Fabrication and Characterization of Nanoimprinted Organic-inorganic Multiferroic Nanocomposites

Pedro Sá*, Bernard Nysten, Luc Piraux and Alain M. Jonas
Institute of Condensed Matter and Nanoscience, Bio & Soft Matter Division, Université catholique de Louvain, Louvain-La-Neuve, 1348 Belgium
*Pedro Sá: pedro.pereira@uclouvain.be

Investigations of magnetoelectric coupling have been intensively performed on inorganic multiferroic materials. On the other hand, organic multiferroics have been much less studied, despite an increasing demand for flexible material-based applications. Polymer-based multiferroic materials can be prepared by the nanocomposite approach, which is an attractive way to tailor multiferroic materials through the choice of shape, size and microstructure of the constituents. Using rationally designed nanoscale building-blocks with properly-designed interfaces may enhance the magnetoelectric coupling between magnetic and ferroelectric components with potential applications for new multifunctional devices.

Our work thus seeks to develop and optimize new hybrid two-phase nanocomposites, comprising inorganic ferromagnetic and organic ferroelectric components. In addition, because most studies have been concentrated on the electric control of the magnetism, we focus our efforts on the magnetic control of the electric polarization, much less reported coupling properties even for inorganic multiferroics. Our organic-inorganic thin films consist of ferromagnetic $CoFe_2O_4$ nanostripes embedded in a matrix of organic piezo-and-ferroelectric poly(vinylidene fluoride-*ran*-trifluoroethylene) copolymer (P(VDF-TrFE)). To reach this, $CoFe_2$ nanostripes were fabricated by electrodeposition within a poly(methyl methacrylate) (PMMA) template fabricated by nanoimprint lithography, and further oxidized to form $CoFe_2O_4$ stripes after template removal. In a final step, P(VDF-TrFE) was embossed in the magnetic line grating acting as mold, thereby forming a continuous composite layer.

The effect of the annealing treatment on the oxidation of $CoFe_2$ nanostructures was first investigated. The M(H) magnetization curves and the magnetic properties of the ferromagnetic nanostructures (coercive field, saturation magnetization, saturation field) were investigated by Alternating Gradient Magnetometry (AGM). Local ferroelectric characterization was then performed on the nanocomposite using Piezo Force Microscopy (PFM). The local magnetoelectric coupling in these layers was also investigated, by measuring the local ferroelectric properties under a magnetic field using PFM, and attempts were performed to influence the electric polarization of the polymer by a magnetic field. We show that using proper design of a nanoimprinted organic-inorganic composites layer, offers the possibility to manipulate the electric polarization at room temperature, aided by an electric field, under a magnetic field.