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Article / Book Information

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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Among magnetic recording technologies for HDDs, perpendicular magnetic recording is considered to be advantageous for overcoming superparamagnetic limitation and achieving high areal recording density. As the core element of such technology, recording media with perpendicular magnetic anisotropy have attracted much research interest in the past decades. For example, metallic layered structures (such as Co/Pt, Co/Pd) and $L1_0$-FePt/CoPt alloy films have been intensively studied as promising materials for ultrahigh density magnetic recording.

In this thesis, magnetic anisotropy of metal/ceramic-FePt/AlN layered structures has been systematically studied. By using nitride layer, the interface diffusion which often occurs in metallic layered structure can be effectively avoided. It is found that FePt/AlN layered structure shows unconventional magnetic anisotropy transition after thermal annealing comparing to the well-studied metallic layered structures. The interface anisotropy and magnetoelastic effect introduced by layered structure are also unique in the past studies of FePt alloy. Microstructures, residual stress and interface quality are investigated to disclose the origin of perpendicular magnetic anisotropy in FePt/AlN layered structure and the mechanism of magnetic anisotropy transition. The experimental results are summarized, and the conclusions of this thesis are made as following.

The FePt/AlN layered structures with good periodicity and accurate layer thickness are successfully fabricated. The as-deposited layered structure shows weak in-plane magnetic anisotropy (the easy direction of magnetization is along the film plane) comparing to the FePt single layer film, indicating the formation of layered structure can favor the magnetization in perpendicular direction. As the FePt layer thickness increases, the in-plane magnetic anisotropy of layered structure is enhanced.

The magnetic anisotropy of FePt/AlN layered structure can be altered through annealing. For layered structure with small FePt layer thickness, it is found that the easy magnetization direction gradually changes from in-plane direction to perpendicular direction as annealing temperature increases. The AlN 20nm/(FePt2nm/AlN10nm)$_5$ layered structures annealed at 600°C show strong perpendicular magnetic anisotropy (the easy direction of magnetization is along the film normal) with magnetic anisotropy energy of 1.06×10^6 erg/cc. As the FePt layer thickness increases, the annealed layered structures undergo a transition of magnetic

anisotropy from perpendicular to in-plane direction. However, in contrary to the layered structure with thin FePt layer, the in-plane magnetic anisotropy of layered structures with larger FePt layer thickness is enhanced with the increase of annealing temperature. It seems that 5nm is the critical FePt layer thickness for the different annealing effects.

The interface quality analysis shows that the interface quality of FePt/AlN layered structure is improved by annealing. The flattening of interface can strongly enhance the Néel-type interface anisotropy and promote the magnetization in perpendicular direction. On the other hand, according to the stress analysis we find the residual stresses inside FePt layer turn from compressive to tensile as annealing temperature increases. With a positive magnetostriction constant, this will decrease the positive magnetoelastic energy which can contribute to the perpendicular magnetic anisotropy. In conclusion, FePt/AlN layered structures show strong interface anisotropy, which is the main origin of perpendicular magnetic anisotropy in FePt/AlN layered structures.

The effective magnetic anisotropy energies K_{eff} of the FePt/AlN layered structures with different FePt layer thicknesses and annealing temperatures have been calculated. The effective magnetic anisotropy energy K_{eff} (erg/cm^3) is phenomenologically separated in a volume contribution K_V (erg/cm^3) and an extra interface contribution K_S (erg/cm^2). Because of the large lattice misfit between FePt and AlN layer, it is reasonable to consider that K_S is solely Néel-type interface anisotropy and the magnetoelastic anisotropy is part of K_V. The K_S is gradually enhanced by annealing and shows a value of 0.4 erg/cm^2 in the layered structures annealed at 500°C, indicating the perpendicular magnetic anisotropy of the annealed FePt/AlN layered structure is mainly from the interface anisotropy. Therefore, for layered structures with FePt layer thickness below 5nm, although the relief of compressive stress caused by annealing will decrease the perpendicular (positive) magnetoelastic anisotropy as discussed above, the enhanced interface anisotropy becomes dominant then K_{eff} of annealed films increases. When the FePt layer is thick, the contribution from K_S (interface anisotropy) is relatively small according to the equation of $K_{eff} = K_V + 2K_S/t$, and tensile stresses developed during annealing will result in a negative magnetoelasitc anisotropy which overwhelms the interface anisotropy, thus decreases K_{eff}. Therefore, in this work, we have proved that Fe40Pt60 alloy has positive magnetostriction coefficient, and the magnetic metal/nitride layered structures can show strong interface anisotropy. For FePt alloy, such interface anisotropy can overcome the magnetoelastic effect below a critical thickness for FePt layer.

The perpendicular magnetic anisotropy of FePt/AlN layered structure can also be enhanced by decreasing the AlN layer thickness. The AlN(5nm)/[FePt(2nm)/AlN (5nm)]$_5$ layered structure annealed at 500°C shows strong perpendicular magnetic anisotropy with magnetic anisotropy energy of 1.40×10^6 erg/cc. According to the results of microstructure analysis, such enhancement of perpendicular magnetic anisotropy is attributed to the decrease of interface roughness and the improvement of FePt crystallinity, as the AlN layer thickness decreases.