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Thermodynamic and magnetic properties of a mixed Ising system on a triangular array in presence of longitudinal field

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Abstract

Using the effective-field theory with correlations (EFT), the effects of a longitudinal field on the magnetic properties of a ferrimagnetic system, consisting of two triangular magnetic sublattices A and B (with a coordination number $z = 6$) with spins $S_A = \frac{1}{2}$ and $S_B = \frac{3}{2}$, are investigated. The influence of the crystal-field interaction D_B within the sublattice B and the longitudinal applied field on these properties are examined. We determine the total magnetization in absence and under the magnetic field, whereas the initial susceptibility is carried out. The Arrott plots shapes in the $(H_0/M, M^2)$-plane are determined. They indicate a region of strong competition between the inter-sublattices (J_{AB}) exchange coupling and the applied field. Other striking features have been revealed in the magnetization behavior especially near the critical and the compensation temperatures.

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Keywords: Ising model; Ferrimagnetism; Exchange coupling; Single-ion anisotropy; Magnetization; Arrott plots

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1. Introduction

There has been a great deal of interest in recent decades in the study of layered ferrimagnetic systems. A lot of activities in this field were stimulated by their remarkable applications especially in advanced modern technologies such high speed digital recording and other usefully utilizations [1]. In the theoretical point of view, progressive attention has been devoted to the examination of the spin arrangement as well as the types of couplings governing the magnetic behavior of these systems. In order to obtain a theoretical understanding of various phenomena that arise in these materials, it is instructive to consider simple models such the two-sublattice Ising one that allow to calculate exactly or realistically observable quantities. Thus, a large varieties of approaches have been used such mean-field approximation (MFA) [2–4], effective-field theory with correlations (EFT) [5,6], Bethe–Peierls method (BPM) [7,8], renormalization-group approach (RGA) [9,10], high-temperature series expansions (HTSE) [11] and Monte Carlo simulation (MCS) [12,13]. However, the most frequently studies have been realized on the Ising spin ferrimagnetic systems with a coordination number restricted to $z = 2$, 3 or 4. Only few works have focused on higher coordination number ($z = 6$) systems in presence of a restricted kinds of magnetic interactions [14–16]. In fact, for such systems when one takes account on realistic couplings as crystal-field, intra- and inter-sublattices exchange couplings, the problem becomes unmanageable either analytically or numerically. Indeed, a number of magnetic materials studied experimentally may be concerned by such a model. In a recent work [17], we have examined the role of the spin and the single-ion anisotropy on the magnetic behavior of a ferrimagnetic system with $S_A = \frac{1}{2}$, $S_B = 1$ or $S_B = \frac{3}{2}$ and $z = 6$. In particular, we have shown that if a compensation temperature exists, its behavior as a function of D_B is strongly affected by changing the spin S_B from the integer value ($S_B = 1$) to the half-integer value ($S_B = \frac{3}{2}$). We have also carried out the environmental effects directly caused by the higher coordination number.

In this paper, we will carry out the analytical and numerical studies of an Ising ferrimagnet with spins $S_A = \frac{1}{2}$ and $S_B = \frac{3}{2}$ on a triangular array in which the spins S_A and S_B of the two sublattices interact antiferromagnetically, we will examine the influence of an applied longitudinal magnetic field on the spontaneous magnetization. Furthermore, we will derive the initial susceptibility, since the susceptibility measurements constitute one of the principal techniques in the experimental study of magnetic compounds. For this aim, we use the effective-field theory with correlations (EFT) which takes account correctly on the single-site kinematic relations of the spin operators [18,19].

The theoretical framework used here (EFT) goes beyond the standard mean-field theory (MFT) and has been successfully applied to a variety of Ising problems. A review of certain principles of this approach has been given by Kaneyoshi [1].

In this work, therefore, the spin S_A of the sublattice A is fixed at $S_A = \frac{1}{2}$ and the spin S_B of the sublattice B is taken at the arbitrary value $S_B = \frac{3}{2}$.

Since $S_B > \frac{1}{2}$, the crystal-field term caused by the ionic environment of a given spin within the sublattice B is then included and the effects of D_B on the magnetic