

Heisenberg Hamiltonian Solution of Thick Ferromagnetic Films with Second Order Perturbation

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For the first time, in this report the effect of second order perturbations on the Heisenberg Hamiltonian of thick ferromagnetic films up to $N = 10000$ will be discussed in detail. Introducing the second order perturbation increases the energy of sc(001) and fcc(001) ferromagnetic thick films. The energy curve of the fcc(001) film is smoother than that of the sc(001) films with $N = 10000$. Some overshooting is visible in the perturbed sc(001) films compared with the smooth curves of oriented films. Curves of thick films with second order perturbation are different from those of ultra-thin films with second order perturbation. The angle between the easy and hard directions of an sc(001) film with $N = 10000$ is 90° only after considering the smooth part of the curve. But the angle between the easy and hard directions of fcc(001) is not 90° . For the values used in this simulation, the energy separation between the easy and hard direction is very small at $N = 22$ and 44 , for sc(001) and fcc(001) ferromagnetic materials, respectively. To avoid tedious calculations, $D_m^{(2)}$ and $D_m^{(4)}$ were assumed to be constants for the whole film. The maximum and minimum energy values fluctuate for the thicknesses up to $N = 10000$ according to the 3-D plots of the sc(001) and fcc(001) ferromagnetic thick films.

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I. INTRODUCTION

Although the studies of ultra-thin ferromagnetic films can be found in many early theoretical reports, the theoretical aspects of thick films have not been studied in detail. But many samples available in reality are thick films with thousands of layers. In early reports, the properties of ultra-thin films were also investigated, without taking the effect of stress induced anisotropy and the demagnetization factor into consideration. However, because the stress induced anisotropy is comparable to the crystal anisotropy of soft magnetic materials, the stress induced anisotropy is an important factor in the studies of soft ferromagnetic films. The demagnetization factor (N_d) is 0 and 1 (or 4π) in SI (or CGS) units in the in-plane and out-of-plane directions, respectively. The stress induced anisotropy constant (K_s) depends on the magnitude of the applied stress (σ) and the magnetostriction coefficient (λ_s). The Heisenberg classical Hamiltonian has been used to describe the second order perturbation of ultra-thin ferromagnetic films without the demagnetization factor and stress in some previous reports [1].

Because of the difficulties of understanding the behavior of exchange anisotropy and its applications in magnetic sensors and media technology, theoretical investigations of ex-