Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information	
Family name	KUZHIR
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Polytech name	Polytech Nice Sophia
University name	University of Côte d’Azur
Country	France

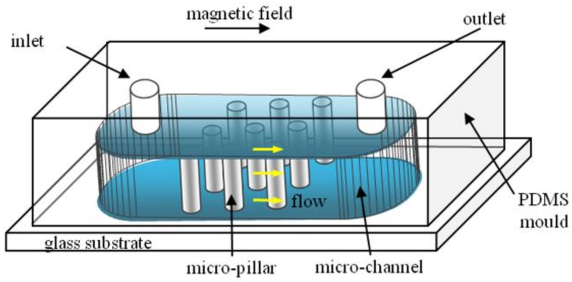
PhD information	
Title	Enhancing microfluidic manipulation of magnetic nanoparticles by molecular adsorption: towards applications to water remediation and immunoassays
Main topics regards to CSC list (3 topics at maximum)	IV-2. Nanomaterials

Required skills in science and engineering	Basic knowledge in soft matter and nanomaterials; basic skills in physical experiments and chemistry

Subject description (two pages maximum)

Microfluidic manipulation of magnetic nanoparticles is a smart tool for various environmental and biomedical applications, such as water remediation from pollutant molecules (heavy metals, pesticides, …), high-sensitivity immunoassays, cancer treatment by controlled drug delivery, hyperthermia or mechanical destruction of cells, protein purification, gene transfection, etc. In most of these applications, magnetic nanoparticles bear on their surface adsorbed molecules (either pollutants or biomolecules), which should either be delivered to the target site (drug delivery, gene transfection) or be extracted from the solvent (immunoassays, protein purification, water remediation). Unfortunately, these technics have strong limitations related to low efficiency of the magnetic manipulation of nanoparticles because of their strong Brownian motion and low efficiency of their separation from the suspending fluid (magnetic separation) under flows in microfluidic devices. However, molecules adsorbed on the nanoparticle surface often reduce repulsive colloidal interactions between nanoparticles and provoke a weak agglomeration of nanoparticles. Such agglomeration in the absence of applied magnetic field leads to an increase of the effective size of nanoparticles (or rather primary aggregates) and, once the magnetic field is applied, the magnetic force acting on primary aggregates is strongly amplified as compared to the situation of single non-aggregated nanoparticles. In this case the adsorbed molecules not only fulfill their function in water remediation or biomedical applications but allow a drastic enhancement of nanoparticle manipulation by magnetic fields, thereby broadening the application fields of nanoparticles.

The objective of this PhD project is to establish the effect of the nature and amount of the adsorbed molecules on the nanoparticle surface on the efficiency of magnetic manipulation and magnetic separation of nanoparticles. Two distinct systems will be considered. First, the ions of opposite sign (counter-ions) will be adsorbed onto the electrically charged nanoparticle surface, in which case a progressive counter-ion adsorption is expected to decrease the overall nanoparticle charge and thus reduce electrostatic repulsion between nanoparticles leading to their agglomeration. To simulate water remediation system, model organic charged pollutants as methylene blue and methyl orange will be used as counter-ions. Second, adsorption of biomolecules, such as bovine serum albumin (BSA) or antibodies (used in microfluidic immunoassays), will be studied. Adsorbed biomolecules are expected to partially screen the nanoparticle charge and also induce hydrophobic attractive interactions between particles. Magnetic manipulation and separation of nanoparticles with adsorbed molecules will be tested in a microfluidic device (relevant for modern biomedical applications) allowing easy visualization of filed-induced aggregation of magnetic nanoparticles, their cooperative migration towards the magnets (magnetophoresis) and separation from the suspending fluid under flow (magnetic separation) on the ordered arrays of micron-sized pillars (see the figure below).



The obtained results on the behavior of nanoparticles coupled to antibodies will be used for testing a magneto-microfluidic immunoassay for detection of a polyhistidine amino-acid, in collaboration with Dr. G. Sandoz from the institute of Biology of Valrose (iBV).

The INPHYNI laboratory has all the facilities (fabrication in a clean room, hydrodynamic and magnetic test-benches) and necessary skills (microfabrication by photolithography or 3D-printing, nanoparticle synthesis, physico-chemistry) for successful realization of the project. Collaboration with Dr. Agnès Bee (PHENIX laboratory, Sorbonne University, Paris) is previewed on water remediation topic and with Prof. A. Zubarev (Ural Federal University, Ekaterinburg, Russia) on theoretical background of the magnetic manipulation/separation. The collaboration with the French start-up JYTA in the frames of the on-going research and development (R&D) project related to biomedical applications of magnetic nanoparticles is also expected.

The applicative aspects of the PhD project are expected to be beneficial for Water science and engineering department (water remediation topic) and for Biological engineering department (microfluidic immunoassays) of the Polytech Nice-Sophia.

The candidate will have opportunity (if he/she wishes) to give classes on general physics at the Polytech Nice-Sophia and/or faculty of Sciences of the University of Nice. The candidate will also have opportunity to communicate his/her results in different international scientific conferences related to magnetic nanoparticles.