Enhancement of perpendicular exchange bias in [Pd/Co]/FeMn thin films by tailoring the magnetoelastically induced perpendicular anisotropy

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(Received 12 September 2010; accepted 22 November 2010; published online 17 December 2010)

The effects of magnetoelastically induced perpendicular anisotropy, $K_{FM,me}$, on the perpendicular exchange bias (PEB) characteristics in $[Pd/Co]_5/Fe_{50}Mn_{50}$ thin films have been explored by inserting ultrathin CoFe magnetic layers with different thicknesses, compositions, and Ar sputtering gas pressures ($P_{Ar,CoFe}$) at the interface between $[Pd/Co]_5$ and FeMn. It was clearly found that the $[Pd/Co]_5/CoFe/FeMn$ with CoFe sputtered at a low $P_{Ar,CoFe}$ showed great enhancement in PEB due to the development of intrinsic compressive stress in the CoFe resulting in improving $K_{FM,me}$ and interfacial exchange coupling. Additionally, this effect was more significant for $Co_{80}Fe_{20}$ insertion than $Co_{90}Fe_{10}$ due to its larger magnetostriction. © *2010 American Institute of Physics.*
[doi:10.1063/1.3526735]

Recent interests in perpendicular exchange biased spin-valves (PEBSVs) for spintronics and magnetoelectronics have been dramatically increased due to their high magnetic stability and low device operating current density.[1] Accordingly, a great deal of research efforts has been made toward the applications in various spintronics devices.[2] However, although perpendicular exchange bias (PEB) characteristics in PEBSVs have been extensively studied for the past 10 years, they are still facing critical challenges of small exchange bias field (H_{ex}) and large coercivity (H_c) limiting their advanced applications in spintronics devices. The PEB systems considered for PEBSV devices have been mostly based on perpendicularly magnetized [Co/Pt(Pd)] multilayers (PMLs)/antiferromagnetic (AFM) layer or perpendicularly magnetized FePt (or CoPt) single layer/AFM structure.[3,4] According to the previous reports, it was found that controlling the net magnetization between the top layer of PMLs (or single FM) and AFM interface, as well as the effective anisotropy of both AFM and FM layers, is the most crucial factor to determine the physical characteristics of PEB.[5] Hence, the research approaches to improve the PEB characteristics done so far were mainly focused on enhancing either interfacial exchange coupling (J_{ex}) by adjusting the surface roughness of perpendicularly magnetized ferromagnetic (FM)/AFM interface, or crystalline effective anisotropy of AFM or FM layer ($K_{AFM,eff}$, $K_{FM,eff}$) by employing different seed layers and optimizing the crystalline structures.[3,6,7]

In this letter, we report on another effective technical approach, which can significantly enhance the PEB characteristics in $[Pd/Co]_5$ PMLs/FeMn exchange biased thin films by tailoring the stress-induced perpendicular anisotropy, which is considered as another crucial physical origin of the perpendicular anisotropy of [Co/Pd] PMLs ($K_{FM,eff}=K_{crys}+K_{FM,me}$).[8] In order to control the stress-induced perpendicular anisotropy, "magnetoelastically (ME)-induced perpendicular anisotropy, $K_{FM,me}$," at the interface between $[Pd/Co]_5$ PMLs and FeMn AFM layer, ultrathin CoFe films were inserted due to its pseudomagnetic property, which induces a strong perpendicular anisotropy in the CoFe layer when it is adjacent to the $[Pd/Co]_5$ PMLs with strong perpendicular anisotropy. In addition, to systematically study the effects of tailored $K_{FM,me}$ on the PEB characteristics, the crystal structure, the magnetostriction (λ_{CoFe}), and the intrinsic film stress (σ_{CoFe}) of the CoFe insertion were changed by varying the film thickness, the composition kept at a face centered cubic (fcc) structure (i.e., $Co_{90}Fe_{10}$ and $Co_{80}Fe_{20}$) and the Ar working gas pressure ($\boldsymbol{P}_{Ar,CoFe}$) during the sputtering. The physical nature of the ME-enhanced PEB characteristics was primarily interpreted in terms of the correlation between J_{ex} at the CoFe/FeMn interface and the enhancement in $K_{FM,me}$.

The $Ta(2.1)/[Pd(0.6)/Co(0.23)]_5/CoFe(t)/FeMn(11.6)/Ta(2.1\ nm)$ PEB thin films with different CoFe insertions were deposited on a Si (100) substrate using a dc-magnetron sputter at room temperature. The base pressure was kept below 3.0×10^{-7} Torr and the Ar working gas pressure was kept at 2.0 mTorr except for CoFe insertion layer. In order to study the effects of $K_{FM,me}$ on the PEB characteristics, the CoFe with different compositions ($Co_{80}Fe_{20}$ and $Co_{90}Fe_{10}$) and film thicknesses (4–6 Å) were inserted at the interface between $[Pd/Co]_5$ PMLs and FeMn AFM layer. In addition, to systematically control the σ_{CoFe} from compressive (−) to tensile stress (+) during the CoFe film growth, $\boldsymbol{P}_{Ar,CoFe}$ was changed from 1.7 to 20 mTorr. The magnetic properties of the PEB thin films were measured using an extraordinary Hall effect (EHE) measurement system. The dependence of the film microstructure on $\boldsymbol{P}_{Ar,CoFe}$ was analyzed in terms of film resistivity (ρ), surface roughness, and grain size using a computer-controlled four point probe system and an *ex situ* atomic force microscopy (ex-AFM). The crystalline structure of single-layered CoFe, $[Pd/Co]_5$ PMLs/CoFe/FeMn PEB thin films, and stress effects were analyzed using a Cu $K\alpha$ radiated x-ray diffractometer (XRD).

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