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Improving atomic ordering in iron platinum magnetic film by suppressing grain growth by rapid thermal annealing with a high heating ramp rate

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ABSTRACT

In this study the structural and magnetic properties of FePt thin film processed at different annealing temperatures were studied. The FePt thin films were deposited by direct current (dc) magnetron sputtering on Si/SiO_2 (110) wafer at a room temperature. The films were then annealed at temperature range of 575–675 °C for 20s with a rapid thermal annealing (RTA) process at a high heating ramp rate of 100 K/s. The structural, magnetic and surface properties of samples were studied by X-ray diffraction (XRD), scanning electron microscopy and vibrating sample magnetometer. XRD results showed that the ordered structure of FePt phase is formed at 600 °C. The grain size of thin films was increased with an increase in annealing temperature. The uniform thickness was achieved for the whole series of samples. The maximum out-of-plane coercivity reached to 1.7 MA/m for sample annealed at 650 °C. Magnetic interaction which was evaluated by Henkel plots reflects the existence of exchange interaction in thin films.

1. Introduction

Due to the expanding need in various fields of information technologies such as high density recording media, ferromagnetic nanostructured thin films with moderate saturation magnetization and high coercivity have been attracted extensive interest [1–3]. For this purpose the grain size of thin film should be decreased [4]. Due to the superparamagnetism limit, the thermal stability of magnetic properties of thin film decreases with reducing the grain size which hinders their applications [5]. Consequently, new concepts are required to satisfy the growing demand for reliable data storage devices. Hard ferromagnetic materials with high magneto-crystalline anisotropy were used to overcome this problem. FePt-based recording layers are one candidate for high storage densities due to the high magneto-crystalline anisotropy. FePt alloys in their L10 phase allowing a further reduction in grain size without losing the thermal stability [6–9].

According to the FePt binary phase diagram, around the equi-atomic composition, a disorder–order structural transition occurs when the temperature decreases less than 1300 °C. At temperatures above 1300 °C, atomically disordered fcc phase (Al type structure) forms with lattice constant of a = 3.807 Å. Low magnetic anisotropy (K_u) and coercivity (H_c) make it less suitable for use as magnetic recording

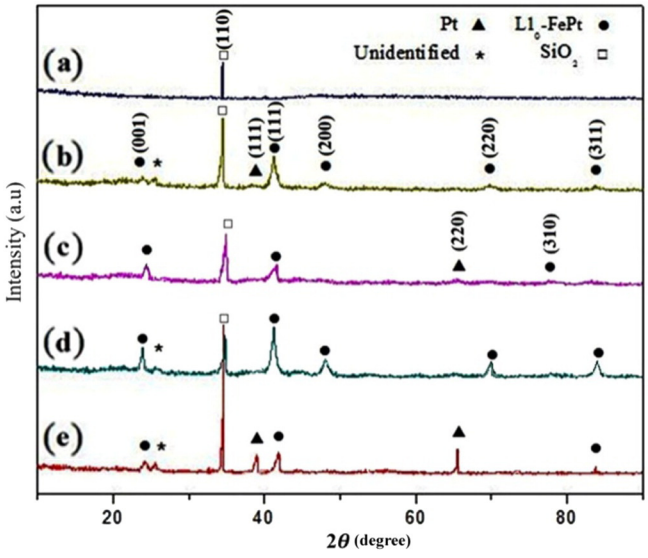

Fig. 1. XRD patterns of FePt thin films after post annealing at (a) 575 °C, (b) 600 °C, (c) 625 °C, (d) 650 °C and (e) 675 °C.

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medium. On the other hand, FePt ordered structure with $L1_0$ superlattice has considered as a potential candidate for hard-disk drives with ultrahigh recording density because it has extremely high magnetic anisotropy constant ($K_u = 7 \times 10^7$ erg/cm^3$\times 10^7$ $\frac{erg}{Cm^3}$) [10–11].

However, the challenge involved in the growth of chemically ordered FePt layers with sufficient precision is still on the way of several researches. For this reason, substantial research activities have been established around the world [12–15].

The rapid thermal annealing (RTA) technique with a high heating ramp rate has some advantages, such as improving the chemical ordering of FePt nano-sized grains at a lower temperature and a shortened time to reduce grain size, thereby increasing the magnetic recording density and improving the domains structure orientation and reducing the media noise [16–17].

In this study, deposition of FePt thin films on Si/SiO_2 (110) substrates was done. Then annealing process on the $L1_0$-FePt/PtIr layers was carried out by using a rapid thermal annealing (RTA) furnace. Hard ferromagnetic FePt phase with a high perpendicular coercivity was obtained. The magnetic properties and structural characteristics of the annealed FePt thin films were investigated. The enhancement of coercivity with annealing temperature was attributed to an increase in magneto-crystalline anisotropy and reduction of grain size. Considering the magnetic features and morphology of thin films, the optimum annealing temperature was selected.

2. Experimental procedures

FePt alloy thin films with 100 nm thickness were sputter-deposited on Si/SiO_2 (110) substrates using dc magnetron sputtering method with composite target of $Fe_{50}Pt_{50}$ at a room temperature. In order to form an epitaxial growth of thin film, the PtIr was employed as a buffer layer with thickness of 5 nm. Pre-sputtering treatment was performed to

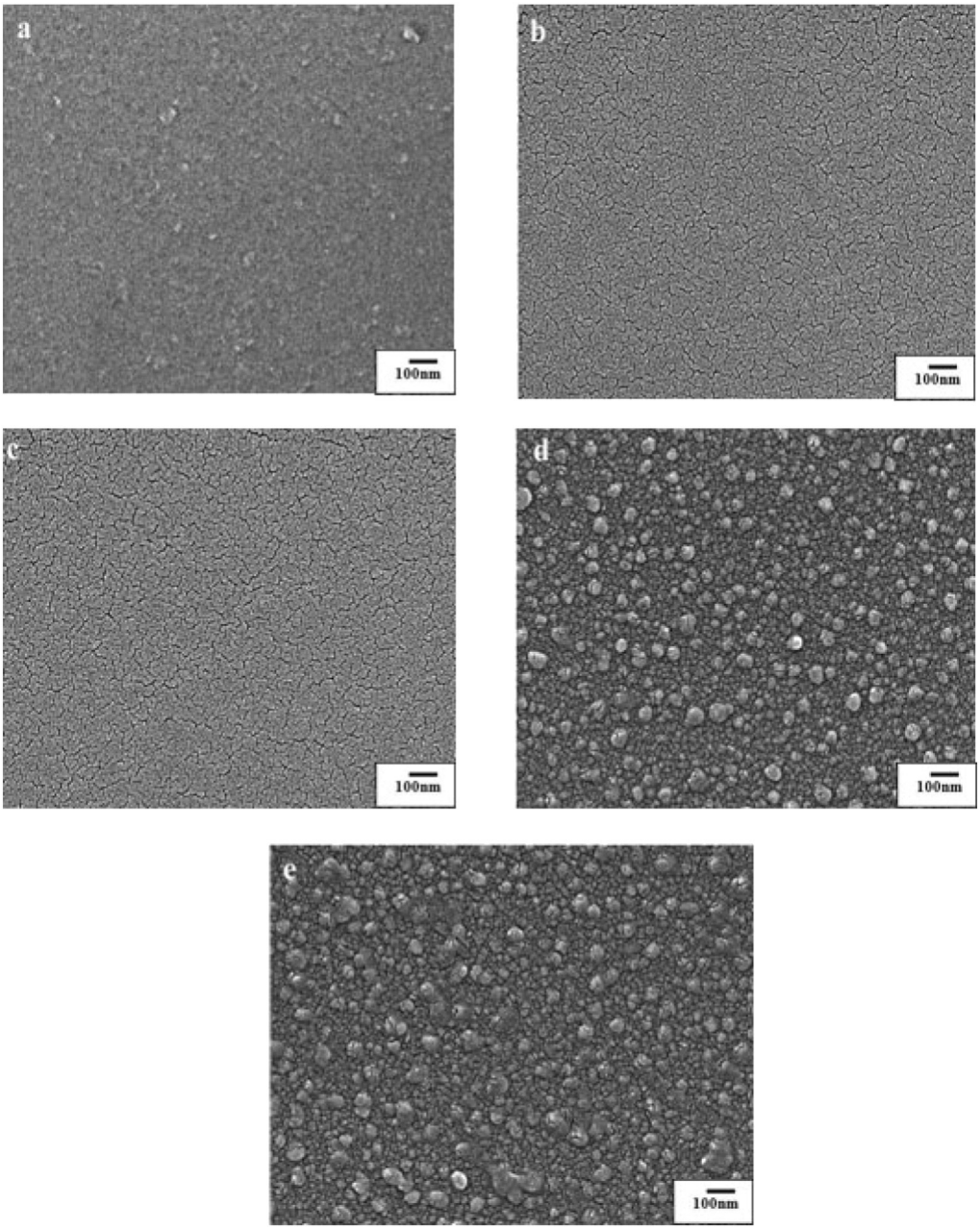

Fig. 2. FE-SEM images of FePt thin films after post annealing at (a) 575 °C, (b) 600 °C, (c) 625 °C, (d) 650 °C and (e) 675 °C.