Thin Solid Films 527 (2013) 278–284

Contents lists available at SciVerse ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Influence of various underlayers on [001] texture and magnetic properties in FePt and $Fe_xNi_{1-x}Pt$ thin films

Bianzhu Fu, Gregory B. Thompson *

Department of Metallurgical & Materials Engineering, The University of Alabama, Tuscaloosa, AL 34587-0202, USA

ARTICLE INFO

Article history:
Received 23 February 2012
Received in revised form 13 November 2012
Accepted 13 November 2012
Available online 28 November 2012

Keywords:
FePt
Fe–Ni–Pt
Graded media

ABSTRACT

Perpendicular magnetic recording thin films require proper crystallographic growth to ensure that the magnetic easy-axis is aligned normal to the growth plane. The texture and *in situ* growth stresses of (001) FePt and $Fe_xNi_{(1-x)}Pt$ thin films on various underlayer combinations are studied. These were correlated with the magnetic properties allowing self consistent direct comparisons of the various parameters to be made. It was found that the (001) texture, $L1_0$ chemical ordering and perpendicular magnetic alignment was improved with the smaller lattice misfit that accompanied a combination of Pt/Cr multilayered and compositionally graded underlayers on a (001) MgO substrate. A Cr underlayer allowed the Pt film to deposit in a relatively strain-free lattice condition from which the FePt based films could grow in a similar strain-free epitaxial condition. *In situ* stress measurements confirmed that these underlayers reduced the intrinsic compressive growth stresses to approximately one-fifth the FePt stress value for being directly deposited onto the MgO surface. The incorporation of Ni to the (001) growth of FePt facilitated in-plane and out-of-plane c-variant growth for the $L1_0$ structure. Finally, a linear compositional gradient $Fe_xNi_{0.48-x}Pt_{0.52}$ ($0<x<0.48$) thin film was deposited, which exhibited good [001] orientation and perpendicular magnetic alignment. This has been proposed as a magnetic switching architecture for high density, thermally stable but switchable magnetic media grains using current write head fields.

1. Introduction

The energy barrier for magnetization switching is the product of the uniaxial magnetocrystalline anisotropy, K_u, of the medium and the volume, V, *i.e.* $K_u \cdot V$ [1,2]. As the magnetic volume is decreased, the magnetization direction can randomly fluctuate because of thermal energy, k_bT, effects, where k_b is Boltzmann constant and T is temperature. This is particularly concerning for developing next generation magnetic media films, where the magnetization direction stores binary data and whose bit sizes must decrease to achieve ever increasing areal storage densities [3].

The $L1_0$ FePt alloy has attracted particular attention because of its high magnetocrystalline anisotropy making it thermally stable at these proposed smaller volumes [4]. The magnetic easy-axis for this crystal structure is along [001], requiring the film to be grown parallel to this direction for perpendicular recording. When sputter-deposited, these films nominally adopt the low energy close-packed {111} growth surface requiring forced epitaxy to achieve the proper magnetic easy-axis alignment. In addition, this $L1_0$ FePt alloy's K_u is so large that it creates an additional problem of equal importance. The alloy is magnetically too hard to intentionally switch or write the magnetic volume using current head field strengths [5].

To solve this write-ability problem, exchanged-coupled-composites (ECC) and continuous gradient media films are proposed [6,7]. The ECC film consists of exchange-coupled hard–soft magnetic layers in which the reversal of the soft layer at low fields facilitates the reversal of the hard layer. This allows a lower writing field for a given thermal stability as compared to conventional media. By increasing the number of discrete layer interfaces in the multilayered ECC, the switching field further decreases. By smoothly varying the magnetic anisotropy, *i.e.* a gradient of K_u throughout the film, the switching field to thermal stability advantages is suggested to be even further improved over ECC [7]. One method to fabricate these magnetic layers with controlled magnetic anisotropy is to alloy the magnetic thin film at specific compositions. A recent alloying of Cu in FePt for this purpose has been reported [8,9]. However, Zha et al.'s Fe–Cu–Pt thin film had the <111> orientation [9], which is not the aligned magnetic easy-axis required for perpendicular magnetic recording. Thus, an outstanding issue is to deposit a compositionally continuous gradient thin film where K_u consistently varies and the crystallography of the growth direction aligns with the magnetic easy axis.

While there are several reports on optimizing the [001] growth orientation in FePt thin films on (001) MgO substrates with the addition of Cr and Pt underlayers [8,10–15], none of these studies have provided *in situ* stress measurements. Such *in situ* studies provide real-time insights in adatom mobility and its relationship to epitaxy [16], of which can only be inferred from post-growth analysis. Few studies have been reported on how growth epitaxy is altered by the addition of

* Corresponding author. Tel.: +1 205 348 1589.
E-mail address: Gthompson@eng.ua.edu (G.B. Thompson).

0040-6090/$ – see front matter
http://dx.doi.org/10.1016/j.tsf.2012.11.022

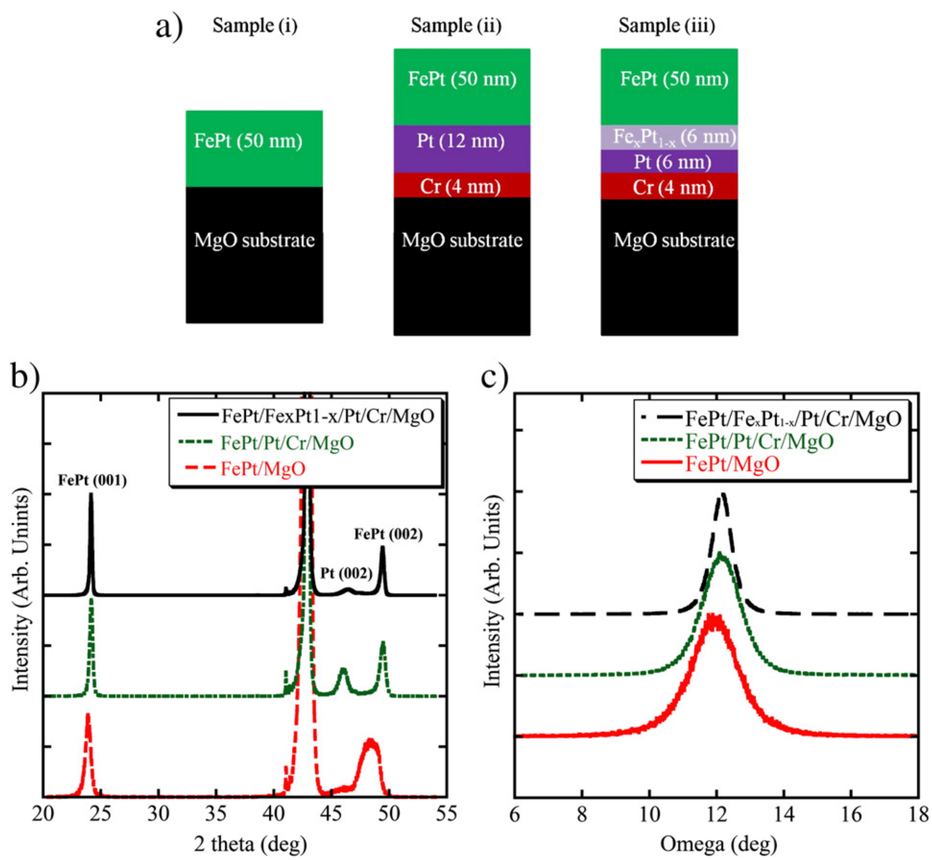

Fig. 1. (a) The deposited structure of the three thin films studied. (b) Out-of-plane XRD scan for the three FePt thin films with various underlayers. (c) The (001) rocking curve for the three FePt thin films with various underlayers.

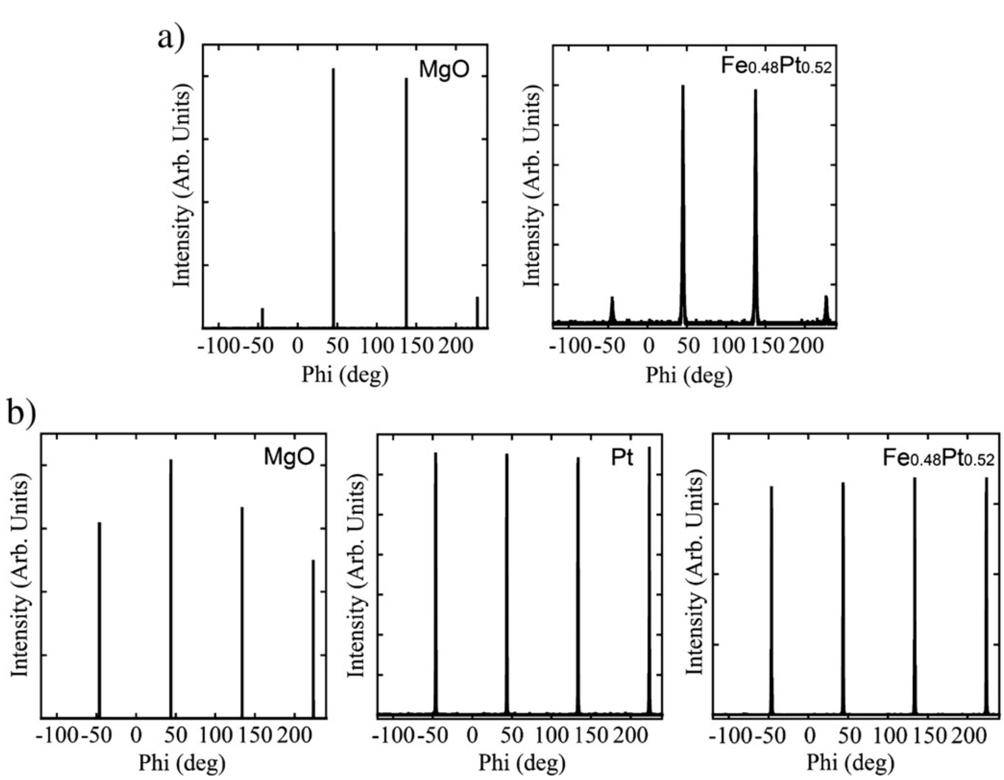

Fig. 2. Azimuthally scans of (a) MgO {111} and FePt {111} for Sample (i), and (b) MgO {111}, Pt {111} and FePt {111} for Sample (ii).