Structural and Magnetic Properties of Fe-Pd Thin Films with Gd-Substitution

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We have studied the effect on the microstructure and magnetic properties of partial Pd substitution by Gd in Fe-Pd thin films of nominal composition $Fe_{56}Pd_{44-x}Gd_x$, deposited onto Si(100) and Si(100)/SiO_2 substrates by thermal evaporation. Several techniques contribute to the characterisation of their microstructure and magnetic properties, such as, X-ray Diffraction, Scanning Electron Microscopy, Alternating Gradient Field Magnetometry and Magnetic Force Microscopy. The transformation of disordered fcc-FePd into ordered fct-FePd has been induced by a heat treatment at 530 °C for 4 hours. The addition of gadolinium leads to a reduction of the coercivity as a consequence of emergence of soft phases and of the progressive reduction of the fct-FePd phase which is primarily responsible for the observed maze magnetic domains. The exchange coupling between the soft phase and the hard fct-FePd phase is demonstrated by first order reversal curves.

Keywords: Magnetic hysteresis; Ferromagnetic materials; Phase transition; Magnetic force microscopy.

1. Introduction

The addition of rare earth elements (REE) to binary alloys has become attractive for many different reasons, such as tailoring their magnetic properties to match the needs of many different applications [1]. Gd has recently been deemed more appropriate. Moreover, the Gd is much cheaper than Nd, Tb, Pr and Dy. In addition, for some alloys, such as Fe-Pd, even if there is not a rare earth, the replacement of Pd, a precious metal, with less costly materials may be desirable. It would be interesting to check whether the substitution of some of it by Gd could lead to different properties than the conventional ferromagnetic Fe-Pd system [3]. By developing a ternary Fe-Pd-Gd compound, it is therefore hoped that a more complex and varied microstructure can develop, affecting the magnetic properties of the Fe-Pd system. It has to be pointed out that even though many reports indicate an improvement of the hard magnetic properties of ferromagnetic materials when REE are added, the complexity of the system does not ensure successful results, and their weakening is also possible [4], [5]. An in-depth investigation of the structural and magnetic properties has therefore been performed of both as-prepared and thermally annealed samples, with the aim of helping clarifying the magnetic properties of the so far almost unexplored Fe-Pd-Gd ternary system.

2. Results and discussion

To study the effect of Gadolinium on the structural and magnetic properties of the $Fe_{56}Pd_{44-x}Gd_x$ ternary films were prepared by vacuum evaporation on Si(100) and Si/SiO_2 substrates. Annealing at 530 °C for 4 h transformed the disordered fcc FePd phase into the ordered $L1_0$ FePd pahse in films with lower content of Gd, with local anisotropies oriented randomly.

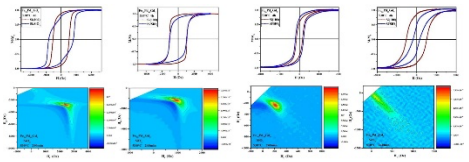

Figure 1: Room-temperature hysteresis loops and FORC distribution in the (H_C, H_B) plane for annealed $Fe_{56}Pd_{44-x}Gd_x$ thin films.

On increasing the Gd content, the appearance of soft phases ($L1_2$ FePd, Fe_3O_4) after annealing leads to a reduction in the coercivity (see Figure 1, top row), as a consequence of a progressive reduction of the fct phase. Also, magnetic saturation values are affected by the phases present in the film, in particular by the soft phases. First order reversal curve measurements (Figure 1, bottom row) show a single peak corresponding to the hard phase, with signs of the interaction between the soft and hard phases in the samples with lower Gd content.

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