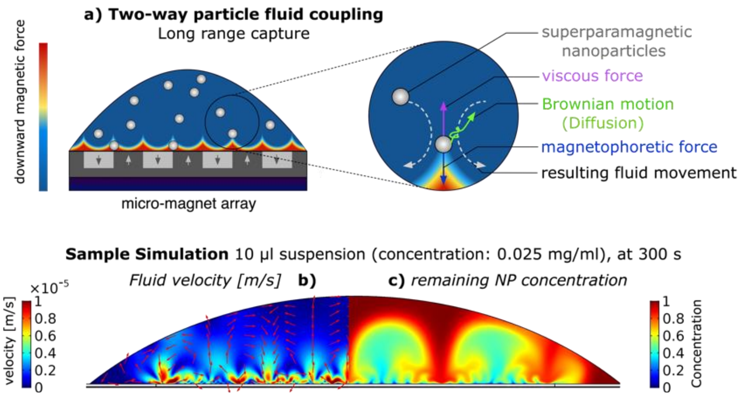

Figure 1: Nanoparticles will be captured at the junctions between micro-magnets, accelerating their surrounding fluid (a). Numeric simulation shows that the nanoparticles attracted by micro-magnets will drag the fluid towards the magnetic array (b). There, the suspension will be depleted and the fluid will flow back to the top of the droplet, eventually pushing more nanoparticles toward the magnetic junction. This bi-directional magnetic-viscous coupling leads to a self-organization of the suspension (magnetophoretic convection) (b), finally resulting in efficient trapping of highly diffusive particles.

References

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