Simulations of the magnetic field-induced force for the magnetic navigation of carbon-based nanomaterials (drug delivery)

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Carbon nanomaterials, such as fullerenes, carbon nanotubes (CNTs) and graphene have attracted major interest, due to their unique mechanical and electrical properties, for drug delivery applications. In this context, iron oxide nanoparticles of magnetite (Fe_3O_4) (10-20 nm inner core diameter), were attached on the multi-walled carbon nanotube's (MWCNTs) outer wall, aiming to form a magnetically controlled nano-platform.

In this study, the navigation capabilities of the hybrid MWNTs/iron nanoparticles system in a microfluidic channel were investigated by simulating the magnetic field and the magnetic force applied on the magnetic nanoparticles inside the microfluidic chip (Figure 1a, b). The simulations have been performed using the ANSY'S Maxwell 15.0 3D software. All calculations have been made following the finite element analysis. The optimum setup which intends to simulate the magnetic navigation of the nano-capsule, by the use of MRI-type fields, in the human circulatory system, consists of:

- Two parallel permanent magnets to produce a homogeneous magnetic field, in order to ensure the maximum magnetization of the magnetic nanoparticles.
- An electromagnet for the induction of the magnetic gradients and the creation of the magnetic force.
- A microfluidic setup including valves, pumps and micro-tubing, so as to simulate the blood flow inside the human blood vessels.
- An imaging / fluorescence configuration for the observation of the fluids movement.

The results so far have shown that, the magnetic forces that can be developed on the nanoparticles by this setup, are able to attract them to a desired direction.

The field close to the tip of the electromagnet is quite strong and deteriorates rapidly at larger distances, forming large enough field gradients, which induce the magnetic forces on particles entering into this field.

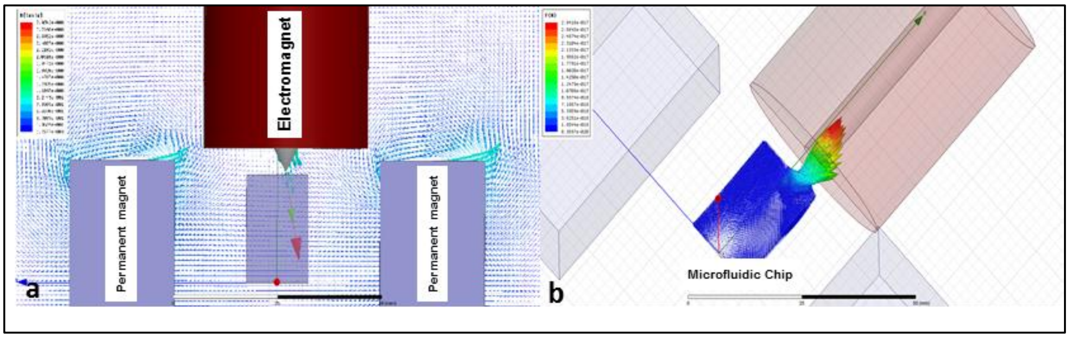

Figure 1: **a)** Calculated magnetic field induced from the magnetic setup, inside and at the area of the microfluidic chip. **b)** The calculated magnetic force applied by the magnetic field on spherical magnetic nanoparticles considered at each node of the computational mesh inside the microfluidic chip.

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