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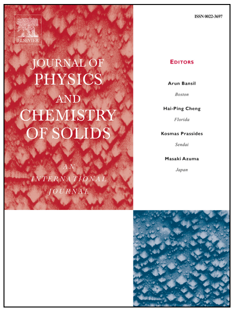

A comparative study of critical phenomena and magnetocaloric properties of ferromagnetic ternary alloys

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A comparative study of critical phenomena and magnetocaloric properties of ferromagnetic ternary alloys

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Abstract

Magnetic and magnetocaloric properties, as well as the phase diagrams of a ferromagnetic ternary alloy system have been studied. A detailed comparison of two different methods, namely the effective field theory (EFT), and Monte Carlo (MC) simulations has been provided. Our numerical data show that the general qualitative picture presented by two methods are in a good agreement with each other. In terms of the magnetocaloric properties, our results yield that it is possible to design magnetic materials with a variety of working temperatures and magnetocaloric properties (such as large ΔS_M and q values) by manipulating the magnetic phase transition via tuning the compositional factor (i.e. the mixing ratio of sublattice ions). The observed magnetocaloric effect has been found to be a direct one with $\Delta S_M < 0$ associated with a second order phase transition.

Keywords: Alloy, Critical phenomena, Magnetism, Magnetocaloric, Phase transition

1. Introduction

Magnetocaloric effect (MCE) [1, 2, 3, 4, 5, 6, 7] which is the manifestation of temperature change in a magnetic material due to adiabatically varying magnetic fields has recently attracted particular attention not only from academical point of view, but also due to its potential in technological [8, 9, 10], as well as biomedical applications [11]. The theoretical and experimental aspects regarding the phenomenon have been widely investigated in the literature [12, 13, 14, 15, 16, 17, 18].

Indeed, it is directly related to the magnetic entropy change of a magnetic material under adiabatic conditions. Fundamentally, the total entropy of a magnetic material can be written as

$$S_{tot}(T, H) = S_L(T, H) + S_e(T, H) + S_M(T, H), \quad (1)$$

where the first term is due to lattice vibrations, the second one comes from the electronic contribution, and the third term represents the magnetic entropy. Under adiabatic conditions, the total entropy does not change. Hence, upon application of a magnetic field on a magnetic material, the magnetic dipole moments tend to align parallel with each other which reduces the magnetic entropy. However, lattice and electronic entropy should increase, and consequently the temperature of the material increases. On the other hand, when the magnetic field is reduced towards zero, the magnetic entropy increases due to increasing magnetic disorder. In this case, in order to keep the total entropy unaltered, the electronic and lattice contributions become reduced, and the material is cooled. Using this process, one can utilize the magnetic material for cooling/heating applications. Former studies suggest that MCE is maximized around the ferromagnetic-paramagnetic transition temperature [1]. For a potential candidate to be used in magnetocaloric applications, the material should exhibit magnetic phase transition around the room temperature.

Theoretically, one can calculate the MCE indirectly using the relations [19]

$$\Delta T_{ad} = -\int \frac{T}{C_x}\left(\frac{\partial M}{\partial T}\right)_H dH, \quad \Delta S_M = \int \left(\frac{\partial M}{\partial T}\right)_H dH, \quad (2)$$

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