Exchange Bias in the Exchange Spring-like Ising Bilayer

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Exchange bias is a shift in the magnetization curve away from the zero applied field axis. The phenomenon was discovered fifty years ago [1], since then it is observed in many different film systems, such as antiferromagnetic/ferromagnetic bilayer [2] and antiferromagnetic coupled ferromagnetic/ferromagnetic bilayer [3,4]. Recently, ferromagnetic coupled exchange spring has attracted many attentions due to the application in the magnetic recording. Many details of experiments and theories exhibit the unusual mode of the exchange spring [5,6], however, the exchange bias is not mentioned in their works.

In this paper, an Ising model is utilized to describe the exchange spring-like bilayer. The spins are equal to 1 in both ferromagnetic layers, in which a hard ferromagnetic layer (HL) with big anisotropy couples with a soft ferromagnetic layer (SL) with small anisotropy, ferromagnetically. In this system, the switching field of the hard magnetic layer is larger than that of the soft layer due to the big anisotropy, resulting in a bias field. Using the linear cluster approach, we study the magnetic behavior of the system in applied field and demonstrate the exchange bias existing in certain parameters zone.

For the small easy-plane anisotropy of the soft layer, it is found that the exchange bias does not occur in the small range of the interlayer interaction, but appears with the interlayer interaction increasing, then vanishes as the interlayer interaction increases to a certain value, as shown in Fig.1. Moreover, the absolute value of exchange bias $\Delta m(0)$ increases and coercivity $H_c$ decreases as the interlayer interaction increases in certain parameter zone (Fig.2).

In the presence of the easy-axis anisotropy in the soft magnetic layer, the exchange bias only occurs for several special parameters in applied field (Fig.3).

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\[ \text{Fig. 1. The hysteresis loops of the soft layer with easy-axis anisotropy in} \]
\[ \text{applied field for various interlayer interactions}\]