The Effect of Time-Varying Magnetic Field on Magnetic Nano-Thickness

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ABSTRACT

We report the results of Monte Carlo simulations on Ising nano-thickness films, i.e., an ultra-thin-film under the effect of time-varying magnetic fields in both sinusoidal and triangular patterns. The study was performed using the Metropolis spin-flip algorithm to investigate how the hysteresis loop-area of Ising spins depends on the frequency of the external time-dependent magnetic field in a ferromagnetic phase. From our results, it is found that the response of the system from both sinusoidal magnetic field and triangular magnetic field are of a similar trend. In terms of the frequency dependence, at low frequencies, the hysteresis loop-area increases with the increase of the frequency of the external magnetic field because the effective delay, i.e., the phase lag, increases. On the other hand, at high frequencies, the hysteresis loop-area decreases with increasing frequency due to that the effective delay is moving away from its optimum point, i.e., $\pi/2$. These results qualitatively agree well with experiments.

Key words: Nanostructure, Magnetic ultra-thin-film, Ising model, Monte Carlo, Hysteresis, Time-varying field

INTRODUCTION

When an interacting many-body system, such as a magnet, is driven in time by an external perturbation, such as a time-varying magnetic field, the system cannot respond instantaneously due to a relaxation delay. As a result, the magnetization will lag behind the applied field, and this gives a nonzero area of the hysteresis loop (magnetization-field loop). The response of such a system under a time-dependent field leads to many novel physical phenomena intriguing physics and important technical applications (Johnson et al., 1996). Considerable points in hysteresis loop are coercivity and remanence which are interesting in terms of physical designs as they are important parameters to make an efficient transformer or a high-capacity magnetic recording media (memory). Consequently, in this study, we tried to model this dynamic magnetic behavior in magnetic thin-films with a thickness lies in nanometer-range, i.e., very thin films, which is the key factor to obtain a high-density memory application.

In modelling such a thin-film structure, we considered the use of Ising model since both theoretical (Binder and Hohenberg, 1974; Bander and Mills, 1988) and experimental (Li and Baberschke, 1992; Elmers et al., 1994; Dunlavy and Venus, 2004) investigations confirmed that the magnetic behavior in nano-thickness ferromagnetic-films is an Ising-like. In literatures, there are considerable number of studies on magnetic thin-film system and its perturbation. Nevertheless, most studies concentrated on the effect of sinusoidal magnetic field to the dynamic hysteresis properties which depends on temperature T of system, amplitude h_0 and frequency f of applied field. A very good review was given by Chakrabarti and