論文 / 著書情報
Article / Book Information

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種別(和文)	論文要旨
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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	材料工学専攻　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
学籍番号： Student ID Number		指導教員（主）： Academic Advisor(main)	中村 吉男
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The exchange bias (EB) effect was firstly discovered by Meiklejohn and Bean when studying Co particles embedded in its native antiferromagentic 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 with CoPt layer thickness of 2.5nm. It should be noted that **the PMA here is the first time established with AF oxide/transition metal alloy interfaces**. The PMA of the RT as-deposited CoPt/CoO multilayer is found to exhibit an interface characteristic. With increasing CoPt layer thickness, the magnetization easy axis of the multilayer films transits from film normal to in-plane direction. It indicates that the PMA found here is an interface effect and the interface anisotropy is one of the main sources for the established PMA. Moreover, a weak PEB is observed with the multilayer after the perpendicular field cooling. Furthermore, in order to get large enough PEB for actual application, microstructure optimization was carried out to improve the magnetic properties. The improved CoPt/CoO multilayer films show good (111) texture, smooth FM/AFM interfaces and even local epitaxial relationship at the CoPt/CoO interfaces. Correspondingly, significant improvement of the magnetic property was also observed. The strong PMA can preserve until a threshold CoPt layer thickness around 6.5 nm (usually 1 nm for FM/Noble metal multilayer system). Also after perpendicular field cooling, the multilayer with ferromagnet/antiferromagnet interfaces exhibits strong perpendicular exchange bias (PEB). **The largest PEB of 1800 Oe (interface exchange energy 0.23 erg/cm^2) was found at CoPt layer thickness around 2.5nm. It is the largest value compared with similar reported multilayer structure**. The strong PMA here is attributed to the positive magnetoelastic energy due to the remarkable in-plane tensile stress which is originated from the local epitaxial growth. On the other hand, it was found that the antiferromagnetic anisotropy energy and interface quality play a critical role on determine the final PEB in CoPt/CoO multilayer films.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 2 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 2 copies of 800 Words (English).