*Please use the following format for the title of the file so as to ease the management of the web site.*

***ECXX_LABYY_ NOMChercheur_ Numer***
*ECXX = ECLi, ECL, ECM, ECN, CS*
*LABYY = acronyme du laboratoire*
*NOMChercheur = nom du chercheur émetteur du sujet*
*Numer = numéro de la proposition (01, 02, ….) pour le chercheur*

## PhD Proposal 2017

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|---|---|
| **School: Centrale Lille** | |
| **Laboratory: LIA LICS**<br>**IEMN UMR CNRS 8520** | **Web site: www.iemn.univ-lille1.fr** |
| **Team: AIMAN-FILMS** | **Head of the team: Pr. Philippe PERNOD** |
| **Supervisor: Olivier BOU MATAR**<br>**Co-supervisor : Marc GOUEYGOU** | **Email: olivier.boumatar@ec-lille.fr**<br>**marc.goueygou@ec-lille.fr** |
| **Collaboration with other partner during this PhD:**<br>**In France:** | **In China:** |

| |
|---|
| **Title: Modeling and design of magnetic microbubbles** |
| **Scientific field: Material Science, Optics, Electronics, Nano technology, Micro-system, Bioscience** |
| **Keywords: Magnetoacoustics, Ultrasound, Magnetic nanoparticles, Medical imaging** |

**Details for the subject:**

**Background, Context:**
LICS – Laboratoire International des Phénomènes Critiques et Supercritiques – is an international laboratory dedicated to the study of static, quasi-static and dynamic critical and supercritical phenomena in multi-physical systems - electronic, magnetic, acoustic and fluidic systems. Our research is focused on specific features of coupled nonlinear systems. Near equilibrium and non-equilibrium phase transitions, as critical properties of one subsystem are transferred to the other one, these coupled systems may exhibit exceptional or unconventional dynamic properties, such as extreme softness or giant values of coupling parameters. In magneto-acoustic coupled systems, for example, elasticity can be controlled by an external magnetic field and, inversely, the magnetic state can be modified by static stress or elastic wave propagation. The subject of this PhD is in close connection with two of the strategic axes of the LICS scientific project:

- Task 1: Critical State (CS) materials.
- Task 2: Multistable bosonic (phononic, magnonic, photonic) micro/nano structures.

**Research subject, work plan:**
The objective of this PhD is to fabricate, model and design magnetic microbubbles (MMBs). The microbubbles (MBs) are made of a gas entrapped into an elastic shell, on which magnetic nanoparticles (MNPs) are covalently linked (Fig. 1). These micro-objects are illustrative of the nonlinear coupling between two subsystems, an elastic subsystem - the MBs – and a magnetic one – the group of MNPs on a single microbubble. The nonlinear coupling arises, first, from the large displacement of the MB shell when excited ultrasonically at its resonant frequency, and second, from the nonlinear magnetization and spin reorientation phase transitions in the group of MNPs. A solution of such microbubbles may display controllable elasticity under a magnetic field, controllable magnetic state under static pressure, as well as parametric magneto-acoustic instabilities. Besides fundamental studies on nonlinear coupled systems, the MMBs may have applications in medical imaging, as contrast agents or targeted drug carriers.

*(a)* *(b)*

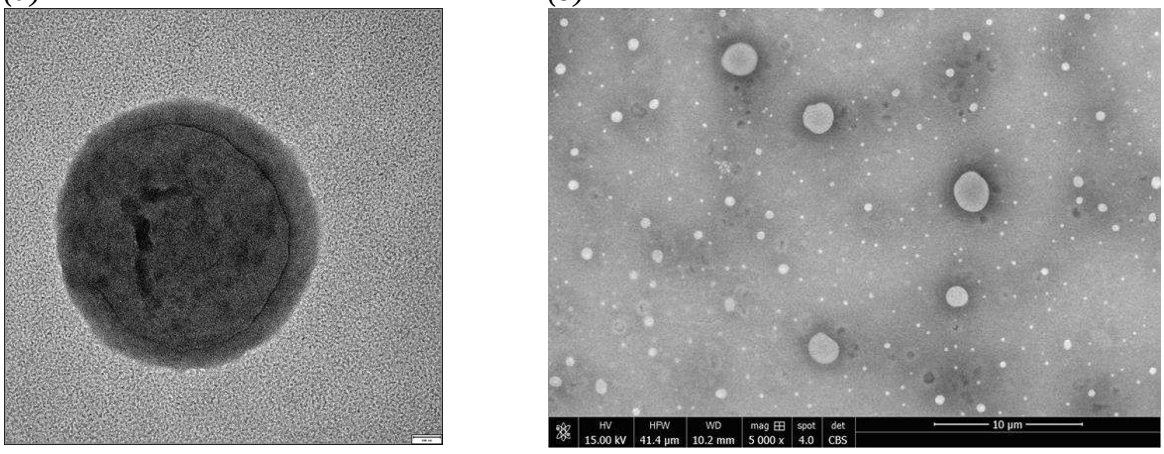


*Figure 1 : TEM (a) and SEM (b) images of magnetic microbubbles*

The work of the PhD student consists in 3 main steps:

1. Fabrication of magnetic microbubbles: that involves separate fabrication of MBs and MNPs, then application of a chemical process to attach MNPs to MBs. The fabrication process should yield durable and reproducible MMBs.
2. Characterization of MMBs: that involves structural, ultrasonic and magnetic characterization techniques at the macroscopic and microscopic scale.
3. Modelling: that involves the development of a coupled, multiphysical model to help with interpreting experimental results from step 2.

As this research is highly interdisciplinary, the PhD candidate is expected to have or develop competences in various fields: solid state physics, wave physics and chemical engineering.

**References:**

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P. Pouponneau et al., Biomaterials 31, 2009

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X. Cai et al., Theranostics 2(1), 2012

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