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Finite temperature magnetic phase transition features of the quenched disordered binary alloy cylindrical nanowire

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Abstract

Thermal and magnetic phase transition properties of a quenched disordered binary alloy cylindrical nanowire of the type A_pB_{1-p} have been elucidated by making use of Monte Carlo simulation based on a local spin update Metropolis algorithm. Magnetic components A with spin-$\frac{1}{2}$ and B with spin-1 are distributed randomly throughout the cylindrical nanowire with a probability of p and $1-p$, respectively. The phase boundary lines, magnetization and also magnetic susceptibility profiles of the system in both presence and absence of a single-ion anisotropy term are investigated. Our Monte Carlo simulation results indicate that the critical behavior of the system sensitively depends on the concentration value of the type-A atoms, the spin-spin exchange interaction strength between unlike magnetic components as well as on the single-ion anisotropy interaction. Finally, a comparison of our observations with those of recently published studies for the clean cylindrical nanowire systems corresponding to $p = 0.0$ and $p = 1.0$ cases is presented and it is found that there exist satisfactory agreements.

Keywords: Quenched disordered binary alloy systems, Magnetic cylindrical nanowires, Monte Carlo simulation.

1. Introduction

In the last decades, the magnetic nanostructures such as magnetic nanoparticles, nanowires, nanotubes are center of interest because of their technological and scientific importance. Among these nanostructures, magnetic nanowires are potential candidates for applications in advanced nanotechnology including magnetic memory devices [1, 2] and biomedical applications [3, 4] due to their outstanding magnetic and structural properties. Experimentally, arrays of Fe, Co, Ni ferromagnetic (FM) nanowires and binary alloy nanowires for example CoNi [5, 6], FeNi [7], CoFe [8] can be synthesized straightforwardly by electrodeposition into nanopores of anodic aluminum oxide membranes. Moreover, it is possible to tune the magnetic properties (like coercivity and remanence) of binary alloy nanowires by varying the composition of one of the magnetic components in the alloy [9, 10].

In addition to the above mentioned experimental motivations, magnetic nanostructure systems have received considerable attention from the theoretical point of view since they stand for excellent tools to deepen our understandings about nanomagnetism and phase transitions in nanoscale limit. They have been investigated by several methods such as Mean Field Theory (MFT) [11, 12], Effective Field Theory (EFT) [13, 14, 15, 16, 17, 18, 19], Green Function Formalism (GFF) [20], Cluster Variation Method (CVM) [21] and Monte Carlo (MC) simulations [22, 23, 24, 25, 26, 27, 28]. In particular, much effort has been devoted to understand the critical behavior of magnetic nanowires with a core/shell morphology. Boughazi and co-workers have studied ferrimagnetic core/shell spin-1 Ising nanowire by means of MC simulations and analysed the effects of the single-ion anisotropy, shell and interfacial exchange coupling strengths on the critical and compensation temperature of the system [29]. Mixed spin Ising nanowires with a core/shell structure and antiferromagnetic (AFM) interface coupling have been widely studied with both MC simulation method [30, 31, 32, 33] and EFT [34, 35, 36]. Besides, the influences of randomness on the phase transition properties of magnetic nanowires have been studied extensively. In references [37, 38], the phase diagrams

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