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MAGNETIC PROPERTIES OF $FePt_3$ ORDERED ALLOY

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The magnetic properties for $Fe_{24}Pt_{76}$ and $Fe_{26}Pt_{74}$ have been investigated. The temperature vs. magnetic susceptibility curve for $Fe_{24}Pt_{76}$ had no peak near the Néel temperature. The magnetization process at 4.2 K showed only a linear variation up to the high magnetic field of 240 kOe. That for $Fe_{26}Pt_{74}$ at 77 K showed a metamagnetic transition at 100 kOe. These properties were discussed on the basis of a band picture.

I. INTRODUCTION

In the system of ordered MPt_3 alloys(M=3d elements) with a Cu_3Au type crystal structure, the magnetic interaction between 2nd nearest neighbors in a fcc crystal structure plays an important roll since M occupies only cubic corner sites. At Pt atoms placed at a face centered position, magnetic moment is also induced. The induced magnetic moment is in an antiparallel direction to M's moment for M=V , Cr and is in parallel one for M=Mn,Co. No magnetic moment is induced at Pt in ordered $FePt_3$ alloys which is antiferromagnetic. According to the neutron diffraction study by Bacon et al.[1], $FePt_3$ has two types of the antiferromagnetic order. There appears a ($\pi\pi$ 0) type antiferromagnetic order from a paramagnetic state below 170 K . By cooling below 100 K ,moreover, the appearance of a (π 0 0) type order is observed, which coexists with the (π π 0) type antiferromagnetism. The intensity of magnetic reflection lines of the ($\pi\pi$ 0) type antiferromagnetic order decreases 30~40 % accompanying with the appearance of the (π 0 0) type one. It shows that a part of (π π 0) type antiferromagnetic state transforms to a (π 0 0) one. The $Fe_{24}Pt_{76}$(~$FePt_{3.17}$) alloy with a small amount of excess Pt has only a (π π 0) magnetic order. Ishikawa[2] lead the distance dependence of exchange integral coefficient for $FePt_3$, $FePd_3$ and $MnPt_3$ from spin wave dispersion curves. The exchange interaction between 2nd nearest neighbors in $FePt_3$ has a negative sign and takes the absolute value of 0.87 meV. This fact shows that antiferromagnetic state is stabilized. In $FePd_3$ and $MnPt_3$ with the negative but week exchange interaction between 2nd nearest neighbors, ferromagnetic ordering is stabilized. Suda et al.[3] carried out a band calculation of $FePt_3$ and $FePd_3$, and examined the stability of magnetic phase and obtained the same condition mentioned the above. Kohgi et al.[4] observed the temperature dependence of sublattice magnetization of $FePt_3$ and compared with theoretical values calculated by 2 magnon theory and green function method. The observed sublattice magnetization disappears at lower temperature than the calculated ones. This is explained as that the lower temperature diminution of the sublattice magnetization is due to the induced magnetic moment at Pt atoms to contribute yielding spin wave at a finite temperature in an antiferromagnetic state. Because the induced moments enhances the excitation of spin wave and then the expectation value of magnetic moment at spin wave with q is reduced. When ordered $FePt_3$ alloys are disturbed and Fe is located at a face centered position, Fe moments in the face couples ferromagnetically and a ferromagnetic state appears locally. Therefore, the appearance of dislocation or local stress yields a ferromagnetic portion along an imperfection[5]. The magnetic susceptibility of $FePt_3$ shows a peculiar temperature dependence. There appears a peak near 100 K corresponding to the Néel temperature of the (π 0 0) type antiferromagnetic order. However, there is no peak at the Néel temperature of the (π π 0) one and in the reciprocal susceptibility vs. temperature curve, a bending is observed at 170 K which is the Néel temperature of the (π π 0) antiferromagnetic state.

We prepared the sample of $Fe_{24}Pt_{76}$ which has only a (π π 0) type antiferromagnetic phase and $Fe_{26}Pt_{76}$ which has coexisting magnetic phases and examined their antiferromagnetic properties under the high magnetic field.

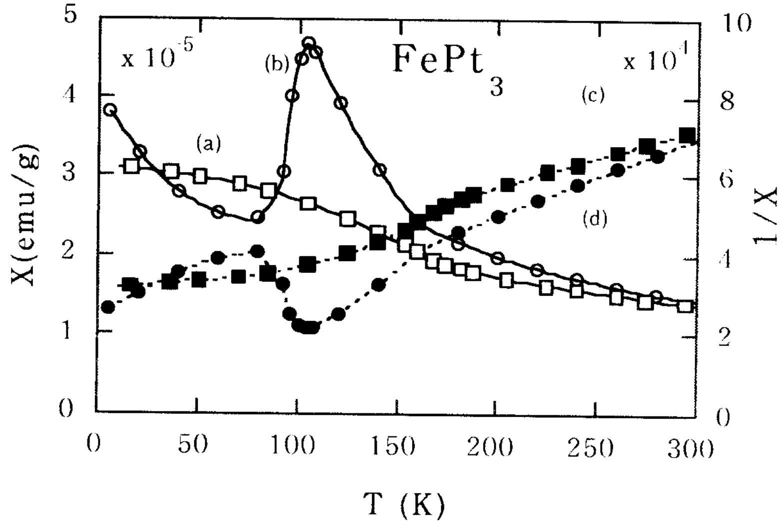


Fig. 1 Temperature dependence of magnetic susceptibility and reciprocal one. Curve (a) and (c) are for X and X^{-1} of $Fe_{24}Pt_{76}$, and curve (b) and (d) are for those of $Fe_{26}Pt_{74}$, respectively.

II. EXPERIMENTAL RESULTS

The samples were prepared by melting the constituents in an induction-furnace. The sample chips were heattreated at 1100 ℃ for 100 hrs and then at 600 ℃ for 100 hrs to achieve the ordered state. The lattice parameter of $Fe_{24}Pt_{76}$ was 3.8740 Å. The magnetic measurements were carried out with SQUID under magnetic fields up to 5 T at temperatures from 5 to 500 K and the magnetization was measured by using an extraction method under static magnetic fields up to 150 kOe by a water cooled bitter type magnet and up to 240 kOe by a hybrid type magnet at Institute for Materials Research, Tohoku University.

In Fig, 1 the temperature dependence of magnetic susceptibility (χ) and reciprocal magnetic susceptibility (χ^{-1}) are shown. The curve (a) is for $Fe_{24}Pt_{76}$ and (b) for $Fe_{26}Pt_{74}$. There is no peak of χ in the curve (a) and appears a breaking point at 170 K. This temperature corresponds to the Néel point for a (π π 0) type antiferromagnetic state. χ^{-1} follows the Curie-Weiss law above 170 K. The obtained paramagnetic Curie temperatures and effective Bohr magneton numbers are −267 K, ~ 6 μ_B for $Fe_{24}Pt_{76}$ and −59.9 K, 5.1μ_B for $Fe_{26}Pt_{74}$ respectively. The effective Bohr magneton number is larger than the magnetic moment determined by neutron diffraction(3.3 μ_B)[1] and corresponds to the enhanced magnetic moment in a dilution of Fe to Pt metal. A χ maximum and a breaking point are observed at 104 K and 170 K in curve(b). Below 104 K, there appears the (π 0 0) type antiferromagnetic order which coexists with the (π π 0) type one. In the low temperature region, χ in

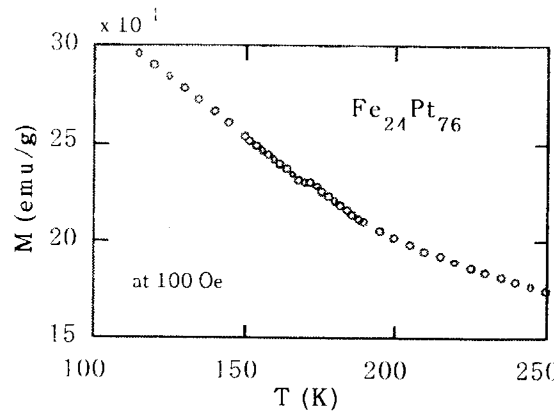
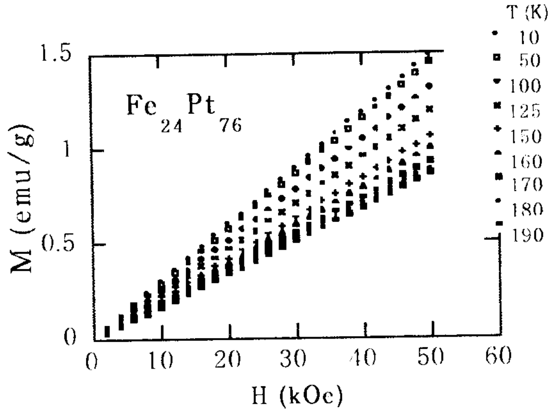
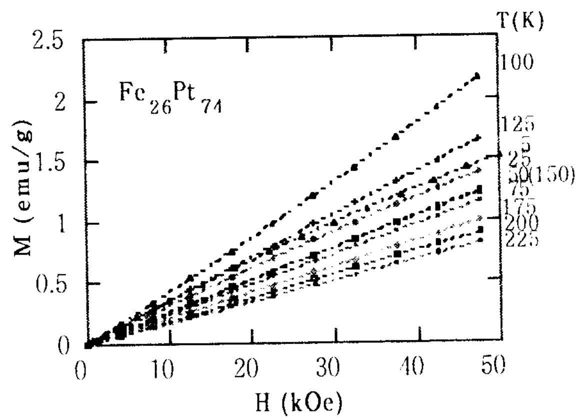


Fig. 2 The enlarged magnetization vs. temperature curve in a low applied field 100 Oe.

the curve (b) becomes large with decreasing temperature . The magnetization vs. temperature curve at a low field (H=100 Oe) is shown in Fig. 2. The magnetization shows a slight jump around the Néel temperature. According to ref. [1], there arises only a (π 0 0) type antiferromagnetic order



(a)



(b)

Fig.3　Magnetization curves for (a) : $Fe_{24}Pt_{76}$ and (b):$Fe_{26}Pt_{74}$ at various temperatures.

phase for $Fe_{28.8}Pt_{71.2}$ and the magnetic susceptibility in a low temperature range in the ordering state is almost constant after making a peak. Therefore, the increment of χ for $Fe_{26}Pt_{74}$ by decreasing temperature is due to the coexistence of two type antiferromagnetic states. In Fig. 3, the magnetization processes up to 50 kOe for $Fe_{24}Pt_{76}$ (a) and for $Fe_{26}Pt_{74}$ (b) are shown. All curves in figure (a) are straight line through the origin. The slope is varying continuously with temperature. As shown in figure (b), the responce of magnetization at 100 K with respect to the applied field is the largest and bends upwards. It is considered that this behavior is related to the metamagnetic transition near the Néel temperature. On the other hand, the magnetization at 5 K increases linearly along the curve at 125 K at first and after that deviates downwards above about 15 kOe. Such an inclination is also observed on the curve at 25 K. The magnetic susceptibility at various magnetic fields varies with temperature as shown in Fig. 4. Up to 10 kOe, the value of maximum susceptibility increases with the magnetic field and the maximum temperature does not vary. This temperature, however, moves to a lower temperature under 50kOe. It suggests that there arises a metamagnetic transition from the (π 0 0) type to the ferromagnetic order state caused by the magnetic field. The transition from the (π π 0) type to the (π 0 0) type has been observed by neutron diffraction[1]. It seems that the field dependence of the maximum susceptibility is related with this transition. The magnetization process under the high magnetic field has been examined. The observed processes

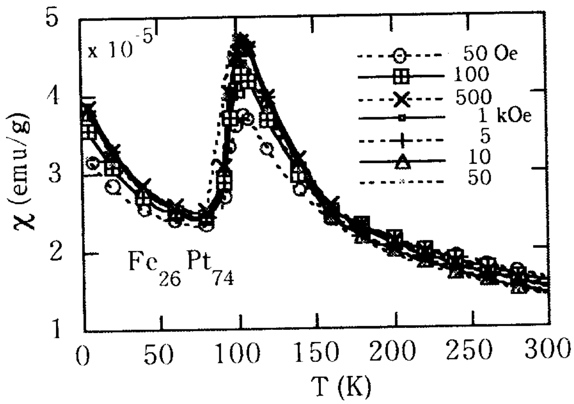


Fig.4 Magnetic susceptibility of $Fe_{26}Pt_{74}$ as a function of temperature at various applied fields.

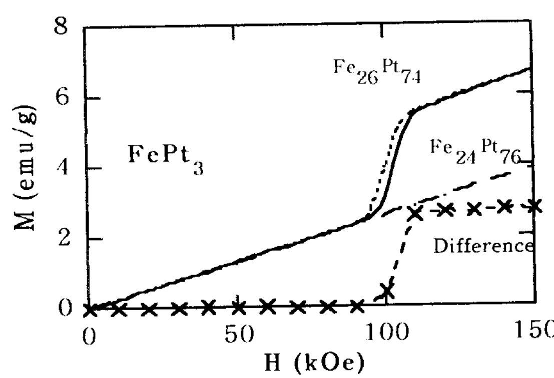


Fig.5　Magnetization process under high magnetic fields for $Fe_{24}Pt_{76}$ and for $Fe_{26}Pt_{74}$ at 77 K.

at 77 K are shown in Fig. 5. The steep increase of magnetization arises at 100 kOe for $Fe_{26}Pt_{74}$. The magnetization process for $Fe_{24}Pt_{76}$ has almost the same slope to that for $Fe_{26}Pt_{74}$ in low magnetic fields. The difference between them is shown in the figure and has a constant value above 100 kOe. This difference curve shows the metamagnetic transition of the (π 0 0) type antiferromagnetic state to a ferromagnetic one. The linear variation of the magnetization above 100 kOe for $Fe_{26}Pt_{74}$ is ascribed to only the (π π 0) type antiferromagnetic phase and then the magnetization variation for $Fe_{26}Pt_{74}$ at low magnetic fields should be very small.

III. DISCUSSION

We are interested in an appearance of antiferromagnetic order near a concentration of $FePt_3$ in the system of Fe-Pt ordered alloys and in the peculiar magnetic properties, especially the temperature dependence of the magnetic susceptibility and magnetization process for $Fe_{24}Pt_{76}$. Ishikawa[6] pointed out that the magnetic state is a coexisting state of the localized Fe and paramagnetic Pt band. The results of the band calculation[3] show that the (π π 0) type antiferromagnetic state in $Fe_{24}Pt_{76}$ ordered alloys is more stable than ferromagnetic one. The main up spin band and down spin one separate and the difference between them is about 3 eV where up spin band spreads, and Fermi level places at a middle of them. In the ferromagnetic state, the Fermi level is in a main down spin band and up spin band is approaching to Fermi level. Moreover, a peak of DOS is growing up near the top of up spin band. Considering that the (π 0 0) type antiferromagnetic state easily transforms to ferromagnetic one by field, this state can be considered to be an intermediate state between a (π π 0) type order and ferromagnetic one. The temperature dependence of χ of $Fe_{24}Pt_{76}$ can be understood on the basis of the band picture that band structure near the Fermi energy level in the (ππ 0) type antiferromagnetic state has a flat density of state so that the Fe band susceptibility is almost temperature independent or very small and then Pt band one shows a temperature dependence interacting with Fe spin wave. In the case of the (π 0 0) type antiferromagnetic, Fermi level is close to the main down spin band and then the value of the susceptibility is affected strongly from the down spin band near the Néel temperature so that this type antiferromagnetic state has a susceptibility peak. A slight increase of magnetization as seen in Fig. 2 and the pressure dependence of the Néel temperature for $Fe_{24}Pt_{76}$ which is equal to zero is also understood in terms of the band model.

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