The Effect of Nano-Vacancy Defect on Ising Magnet in a Reduced Geometry

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ABSTRACT

Monte Carlo simulation was performed to observe the effect of nano-vacancy defects on the magnetic behavior of Ising spins in a reduced geometry, i.e., a porous ultra-thin-film. The magnetic properties were investigated as a function of the vacancy concentration and as a function of temperature, especially in the magnetic phase transition region. The fourth-order cumulant and finite-size-scaling via a double logarithmic plot were used to extract critical temperatures and effective critical exponents for each vacancy concentration. From the results, with increasing magnitude of the porosity, it was found that the Ising phase-transition-point shifted from its two-dimensional value, that the critical temperature $k_B T_C / J \approx 2.269$ to a lower temperature and towards zero temperature. Furthermore, in the phase transition region, the power law relation between the magnetic properties and the linear dimension of the system was found. Consequently, this supports the validity of the finite-size-scaling theory even in the porous structure. Additionally, the finite-size-scaling extraction of the effective critical exponents indicated that for small numbers of vacant defects, the considered nano-vacancy defects structure fell into the two-dimensional universality.

Key words: Nanostructure, Vacancy defect, Magnetic ultra-thin-film, Ising model, Monte Carlo simulation

INTRODUCTION

The magnetic system in a reduced geometry, i.e., thin-film or ultra-thin-film, has been known to be of technological and application importance, especially in the magnetic recording industries according to their exceptionally-high magnetic anisotropy (Murayama et al., 2000; Plumer et al., 2001; Johnson et al., 1996). However, it is also known that under the normal condition, vacancy defects in material frequently occur during the material processing. The vacancy defect, i.e., the porosity at nanometer size is often found to randomly distribute in the material structure. As a result, the magnetic properties of the material are altered from its ideal condition and any calculation based on this ideal condition will lead to an incorrect application design. On the other hand, inclusion with porosity, the porous magnetic media becomes a novel artificial structure with interesting properties such as enhanced coercivity. Furthermore, the porous magnetic structure is also a key factor to control the magnetic critical properties. Because of the smaller number of neighboring atomic sites, there is a reduction in the average ferromagnetic exchange coupling. As a result, this nano-defect can be used to control the magnetic phase transition and hence the Curie temperature. As can be seen, all of these draw a significant interest in using porous magnetic as a new medium for exploring novel magnetic phenomena and may lead to innovative industrial applications.