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Magnetovolume effect of CrNiP

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Abstract

The magnetic properties of an itinerant ferromagnet CrNiP have been determined in the hydrostatic pressure, temperature, and magnetic field ranges 0–11.3 kbar, 4.2–276 K, and 0–309 kOe, respectively. The pressure derivatives of the Curie temperature and the spontaneous magnetization at 4.2 K are found to be $+0.20$ K/kbar and -3.7×10^{-2} emu/g kbar, respectively.

Keywords: Ferromagnetism; Magnetovolume effect; CrNiP; Pressure effect

1. Introduction

The ternary compound CrNiP is an itinerant ferromagnet with the Curie temperature T_c of 146 K. CrNiP has the crystal structure of the orthorhombic TiNiSi-type. Iwata et al. reported that the magnetism of $Cr_{2-x}Ni_xP$ might be explained by the itinerant electron model on the basis of spin-fluctuation scheme [1].

To investigate the electronic properties of CrNiP in more detail, the measurements of the pressure effect on the spontaneous magnetization σ_s at 4.2 K and the Curie temperature T_c were carried out.

2. Experimental

A polycrystalline sample of CrNiP was prepared with the same heat treatment as that reported previously [2]. X-ray diffraction study showed that all diffraction lines can be assigned by Miller indices to the orthorhombic structure. The lattice parameters a, b and c were determined to be 5.789, 3.531 and 6.807 Å, respectively.

The magnetization curve up to 309 kOe was measured by the induction method. The magnetization at 15 kOe was measured in the temperature range 4.2–277 K using a pendulum-type magnetometer. The pressure dependence of T_c was determined by measuring the temperature variation of the AC permeability under various pressures up to 11.3 kbar. The magnetization measurement under hydrostatic pressures up to 6.0 kbar was carried out in the subtraction magnetometer under applied field up to 90 kOe.

3. Experimental results and discussion

The temperature dependence of the magnetization σ at 15 kOe and the inverse susceptibility $1/\chi_m$ above T_c are shown in Fig. 1. The Curie

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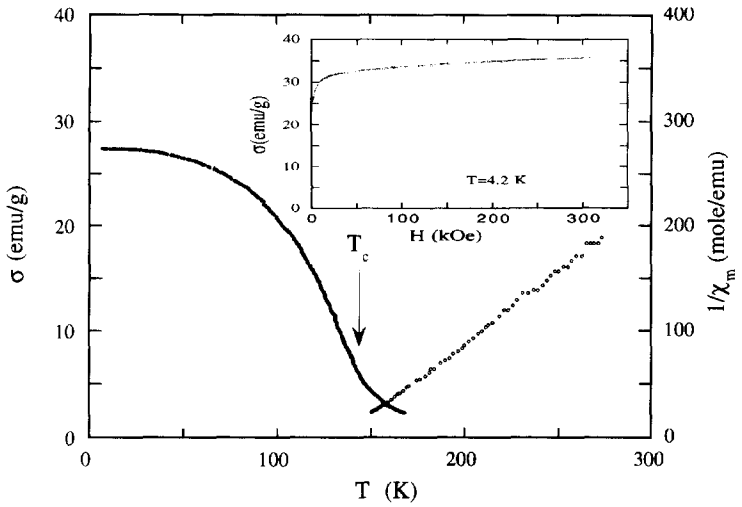

Fig. 1. Temperature dependence of the magnetization σ at 15 kOe and the inverse susceptibility $1/\chi_m$ of CrNiP. The inset shows the magnetization curve at 4.2 K of CrNiP.

temperature was found to be 145 K. This was determined from the linear relation between σ^2 and T just below T_c. The observed $1/\chi_m$ versus T curve can be well expressed by the Curie–Weiss law. The paramagnetic Curie temperature θ_p and the Curie constant were found to be 142 K and 0.70 emu K/mol, respectively. From the value of C_m, the effective Bohr magneton μ_{eff} is evaluated to be 2.36 μ_B/mol. The inset in Fig. 1 shows the magnetization curve at 4.2 K. The saturation magnetization and the high-field susceptibility χ_{hf} were obtained to be 33.4 emu/g(0.85 μ_B/f.u.) and 0.81×10^{-2} emu/g kOe.

The magnetization σ at 4.2 K decreases with pressure at all values of the applied field. Then, σ_s at 4.2 K under each pressure was determined by linear extrapolation to $H/\sigma = 0$ of σ^2 versus H/σ plot at high fields. As shown in Fig. 2, σ_s at 4.2 K decreases linearly with pressure. The value of $d\sigma_s/dp$ is -3.7×10^{-2} emu/g kbar. The inset in Fig. 2 shows the pressure dependence of T_c for CrNiP. The Curie temperature increases linearly with applied pressure. The value of dT_c/dp is found to be +0.2 K/kbar.

Ishida et al. calculated the band structure of CrNiP [3]. According to their calculation, Ni atoms in CrNiP are nonmagnetic and only Cr

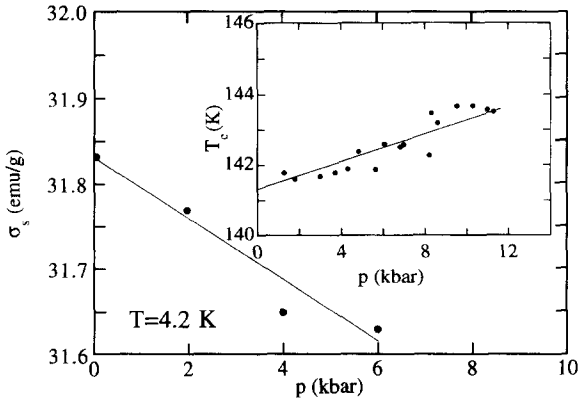

Fig. 2. Pressure change of the spontaneous magnetization σ_s for CrNiP. The inset shows the pressure change of the Curie temperature T_c.

atoms carry magnetic moment. Therefore, the magnetic moment of CrNiP observed in this study may be attributed to that of Cr atom. Their calculation also shows that the Cr 3d states hybridize strongly with the Ni 3d states and the P 3p states in a wide energy range. The negative pressure derivative of σ_s may be attributed to the increase of the hybridization between the valence states of Cr, Ni and P atoms. The Curie temperature of CrNiP was

found to increase with pressure. As far as we know, this behaviour is the first case for transition metal compounds where the only potentially magnetic element is Cr. It is not clear that the positive pressure derivative of T_c is due to spin-fluctuation effect or any other effects such as the two-dimentional character of CrNiP.

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