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著者(和文)	WANGJIAN
Author(English)	Jian WANG
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# Abstract

The exchange bias (EB) effect was firstly discovered by Meiklejohn and Bean when studying Co particles embedded in its native antiferromagnetic oxide CoO. EB arises from the interfacial exchange coupling between a ferromagnetic (FM) and an antiferromagnetic (AFM). Since 1957, EB was observed in a variety of different materials and it was the subject of many different theoretical approaches, but until now its microscopic origin is still open to debate. The extensive study of EB is motivated by its unique physical properties and also by its application such as giant magnetoresistive spin-valve read heads and magnetic memory devices. With the progress of the research in this attracting topic, EB system with layered structure has been developed into two branches:

(a). Longitudinal exchange bias (LEB), in which the ferromagnetic layer shows in-plane anisotropy (in-plane magnetization easy axis). Consequently, the unidirectional anisotropy induced by LEB at FM/AFM interface also lies within the thin film plane;

(b). Perpendicular exchange bias (PEB), in which the ferromagnetic layer holding whether in-plane anisotropy or perpendicular magnetic anisotropy (PMA, out-of-plane magnetization easy axis). PEB can be established after perpendicular field cooling along the thin film normal direction. Perpendicular exchange bias established in ferromagnetic films with perpendicular magnetic anisotropy (PMA) was recently introduced as a new topic. Its application in spin transfer torque MRAM (STT-MRAM) was proved can significantly reduce the operation current and speed up the write and read process.

In this work, exchange bias effect was systematically studied with Co-Pt/CoO multilayer films which have whether longitudinal magnetic anisotropy (LMA) (Co/CoO multilayer films) or perpendicular magnetic anisotropy (PMA) (CoPt/CoO multilayer films).

For Co/CoO multilayer films with LMA, the effect of interface roughness on the magnetic properties of ferromagnetic/antiferromagnetic multilayer has been studied by comparing the interfaces within identical multilayer (lower vs. upper) or from different Co/CoO multilayers (different deposition sequence). It has been found that for identical multilayer, the upper Co/CoO interfaces grow rougher and show stronger exchange bias than the lower Co/CoO interfaces. Structural analyses indicate that the successive layer deposition gives rise to a cumulative roughness at the upper interface, which affects the magnetic properties of ferromagnetic layer and its coupling to the antiferromagnetic layers. The interface roughness strengthens the interfacial exchange coupling by the increase of defect-generated uncompensated antiferromagnetic spins; such spins form coupling with the spins from Co layer at the interface. Due to the different coupling strength of each Co layer to the neighboring CoO layers, the multilayer showed distinct switching fields during the magnetization reversal process.

With specific external magnetic field, anti-parallel spin configuration among each ferromagnetic Co layer can be established within the multilayer and would result in a high resistance state. For its unique spin structure and simplified fabrication process Co/CoO multilayer films is consider as a potential candidate for spintronic device application such as MTJ.

For CoPt/CoO multilayer films with PMA, strong PMA was successfully established with RT sputter-deposited CoPt/CoO multilayer film. It should be noted that **the PMA here is the first time established with AF oxide/transition metal alloy** interfaces. Moreover, after perpendicular field cooling below the Néel temperature of CoO layer, the multilayer with anti-ferromagnet (AF) / ferromagnet (FM) interfaces exhibits perpendicular exchange bias (PEB). And also the PMA of the multilayer is enhanced after field cooling process. This is considered due to the strong interfacial exchange coupling between the CoPt and CoO layers, which is further confirmed from the significantly enhanced perpendicular coercivity. Similar with the reported Co/noble-metal structures, the strong PMA found here

also shows clear interface effect. However, with the multilayer structure studied here, the PMA can survive with relative thicker ferromagnetic layer at as-deposited state. Therefore, the PMA found in AF/FM multilayer could be partially attributed to the interfacial AF-FM exchange coupling. On the other hand, structural characterization results indicate a well-defined layer structure and strong (111) texture for CoPt layers. CoO layer here provides a good seed layer for the growth of textured CoPt layer. As [111] is one of the easy axis for the fcc CoPt, the (111) texture should also benefit the PMA. Such PMA and PEB originating from the interface would give new parameters to control the magnetic properties especially for multilayer systems.