The Manipulation of Magnetic Nanoparticles in Micro/Nanofluidics

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Research combining magnetism with microfluidics has only begun to emerge in recent years despite the many advantages magnetic fields offer over electric fields. For example, in contrast to electric manipulation, magnetic interactions are generally not influenced by surface charges, pH, ionic concentrations or temperature. In addition, objects inside a microfluidic channel can be manipulated by an external magnet that is not in direct contact with the fluid. Hence, magnetic forces can be exploited for microfluidic applications in a remarkable number of ways, such as pumping and mixing of fluids, and the manipulation of magnetic particles in fluids. Similarly, while considerable research has been explored in the microfluidics area, nanofluidics is still a nascent field. The ability to make channels with dimensions on the order of nanometers is desirable for two reasons. First, it allows for the study single domains because extremely low volumes enable single-molecule measurements. Second, it results in reduced interference as a consequence of downscaling detection volumes.

The main issue with reducing channel size is that pressure-driven pumping becomes very difficult in the nanoscale because the viscosity (or shear stress) of fluids increases dramatically, by as much as 10^5. The fluid essentially loses its liquid-like behavior and assumes solid-like characteristics. Using external magnets to generate magnetic fields for actuating nanoparticles lining the walls of the channel may provide the necessary force required to transport fluids. The goal of this project will be to investigate the use of magnetic nanoparticles for the manipulation of fluid flow in small (micro- and nano-) channels. In particular, we would like to know if magnetic nanoparticles can be used to drag fluids along a channel and/or to plug/unplug channels. Fluorescence microscopy could be used to probe experimentally the mechanics and interactions of magnetically-actuated nanoparticles.

The design of the channels involves several key considerations. First, the dynamics of fluid flow in micro- and nanochannels imposes limits on the geometry and sizes of the channels that can be fabricated. Second, the physics governing the behavior of magnetic nanoparticles determines the magnetic field strengths and gradients required to manipulate the particles. Finally, surface chemistry plays an important role in determining whether the nanoparticles will stick to each other or to the walls of the channel.

References:

- N. Pamme, “Magnetism and microfluidics,” Lab on a Chip, 6, 24-38 (2006).
- E. Verpoorte, “Beads and chips: new recipes for analysis,” Lab on a Chip, 3, 60N (2003).
- H. H. Bau, S. Sinha, B. Kim, and M. Riegelman, “The fabrication of nanofluidic devices and the study of fluid transport through them,” Proc. SPIE Int. Soc. Opt. Eng. 5592, 201 (2005).
- Q. A. Pankhurst, J. Connolly, S. K. Jones, and J. Dobson, “Applications of magnetic nanoparticles in biomedicine,” J. Phys. D., App. Phys: 36, pp.167-181 (2003).
- M. A. M. Gijs, “Magnetic bead handling on-chip: new opportunities for analytical applications,” Microfluid Nanofluid, 1:22-40 (2004).