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Exchange Bias Enhancement by Ultra-thin Mn Insertion at the Interface of Mn-Ir / Co-Fe Bilayers

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Exchange bias is one of the indispensable physical phenomena to realize high-density data storage devices such as hard disk drives (HDDs) and magnetic random access memories (MRAMs). Recent minitualization of spin valve elements in HDDs and MRAMs strongly requires the enhancement of exchange biasing strength. Many kinds of antiferromagnetic (AFM) materials have been developed to induce strong exchange anisotropy for ferromagnetic (FM) / AFM bilayers, but it generally takes long time to find out a new materials havinghigh application potentials. One different approach to obtain high performance of exchange bias withconventional materials is spin engineering at the FM / AFM interface [1]. Since the exchange anisotropy is originated from the exchange interaction at the interface, the interfacial spin structure modification, especially for the surface of AFM layer, will result in the change of exchange biasing strength. In the present study, we successfully enhanced the exchange biasing strength in Mn-Ir / Co-Fe bilayers with inserting an ultra-thin Mn layer.

Specimens in a stacking sequence of substrate / Ta / Ru / $Mn_{75}Ir_{25}$ / X / $Co_{70}Fe_{30}$/ Ru were deposited on thermally oxidized Si wafers with DC magnetron sputtering method. Mn, Cr, Ta, Pd, Ru, Tb, and Gd were examined as an inserted layer, X, with changing their thickness up to 1 nm. Thermal annealing was performed for the specimens in vacuum at 250°C ~ 400°C for 1 hr under applied field of 1 kOe. The magneticproperties were measured at room temperature, and unidirectional anisotropy constant, JK, was determined as a product of the saturation magnetization per unit area and the exchange bias field.

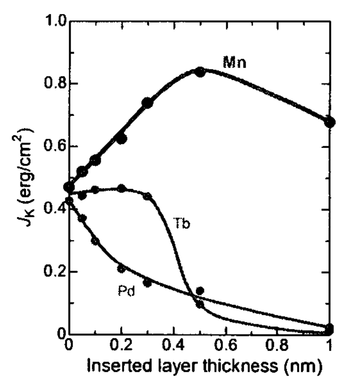

Figure shows an inserted layer thickness dependence of J_K. The J_K of the bilayer without insertion layer is 0.45 erg/cm^2. With inserting a non-magnetic layer, represented by Pd, the J_K monotonously decreases with increasing the inserted layer thickness, similarly to the previous reports [2]. For the case of rare-earth elements, represented by Td, the J_K also decays with increasing the inserted layer thickness beyond 1 monolayer (ML), while it does not change below 1 ML. Only for the case of Mn, strong enhancement of J_K is observed. It reaches 0.85 erg/cm2 with 0.5 nm-thick inserted Mn, roughly corresponding with 2 MLs of fcc-Mn. Significant point to be noticed here is that this enhancement is not elucidated with a dependence of J_K on chemical composition of the Mn-Ir layer. It might be due to the modification of AFM spin structure at the interface.

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AC06

Exchange Effects in Iron Films Grown on Si(100) Substrates

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INTRODUCTION

An exchange bias (EB) effect occurs due to the exchange coupling at antiferromagnetic (AFM)/ferromagnetic(FM) interfaces leading to a shift of the magnetic hysteresis loop along the field direction [1]. This shift of the hysteresis loop can be established either by cooling the AFM/FM bilayers in a magnetic field below the Neel temperature of the AFM or by depositing the bilayers in an external magnetic field. Although many features of this effect are not well understood, the exchange bias effect has been used over several decades and more recently for pinning the magnetization of one of the two electrodes in magnetoresistivedevices [2]. In this paper, we report on the exchange effects in Fe films grown on Si(001), where there is a thin native SiO_2 cover layer on top of the substrates. In addition, the temperature dependence of the shift and the coercivity, and its thickness dependence, are reported.

EXPERIMENTAL DETAIL

The Fe films used in this study were deposited onto a Si(001) substrate at room temperature in an ultrahigh-vacuum sputtering system with a base pressure below $\sim 5\times10^{-7}$Pa. The deposition rate was 2 nm/min. The surface morphology of the deposited films was observed by atomic force microscopy (AFM). For the structural investigation the x-ray diffraction (XRD) measurement was performed. The information about the local atomic order around the Fe atoms was provided by an extended x-ray absorption fine structure (EXAFS) measurement. The magnetization curves were measured using superconducting quantum interference device (SQUID) magnetometer.

RESULTS AND DISCUSSION

The main experimental observation in the data is a shift in the hysteresis loop for the Fe films deposited on Si(001) with the native SiO_2 cover layer and cooled in the presence of an applied magnetic field as illustrated in Fig. 1. The shift results from a coupling between the ferromagnetic Fe film and the antiferromagnetic iron oxide that forms spontaneously in the interface. It is noted that the temperature dependence of the measured exchange coupling is different from that which is usually reported: a shift of the loops towards the negative field values was observed for T<20K, which is the usual field-cooling behavior that is a signature of exchange bias. However, at T>20K, we observed a shift towards the cooling-field direction, which was not observed in previous reports. The sign change with temperature we observed in our data is qualitative similar to Co/CuMn bilayer system [3].

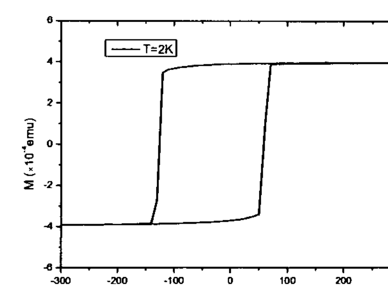

Fig. 1. The measured shifted hysteresis loop at 2K for a 10 nm Fe film after cooling in a 10000 Oe applied field.

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