Proposition de sujet de thèse 2013

Titre :
Characterization and modeling of composite magneto-electric devices
Caractérisation et modélisation de dispositifs magnétoélectriques composites

Thèmes : Conversion d'énergie et systèmes électromagnétiques

Laboratoires : **LGEP**

Context and thesis description

There has been a renewed interest in recent years in the phenomenon of magnetoelectric (ME) effect in ferromagnetic-ferroelectric heterostructures. This effect is characterized by an induced dielectric polarization in response to an applied magnetic field, or by an induced magnetization in response to an applied electric field. The ME in such composite materials exceeds by several order of magnitude the ME response of single-phase compounds. This composite ME effect rises opportunity for a new range of technical applications for microwave devices, sensors, transducers and heterogeneous read/write devices. Fig. 1 presents an example of a basic magnetic field sensor using such ME effect.

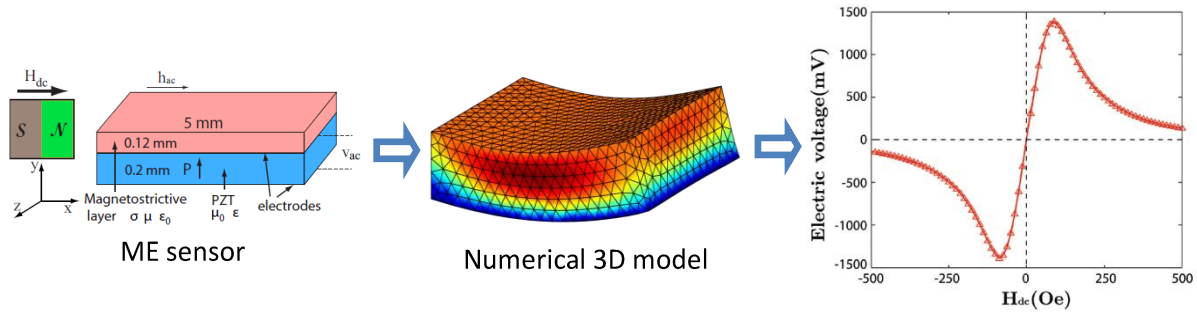

Fig 1: Magnetic field sensor and corresponding electric voltage vs magnetic field

The proposed PhD is focused on the modeling of composite ME effect using original homogenization techniques and finite element methods. The challenge of the thesis is to build a tridimensional model to describe magneto-electric effects. Applications will be oriented towards microsystems through a collaboration with the Institut d'Electronique Fondamentale (IEF, Orsay). The PhD student will be encouraged to spend several periods in these laboratories for the elaboration and characterization of composite ME devices. As a first step, the applications foreseen concern high-sensitivity 3D magnetic sensors. Microsystems developed at IEF will then be considered.

The work expected from the PhD student includes:
- Material modeling: definition of the appropriate constitutive laws for the description of magneto-electric effect in microsystems. Due to the lengthscales involved, the standard macroscopic constitutive laws for bulk materials is not appropriate in many microsystem applications.
- Finite element nonlinear modeling: original algorithms should be developed to treat the nonlinear magneto-electric problem in 3 dimensions.
- Experimental validation: the experimental validation will be performed in strong interaction with IEF (Pr. P. Lecoeur).

The PhD will take place at LGEP, a laboratory that has a long time expertise in finite element modeling and coupled phenomena. The topic of this thesis is part of a very active research area at LGEP aiming at the study of multi-physical problems by the mean of homogenization, discrete numerical methods and experimentations involving more than 10 permanent researchers and engineers and 13 PhD students, see http://www.lgep.supelec.fr/muphy for more details.

Specific requirements for the applicant:
- Master in Mechanical Engineering, Electrical Engineering or Applied Mathematics,
- Good English skills,
- Basic knowledge on finite elements methods applied to electromagnetism and/or mechanics
- Basic programming skills in any language (Matlab, C++, C…)

Contacts:
Frédéric BOUILLAULT: frederic.bouillault@lgep.supelec.fr
Laurent DANIEL: laurent.daniel@lgep.supelec.fr
Xavier MININGER: xavier.mininger@lgep.supelec.fr

Recent related publications:
- T. Nguyen, X. Mininger, F. Bouillault, L. Daniel, "Finite Element Harmonic Modeling of Magnetoelectric Effect ", "IEEE Trans. on Magnetics", Vol. 47, Issue: 5, pp. 1142 - 1145 (2011)
- T. Nguyen, F. Bouillault, L. Daniel, X. Mininger, "Finite element modeling of magnetic field sensors based on nonlinear magnetoelectric effect ", "Journal of Applied Physics", Vol. 109, Issue: 8, 21 April 2011, pp. 084904 (2011)