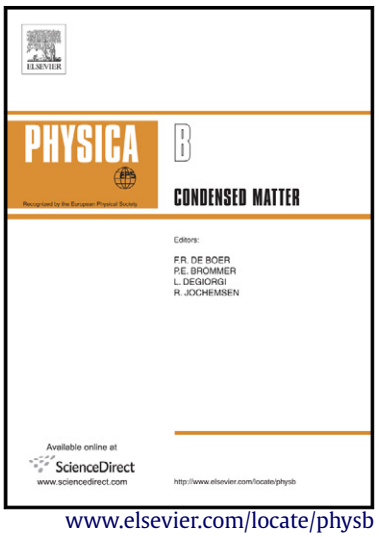

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Universality Aspects of Layering Transitions in Ferromagnetic Blume-Capel Thin Films

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Abstract

Critical phenomena and universality behavior of ferromagnetic thin films described by a spin-1 Blume-Capel Hamiltonian has been examined for various thickness values ranging from 3 to 40 layers. Using effective field theory, we have found that crystal field interactions significantly affects the critical value of surface to bulk ratio of exchange interactions R_c at which the critical temperature becomes independent of film thickness L. Moreover, we have extracted the shift exponent λ from computed data. Based on the results, we have shown that in the presence of surface exchange enhancement, the system may exhibit a dimensional crossover. We have also found that presence of crystal field interactions does not affect the value of λ. Hence, a ferromagnetic spin-1/2 thin film is in the same universality class with its spin-1 counterpart.

Keywords: Crystal field, Effective-field theory, Magnetic thin film, Surface magnetism

1. Introduction

In recent years, influences of surface effects on the magnetic properties of finite systems such as ferromagnetic thin films have attracted a considerable amount of interest [1, 2]. In addition to remarkable theoretical efforts, preparation of thin films by depositing a magnetic material on a non-magnetic substrate became experimentally accessible even in the monolayer limit with the development of modern vacuum techniques including molecular beam epitaxy. Due to the presence of free surfaces, magnetic properties of thin films may differ from those of bulk materials. This difference mainly originates from a number of physical phenomena. Namely, the surface atoms have a lower symmetry in comparison with that of the inner atoms [3], and the exchange interactions between the surface atoms may be different from those between the corresponding bulk counterparts. As a consequence of these facts, the surface may exhibit an ordered phase even if the bulk itself is disordered which has already been experimentally observed [4, 5, 6].

In this context, an extraordinary case is defined as the transition at which the surface becomes disordered at a particular temperature T_c^s which is larger than the bulk transition temperature T_c^b. From the academic point of view, due to the fact that many thin films such as the Fe/Ag(100) system [7] exhibit a strong uniaxial anisotropy, phase transition characteristics of thin ferromagnetic films are often modeled by several extensions of an Ising type spin Hamiltonian [8]. It is theoretically predicted that there exists a critical value of surface to bulk ratio of exchange interactions R_c above which the surface effects are dominant and the transition temperature of the entire film is determined by the surface magnetization whereas below R_c, the transition characteristics of the film are governed by the bulk magnetization. The critical value R_c itself is called as the special point, and the numerical value of this point has been examined within various theoretical techniques for spin-1/2 case [9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. Among these works, within the framework of effective field theory (EFT), Sarmento *et al.* [16] clarified that a transverse field in the surface layer causes the critical value of the surface exchange enhancement R_c to move to a higher value whereas the presence of a bulk transverse field causes R_c to decrease to a lower value.

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