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Giant Parallel and Perpendicular Exchange Biases in MnPd/Co Bilayers

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Exchange bias coupling between ferromagnetic (FM) and antiferromagnetic (AF) layers was first discovered nearly fifty years ago [1] and has been attracted a great attention. However, the origin of this phenomenon is not yet fully understood, especially the magnitude of the unidirectional anisotropy is still open to question [2]. In the present study, a systematic study of parallel and perpendicular exchange biases in MnPd/Co bilayers has been carried out in order to clarify the mechanism of this giant exchange bias.

Samples with structure of Si(100)/MnPd/Co were grown at room temperature using a RF sputtering system with a base pressure of 10^{-6} mbar. After the bilayers were deposited, the samples were heated to 300°C in a vacuum oven (10^{-5} mbar) and then cooled in a magnetic field of about 15 kOe down to room temperature.

The dependence of parallel and perpendicular exchange bias fields (H_E), unidirectional anisotropy constant (J_K) and coercive fields (H_C) on the thicknesses of both FM and AF layers and on the temperature have been investigated. Of particular interest is that the observation of a huge value of the unidirectional anisotropy constant of $J_K = H_{EB}t_{Co}M_{Co} = 4.2$ erg/cm^2 setting these bilayers to the class of giant exchange bias effect, which is in reasonable agreement with the theoretical prediction based on the model by Meiklejohn and Bean. The blocking temperature of parallel exchange bias is higher than that of the perpendicular one. As observed in Fig. 1 this result is similar to that reported by Phuoc and Suzuki [3] and can be explained as due to spin canting at the FM/AF interface.

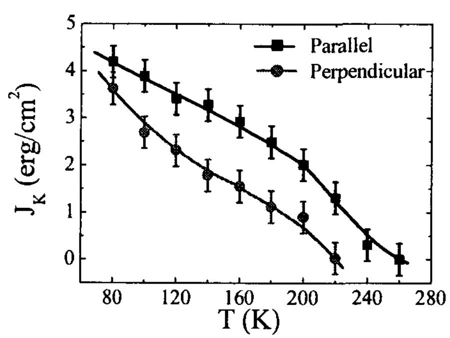

Fig. 1. The dependence of unidirectional anisotropy constant J_K on temperature of the MnPd(36nm) /Co(48nm) sample.

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RE11

Role of Switchable Uncompensated Interfacial Antiferromagnetic Spins in Exchange Biasing

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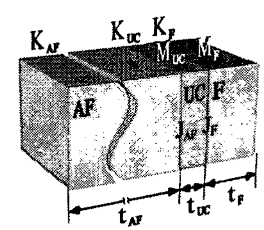
Since the exchange bias (EB) effect was first discovered by Meiklejohn and Bean[1], its underlying physics has been intensively studied over the past two decades. However, there are still unsolved problems about experimentally observed reductions in the EB field and enhanced coercivity. Typically measured EB field values are two orders of magnitude less than theoretically predicted values. Until now, various models have been developed to estimate the reasonable EB fields, but their different underlying physics are still controversial. To solve the problems, we propose an interface-proximity model [2] that provides a better insight about the experimental observations of enhancements in coercivity as well as the reductions in EB field. In our model, experimentally found switchable uncompensated (UC) region [3] is inserted between the AF and the F layer, as showed in Fig. 1. Different exchange coupling constants of J_F and J_{AF} are considered at the two different UC/F and AF/UC interfaces.

To support our model, we experimentally observed element-specific magnetization reversals in exchange biased thin films: NiFe(5)/IrMn(t)/CoFe(0.5)/IrMn(16-t), where t = 0, 2, 4, and 6 nm, and Ta/NiFe/Cu/CoFe/IrMn/NiFe/Cu/NiFe/Ta. From the two different samples, element specific reversals of magnetizations were investigated by measuring intensities reflected as a function of both the grazing angle and photon energy of circularly polarized soft x rays. We found that switchable UC antiferromagnetic interfacial spins exist and are strongly coupled to the individual ferromagnetic layers in close contact with the antiferromagnetic layers.

(a)



(b)

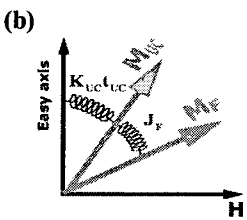


Fig. 1. (a) Illustrations of the interface-proximity model, (b) Conceptual illustration of the microscopic origin of the magnetocrystalline anisotropy. Spin and orbital magnetic moments are coupled via spin-orbital coupling.

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