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Coexistence of positive and negative exchange bias in CrMn/Co bilayers

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Abstract

Exchange-biased CrMn/Co bilayers with various thicknesses of Co sputtered onto Si(1 0 0) substrates by the RF sputtering system have been studied. Double-shifted loops have been observed with the thickness of Co layer in a narrow range and become single-shifted loops after some cycles of measurement. Those results are interpreted as the association of positive and negative exchange bias.

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Keywords: Exchange bias; Magnetic thin film; Double-shifted loop; Training effect

1. Introduction

Discovered in 1956 [1], the phenomenon of exchange bias between an antiferromagnet (AF) and ferromagnet (FM) is of great interest due to its widespread application in spin valves and magnetic tunnel junctions. Nevertheless, its physical origin remains unanswered [2].

Usually, exchange bias is described as an additional unidirectional anisotropy induced by the AF into the FM via exchange coupling at the interface, producing a single magnetic hysteresis loop shifted along the magnetic field axis after field cooling procedure through the Néel point of the AF. The magnitude of this shift is named exchange bias field (H_E) and in almost all cases, the magnetic hysteresis loop is shifted in the negative field if one defines the direction of the cooling field (H_{FC}) as

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the positive direction. This case is referred to as negative exchange bias. The phenomenon of positive exchange bias was first observed in 1996 by Nogués et al. [3] when studying the systems of Fe/FeF_2 and Fe/MnF_2. They found that the sign of exchange bias field changes from negative to positive as the cooling field increases. Very recently, Roshchin et al. [4] have found that the state of coexistence of positive and negative exchange bias can be achieved by cooling the sample of FeF_2/Co in a properly chosen constant applied magnetic field. This state manifests itself as a double hysteresis loop.

In this paper, we report the observation of the double-shifted loop in CrMn/Co bilayers with a proper thickness of Co layer. A training-like effect has been observed in the sample exhibiting the double-shifted hysteresis loops, which becomes a single-shifted hysteresis loop after some cycles of measurement. The results are interpreted as the association of positive and negative exchange bias, in which the portion of positive exchange bias

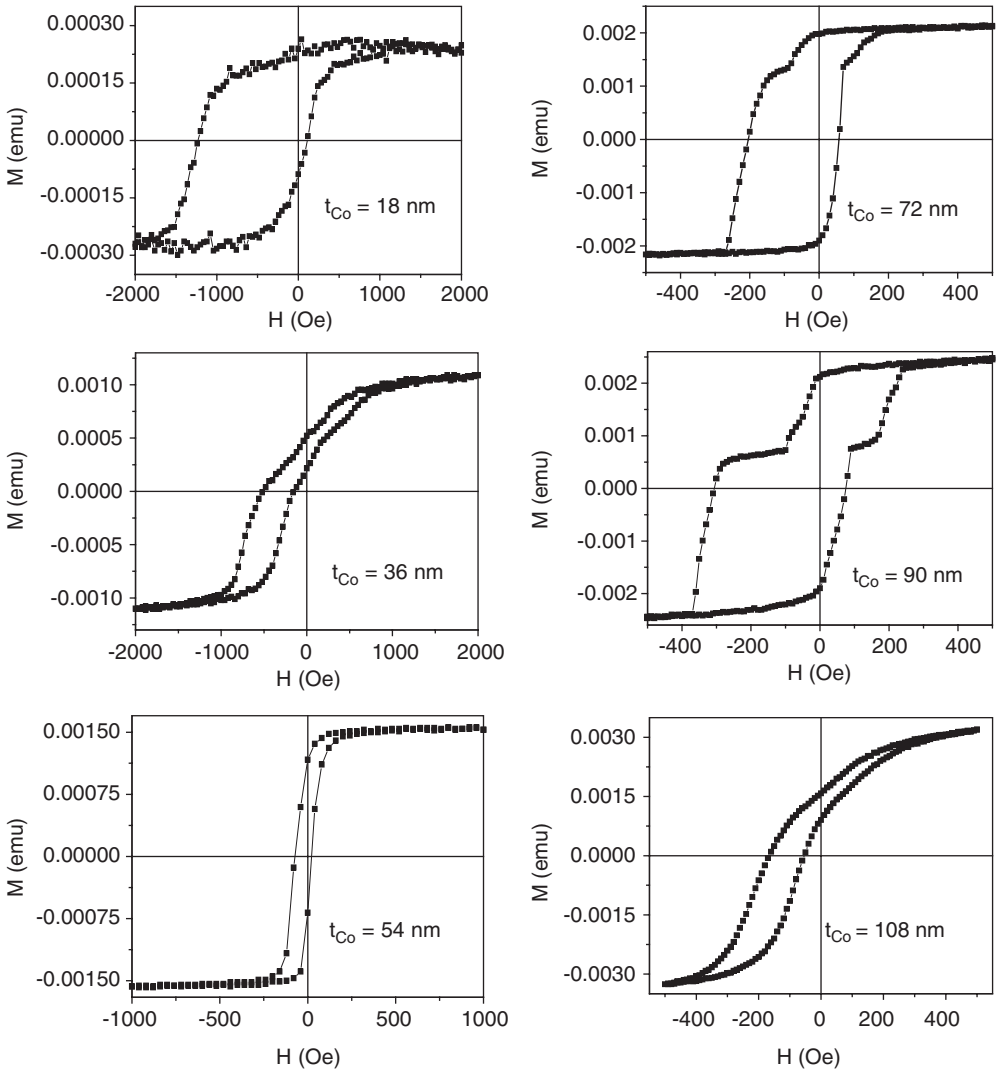

Fig. 1. Hysteresis loops of the CrMn(12 nm)/Co (*x* nm) samples measured at 123 K. The thickness of Co layer is indicated in the figure.