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Review

Magnetic anisotropy of Co/Pt/FeMn multilayers grown on polystyrene nanospheres

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ABSTRACT

The magnetic anisotropy of Co/Pt/FeMn multilayers grown onto two-dimensional arrays of nanospherical polystyrene particles is studied at room temperature using Ferromagnetic Resonance measurements with *X*-band microwave frequency. The in-plane and out-of-plane resonance spectra display two uniform absorption modes due to two distinct magnetic phases, revealing an inhomogeneous magnetization profile through the thickness and at the top and the equator of the magnetic caps. The in-plane measurements of the angular dependence of the two absorption fields reveal that the distinct magnetic phases exhibit the effects of twofold and fourfold magnetic anisotropy fields. Out-of-plane measurements show that the magnetization of each magnetic phase depends on the structure of the multilayer and is oriented at a specific direction oblique to the plane of the film.

1. Introduction

Nanostructures built with Co/Pt multilayers have been intensively studied due to the possibility of manipulation of the magnetic anisotropy, from in-plane to perpendicular anisotropy, for instance, just by varying parameters such as the number of Co/Pt bilayers, the thickness of the buffer layer, or the relative Co/Pt thicknesses [1,2]. In these systems, the magnetic anisotropy is guided by the competition between the Co/Pt interfacial anisotropy, which contributes to the perpendicular anisotropy, and the shape anisotropy, which favors the in-plane anisotropy [3]. This competition can be enhanced by an additional exchange-biased top FeMn layer. Recently, interesting results on Co/Pd and Co/Pt magnetic multilayers deposited onto two-dimensional arrays of nanospherical polystyrene particles have been reported [4,7]. When deposited over nanospheres, the magnetic film forms a cap with variable thickness which is thinner at the equator of the spheres. Experimental results showed that it is possible to tailor the easy magnetization direction simply by performing a tilted film deposition [5]. The spherical shape of the polystyrene particles leads to different properties of the magnetization and anisotropy at each point of the magnetic cap, raising the questions about how the thickness gradient affects the surface and shape anisotropies, and the presence of distinct magnetic phases affects the effective anisotropy. From the technological point of view, this magnetic caps system may be promising for applications as sensor, information storage, and spintronic devices.

In this work, the effective magnetic anisotropy of Co/Pt/FeMn multilayers grown onto two-dimensional arrays of nanospherical polystyrene particles was studied using the Ferromagnetic Resonance (FMR) technique. It is well known that FMR is a very convenient technique to study the properties of magnetic thin films and multilayers in general [8,9]. Our aim in this work is to identify the anisotropies present in the samples studied and correlate them with the results given by different characterization techniques.

2. Experimental procedure

The Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$/Pt(0,3)/FeMn(10)/Pt(2) (nm) multilayers investigated in this work were grown at room temperature by dc magnetron sputtering onto planar Si/SiO$_2$ substrates covered by an hexagonal closed–packed array of monodisperse 1000 nm polystyrene nanospheres. The samples were capped with a 2 nm thick Pt layer to protect them from oxidation. Using the same deposition conditions, the reference multilayers Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$ (nm) and Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$/Pt(0,3)/FeMn(10)/Pt(2) (nm) grown directly onto planar Si/SiO(2) substrates were also investigated. More details about the production of the hexagonal closed–packed arrays of 1000 nm nanospheres and the growth of the magnetic multilayers can be found elsewhere [10].

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The FMR data were taken at room temperature using a commercial electron magnetic resonance spectrometer (Bruker ESP-300) operating with the *X*-band microwave system (9.6 GHz) and swept static magnetic field. The sample was located at the center of a standard TE-102 resonant cavity and fixed to a goniometer, allowing the study of in-plane and out-of-plane angular dependence of the absorption field and line width. The FMR spectra were taken using standard phase sensitive detection techniques, applying modulation fields of up to 20 Oe, modulation frequency of 100 kHz, and microwave power of up to 10 mW. The direction of the applied field in the plane of the film or with respect to its normal was measured with an error of ± 0.5°, and the absorption field and line width, with an error of ± 5 Oe.

3. FMR results

The FMR data of the reference multilayers with and without a FeMn layer reveals different magnetic anisotropies. For both films, the in-plane and out-of-plane FMR spectra display a single uniform resonance mode (Fig. 1). The uniform FMR mode is excited when the magnetization of the sample is parallel to the static magnetic field and the resonance condition is attained. As displayed in Fig. 2, the angular dependence of the out-of-plane resonance field exhibits the effect of perpendicular magnetic anisotropy for Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$ (nm) multilayer (Fig. 2(a)), and in-plane magnetic anisotropy for Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$/Pt(0,3)/FeMn(10)/Pt(2) (nm) multilayer (Fig. 2(b)). The effective magnetic anisotropy can be deduced from the experiments and is larger for the film with the FeMn layer.

Quite different from to the reference films grown directly onto Si/SiO$_2$ substrates, the in-plane and out-of-plane spectra of the Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$/Pt(0,3)/FeMn(10)/Pt(2) (nm) multilayer grown onto 1000 nm nanospheres display two uniform FMR modes, denoted as *A* and *B* (Fig. 3). The excitation of two uniform modes reveals the presence of two distinct magnetic phases in the film. As the intensity of mode A is much higher than that of mode B, the amount

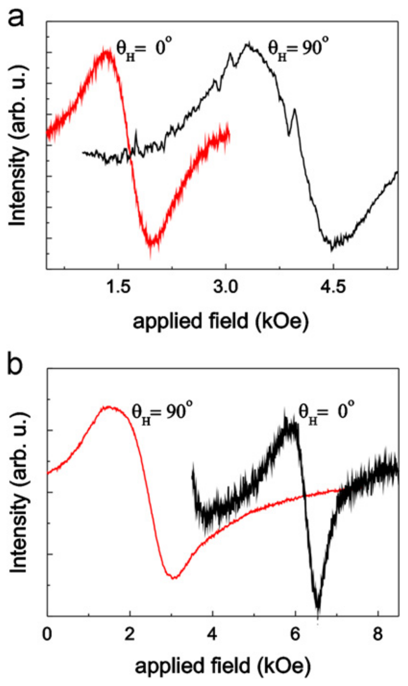

Fig. 1. FMR spectra of (a) Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$ (nm) and (b) Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$/Pt(0,3)/FeMn(10)/Pt(2) (nm) multilayers grown directly onto planar Si/SiO(2) substrates. The angle θ_H gives the direction of the applied static field *H* with respect to the film normal.

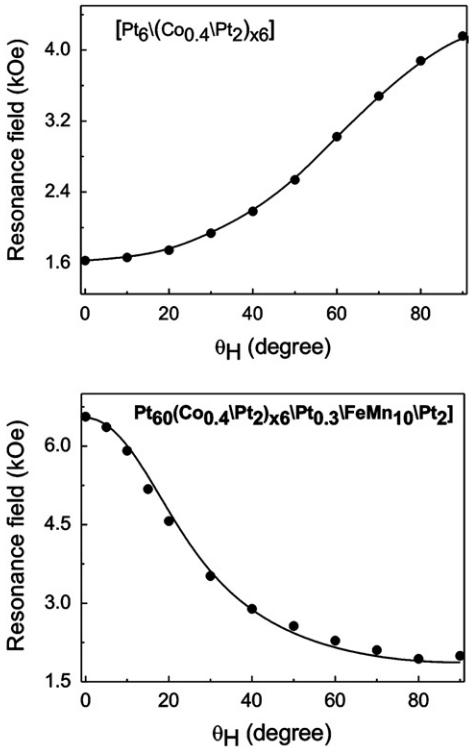

Fig. 2. Angular dependences of the out-of-plane resonance fields of (a) Co/Pt and (b) Co/Pt/FeMn multilayers grown directly onto Si substrates. The solid lines represent the fittings of the experimental data.

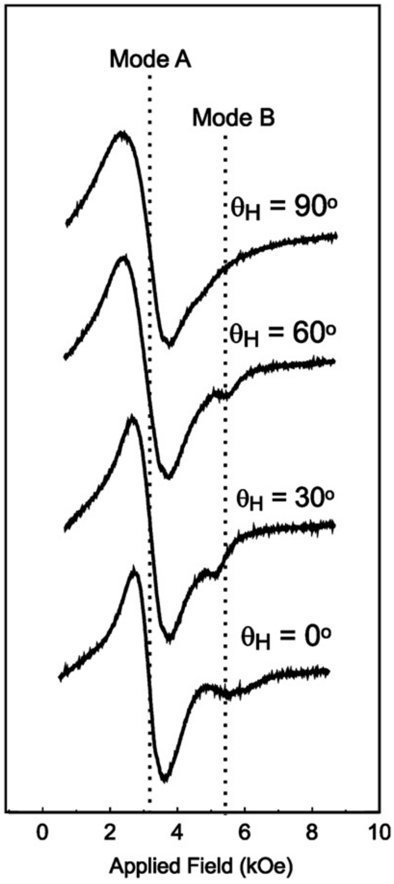

Fig. 3. FMR spectra of Pt(6)/[Co(0,4)/Pt(2)]$_{x6}$/Pt(0,3)/FeMn(10)/Pt(2)/nano(1000) (nm) multilayer film. The angle θ_H gives the direction of the applied static field *H* with respect to the film normal.