Magnetic properties of weak itinerant ferromagnet Ni-Pt alloy

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Abstract

Magnetization measurements have been performed on a $Ni_{0.45}Pt_{0.55}$ alloy in the magnetic fields up to 130 kOe and in the temperature range from 5 K to 280 K. The spontaneous magnetization σ_S(T) follows a [1-$(T/T_C)^2$]-dependence below 15 K. In the temperature range from 15 K to the Curie temperature (41.2 K), however, σ_S(T) decreases with the proportional to [1-$(T/T_C)^{4/3}$]. Obtained results can be explained with a new spin fluctuation theory of Takahashi.

Key words: Ni-Pt alloy, magnetization measurement, spin fluctuation

Disordered Ni-Pt alloys with a face-centered cubic structure can be synthesized in any proportions. With increasing the concentration of Pt, the magnetic moment and the Curie temperature decrease, and then the ferromagnetism vanishes at about 58 at.% Pt [1]. It has been supposed that the Ni-Pt alloys in the critical concentration region for the onset of ferromagnetism are good reference materials for studying weak itinerant electron ferromagnetism. Many experimental data for the magnetic properties of the Ni-Pt alloys have been discussed using a thermodynamic treatment based on weak itinerant ferromagnetism model (so-called Stoner-Edwards-Wohlfarth model) [2]. However, some inconsistencies with experiments remain, and these discrepancies have been considered due to the influence of spin fluctuations.

In this paper, we show the results of the precise magnetization measurements and high field magnetization measurements on a $Ni_{0.45}Pt_{0.55}$ alloy with near critical concentration. The obtained results are discussed on the basis of the quantum spin fluctuation theory developed by Takahashi [3,4].

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The polycrystalline sample was prepared by arc-melting. The as-melted ingot was annealed at 1000 ^{0}C for 3 days, and then quenched in water. Magnetization σ was measured using a SQUID magnetometer (Quantum Design) and a VSM (Oxford) in the magnetic field H up to 10 kOe and up to 130 kOe, respectively, and in the temperature T range from 5 K to 280 K.

Fig.1 shows the σ^2 *vs.* H/σ plots at 5 K. As seen in this figure, the plots show a straight line in the wide field region. However, the plots deviate slightly from the linear relation in higher field with increasing temperature, which will be reported in near future in detail. The spontaneous magnetizations $\sigma_S(T)$ were determined by the linear extrapolation to $H/\sigma = 0$ of the σ^2 *vs.* H/σ curves. σ_S and the magnetic moment p_S are determined to be 3.48 emu/g and 0.182 μ_B/Ni at 5 K, respectively, which is in good agreement with the previous report [1,3,4]. The Curie temperature T_C was defined as the temperature at which $\sigma_S(T)$ goes through the origin and was determined to be $T_C = 41.2$ K.

Recently, Takahashi reported a new spin fluctuation theory for weak itinerant electron ferromagnets, in which a quantum spin fluctuations (zero-point spin fluctuations) are considered [3,4]. According to the the-

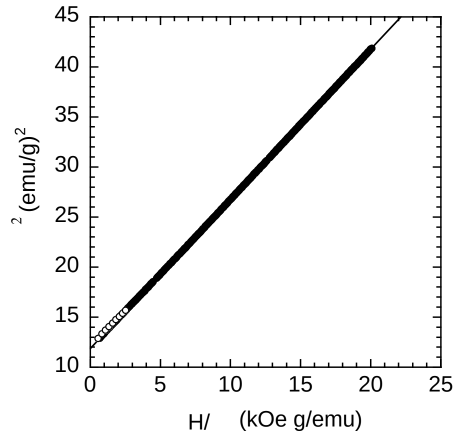

Fig. 1. σ^2 versus H/σ plots for $Ni_{0.45}Pt_{0.55}$ alloy at 5 K. The open and closed circles indicate the obtained data using a SQUID magnetometer and a VSM, respectively.

ory, the magnetization of a weak itinerant electron ferromagnet in the ground state is expressed by following equation;

$$-2c\eta^4 k_B T_A p + 4k_B T_A^2/15T_0(p^3/8) = h, \tag{1}$$

with $p = \sigma(H,T)/\mu_B N_0$ (here $T = 0$ K), $h = 2\mu_B H$, $\eta^3 = T_C/T_0$ and $c = 0.3353$. Here k_B is the Boltzmann constant, N_0 the number of magnetic sites. The parameters T_0 and T_A characterize the energy width of the dynamical spin fluctuation spectrum and the dispersion of the static magnetic susceptibility in wave vector space, respectively. We can estimate quantitatively the values of the energy scale of the spin fluctuation spectrum as T_0 and T_A from the σ^2 *vs.* H/σ plots at low temperature. As shown in Fig. 1, the experimental data at 5 K is in good agreement with the relation of eq. (1) in wide field region, and the obtained values are $T_0 = 2.6\times10^3$ K, $T_A = 6.9\times10^3$ K and $\eta = 0.26$. These values are comparable to those determined by MNR and/or neutron scattering measurements for typical weak itinerant ferromagnets such as $ZrZn_2$, Ni_3Al, Sc_3In, *etc.* [3,4].

According to Takahashi theory, the very weak itinerant electron ferromagnets show very small values of η. His theory also predicts that $\sigma_S(T)$ follows the $T^{4/3}$-dependence in the wide temperature range below T_C except for very low temperature at which the T_2-dependence is observed. Figs 2(a) and 2(b) show the $\sigma_S(T)^2$ *vs.* T^2 and $T^{3/4}$ plots, respectively. As seen these figures, $\sigma_S(T)^2$ shows a T^2-dependence at lower temperature and a $T^{3/4}$-dependence in the wide temperature range below T_C. In addition, this theory shows that the temperature dependence of $p_S(T)^2$ is simply given by

$$[p_S(T)/p_S(0)]^2 = 1 - 153/p_S(0)^4(T/T_A)^2, \tag{2}$$

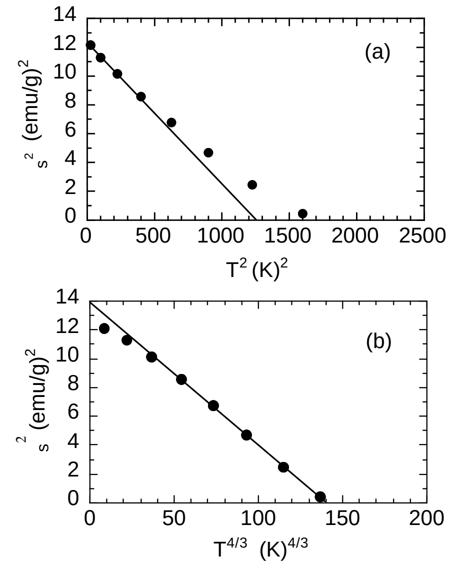

Fig. 2. (a) σ_S^2 versus T^2 and (b) σ_S^2 versus $T^{4/3}$ for $Ni_{0.45}Pt_{0.55}$ alloy.

with $p_S(T) = \sigma_S(T)/\mu_B N_0$. From the eq.(2) and our experimental data $\sigma_S(T)$ in 5 K $\leq T \leq$ 15 K, T_A is estimated to be 1×10^4 T, which is in good agreement with the value (6.9×10^3 T) determined by the magnetization process in the wide field range at 5 K. Consequently, the obtained results are consistent of Takahashi theory.

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