論文 / 著書情報
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題目(和文)	熱処理によるCoO/CoPt多層膜の垂直磁気異方性および垂直交換バイアスの向上
Title(English)	Enhancement of Perpendicular Magnetic Anisotropy and Perpendicular Exchange Bias in CoO/CoPt Multilayer Films by Thermal Annealing
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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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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 ）

Perpendicular magnetic recording, which is based on up and down magnetization in perpendicular magnetic anisotropy (PMA) thin film, was firstly proposed in the late 1970s. After that, PMA has been proposed in various configurations during the past decades, since it is of great importance in high density perpendicular magnetic recording. Recently, with the development of PMA, perpendicular exchange bias (PEB) was also introduced as an active topic. Nowadays, multilayer films with PEB are considered to be a potential effect used in the perpendicular spin valve and perpendicular magnetic tunneling junction e.g. With such industrial background as well as scientific interest, PEB has been widely studied in FM/AFM multilayer films.

Since their discoveries, PMA and PEB phenomenons have been widely studied due to their complicated mechanisms and technological applications. In fact, despite the active researches in this field, many aspects of PMA and PEB are still controversial so far. On the other hand, at present there are few works mentioning the correlation between PMA and PEB. So, considering the important values in theory and application, it is significant to further explore the nature and the correlation between PMA and PEB.

In this thesis, PMA and PEB of $[CoO_x/CoPt_y]_n$ multilayer films have been studied systematically. $[CoO_x/CoPt_y]_n$ multilayer films were deposited on glass substrate by magnetron sputtering at room temperature. After deposition, $[CoO_x/CoPt_y]_n$ multilayer films were annealed in vacuum at different temperatures. The micro-structural characterizations of $[CoO_x/CoPt_y]_n$ multilayer films, including crystallinity, cross-section, top-surface and interface, were carried out by x-ray diffraction (XRD), transmission electron microscope (TEM), atomic force microscope (AFM) and x-ray reflectivity (XRR) respectively. The magnetic anisotropy of $[CoO_x/CoPt_y]_n$ multilayer films were measured by vibrating sample magnetometer (VSM) at room temperature and the exchange bias effect of $[CoO_x/CoPt_y]_n$ multilayer films were measured at low temperature after field cooling.

The influences of post-annealing temperature, CoPt thickness, CoO thickness, repetition period and CoO seed layer on PMA and PEB were studied step by step. Enhancement of PMA and PEB by thermal annealing has been confirmed in $[CoO_x/CoPt_y]_n$ multilayer films. We found 300^{o}C-annealed $[CoO_x/CoPt_y]_n$ possess the strongest PMA and the best PEB. According to the experiments, $CoO_{20nm}/[CoPt_{5nm}/CoO_{5nm}]_5$ multilayer films show the best PMA performance and possess the highest thermal stability at the temperature region between -192^{o}C and 400^{o}C. This indicates $CoO_{20nm}/[CoPt_{5nm}/CoO_{5nm}]_5$ multilayer films could be a potential candidate for the PMA application at elevated temperatures, in particular when they need to be processed at the middle high temperature region between 300^{o}C and 400^{o}C. After perpendicular field cooling, 300^{o}C-annealed $[CoO_{5nm}/CoPt_{5nm}]_5$ film shows the best PEB performance, having a PEB value of 1060 Oe with clear rising-edge and falling-edge.

The magnetic anisotropy transition of $[CoO_{5nm}/CoPt_{7nm}]_5$ multilayer film with respect to post-annealing

has been studied systematically. It undergoes a smooth transition from longitudinal magnetic anisotropy (LMA) to PMA upon annealing and returns backward to LMA at high temperature of 550°C. The strongest PMA of $[CoO_{5nm}/CoPt_{7nm}]_5$ is achieved after post-annealing at 300°C and the tolerable post-annealing temperature with strong PMA is up to 400°C. The mechanism responsible for the magnetic anisotropy transition in $[CoO_{5nm}/CoPt_{7nm}]_5$ multilayer films has been studied in detail by analyzing CoO/CoPt interface and CoPt layer internal stress. It is found the effective PMA energy is proportional to the CoPt layer in-plane tensile stress but is inversely proportional to the CoO/CoPt interface roughness. By means of low temperature experiment, we demonstrate the magnetic anisotropy transition observed in $[CoO_{5nm}/CoPt_{7nm}]_5$ multilayer film is mainly attributed to the change of CoPt layer in-plane tensile stress. In other words, it is magnetoelastically induced magnetic anisotropy transition in $[CoO_{5nm}/CoPt_{7nm}]_5$.

The effects of magnetoelastically induced PMA on PEB have been studied in $[CoO_{5nm}/CoPt_{5nm}]_5$ multilayer films. Significant enhancement of PMA was achieved in $[CoO_{5nm}/CoPt_{5nm}]_5$ multilayer films after annealing due to the increase of CoPt layer in-plane tensile stress. With the enhancement of magnetoelastically induced PMA, great improvement of PEB was also achieved in $[CoO_{5nm}/CoPt_{5nm}]_5$ multilayer films, which increased from 130 Oe (as-deposited) up to 1060 Oe (300°C-annealed), showing the same change tendency as PMA and the strong correlation with CoPt layer in-plane tensile stress. We consider it is the increase of CoPt layer in-plane tensile stress that leads to the enhancement of CoPt layer PMA, which is favorable for the spins in CoPt layer aligning to a more perpendicular direction. And thus the enhanced PMA with more perpendicular spins alignment in CoPt layer results in the improved PEB in $[CoO_{5nm}/CoPt_{5nm}]_5$ multilayer films through enhanced perpendicular spins coupling at CoO/CoPt interfaces.

To our knowledge, the PMA surviving at temperature region between 300°C and 400°C in $[CoO_x/CoPt_y]_n$ multilayer film is obtained for the first time. On the other hand, the positive effect of PMA on PEB at FM/AFM interface in $[CoO_x/CoPt_y]_n$ multilayer films is also reported for the first time.