Itinerant electron ferromagnetism of $Fe_xCo_{1-x}Si$ ($x = 0.3, 0.4, 0.5, 0.7$) under high pressure

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Abstract

The intermetallic compound $Fe_xCo_{1-x}Si$ has a cubic B20-type crystal structure and shows a weak itinerant electron ferromagnetism in the Fe-concentration range of $0.2 < x < 0.95$. We have measured ac susceptibility for $Fe_xCo_{1-x}Si$ ($x = 0.3$, 0.4, 0.5 and 0.7) under various pressures up to 7.5 GPa using a cubic anvil press in the temperature range from 4.2 K to 300 K. It was found that the Curie temperature decreased with pressure P and was proportional to $P^{3/4}$ for all the concentrations.

Key words: $Fe_xCo_{1-x}Si$; Weak itinerant electron ferromagnetism; High pressure

1. Introduction

The intermetallic compound $Fe_xCo_{1-x}Si$ is a disordered solid solution between FeSi and CoSi with a cubic B20-type crystal structure (space group $P2_13$) for all concentration range [1,2]. Although FeSi and CoSi are paramagnetic and diamagnetic, respectively [2,3], their solid solution $Fe_xCo_{1-x}Si$ shows the magnetic ordering in a concentration range of $0.2 < x < 0.95$ [2,4]. The magnetic ordering in the ground state is of a helical spin structure with a long period (> 300 Å) [5]. This helical state, however, is easily transformed to a ferromagnetic state by applying a magnetic field. Several investigations suggest that $Fe_xCo_{1-x}Si$ is a weak itinerant electron ferromagnet with the magnetic moment of about $0.1 \sim 0.2$ μ_B. The magnetization and the Curie temperature T_C take the maximum values of $\mu = 0.21$ μ_B/F.U. and $T_C = 65$ K, respectively, at around $x = 0.6$ [4].

In order to investigate the itinerant electron ferromagnetic character in these alloys, it is a good way to make a measurement of the pressure dependence of T_C up to several GPa where T_C would be expected to become 0 K.

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2. Results and Discussion

We have measured ac susceptibility χ_{ac} of $Fe_xCo_{1-x}Si$ ($x = 0.3$, 0.4, 0.5 and 0.7) under various pressures up to 7.5 GPa using a cubic anvil press in the temperature range from 4.2 K to 300 K. Fluorinert was used as a liquid transmitting medium. Experimental results of χ_{ac} measurements for the concentration of $x = 0.4$ under high pressure are shown in Fig. 1. As shown in this figure, T_C decreases with pressure, where T_C was deduced from an inflection point of each curve. The gradient of χ_{ac} at T_C becomes steeper above 5.0

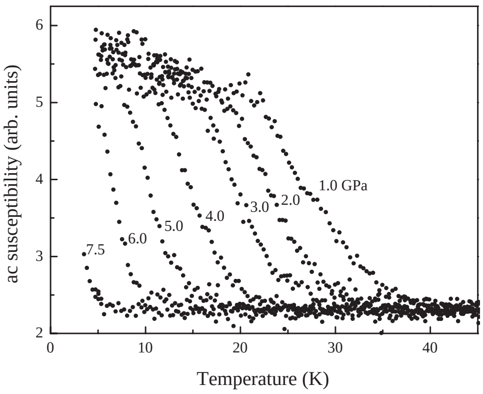

Fig. 1. The ac susceptibility vs. temperature for $Fe_{0.4}Co_{0.6}Si$.

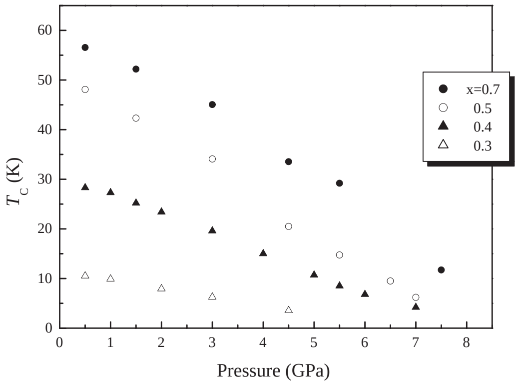

Fig. 2. The pressure dependence of T_C for x=0.3, 0.4, 0.5 and 0.7.

GPa. This suggests an appearance of a crossover from the second order to the first order phase transition at around this pressure, which is very similar to the results in MnSi [6]. Figure 2 shows the pressure dependence of T_C for all samples investigated. The values of ${T_C}^{-1} \mathrm{d}T_C/\mathrm{d}P \mid_{P=0}$ for $x = 0.3$, 0.4, 0.5 and 0.7 are -0.15, -0.11, -0.13 and -0.074 (GPa^{-1}), respectively.

The pressure dependence of T_C was first treated by Stoner:

$$T_C \propto (P - P_C)^{1/2} \tag{1}$$

Taking account of the effect of the spin fluctuations, we have a new dependence of T_C as follows [7]:

$$T_C \propto (P - P_C)^{3/4} \tag{2}$$

It appears that this relation (2) accounts well for the experimental data at the whole pressure range as shown in Fig. 3, where ${T_C}^{4/3}$ is plotted against pressure for all samples.

Concerning the pressure dependence of T_C for weak ferromagnet, MnSi has been extensively investigated, which has the cubic B20-type structure and has been known as a typical weak itinerant ferromagnet. For MnSi, T_C decreases rapidly with pressure and collapses towards absolute zero at $P \simeq 1.46$ GPa [6]. For $P >$ 1.46 GPa, the non-Fermi-liquid state appears [8]. In the low pressure region, T_C of MnSi obeys the 3/4 power law of P and 1/2 power law in the high pressure region. In the present experiment, however, it is confirmed that T_C of $Fe_xCo_{1-x}Si$ is in direct proportion with $P^{3/4}$ for the whole pressure range, the maximum pressure of which is much higher than that of MnSi. The reason has not been clarified yet at this moment why such a defference between $Fe_xCo_{1-x}Si$ and MnSi has been observed, although they seem to belong to the same weak ferromagnetic group.

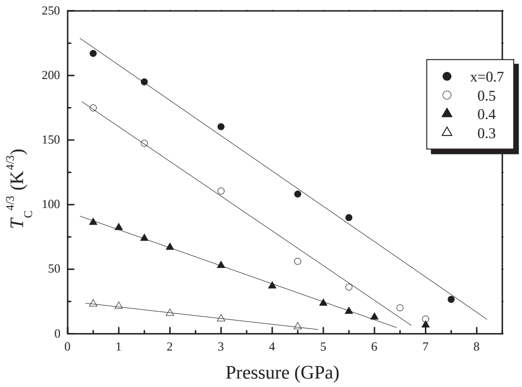

Fig. 3. The pressure dependence of ${T_C}^{4/3}$ for x=0.3, 0.4, 0.5 and 0.7.

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