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Magnetic domain crossover in FePt thin films

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Abstract – We have investigated the crossover in the magnetic domain structure of FePt thin films as a function of film thickness. We have directly observed by Magnetic Force Microscopy (MFM) that at a critical thickness t_{cr} ~ 30 nm the orientation of the magnetization in the magnetic domains changes from in-plane alignment to a system of stripes in which a component perpendicular to the film plane points alternately in opposite directions. We have also found that the stripe period is an increasing function of the film thickness. The rotational anisotropy field has been determined with dc magnetization measurements and was also found to increase with the film thickness.

FePt thin film alloys of equiatomic composition present a great technological interest because of their unique magnetic properties, particularly the very large coercivities and the high magnetic anisotropy, which can exceed $7x10^7$ emu/cm^3 in the ordered FCT phase. However, as–made films often form in an FCC crystalline-disordered relatively soft magnetic phase, and the high coercivity, high anisotropy properties are observed only after proper annealing at elevated temperatures.

In this work we have investigated a series of as-made disordered FePt films which have been fabricated by dc magnetron sputtering on oxidized Si (100) substrates. In order to study the dependence of the magnetic properties with film thickness we have deposited eight different thicknesses in the range 9 nm – 94 nm. The thickest film was characterized by X-ray diffraction and EDX studies. We have found an Fe/Pt atomic ratio of 45/55 and a lattice parameter that was slightly larger than the corresponding bulk value for the equiatomic alloy. This can be due to some degree of tensile stress and/or a shift in the composition.

The remanent magnetic domain structure was investigated by MFM in a Veeco Dimension 3100 system. We have found that for a critical film thickness t_{cr} ~ 30 nm there is a notable change in the magnetic domain structure. Films thinner than the critical thickness show an almost square in-plane hysteresis loop, with magnetic domains that are completely oriented parallel to the film plane. For t_{cr} > 30 nm the domain structure develops a stripe-like pattern (as shown in Fig. 1) in which a small uniaxial out of plane component of the magnetic anisotropy favors the misalignment of the domains from the film plane. The period of the stripe structure varies with film thickness as shown in Fig. 2. It increases almost linearly at first, following the film thickness, but it tends to saturate as the film thickness is further increased. The stability of the stripe structure under the influence of a transverse field was also studied as a function of the film thickness. It was observed that with a moderate field (100-1200 Oe) it is possible to rigidly rotate the stripe structure in an irreversible way. This behavior, which is known as rotational anisotropy, was characterized by the minimum perpendicular field that is necessary to apply in order to rotate the stripe structure by 90 degrees. These measurements have been made in a Vibrating Sample Magnetometer in which the sample was saturated with a field of 10 kOe in one direction, it was rotated by 90 degrees and then a magnetization curve was measured from zero field to 10 kOe and back to zero. The maximum field at which irreversibility is observed is defined as the rotational field and is presented in Fig. 3 as a function of the film thickness. In Fig. 4 we show an MFM image of the sample of 56 nm in which the stripes were previously aligned in the vertical direction, after that a field of 500 Oe (below the rotational field) was applied in the horizontal direction. It is observed that the stripe structure rotated rigidly, but the field was not strong enough to fully rotate the stripes by 90 degrees.

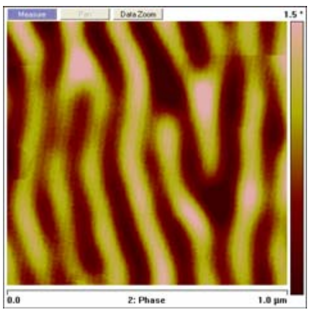

Fig.1: stripe-like magnetic domain structure in a film of 100 nm.

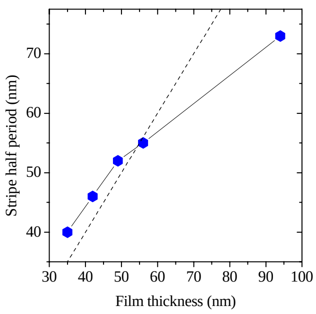

Fig.2: half period of the stripe domain structure as a function of film thickness.

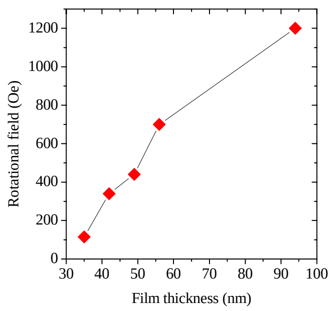

Fig.3: minimum field necessary to rotate the stripe structure by 90 degrees as a function of film thickness.

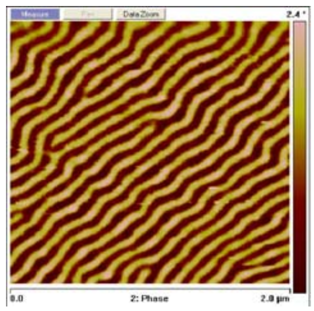

Fig.4: stripe domain structure in a film of 56 nm after a field of 500 Oe was applied in the horizontal direction.