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INVESTIGATION ON FERROMAGNETIC $Mn_{1-X}Co_XPt_3$ ORDERED ALLOYS

T.Kaneko, H. Fujimori, H.Yoshida, K.Watanabe[a], S.Abe, M.Matsumoto[b] T.Yoshida[a] and T.Kanomata[a]

IMR,Tohoku University,Sendai,980, Japan; [a] Tohoku Gakuin University, Tagajo, 985, Japan; [b] Institute for Advanced Materials Processing, Tohoku University, Sendai, 980, Japan

The magnetization of $Mn_{1-X}Co_XPt_3$ ordered alloys was measured at various temperatures and the pressure effect on T_C for X=0.25, 0.5 and 0.6 was examined. The X dependence of T_C determined by Arott plot has a minimum near X=0.6. The field-cooling effect measurement for X=0.5 shows a reentrant spin glass behavior. It is found that there is a concentration showing no pressure dependence of T_C between X=0.25 and 0.5. These magnetic properties are discussed with a rigid band model.

I. INTRODUCTION

Ordered alloys formed by 3d transition metal (M) and platinum (Pt) have been extensively studied because of their interesting magnetic properties in great variety. $MnPt_3$ and $CoPt_3$ are ferromagnetic with the Curie points of 395 K and 290 K but $FePt_3$ is antiferromagneic with the Néel point of 170 K. In the system of MPt_3, the alloying effect by replacing M(=Cr) with another 3d element(=Mn) was studied by Williams et al [1]. The induced magnetic moment on Pt for M=Cr is in an antiparallel direction to the magnetic moment of M=Cr and for M=Mn is in a parallel one. The concentration X dependence of T_C has a minimum at X=0.7 in $Cr_{1-X}Mn_XPt_3$ without maxima. According to the investigation [2] on spin wave dispersion of $MnPt_3$, the interaction between corner Mn atoms was estimated to be ~−0 meV and the one between Mn-Pt is 1.3 meV. It is noted that the interaction between Mn and Pt is larger than that between Mn and Mn. Suda et al. [3] calculated band structures for M=V, Cr, Mn, Fe, Co. The band shapes for M=Mn, Fe, Co are same each other in paramagnetic state and then it is permitted to apply the rigid band model. Recently, Yoshida et al. [4] and Kim et al.[5] have reported that there was found a reentrant spin glass phase (RSG) in the system of $Mn_{1-X}Co_XPt_3$. They [5] examined magnetization hysteresis loops and the temperature dependence of magnetization at low magnetic field for X=0.5. The loop width becomes zero at 60 K and the magnetization in low field begins to decrease with decreasing temperature. Kim et al. [5] also found by observing a field-cooling effect that there appears RSG phase at X=0.4, 0.6 and 0.8. They also proposed the magnetic phase diagram of $Co_{1-X}Fe_XPt_3$. There appears a spin glass state in almost whole concentration X except near $FePt_3$ and a superparamagnetic phase near X=0. Both of ordered and disordered $CoPt_3$ alloys are ferromagnetic and their Curie temperatures distribute widely from 290 to 590 K depending on the degree of order. Tohara et al. [6] carried out the calculation of total energy in ferromagnetic and antiferromagnetic state of the ordered $CoPt_3$ alloy and found an antiferromagnetic state to be more stable than ferromagnetic one. Matsumoto et al. [7] measured the forced magnetostriction of MPt_3 (M=Cr, Mn, Co) to examine the atomic distance dependence of the magnetic moment. It is interesting to produce the pseudobinary alloys of $MnPt_3$ and $CoPt_3$ with the same valence electron number to antiferromagnetic $FePt_3$. As mentioned above, many problems on occurrence of different magnetic state depending on M in MPt_3 alloys remains to be solved.

In this paper, the temperature dependence of magnetization of the pseudobinary alloys $Mn_{1-X}Co_XPt_3$ are measured in order to examine the relation between the number of valence

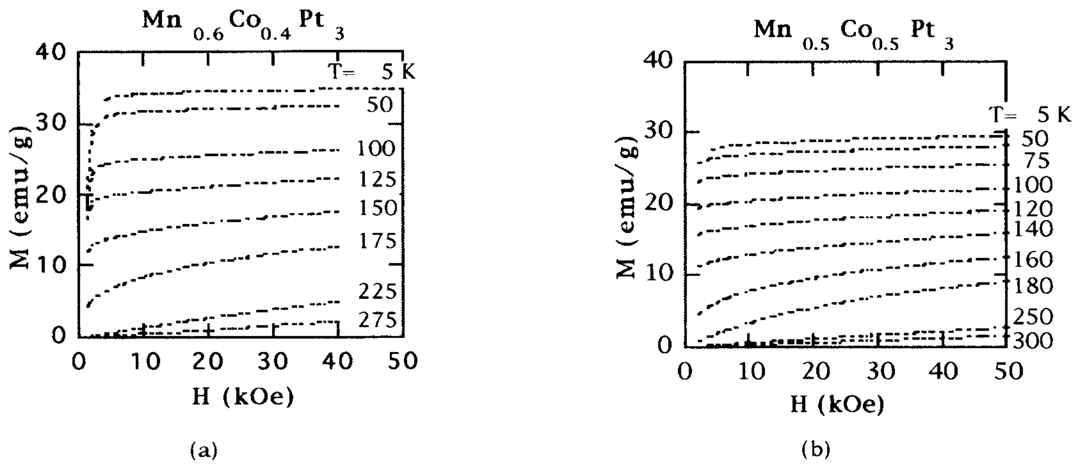

Fig. 1 Magnetization curves at various temperatures; (a): for $Mn_{0.6}Co_{0.4}Pt_3$ and (b): for $Mn_{0.5}Co_{0.5}Pt_3$.

electrons and the occurrence of ferromagnetism or antiferromagnetism in these ordered alloys.

II. EXPERIMENTAL RESULTS AND DISCUSSION

The specimens $Mn_{1-X}Co_XPt_3$ (X=0, 0.25, 0.5, 0.6, 0.75 and 1) were prepared by melting the constituent elements in induction-furnace and by annealing at 1100 °C for 5 days. The temperature dependence of the magnetization were measured at various fields and the Curie temperatures were determined by the Arott plot method. Figures 1 (a) and (b) shows the magnetization curves for X=0.4 and 0.5 in $Mn_{1-X}Co_XPt_3$ at various temperatures respectively. At low temperatures the magnetization shows a tendency of saturation around 5 kOe. The slope of magnetization curve of X=0.5 at high fields is about 2 times larger than that of X=0.4. The X value at the maximum slope of high field magnetization curves is 0.6. Figure 2 (a) shows the temperature dependence of spontaneous magnetization M_s for X=0.5. The variation of M_s with temperature is not expressed by a Brillouin function. It is found that the magnetization of X=0.5 varies with temperature as a function of T^N (N=2.25) as shown in Fig. 2 (b). The

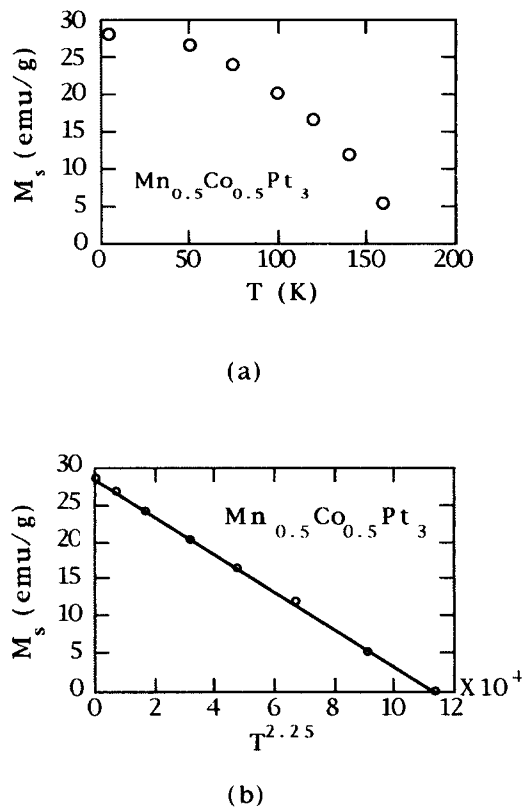

Fig. 2 (a): the temperature dependence of a spontaneous magnetization for X=0.5 determined by Arott plot and (b): the determination of Curie temperature by a extrapolation from the spontaneous magnetization vs. temperature curve (T^N: N=2.25).

temperature at M_s=0 gives us the Curie temperature T_C (177 K). The temperature dependences of M_s for other alloys are also expressed as $M_s(T)= M_s(0)[1-(T/T_C)^N]$, where N ranges from 2 to 2.5. It was reported that there appears a reentrant spin glass state at 60 K in $Mn_{0.5}Co_{0.5}Pt_3$ [4,5]. The field-cooling effect for X=0.5 was examined at H=100 , 500 Oe and 1 kOe and the results are shown in Fig.3. The magnetization at 100 Oe after a zero-field cooling run has a value of about 1 emu/g at 5 K and increases abruptly with increasing temperature as seen in the curve (1). The magnetization has a broad maximum near 70 K and decreases with further increase of temperature. A ferromagnetic state disappears at 165 K. The magnetization was measured on cooling from room temperature under 100 Oe. The magnetization deviates upwards from the zero-field cooling curve (1) from about 100 K and has a almost constant value below 50 K as shown in the curve(2). According to ref. [4], the width of the magnetization loop at X=0.5 becomes zero at 60K and has a finite one below and above 60 K. This temperature has been there defined as the transition temperature T_{RSG} from a ferromagnetic to a reentrant spin glass state. The field-cooling effect at H=500 and 1000 Oe is observed at lower temperature. The existence of spin glass phase shows that there exists at least locally an antiferromagnetic interaction in $Mn_{0.5}Co_{0.5}Pt_3$ ordered alloy. However, there appears no reentrant spin glass above 2 kOe in a whole temperature range. It suggests that the magnitude of the interaction is so weak that the application of about 2 kOe transfers a reentrant spin glass state to a ferromagnetic one. Figure 4 shows the X dependence of spontaneous magnetizations M_s and the Curie temperature T_C determined by Arott plot. In the range of X < 0.4 the value of M_s is nearly constant and has a minimum near X=0.75. This fact means that the X dependence of M_s cannot be explained by a simple dilution analysis. On the other hand, T_C also has a minimum near X=0.6. The pressure dependence of T_C is almost zero for $FePt_3$ and $CoPt_3$ and has a positive sign for $MnPt_3$ by our preliminary experiments[7]. The pressure dependence of T_C for alloys of X = 0.25, 0.5 and 0.6 was measured. The results are shown in Fig. 5 for X=0.25 and 0.5. T_C was determined from temperature dependence of ac susceptibility with 1 kHz. By applying of pressure, T_C for X=0.25 increases linearly with dT_C/dp=0.21 K/kbar , but T_C for X=0.5 decreases with dT_C/dp=−0.13 K/kbar. These results show that there exists a certain concentration value having zero pressure coefficient of T_C

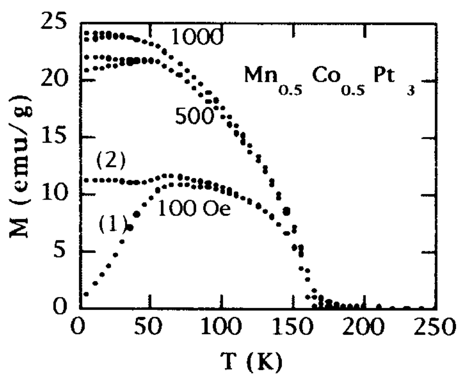

Fig. 3 Field-cooling effect for $Mn_{0.5}Co_{0.5}Pt_3$ in the M-T curves at 100, 500, 1000 Oe. (1) : zero- field cooling; (2) : field-cooling under H=100 Oe.

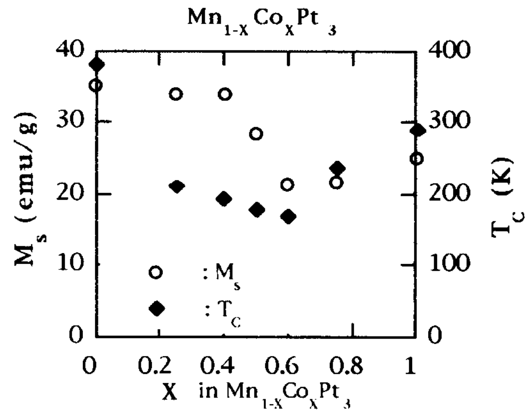

Fig. 4 X dependence of M_s and T_C in the system of $Mn_{X-1}Co_XPt_3$.

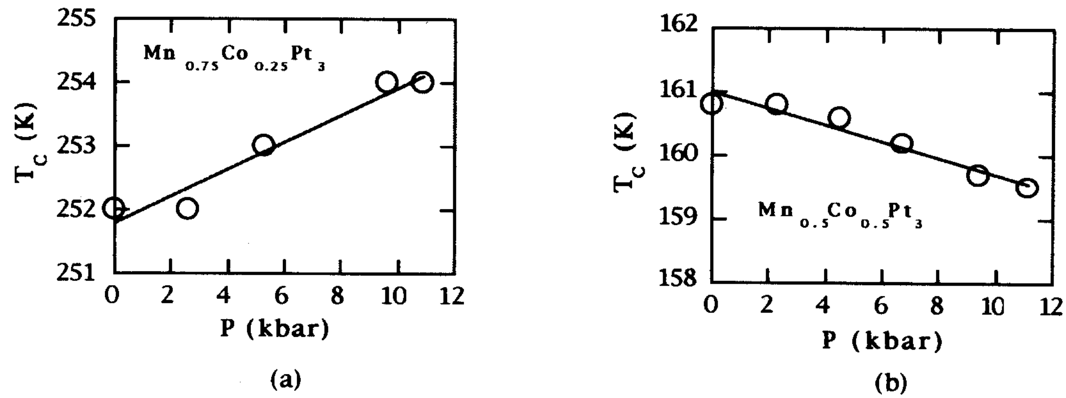

Fig. 5 Pressure dependence of T_C; (a) : for $Mn_{0.75}Co_{0.25}Pt_3$ and (b) : for $Mn_{0.5}Co_{0.5}Pt_3$, where T_C was determined by ac susceptibility measurements with 1 kHz.

between X=0.25 and 0.5.

The X dependent curves of M_s and T_C have a minimum near the concentration with the same valence electron number to $FePt_3$ as seen in Fig. 4. It means that the antiferromagnetic interaction is enhanced even if in ferromagnetic state. The pressure dependence of T_C has also a minimum near X=0.5. It may be related with the electronic band structure. It is desirable to measure the specific heat and to examine the X dependence of γ in order to obtain the information on the electronic density of state.

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