Structural disorder in pseudo-binary $Ce(Fe_{0.9}Co_{0.1})_2$ compound as an origin of ferromagnetism

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The topological disorder in the $Ce(Fe_{0.9}Co_{0.1})_2$ compound was introduced by rapid quenching and severe plastic deformation. The synthesised alloys are single phase with $MgCu_2$-type cubic structure (C15 Laves phase). Two magnetic transitions, with thermal hysteresis for ferromagnetic to antiferromagnetic transition at about 90 K, were observed. A structural disorder enhances ferromagnetic ordering and affects the magnetocaloric properties. However, higher structural disorder caused a reduction of the isothermal entropy change for the plastically deformed $Ce(Fe_{0.9}Co_{0.1})_2$ alloy.

Keywords: Laves phases; magnetostructural phase transition; magnetocaloric properties

1. Introduction

The aim of our research in $Ce(Fe_{0.9}Co_{0.1})_2$ compound was to investigate the influence of topological disorder on the magnetic properties. The rapid quenching method was used to introduce structural disorder. Additional modifications were made by severe plastic deformation. The previous reports show that structural disorder can enhance ferromagnetic ordering and significantly impact the magnetocaloric properties [1]. The ab-initio calculations were also performed to find the source of the emergence and predominance of the ferromagnetic state below the antiferromagnetic-ferromagnetic transition temperature.

2. Results and discussion

The x-ray diffraction results confirm that both the as-quenched and HPT-treated samples of $Ce(Fe_{0.9}Co_{0.1})_2$ are single phase with $MgCu_2$-type cubic structure (C15 Laves phase). Two phase transitions are present in the temperature dependence of magnetization for the as-quenched sample. Starting from higher temperatures, the first one is of a second-order type and represents the transition from paramagnetic to ferromagnetic state at Curie temperature $T_C = 182 \pm 1$ K. The second one, at about 90 K, with a pronounced thermal hysteresis, is a first-order magnetostructural transition from ferromagnetic to an antiferromagnetic state, which can be easily altered by disorder [2]. In the lower temperatures, magnetization measured in zero field cooled mode does not decrease to zero. This can be connected with the existence of a ferromagnetic phase in the alloy.

Magnetization isotherms of the as-quenched sample below the antiferromagnetic-ferromagnetic transition temperature show an increase of magnetization in low fields due to the existence of a ferromagnetic component [3]. In higher fields, metamagnetic phase transition is visible. The antiferromagnetic state transforms into an induced ferromagnetic one. The ferromagnetic state is related to the structural defects introduced by non-equilibrium synthesis methods. At higher temperatures magnetization curve has a ferromagnetic character. In the case of the plastically deformed sample, all measured curves are typical for ferromagnets.

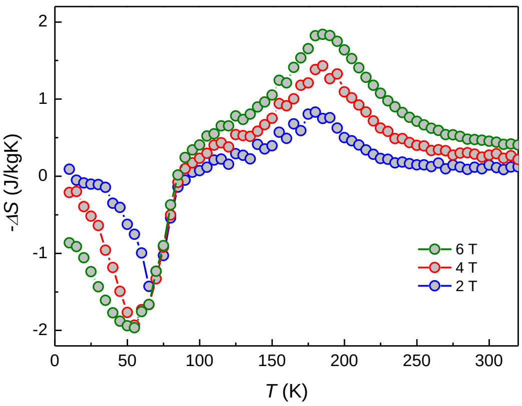

Figure 1: Temperature dependence of isothermal entropy change ($\Delta\mu_0 H = 2, 4, 6$ T) measured for $Ce(Fe_{0.9}Co_{0.1})_2$ in an as-quenched state.

Based on electronic structure calculations, the structural motifs arising from various distortions of the initial $MgCu_2$-type structure, caused by the partial replacement of Fe with Co atoms, are characterized by stable antiferromagnetic order. This neglects simple structural distortions as the source of ferromagnetism. The presence of a strongly defective structure reduced the fraction transformed from a ferromagnetic to an antiferromagnetic state. The isothermal entropy change for the plastically deformed $Ce(Fe_{0.9}Co_{0.1})_2$ alloys is reduced in comparison to the as-quenched sample (Figure 1) due to higher structural disorder. Despite our plans aiming to improve relative cooling power, the decrease in the value of entropy changes is not compensated by a large broadening of the peak [4].

References

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