한국과학기술원 물리학과 및 스핀정보물질연구단 김 상 국*
한국과학기술연구원 박막기술연구센터 김 광 윤
한국과학기술원 물리학과 및 스핀정보물질연구단 신 성 철

Unidirectional Anisotropy in an Exchange-Biased Top Spin Valve Structure Investigated by Magneto-Optical Kerr Vector Magnetometry

Korea Advanced Institute of Science and Technology Sang-Koog Kim*
Korea Institute of Science and Technology Kwang Youn Kim
Korea Advanced Institute of Science and Technology Sung-Chul Shin

I. INTRODUCTION

The macroscopic exchange bias caused in principle by the unidirectional anisotropy of a ferromagnet (FM) exchange-coupled to an adjacent antiferromagnet (AFM) is of an increasingly interesting subject [1-3]. Even though a number of studies of the exchange bias phenomenon in various FM/AFM systems fabricated or heat-treated in an applied magnetic field, have been intensively carried out to date, the underlying physics of the mechanism related closely to a FM/AFM interface still remains unsolved. As an effort to verify the origin of exchange bias driven by unidirectional anisotropy, in the present work we have investigated the effects of both the different field directions and magnetization states of FM on unidirectional anisotropy by using a magneto-optical Kerr effect (MOKE) vector magnetometer [4]. The vector nature of magnetization reversals in a top spin valve structure allows to better understand the mechanism of exchange bias. Furthermore, it is found that the exchange bias is readily controllable through the magnetization state of FM layers, which reveals the surface spin states of AFM can be manipulated by those of the FM layers. Details of correlation between exchange bias and their dependence on field-direction as well as FM magnetization state will be discussed.

II. EXPERIMENTS

An exchange-biased top spin valve structure of Si(100)/Ta/NiFe(45 Å)/CoFe(15 Å)/Cu(26 Å)/CoFe(40 Å)/FeMn(80 Å)/Ta(50 Å) was fabricated by dc magnetron sputtering with a base pressure of 5×10^{-7}. Unidirectional exchange bias was set during the film growth in the presence of a magnetic field of +300 Oe. The sample was transferred to a separate UHV chamber equipped with MOKE vector magnetometer in order to investigate two orthogonal in-plane components of magnetization during the field sweeping. We carried out experiments on the effects of 1) the field-direction and 2) magnetization state of FM on unidirectional exchange bias. The sample was heated up to 230 °C followed by cooling to room temperature in the presence of or without an applied magnetic field whose direction was 0, 30, 60, and 90 degree with respect to the pinning direction set during the film growth.

III. RESULTS AND DISCUSSION

Figure 1 shows the longitudinal Kerr rotation loops measured at room temperature as a function of the field direction θ with respect to the pinning direction for a sample having more than 8 % magnetoresistance ratio as seen in the inset. Exchange bias caused by unidirectional anisotropy is clearly visible along with its dependence on the field direction. We also measured transverse components of magnetization during the reversals. From these data, the vector nature of the magnetization states during the reversal will be presented.

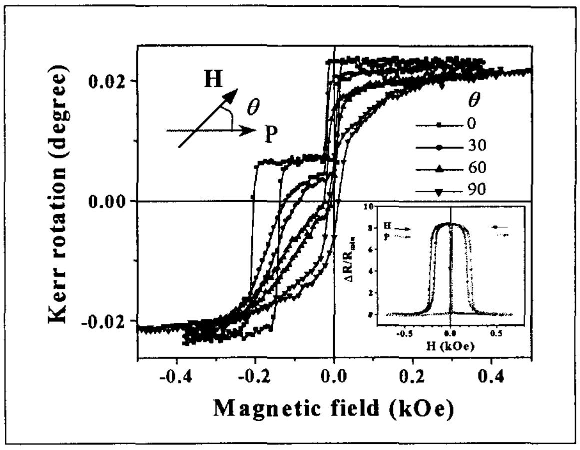

Fig. 1. Longitudinal Kerr rotation loops measured at room temperature after a 300-Oe-field cooling from 230 °C. The inset shows magnetoresistance ratio curves for two opposite field directions.

The effect of the magnetization state of FM layers on unidirectional exchange bias is presented in Fig. 2. To change the magnetization state of FM, the sample was saturated by the positive field as marked in figure and then a magnetic field was set at, below and beyond the negative coercive field as marked by symbols. Clear distinct loops are shown along with different exchange-bias fields of positive as well as negative sense.

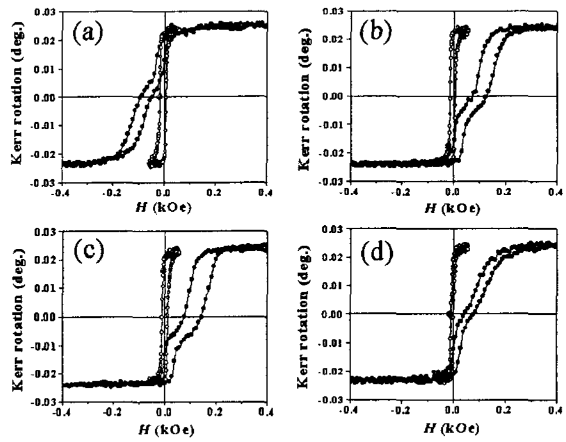

Fig. 2. Dependence of unidirectional exchange bias on the magnetization state of ferromagnetic layer. Open circles indicate loops measured at 130 °C and closed circles represent the corresponding loops measured at room temperature after zero field cooling while keeping the magnetization state of FM at a state as marked by symbols. The field direction is parallel (a)-(c) and perpendicular (d) to the pinning direction.

IV. CONCLUSIONS

The present work has clearly verified that the unidirectional exchange bias is governed by the spin structure of FM layer directly affecting those of AFM in proximity to the FM layers, not by the external magnetic field.

V. REFERENCES

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